“The Radio-T.V. Training Centre”

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AUSTRALIAN RADIO AND TELEVISION COLLEGE PTY. LTD.

Telegrams “RADIOCOLLEGE” Sydney

Post Lessons to Box 43, Broadway

LESSON NO.1.

THE WONDERS OF RADIO & TELEVISION.

You are entering a new field - one probably new to you and comparatively new to the whole world, To those on the outside, radio is a science, a profession, an industry. To those on the inside it may be any or all of these, and in addition it is their greatest pleasure at the same time.

Of all new things that ever came into our lives, radio has had the quickest rise from, an obscure beginning to tremendous importance. Go back only a few short years and there where no homes with radio receivers. To-day there are hundreds of millions of homes having radio receivers and about one hundred million throughout the world with television receivers,

A GREAT INDUSTRY.

Radio and its “offspring” - Television - have brought more real enjoyment to more people in less time and at less cost than any other thing in our history. Before radio, we all pointed to the motor car as the wonder of our time. It too, brought pleasure into the lives of millions of men and women, but the cost was high. The cost of radio entertainment is small - everyone can enjoy it and afford it. To-day there are many millions of people “listening in”.

Radio is a means of communication between men. It is the newest means and already may be called the greatest means because it is free from so many of the limitations which beset the older methods. Before we had radio we had the telephone and the telegraph, but they called for miles of connecting wire. With radio there are no wires between sender and receiver; and we may send signals over vast bodies of water; over impassable mountains and to great distances where these difficulties. would make it impossible or at least very uneconomical to string wires.

RADIO'S ACHIEVMENTS

Because a single radio Signal sent from one transmitting station may be picked up and reproduced at thousands of receivers, this new science has done wonderful things. First among radio's benefits we should mention life saving at sea because this was the earliest great accomplishment and is still The greatest from The standpoint of doing good for humanity. The importance of life saving is recognised by all branches of radio. When a distress call, the well known "S.O.S," goes over The air, everything else within bounds stops and the whole world of radio "stands by" until those in trouble have been given assistance.

Some of the greatest achievements of radio have been during times of fire, flood and devastating storms. Wires may go down, rail communication may be washed out and roads may be rendered impassable - but a radio amateur with his low powered transmitting set at the scene of trouble and another of his kind in a distant city will remain as a connecting link to carry appeals for help that will save hundreds of lives and relieve the sufferings of all those in the danger zone. Another great work of radio is done in the service of the law and order, Police departments everywhere are using radio to trace down and capture criminals, within a few minutes of their misdeeds. Fire brigades, Ambulance & services, Electric & Water supply authorities, Taxi cab services and countless other organisations are using radio link to provide us with a better standard of living.

Coming down to the. more ordinary things in radio we find entertainment of every kind - the finest or music from the most famous orchestras, drama from accomplished actors, songs from the greatest artists and a choice of many different programmes to choose from. Religious teachings are carried everywhere, Education is being sent into the most remote places and to those having no other opportunity to. Learn. Lectures are given on every conceivable subject from playing golf to calculating an income tax. The provision of entertainment and information visually as well as audibly made possible by Television has already had a tremendous influence on the lives of millions.

Businesses of every kind are being helped by radio. The finest broadcasts ere in reality forms of advertising. Many stations send out information of special value to tanners and to other classes of business men. This service includes market prices, time signals, weather reports, warnings of wind and temperature changes - in fact almost every class of information that is needed by almost every class of people. News events are broadcast everywhere almost as soon as the events have taken place.

Radio competes with the long established cables in sending telegraphic, messages over the oceans and there is a regular telephone service by radio between Australia and most countries. Now several communication companies carry radio messages, both in telegraphic code and in ordinary spoken words, to every party of the world.

The advancement of aviation as a public convenience depends to a great extent on, radio because here is the only possible means of communication between the aviator when he is far up in the air and those on the ground, and when darkness has fallen radio beacons, guide the airplane straight and true on its course and radio messages warn the pilot of troubles ahead and tell him how to shape his course to avoid them.

YOUR OPPORTUNITIES

What does all this mean to you? It means that you are getting in on the ground. floor of our youngest, healthiest and fastest growing business. Nobody in the whole radio – television industry has more than a few years start on you. Great things are done every year but the year following sees still greater advances. The radio you know to-day will be out of date a year from now, and you may be one of those helping to put through the changes -- who knows?

With such a field of usefulness, with so many important duties to perform, with so many kinds of services to render, is it any wonder that radio grows by leaps and bounds? It is an acknowledged fact, a fact being given the greatest prominence by all radio business organization, that the greatest need to-day is manpower, or to be more correct, brain power. Dealers everywhere are bidding for the services of competent radio and television technicians. Public institutions and all amusement enterprises are demanding men to operate and care for their costly equipment. Manufacturers of receivers and radio parts of all kinds are looking for men with radio training. Radio is a business which, in only one or its branches, that of broadcast reception and receivers, has grown in money value to a total of about Thirty million pounds in Australia alone.

Radio men have not increased their numbers at any such rate nor anywhere near such a rate, In 1922 there were about two thousand receiving sets and a few amateur broadcasters. Now there are more than two million receivers and some hundreds of broadcasters .in Australia. For every single radio man in 1922 there should be a thousand such men to-day just in the building, selling and .servicing of broadcast, receivers, All the other branches of radio have grown proportionately and the newer branches are growing even more rapidly than the older ones.

The growth of radio has opened dozens of different paths to real money, paths too numerous to even allow a listing of them all. In the manufacturing end you can become an inspector, a tester, a valued assistant in some laboratory, a superintendent. You can enter the selling field and make money by telling people about complete receivers, certain accessories, amplifiers for theatres and other amusement places, or complete radio installations for homes, hotels, hospitals and other institutions. You can become a dealer in any of these devices. You can open your own service business or can join some of the growing service organizations. You can enter the employ of a broadcast station. Technicians for the manufacture, installation and maintenance of industrial electronic equipment (for controlling high powered machines and heating equipment), or “X” ray apparatus and of Electronic computers or electronic “brains” are sought from those with a sound basic knowledge of radio and electronic principles. We can't tell you of all the chances you will have because by the time you're ready there will be still more chances than to-day.

Whatever your ambitions are it is essential for you to start with, basic fundamentals and to build up your knowledge progressively on firm foundations. Regular and systematic study of the following lessons will carry you steadily forward until you have covered the carefully planned and comprehensive syllabus of this course. The first section of the course covers mainly fundamental principle's and particularly the characteristics of the various component parts which make up a radio and television receiver. The second section explains the way in which the various parts are grouped together to form “stages” in a receiver. The third section is devoted mainly to efficient and systematic methods of fault location and the fourth section deals with Television.

THE ROMANCE OF RADIO

A little way back we said that nobody in radio had more than a few years start. Practically speaking, that's true, but of course radio history goes back further than that. One of the first, if not the very first patents on radio or “wireless” apparatus was granted to Professor Dolbear in 1882 and he then made the forecast that some day it would be possible to establish wireless communication between points more than a half mile apart. Thirty-six years later a radio telegram was sent from Carnarvon to Sydney, a distance of more than twelve thousand miles.

The very beginning. of radio goes a long way back although the experimenters of that day had little or no idea of what they were starting. In 1840 high frequency oscillations were produced by Joseph Henry and these oscillations are the basis of all radio as we know it now. In 1885 a man named Preece maintained telephonic speech between two electric circuits completely insulated from each other and separated by a quarter of a mile. Two years later Heinrich Hertz founded the theory of modern radio waves which are often called Hertsian waves,

Another ten years passed, each one filled with hard work by many great minds, and then Marconi communicated over a distance of nearly two miles. Thereafter things moved in a hurry and in the year 1897 the distance of transmission was increased first to four miles, then to ten and finally to more than fourteen miles. The public began to hear about this new thing but most people did more laughing than believing.

In all this preliminary work radio telegraphy was the big thing and radio telephony or the transmission of speech and music was little more than an interesting experiment. Marconi received the letter “S” in code, at St, Johns, Newfoundland, from Poldhu, England, seven years before Professor Fessenden in America was able to maintain radiophone communication for a distance of six hundred miles between Washington, D.C., and Brandt Rock, Massachusetts.

In 1918 we saw rapid development of the vacuum tube or valve, without which our home radio and most of the other applications would be still but a shadow of their present perfection. This gave, a great start to the new science, which began its evolution from a curiosity into a necessity, Three yearn later the U.S.A. Government issued the first broadcasting license to station KDKA of the Westinghouse Electric & Manufacturing Company at Pittsburgh, U.S.A. Then the public took up radio in. dead earnest

THE FIRST RECEIVERS

The very first radio sets, as shown in Fig. 1, for home use comprised two coils of wire, a piece of mineral called crystal (generally galena or iron pyrites), a long wire strung out of doors and a pair of headphones operating much like the telephone receiver you hold to your ear.

A little later came receiving nets employing a vacuum tube or valve which worked in a pair of headphones, The “fans” of those days played every conceivable trick on that one tube to make it pull in more miles. It was nothing uncommon to find a receiver with a front panel a foot and a half square with a dozen to twenty knobs and dials - all for working that single tube.

Nowadays our modern home receivers have but one tuning control one volume control and these operate up to ten tubes.

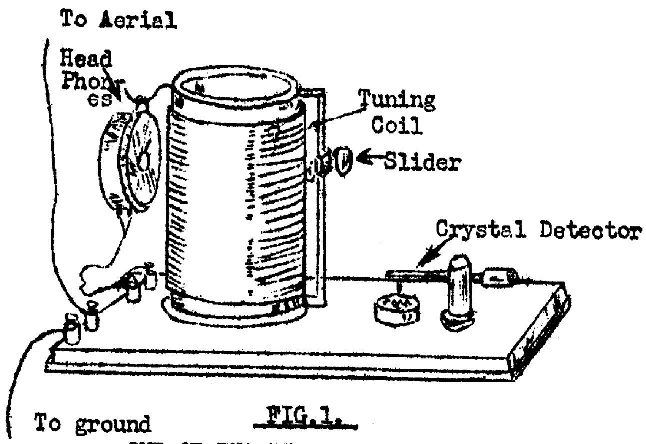


FIG.1.
ONE OF THE FIRST RECEIVERS.

The single tube in the first sets was a "detector" which received the radio waves and turned them into a form which would produce sound on the phones. The more ambitious constructors put one or two extra tubes between the detector and the head-phone connection, replaced the phones with a loud speaker and entertain the whole family at the one time. The next development put tubes ahead of The detector, between the aerial and the detector. Those were the days of "DXing" for everybody, The letters in radio mean long distance reception.

The whole object of early broadcast reception was to listen to some station clear across on the other side of the country. The programme was of no importance whatever, just so that the station was a thousand miles or more away. To-day the emphasis is placed on perfection of tone quality. Most people claim now that they are well satisfied with the programmes from the “locals” provided the selections are worth hearing. But just the same, try stealing up behind some of these local enthusiasts on a cool winters evening and see what they’re tuning for. If what they’re after is a “local”, then their idea of distance must be the moon.

We are sure there can be no denial of this statement that nothing or a scientific nature ever before took such a firm hold on the, popular imagination as did radio. There was no such thing as a factory-built receiver and every one of us built our own. Radio parts stores sprang up everywhere, and you could buy the now obsolete slide tuners, loose couplers, variometers and a hundred other necessities on every corner.

The boy of the family would take a box made of cardboard, add some wire, a crystal. detector. and somehow get hold of a pair of headphones. That started it and about a week later you would see the boy and his dad ride to town on Saturday to come home loaded with bundles. In a few nights the neighbours came in to listen to America -even if they didn’t hear it.

Enterprising manufacturers observed these happenings and concluded that here lay a fertile field for sales. The factory-built receiver entered the contest and gradually made headway. The first of the ready-made sets were expensive in comparison with the home-made article and most of them weren’t so good. But times have changed and to-day The mass produced factory job has the better of the argument with the set built at home by a novice. While the “bread board” set, as the home made receiver has been called, is now way in the background, we still have with us two classes of receivers the factory built and the “custom built”.

Custom built receivers are built by professional radio men, generally using kits or sets of parts which are designed to operate well together in making a really high grade set equal to factory built ones in performance. This business of custom set building is one of the branches of radio in which you can make money even before you complete your course of study. Complete kits of matching parts are readily available from which you can build almost any kind of radio receiver, amplifier, test instrument, or Television receiver, when you have obtained sufficient knowledge from these lessons.

WHAT IS RADIO

We've talked about the radio business and could go on talking about it for a long time, but no doubt you're anxious to get down to radio itself. What is it? what makes it? How does it act? Why is it able to do such wonderful Things? We will find out.

Practically everything in radio is concerned with. one of its two main divisions, the transmitter or the receiver. Between these two parts must be something to carry the signals from one to the other, In many of the commercial applications of radio and in some applications to home use, wires or metal conductors are used to carry the impulses or signals and we have what is called wired radio or carrier telephony. But for broadcasting and for most of the other uses with which you will become familiar we use “space radio” and transmit the signals through space by sending them up into an aerial at the transmitter and catching them on the aerial at the receiver.

TWO WAYS TO LEARN RADIO

If this were to be an ordinary radio course both it and you would be put of date because we would teach you only details and tell you about certain parts and piece of apparatus which are here to-day and gone to-morrow.

What we are going to learn first is the how and the why of it all. Fundamental principles don’t change, only the application of these principles that change. For example, back in 1924 we might have taught you about the construction of the coupling coils for the then famous neutrodyne receiver. But to-day the latest thing is the superheterodyne, and you wouldn't have known a thing about it. So here' s the point - had we taught you about the principles of coupling you would have under-stood the coupled circuits of the Neutrodyne in 1924 and would have been equally well able to understand how two coupled circuits to-day work together in picking out a certain band of frequencies or sounds we want to listen to in the modern superheterodyne

Of course you will learn about the latest applications of all the principles in radio, this to give you a clean start from the day you graduate. But behind all this will be one of the few men who know what makes things happen. Then nothing that comes along in the future will mystify you in the least. It will make the difference between the methods called “cut and try” and the methods of the man who knows his whole subject from the inside out.

The first lessons you will study are more important than you will realise until you are nearly through with your course. Nothing that could be said now will make you understand just how important are these first ideas. They are the foundation of all your future knowledge and like the foundation of a great building, all that is built upon them will fall down if the foundation isn't righ Radio is a branch of the science of electricity and for your studies we will start off with electrical actions Howeve even in the preliminary work we will sti closely to those electrical actions which are used in radio transmission, receptic and reproduction.

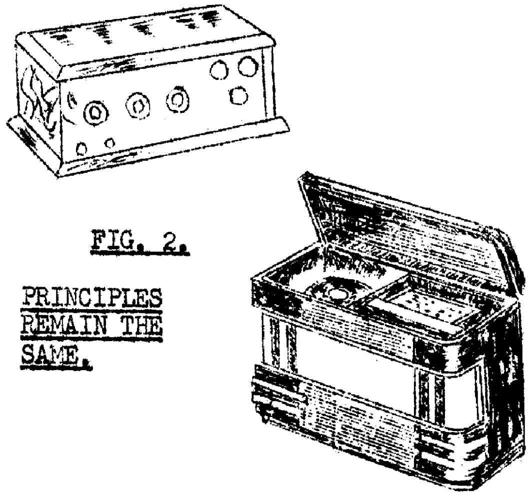


FIG. 2.

PRINCIPLES REMAIN THE SAME.

We might as well tell you, right here that a student of radio must learn quite a great deal about electricity. He needs much more of such knowledge than would actually be required in many of the older applications of electricity. That does not mean that you couldn't learn to operate radio devices, to build radio receivers, or even repair these pieces of apparatus without knowing a single thing about the underlying reasons for electrical actions. With a good memory, a lot of hard work and quite a bit of what is called common sense, it is entirely possible to enter the radio business with very little real knowledge The trouble is that the man who works that way will be of very limited usefulness, his resources will be slight and it won't be long until he'll be looking to the really well trained man as his boss.

ELECTRICITY.

This electricity that makes, radio possible is not easy to define, Ever since Franklin pulled electricity out of the clouds with his kites and a key, men have been trying to discover exactly what electricity is. Scientific workers were carrying out experiments in electricity throughout the whole of the nineteenth century and gradually built up in their minds a picture of the way in which this invisible force behaved in electrical circuits. As will be explained more completely later, these early scientists formed the opinion that an electrical current moved around the circuit from the positive terminal of a battery or generator to the negative terminal.

In 1897, Professor Thompson startled the scientific world with quite a new conception of the nature of electricity and proposed what has become known as the “electron theory”. The electron theory is very convenient for explaining the actions of radio valves, television cameras, television picture tubes and other such electronic devices. However, a great many people with a fundamental knowledge of electrical principles, particularly those who have studied electrical engineering without the necessity for considering valve action, prefer the older fashioned, conventional idea of an electric current as mentally pictured by the early scientists, and for this reason, we will particularly in these early lesson papers, use the conventional idea of current wherever it seems to offer a simpler and more readily understood explanation of some electrical action. However, when we are dealing with the behaviour of radio valves you will find that we will refer frequently to the electron theory and talk in terms of electron flow rather than current. Later on as we advance further into the technicalities you will find that we will use more and more the idea of electron flow for our explanations. This may sound very confusing to you, to have two different pictures of the one action but you find, as we advance steadily from lesson to lesson that a clear mental understanding of electrical behaviour is formed in your, mind without any undue confusion,

Before we dip into radio itself, you must know a little about electricity, This is necessary because radio can’t be described even in the simplest manner without using two or three electrical terms.

In all electrical work, radio or anything else, the electricity itself is used only to carry energy from one place to another or to store energy in one place. Other things besides electricity are used for similar purposes, A belt between a steam engine and some piece of machinery is used to carry energy from the engine to the machine. The steam engine may be compared to an electrical generator, the machine to an electric motor and the belt to the electricity carrying energy between them The two carriers of energy are shown in Figure 3.

A very important thing to realise from an examination of Figure 3 is that it makes little, if any difference to the transmission or energy from the engine to the machine, whether the leather belt moves in a clockwise direction or in a counter-clockwise direction. In either case, the movement of the leather belt is able to carry energy from one device to the other, regardless of in which direction it actually turns,

The same principle applies to the generator and motor shown at the righthand side of Figure 3. The two wires linking the two machines make possible the circulation of electricity which enables energy from the generator to produce a turning force inside the motor. In the case of the leather belt, we could look closely at the belt and find out whether it is turning in a clockwise or an anti-clockwise direction but in the case of the electric wires, at the righthand side of Figure 3, there is no easy way of knowing whether the electricity is moving in a clockwise or counter-clockwise direction in the wires, The important thing is that the actual direction in which the electricity moves does not matter to us. The important thing is to realise that electricity in motion is able to carry energy from one point to another.

Now for an example of storing energy. You store energy every time you wind up the clock store it in the main spring. Electricity may carry energy into a, device called an electrical condenser, keep it there and release it later, The clock spring is like the condenser and the

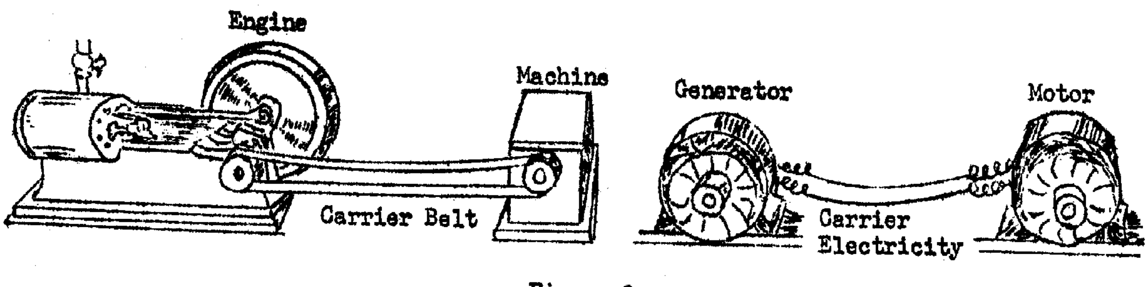


Figure 3.

strain on the spring is like the electrical energy which remains stored until released,

Electricity itself, before any work is done upon it, contains no energy any more than the belt driving a piece of machinery contains energy. Electricity put in notion will do work and so will the moving belt do work the clock spring, until it is put under strain by winding, contains no energy. Electricity put into a condenser places parts of the condenser under strain and electricity from the condenser will then do work, Remember then that the electricity is only a medium through which we may transmit energy by causing the electricity to move or with which we may store energy by causing the electricity to produce a strain, and it is not used up in the process.

If you take a pipe filled with water as in Fig. 4 you may compare the water with electricity. The water might be used to carry energy from one place to another just as is done in any hydraulic system. Once again notice that it does not matter whether the water circulates in a clockwise or counter-clockwise direction in Fig. 4. It will still drive the turbine and carry energy from the pump to the turbine. It is the movement which is important, not the direction.

It you take a tank as in Fig. 5 you may store energy by forcing water up into it. Later on The water will give up its energy and do work if you allow it to flow down, out of the tank over a water wheel or through a water pump.

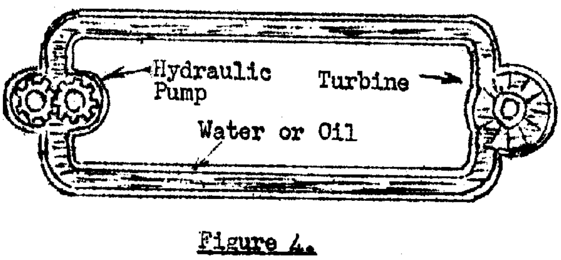


Figure 4.

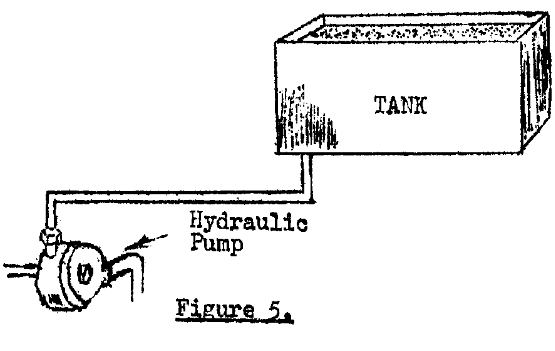


Figure 5.

ELECTRON THEORY

Some of the early workers in electricity, during the eighteenth century, discovered that if a battery were connected to two metal plates, immersed in a conductive liquid as shown in Figure 6, the metal plate connected to the positive terminal of the battery would gradually be dissolved and transferred through the liquid to deposit on the plate connected to the negative terminal. For instance, if the plate connected to the negative terminal, called the “cathode”, is a piece of steel and the sheet of metal connected to the positive terminal, called the “anode”, is copper and the liquid between is a solution of copper sulphate crystals in water then gradually, the copper plate will be dissolved and a film of copper will build up on the steel until all of the immersed surface is coated with copper. Thin is the principle of electro-plating which is used nowadays not only to deposit copper on steel but for the purpose of nickel plating, chromium plating, silver plating and in fact any metal can be deposited in a film on another metal by this technique.

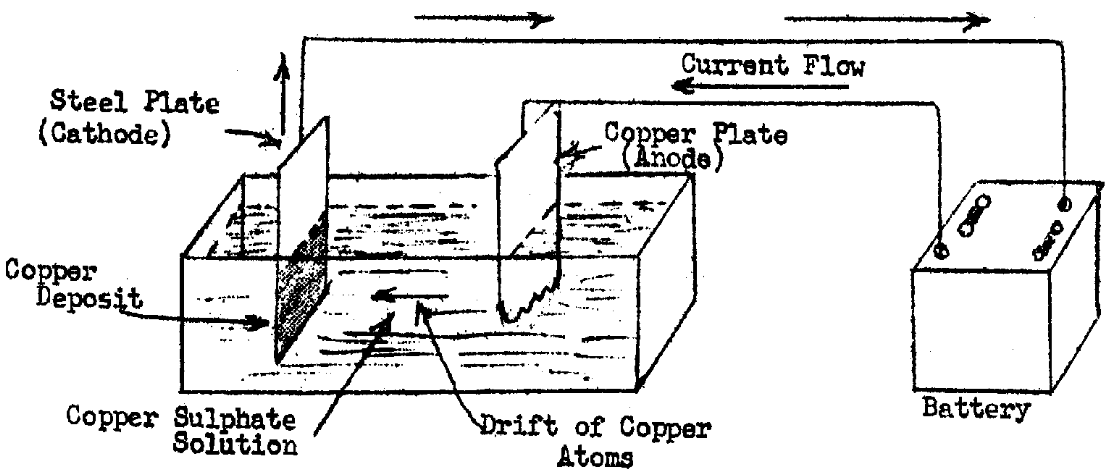


Figure 6.

The fact that the metal connected to the positive terminal dissolves away and is carried across through the liquid to build up on the negative plate suggests that the metal is carried by a current of electricity which appears, consequently, to move from the positive terminal of the battery, to the positive plate, through the liquid from positive to negative, to the negative plate and back, to the negative terminal at the battery.

It was largely the observation of the transference of metal, in electro-plating tanks, which firmly led scientists to believe that currents moved from positive to negative.

As a result of Professor Thompson’s investigations and subsequent work we now know that all materials on this earth are made up of groups of atoms, either of the one kind or of several kinds chemically joined together. There are 92 fundamentally different materials occurring naturally on this earth, and consequently there are 92 different types of atoms. All the other infinite variety of materials are simply made up of mixtures or compounds of the 92 elements. Although for many years, in fact, up until 1897, atoms were thought to be the tiniest particles of any material, we now know that each atom in itself is like a miniature solar system with a a miniature solar system with a central nucleus, like a sun, and a number of tiny little planets called "electrons" which move in orbits around the central body.

Thee central body in all materials is very large and massive compared with the size of the tiny little planetary electrons. In fact, even in the case of the lightest material, which is hydrogen gas, the central nucleus has a mass about 1,836 times an great as that of the single little planet which moves about it. As we progress through the range of 92 different types of elements, from the lightest to the heaviest, which is uranium, we rind that each one in turn has one additional planetary electron capable of moving around the outside of the central nucleus. The tiny electrons are so small that they are usually considered as having no weight or mass but nevertheless each one represents a basic tiny particle or electron charge and we know that any electrical phenomena takes place it is due to the movement of these tiny little electrons and not to the atoms of material themselves.

Of the 92 elementary substances many have their electrons tightly bound to their own particular nuclei. These substances are known as insulators because the electrons cannot be readily made to move from one atom to the next. On other hand, there are quite a large number of materials in which one or more the outer electrons can be easily detached from its own particular nucleus and made to move progressively from one atom to another through the materials. These materials are known as "conductors" and comprise the various metals, carbon and one or two other substances.

The electrons will not move in great quantities in any direction through a length of conducting material unless there in an electrical pressure applied, to push or suck them along. The electrical pressure is often known as an "electron moving force" or "electromotive force" or simply as a "voltage". The tiny little electrons, although they occur as particles of 92 fundamentally different materials, are in themselves all alike. It is only the number and arrangement of electrons together with the different nuclei in the centre which provide each of the 92 substances with entirely different physical. and chemical characteristics. However, the electrons themselves are all identical and consequently are able to move from atoms of one material, say iron, to another material, say copper, end then perhaps on to a third material which may be silver without the materials themselves changing in any way. Figure 7 gives some idea of the way in which the electrons are enabled to drift around a circuit made up of a number of different conducting materials under the influence of an E.M.F. or voltage.

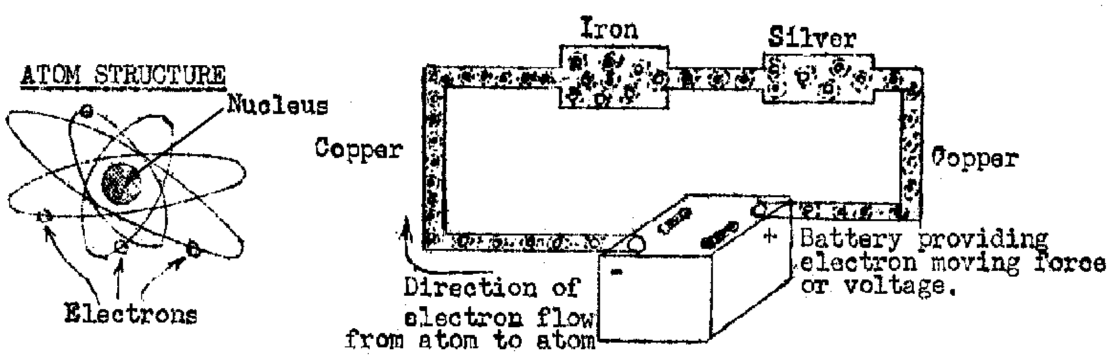


FIGURE 7.

You will notice in the diagram, that we have shown the electrons as moving away from the negative terminal of the battery and towards the positive terminal. This seems completely contradictory to our previous idea of direction of current flow, as illustrated with the electro-plating tank in figure 6.

In practice, we now know that electrons represent individual negative charges of electricity and in electrical work, as with magnetic poles, similar charges repel one on other and dissimilar charges attract, so that the negatively charged electrons are repelled away from the negatively charged terminal of a battery and move around the circuit, travelling from atom to atom throughout the length of conducting materials, until finally they are sucked in by the attraction at the positive terminal of the battery, pumped internally through the battery and recirculated over and over again.

As the electrons move from negative to positive you are doubtless, wondering why the copper appears to move from positive to negative in our illustration of Figure 6. As electrons are identical in all materials and do not have the full properties of copper or of any other metal, on their own, it in obvious that it was not electrons themselves which were responsible for the dissolving of copper at the righthand plate of Figure 6 and the building up of copper at the lefthand plate of Figure 6. Because copper appeared at the lefthand plate it is obvious that what is drifting through the liquid in the tank is actually atoms of copper and not just simply electrons. Had the early scientists been able to see some visible effect of the electrons themselves they would have realised that the electrons are moving from negative to positive but of course due to the very small size of electrons (it would take somewhere about 36,000 million million million million of them to weigh one ounce) it was quite impossible for then to directly see the electrons moving and consequently they could. not tell which way the electrons themselves were flowing.

The reason the copper moved from the positive to the negative side of the circuit in Figure 6 is that each time an electron is torn away from an atom, in order to move on through the circuit it momentarily leaves the atom with a slight positive charge. Each of the atoms in the liquid is at times left momentarily with this slight positive charge and the positive charge is repelled by the positive terminal of the circuit and attracted towards the negative terminal so the atoms of copper are gradually made to drift, through the liquid to deposit on the negative terminal on the lefthand side of, Figure 6.

This drift physical matter from positive to negative can only really take place in the case of liquids or gases. In solid materials such as wires, switch contacts, coils and metal frames, the atoms are so rigidly fixed in place that they cannot more, but this does not stop the electrons from moving inside the atoms from one atom, to another progressively around the circuit.

Because of the earlier ideas of current flowing, from positive to negative people these days still often refer to the tern current as moving from positive to negative, but in reality we now know that the underlying force of all electrical actions are the tiny “electrons” moving from negative to positive. Although this seems very contradictory and difficult, do not worry much about it at this stage because it will become much clearer for you later on.

Just as it made little difference in which direction, the belt rotated in the left hand aide of Fiure3 or whether current flowed in a clockwise or electrons in an anticlockwise direction in the two wires at the right hand side of Figure 3, or whether droplets of water moved in a clockwise or anticlockwise direction at the top of Figure 4, so for these early lesson papers, the important thing is to realise that it is the movement of electricity which enables various electrical actions to occur, and for the time being you should not worry very much about which direction the electricity actually moves in.

VOLTAGE AND CURRENT

You have heard the tern “electric current” and “electron flow” and everyone speaks familiarly about “voltage”. You should know exactly what these terms mean. We can again compare electricity with water to make things clear. Look at a water tap or faucet in any plumbing system, You know that. there is water pressure at the back of that tap and you know that opening the tap will allow that pressure to cause flow of water. Were we talk of electricity the pressure would be the voltage and is measured in a unit called the volt. Water pressure is sometimes called “head” or simply pressure and is generally measured in pounds to the square inch.

Movement of water is often called a current of water and is measured as a rate of flow in gallons per second or gallons per minute. Movement of electricity in wires is called electric current and its rate of flow is measured in a unit called the “ampere”. An ampere of electricity actually consists of a little over 6 million million million electrons passing any point in a circuit in one second. The one word “ampere” takes into account both quantity and time so that we don’t ever say amperes per second or anything like that. Amperage is not a measure of quantity, it is a measure of rate of flow. It does not correspond gallons in hydraulic measurements, but as it takes into account both quantity (electrons) and time(seconds) it corresponds to gallons per minute or second.

In the water system, with the tap shut off there was pressure, but no current of water. Similarly in the electric circuit, with the current shut off by a switch, there is still electric pressure or voltage but there is no current or amperage, (Fig. 8). You may have electric pressure without current, but in no ordinary circuit can you have a current flow without voltage or pressure to produce it, by pushing the electrons around the circuit, remember this and a lot of your work will be easier.

Now here’s something else of importance. Electric current and electric voltage don’t mean the same thing and they don’t measure similar properties of electricity. The question has been asked “How many volts ate there in one ampere?” That amounts to saying “How many pounds per square inch are there in one gallon per minute?” Ridiculous of course. From now on when we speak of volts or voltage remember that we mean electrical pressure or driving force, nothing more. And when, we speak or electric current remember that we mean flow of electricity as measured in amperes and nothing else.

There's nothing wrong in speaking of a "high voltage current" or of a "low voltage current" just so long as you know exactly what you are saying. The first would mean an electric current forced along by a high pressure or voltage and the second would mean a current forced along by a lower voltage. In the following lessons you will learn a lot more about the electric current, but you can't go on with this first one until you have clearly in mind the distinction between voltage and current.

ALTERNATING CURRENTS.

In the greater part of this radio worl
you will be dealing with electricity
in the form of "alternating" current,
so called because the voltage and flc
increase and decrease and work firs
in, one direction, then in the other.
The study of alternating current is v
profitable and intensely interesting.

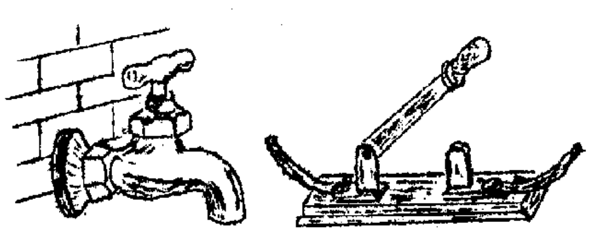


FIGURE 8.

The electricity that comes from a battery is in the form of direct current. This direct, current acts always in the same direction. The things it will do are not nearly so important nor so interesting as the actions of alternating currents and in radio you will find that direct current to of little importance when compared with alternating current.

Once more going back, to a comparison between water and electricity, you realise that all the pipe Fig. 4 is filled with water all the time. In an electric circuit all the wires are filled with electrons all the time. If the wires are separated at some point and a battery connected there, the battery's energy or voltage will push the electrons around through the wires from atom to atom, moving them around through the circuit away from one side of the battery and back into the other side. When electricity is thus moved around through a circuit, always flowing in the one direction, we have a direct current.

Now we, might again take the water piping of Fig, 4 and by means, of a double acting plunger pump, push the water, first one way and then the other as in Fig. 9. The water in one section of piping would sty there end never get around into any other section. It would just move back and. forth in one part of the piping. Since the whole system of piping is completely filled with water, movement back and forth of the water in one section would cause a similar back and forth motion in all the other parts.

An electric circuit, as stated before, is always full of electrons. Now if you make the electrons in one part of the circuit move back and forth or "alternate" you will make the, electrons in all the other parts move in a similar manner and you wilt have an "alternating" current. The electricity in one part or the wiring just moves one way for a little distance, then moves back but never leaves that part of the circuit.

In the direct current circuit, movement of the electricity at any place may be made to do work. In an alternating current circuit, movement of the electricity may likewise be made to do work at any point in the circuit. The moving electricity contains energy whether the movement be always in one direction or alternating back and forth. So you see, it's not really difficult to understand the difference between the action of direct current and the action of alternating current and you can see why we have stressed that the actual direction of movement is not important

The two kinds of current are being explained at the same time because you should understand them equally well. Some of us who went to school a while back learned about direct current first and then took up the study of alternating current or "A.C." So far as radio is concerned that was putting the cart before the horse. In radio we put emphasis on alternating current because that is what is produced in the aerial by the radio wave. In the great majority of modern sets, the sole and only source of power for increasing the signal strength is that taken from the alternating current light and power wires which enter our houses and buildings. In the operation of a radio set it may be necessary to change some of the alternating circuit into direct current - but we always start off with A.C.

In alternating current circuits we will run into many astonishing effects. We can almost always compare electrical effects and actions with other effects and actions of common things that we use in our everyday lives. A comparison of that kind is called an analogy. For example, when we say that a certain action of electricity is illustrated by a similar action of water, we have used analogy

EICTRICAL OPPOSITION

You are going to find conditions under which electricity seems to have inertia. Inertia is that property which makes a thing try to keep on doing just whatever it may be doing at any time. It is inertia that makes it difficult to set a railway car in motion and it is inertia which tends to keep that car going once it is started You will find electric circuits in which it is hard to get the electric current to flow and then, after it is started the current wants to keep on flowing all by itself. Those are the circuits which contain coils of wire.

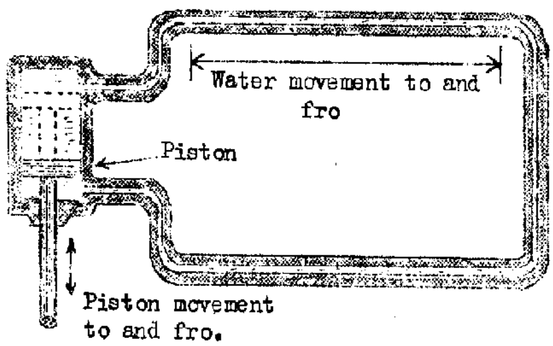


FIGURE 9.

You will find still other circuits containing condensers. A condenser is nothing more than two plates of metal separated or insulated from each other. We can send electricity on to the plate of one of these condensers and it seems to condense there or to remain there.

Alternating current will pass through a coil and will pass through a condenser It does not pass through either of them freely, but meets with considerable opposition in both. We call this opposition "reactance". In a coil we have one kind of reactance, in a condenser we have another kind, but they both oppose the flow of alternating current. Now here is one of the most wonderful effects of alternating current. If you were to take a coil and condenser, as in Fig.10, both of which furnish opposition to the passage of alternating current, you would naturally think that putting them together in a circuit would increase the total opposition, would add the oppositions, or reactances, together. Yet you will find that by taking a given amount of reactance found in a coil and using with it an exactly equal amount of the kind of reactance found in a condenser, the two will cancel and you apparently will have no reactance at all in the circuit. The alternating current will appear to go through that circuit just as though neither the coil nor the condenser were there at all.

FREQUENCY.

While we're talking about alternating current we might as well go a little further. You were told that such a current goes first in one direction and then in the other direction through a wire - that's why it is called "alternating". In ordinary house wiring circuits it goes in one direction for one hundredth part of one second, reverses and goes the opposite way for one hundredth part of a second. The number of complete reversals or cycles in one second is called the "frequency" of the current. If a certain current makes a complete change twenty-five times a second and another current makes the change fifty times in a second, the latter current makes its change more frequently than the former and we say it has higher frequency.

Current at frequencies such as twenty-five or fifty cycles per second behave quite well, stays where it is put and goes about, its work with little fuss. But in radio we are going to get into some extremely high frequencies. When you listen to a radio station that comes in about the middle of the tuning dial you are getting the effects of an alternating current having a frequency of about one million cycles per second. Remember this means that the current goes in one direction a million times per second.

Look at your watch while the little hand passes the space of one second. Then try to count up to a million. Imagine getting one million changes like the four in Fig. 11 in one tick of a clock.

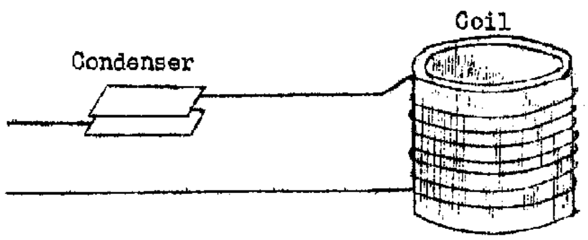


FIGURE 10.

When we get alternating current at such frequencies like this, it does some very astonishing things. Insulating covering such as you find on ordinary electric wiring doesn't mean much to high frequency currents. They fly about through space at their own sweet will. If they're traveling along a wire and come to a corner most of them will turn the corner, but some of them may keep right on in the old direction.

This high frequency current which goes ahead and reveres million times a second is surpassed in radio and television by other currents which alternate their direction hundreds of millions of times a second. Think what that means. These real high frequency currents do things that are still more wonderful. They let men in Australia talk with others in Great Britain, half way around the world. They let men send out a signal in one direction and catch it as it comes from the other direction after having gone right around the earth. It take about one-seventh of second for signal to encircle the globe. They also make possible the modern marvel of Television.

WAVE MOTION

We said a transmitter is the apparatus which changes sound into electric waves, while the receiver is the apparatus which changes electric waves back into round. Since we have talked about electric waves or radio waves, we might as well investigate the subject of wave motion right here

Fortunately there, are many common examples of wave motion and you have see a least two of them many times. One example is found in water waves, another is found in a waving field of grain such as you could see any day in late summer.

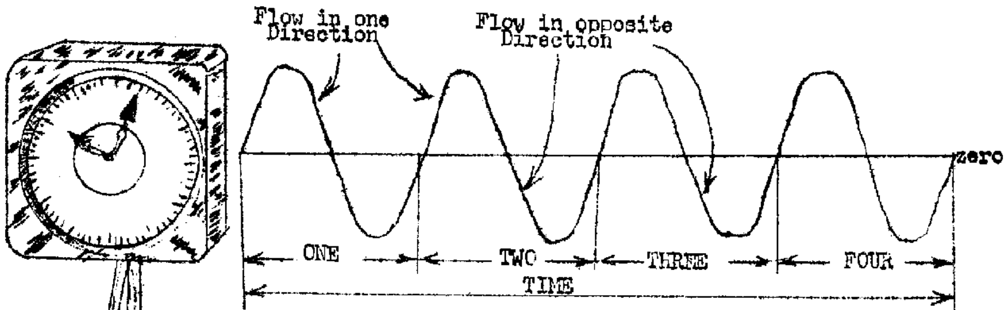


FIGURE 11.

Any "wave" is a disturbance in some substance during a period of time, the disturbance, moving away from the source of the thing which started it.

If you drop a stone into a pool of water a whole series of ring-shaped waves will spread out in all directions at a certain .speed. The wave as a whole appears to move. Yet if you were to place a, cork on the water you would find that the cork moved up on the crests and down into the troughs, but did not travel sideways or get any further away from the point at which you dropped the stone.

If you watch a gust of wind strike a grain field you will see the grain wave in great crests and troughs and the waves will move slowly all the way across the field. Yet you know that when the waves cease you will find every stalk of grain in the same position it occupied before the waves passed. I want you to see that a wave is just a passing disturbance in something or other.

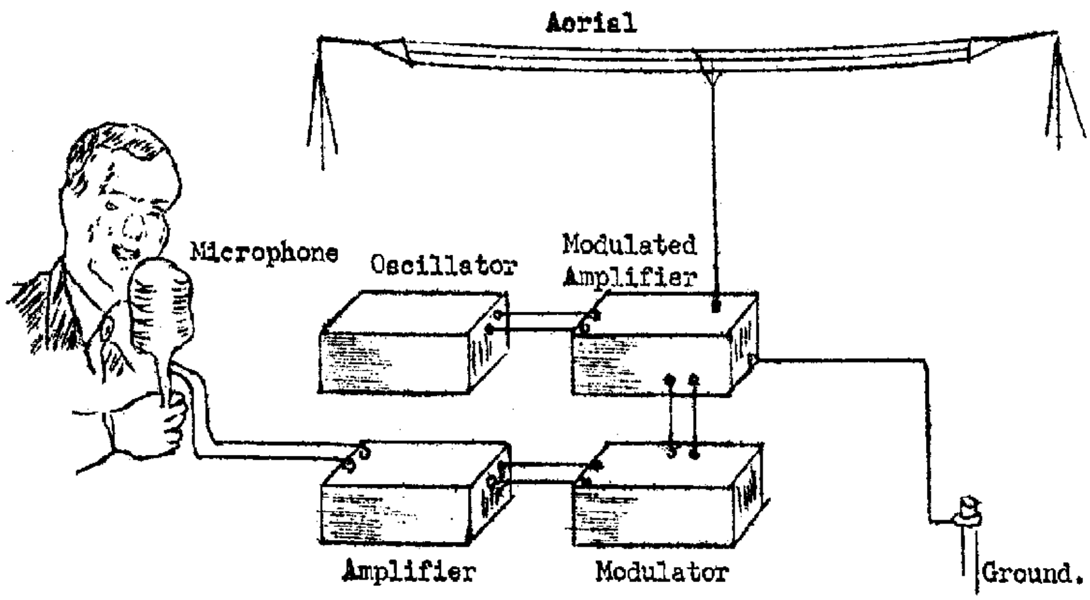
Now if you send up into transmitter's aerial powerful high frequency currents, there will be electric waves or radio waves started off as disturbances.

The disturbance or waves will follow one another out into space at great speed and travel to great distances away from the transmitter

THE TRANSMITTER

Now let's look at some of the parts which enter into a transmitter. All of the main divisions are indicated in Figure 12. First we have a "microphone" which is directly affected by the sounds we desire to transmit and to receive. You probably have in your own home one example of a microphone - the telephone transmitter into which you speak. The microphones used in broadcast stations are much finer types of instruments than the telephone type, yet the underlying principles are much the same. The microphone is a device which causes sound to produce changes in an electric current so that the amount of, current increases and decreases. The next part in the transmitter is an "amplifier", a collection of parts which allows the comparatively feeble microphone currents to control much greater amounts of electrical energy so that from the amplifier we may secure currents carrying considerable energy.

Now we come to two parts of the transmitter which work together. They are cal1ed



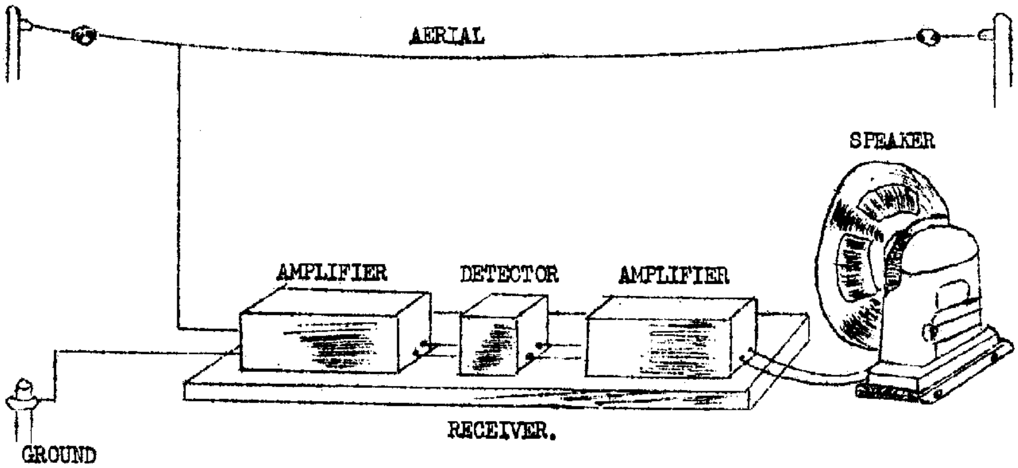
TRANSMITTER.

FIGURE 12.

the "oscillator" and the "modulator". The oscillator consists of radio tubes and other parts which generate or produce alternating currents of very high frequency. The modulator also contains tubes and its function is to take the electric currents from the microphone amplifier and add them to the current from the, oscillator in the modulated amplifier. As a result we have the high frequency oscillator current combined with the other currents which represent the changes in sound that are reaching the microphone.

There may be still more amplifier apparatus to further strengthen the currents and finally the high frequency, oscillations with which have been combined the sound changes are carried into the transmitting aerial where they affect the ether and start the radio waves off toward the receivers which are waiting.

In these few paragraphs we have outlined the functions or purposes of the principal parts of a transmitter. To fill in the gaps and make the descriptions complete will require many lessons further along in the course, but right here we want you to have a fairly complete mental picture of the whole subject. This picture will be of the outlines only but on it we ill build up the whole body of your future knowledge. Much the same process occurs with Television, the television camera which turns light reflected from a subject into corresponding electrical. pulsation taking the place of the microphone in Figure l2.



THE RECEIVER.

FIGURE 13.

We will now assume that the radio waves have left the transmitting aerial, and have reached the aerial of a receiver far away.

Let us see, what parts are needed at the receiving end of our radio system in order to change the radio waves back into sounds, Fig. 13 shows first the aerial consisting of one or more wires placed in space where, they are struck by the radio waves. The waves generate exceedingly small electric voltages in the aerial. The aerial connects to an amplifier quite similar in action to the amplifier used at the transmitter and it increases the signal's power quite a bit.

The third part of cur receiver is called the detector. It is a radio tube operated in such a way that it separates the high frequency currents from the electrical changes that represent the sounds that we desire to hear. You recall that in the transmitter we had a modulator which combined the, sound effect with the high frequency currents and here in the receiver we have a detector which reverse the process and really may be called de-modulator.

Following the detector we will find another amplifier which adds power to the sound signal current and this greater power operates a loudspeaker.

The microphone at the transmitter changed the sound into varying currents and now in the receiver the loudspeaker changes the varying electrical currents back into sound.

SEEING NEW THINGS

You may feel by this time that you have been told so many new things that your mind is fairly muddled and that you don't understand a great deal of what we have been talking about. We don't want you to fee that way. It is necessary for you to have a brief glimpse of the whole matter of electricity and radio, but you are going to find that each thing will be so thoroughly explained in later lessons, that you will have mastered the idea before you are aware of it. Each one of the things taken up in this lesson, and many more which we haven't said anything about, is going to be discussed very, very fully and you are going to see just what the applications are so that you can use them as your tools.

It is going to be necessary for you to learn theory as well as practise because you wont be able to advance without knowing the fundamentals, but you will find that we are going to take up theory in such, easy steps that you are going to learn it without difficulty. You are going to be able to apply it and make money out of it. Were you to learn only about the construction and operation of radio devices, you wouldn't need to do a lot of thinking. This method would only test your ability to remember things - like learning the multiplication tables when you were a little fellow. But when you learn why something happens it is going to start you off on a new mental track many a time. There is no reason at all why you won't discover new things in radio and new or better ways of doing the old things.

An old hand in any branch of science or art has a hard time seeing new things, He has learned to believe that everything has been thought of, that the knowledge he has gained covers the whole field. Anything that can't be explained by the rules he knows just can't be, that's all. He's like the man who saw the elephant for the first time and declared that there ain't no such animal. But you wont feel that some things can't be done - perhaps they can be done, and you can try theme

THE JOB YOU'LL FILL.

Here's a little more advice. For the time being don't attempt to decide just what opening you will fill. As you get into this business it will be only natural that you will like some parts more than others. Now, anyone will agree that a man makes more money and is more successful in work that is a pleasure to him. Therefore, study everything as it comes along and don't make up your mind until you get near, the finish. There are so many specialised applications of electronics that you are sure, to find one which will appeal, particularly to you.

You have started on the road to becoming a radio man. This lesson has just opened door. The next one is the next step on the way. That step is going to give a vision of the broad scope of radio. You should see the whole picture before start, to study the various parts. In the next lesson you will be, told briefly simply of the various steps from the point where music or speech is produced at broadcasting station until it is heard in your loud speaker.

EXAMINATION QUESTIONS – N0. 1.

1. Do we use up the electricity when work is done?

2. Can electrical energy be stored? Explain

3. When electrical pressure is present, must there be electrical current also?

4. Do amperes and volts measure the same thing?

5. What is the name of the unit which measures electrical pressure,?

6. What kind of electric current flows first in one direction, then in the other?

7. What kind flows always in one direction?

8. What kind of electric current has frequency?

9. In what direction do "electrons" move around a circuit, positive to negative or negative to positive?

10. When we use the old fashioned term, "current", in what direction do we generally imagine it as flowing?

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NOTE:- Write on one side of the paper only.
Always write down, in full the question before you answer it.
Answer the questions as fully as you can giving complete explanations and sketches wherever possible.
Remember that you learn by making mistakes; so give yourself an opportunity of having your mistakes found and corrected.
Don't hesitate to ask for further explanations on any point, we are, always ready to help you.

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LESSON NO.2.

FROM TRANSMITTER TO RECEIVER

In this lesson and the one following we will start off with sounds of speech or music going in the at the transmitter and will end with those sounds coming out of a loud speaker at the reviver. This is going to give you a complete birds-eye view of the whole field of radio. I want you to have such a complete picture in your mind that, as you study each separate part, you will know exactly where it fits and how its work affects all the other parts.

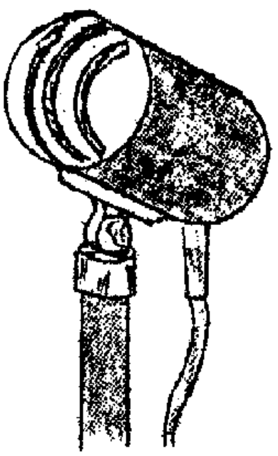
Figure 1.

WHAT WE DO WITH SOUNDS

In the first lesson you leaned that the microphone in a transmitter is quite similar in its action to the telephone in your home. With the microphone we take great precautions to keep vibrations, other than those of the sounds broadcast, from being Transmitted. The microphone is used where-ever possible in a "Sound proof" studio and is supported on sponge rubber. The microphone is so sensitive that it is affected by the slightest noise. While listening at the loud speaker you often will hear the sound of a speaker's breath.

The microphone contains a diaphragm which is caused to vibrate by air movements which represent sounds. Connected to the diaphragm are parts which change their electrical resistance as they are moved by the diaphragm. These parts are carrying an electric current all the time the microphone is in use and the changing resistance makes the current change accordingly. The changing current in the microphone is made to bring about changes of voltage in other circuits and parts, so that we translate the sounds into voltages.

In other types of microphones the movements of the diaphragm cause other parts to move and to generate an alternating voltage. As these voltages are generated by movements caused sound waves they are similar to the sound

sound waves in frequency and in “waveform”. In radio work we often find it convenient to represent. rise and falls of voltage or current which occur as time goes by as a rising and falling line. In Fig. 2 is such line. It shows the changes caused when a speaker utters the sound of the letter “O” as it is used in the word “ton”. The drawing shows the voltage changes during the one two-hundredth part, of a second, These, changes repeat over and over gain as the letter is being sounded.

Alternating voltages or currents, especially those representing radio or television signals, are very frequently represented graphically as in Fig..2. The horizontal line or scale always represents units of time such as seconds or fractions of seconds such as milliseconds or microseconds. A millisecond is one thousandth part of a second and a microsecond is one millionth part of a second. The vertical distance above or below the horizontal line, represents the strength or amplitude. of the Voltage or current

Diagrams such as Fig. 2 are often called “waveform” diagrams as they show the exact way in which the strength of sound waves or radio waves or electrical waves change from moment. to moment of time.

The problem in radio is to take such voltage changes as in Fig. 2, get them through the space between transmitter and receiver, then change them back into sound again. You will grant that the accomplishment of this object is a wonderful thing - one of the most wonderful things in the modern world.

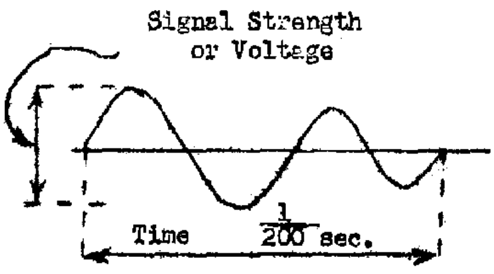

FIG. 2.

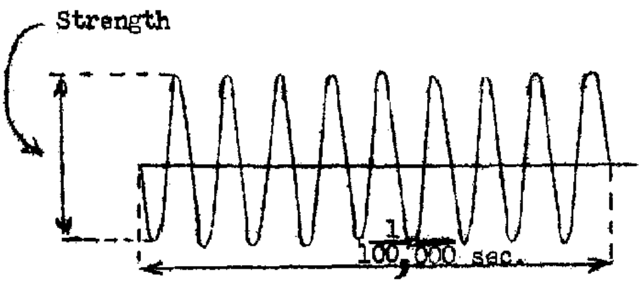

FIG. 3.

<u>THE CARRIER WAVE</u>

The oscillator, about which you were told in the first lesson, is a part of the transmitter which produces alternating current of exceedingly high frequency. You remember that the frequency is the number of complete reversals, or cycles made by the current or voltage in one second. Just as we represented the sound voltages in Fig. 2 by the wavy line, so we will represent the oscillator voltages changes by a line like the one, in Fig. 3 These voltages changes just go up down at a tremendous rate, but they always go up and come down the same distance. These are the voltages that produce the radio waves that leave the transmitters aerial, and fly away into space

“I said the voltage changes are always the same. They remain the same as long as no sounds are being sent out, but in a moment we are going to alter them as the sounds commence to come through. The steady waves produced by voltages like those of Fig 3 make up what we call the transmitter's "Carrier Wave".

Fig. 3 shows ten complete reversals of the alternating current or its voltage. If we were to compare this drawing with the actual frequency of a broadcast station found near the middle of the dial, these ten complete "cycles" would take place in the one-hundred-thousandth (1/100,000) peat of a second.

While on the subject of cycles we want to understand a word which is common in radio language. That word is "Kilocycle". In radio, we frequently have to talk about millions of cycles, and if we did not have this short-cut expression they would sometimes be tongue-twisters. So, we use the term kilocycle to mean one thousand cycles. If we want to say 500,000 cycles, we would usually say 500 kilocycles. You can see that is very much easier.

For high frequency short wave applications, especially in connection with television frequencies of many millions of cycles per second are involved, or describing these frequencies we often use the term megacycle. One megacycle is the same thing as one million cycles

MODULATION

In the process of getting this audio wave ready to leave the transmitter's aerial our next job is that of combining the sound voltages, like those of Fig. 2 with the carrier wave voltages shown by Fig.3.

You can get an idea of how this is done by looking at. Fig. 4. Of course this only shows the general idea of the thing -- do not take all these drawings, for actual complete layouts. In Fig. 4 we have the modulated amplifier handling the carrier frequency the high frequency which produces the carrier wave that travels through space. The modulator is handling the .sound frequencies received from the microphone and acts on the mod. amp. in such a way as to control or, regulate the strength of its output. The output from the mod. amp., controlled in its strength or voltage according to the sounds from the microphone, is fed into the aerial system and is radiated into space as a carrier wave.

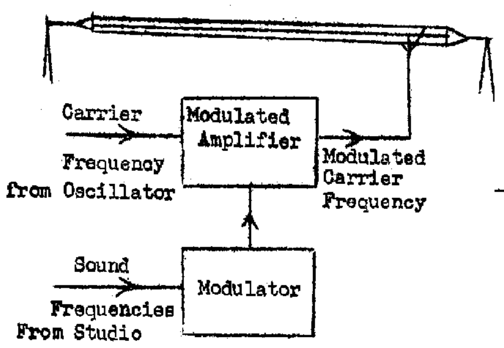

FIG. 4.

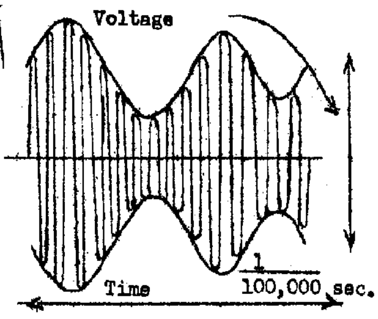

FIG. 5.

The result of combining these two frequencies is this: the rise of sound voltage are added to the voltage of the, carrier and make the carrier voltage higher at that point. The drops of sound voltage then lower the carrier voltage when the sound voltage lowered.

The way the sound voltage combine with the carrier's voltage is shown in Fig. 5. The result is a rise and fall of the carrier voltage. Notice that we have shown the carrier's frequency as remaining unchanged, that it is only the voltage that is altered. Later on you will see how these changes of voltage are made to change the frequency of a different current.

The drawing in Fig. 5 is not very accurate. If we were to compare the carrier frequency of Fig. 3 with the sound frequency change of Fig. 2, you would find that the whole width of the ten cycles in Fig. 3 extend only across the one-five-hundredth part of Fig. 2. To make them actually match and show the true relation of sound changes to carrier frequency, we would have to either divide Fig. 2 into five hundred parts, and use only one of them, or we would have to make Fig. 3 five hundred times as wide as it is Then you would have the real picture. In the actual radio wave there are no such abrupt voltage changes as is indicated in Fig. 5, they are about five hundred times as gradual as this.

The changes of Fig. 5 are, what we call a "Modulated carrier wave". Here, as you can see very plainly, we have both the carrier frequency and the sound frequencies. The gradual rise and fall of voltage represents the sounds sent into the microphone, while the high, frequency part is capable of carrying the disturbance through miles and miles of space. Now we will shoot this modulated carrier up into the aerial of the transmitter and see what happens next.

If the disturbance caused by such a radio wave were to start out from somewhere around Sydney, it would arrive on the exact opposite side of then earth in less than one-fifteenth part of a second. The time required for each change in the wave to reach a receiver anywhere in Australia, would. be a might small fraction of a second. Now we will take it for granted that the wave has reached the aerial of a receiver which you are going to investigate.

CATCHING THE RADIO WAVE

We are going to let the radio wave pass along on an elevated wire, called the receiving aerial, and the earth or ground under the wire. Perhaps it would be better to say that we will put up an aerial where the wave will pass along it, because we do not have to let the wave do anything -- it will do what ever it pleases and we will have to take advantage of its action.

In Fig.. 6 you will Bee these parts as used at a receiver. The aerial is connected to a "lead-in" wire, which, is attached to one end of a coil. The other end of the coil is connected to a "ground-wire" that runs down to a piece of iron or some other conductor of electricity which is buried in the ground.

As the radio wave passes through the space in which the aerial which is erected, the effect of the wave is to first raise the aerials voltage, then lower its voltage. As a general rule we consider that the great mass of earth

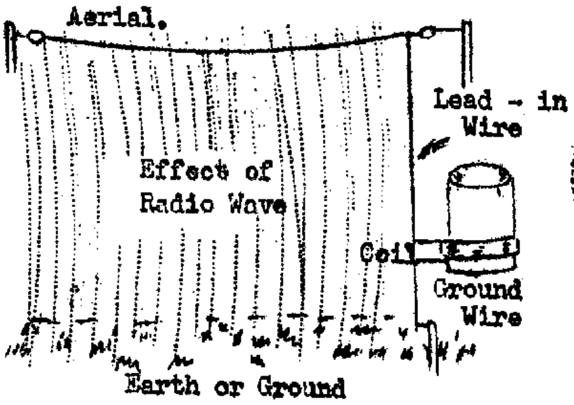

FIGURE 6.

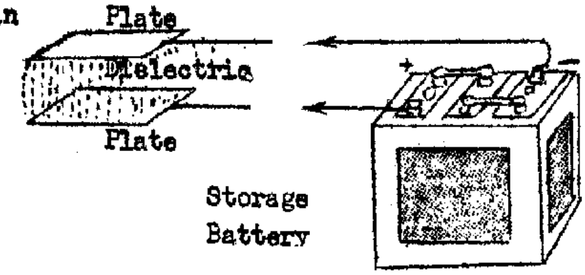

FIGURE 7.

beneath our feet has no voltage at all. Then, when there is electrical pressure, or voltage which could cause a current Of electricity to flow toward the earth, we say that the body or the thing having such pressure is at a "Positive voltage" with respect to the earth. If a body is in such a condition that electric current tending to flow toward it from the earth, then we say it is at a "Negative" voltage with respect to the earth. From this standpoint, voltages that are higher than that of the earth are called positive voltages, while those which are lower than that of the earth are called negative voltage. Of course, we are going into all these things in great detail later on, and we will then consider these actions in terms of "electron" behaviour.

Electrons are minute electrical charges, or "grains" of electricity upon the behaviour of which all electrical phenomena depend. However, until we get around to studying electron characteristics more fully, we will. use the more familiar and conventional, if old fashioned, idea of a current, of electricity which we picture as flowing from a positive point or point of high electrical pressure to a negative point or point of lower electrical pressure or voltage in explanations in these early lessons.

For the time being just remember that the radio wave causes changes of voltage between aerial a earth. First there is a voltage that makes current flow from the aerial down through the coil and to the ground. Then, at the next instant, there is a reversal of voltage and the tendency is for current to flow up into the aerial. Do you see that this gives us an alternating current through the coil?

CONDENSER

For a few moments we Will have to leave the aerial to consider something that was. barely mentioned in the first lesson sheet -- a condenser. There is nothing in all electrical science simpler than a condenser. It is just two metal plates separated by some substance that does not easily permit the flow of electric current. Anything that allows electricity to flow through it easily is called a "Conductor" and, anything which opposes and practically prevents the flow of electricity is called an "insulator". Then we can say that a condenser consists of two conductors insulated from each other. The insulation between the plates or conductors of a condenser is called the dielectric. These parts are shown and named in Fig. 7

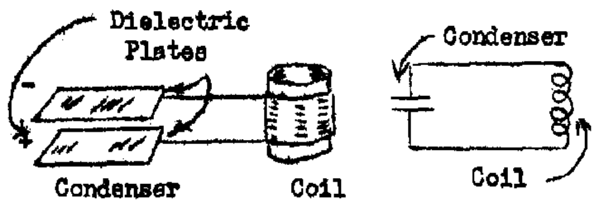

Figure 8.

The condenser of Fig. 7 consists of two flat metal plates with air as the dielectric been them. Over at the right hand side of the drawing is an ordinary electric battery like the one in an automobile. You know that such a battery has two terminals, one marked with a plus (+) sign to indicate that it is positive, and the other marked with a (-) sign to show that it is negative. That means that with those terminals connected together by a wire, the pressure at the positive terminal will be higher than the pressure at the negative terminal and current will flow from positive to negative.

If you were to connect the two terminals of the battery in Fig. 7.to the two plates of the condenser You would not have a flow of current from one side of the battery to the other because, the dielectric of the condenser is an insulator and prevents flow of current through it. Yet, while there would be no continuous flow of current, you would actually change the condition, the electrical condition, of the plates. The top plate would be at a higher pressure than the bottom one. The top plate would, as we say, have a "negative charge" while the bottom plate would have a "Positive charge". You might then remove the battery and the two plates would stay charged.

In Fig. 8 are shown the two "charged" plates connected to a coil of wire. Since the electrical condition of the lower plate is positive and of the upper plate negative, there will be a flow of current through the coil winding from the lower plate to the upper one. Since the condenser plates contain only a little bit, of energy, there will be only a little current flow and then there will not be any voltage difference remaining between the plates.

In radio we have a sort of shorthand system to show the various parts we use. Over at the right hand side Fig. 8 you can see this "Shorthand" for the condenser and the coil. We call these representations of radio parts by the name of "Symbols"

THE AERIAL AS A CONDENSER

In Fig. 9A you will see the receiver's aerial and ground. We said that a condenser consists of two conductors with a dielectric between them. The aerial wire is one conductor, the earth or ground is another conductor and the air between them in a first class dielectric. Therefore, this aerial and ground are, in effect, the same as the two condenser plates shown in Fig, 9C.

We use symbols for everything in radio, so in Fig. 9B you have the corresponding symbols for aerial and a ground, and in Fig. 9D is the symbol for the two plates representing a condenser such as Fig. 9C,

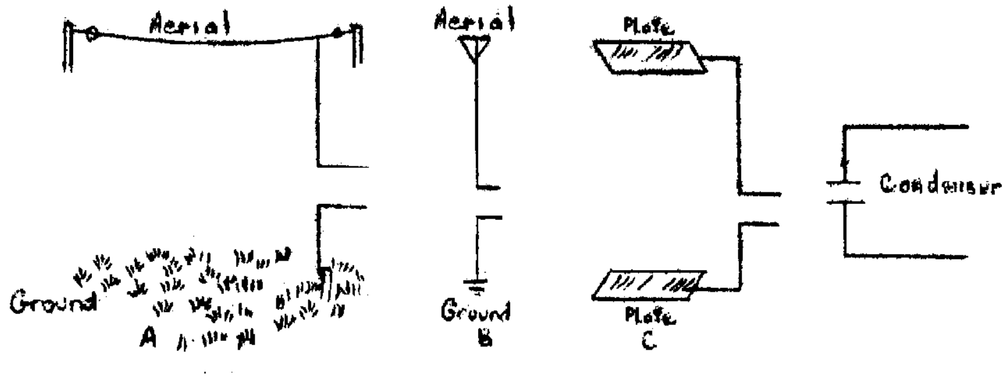

Figure 9

The radio waves passing through the space between aerial and ground, as in Fig. 6, charge the aerial alternately positive and negative. Because such an aerial system when considered in connection with the ground, is electrically similar to a big condenser it is often convenient to think of it as a condenser. The alternating charges on the aerial produce an alternating current in coil connected between aerial and ground as in Fig. 6. store this fact way in your memory for a little while because before long we are going to use something which is produced by this current passing through the coil.

ELECTROMAGNETIC LINES.

At some time or other you have played with a toy horseshoe magnet and have let it pick up nails and other small objects made of iron or steel. If you lay a nail on the table top, as in Fig. 10, and bring such a magnet near it, the nail will finally jump to the magnet and will be held there. Between magnet and nail there is some kind of force at work It is invisible, you cannot see it, but Just the same it is there.

If you were to tie a string around the middle of the nail and hang it up, as in Fig. 11, then bring the magnet near the nail, the nail would swing around and point toward the end of the magnet. Because it is not as difficult to swing the nail around as to pull it across the table top, the action will show up in Fig.. 11 with the magnet much further from the nail than with the arrangement of Fig. 10.

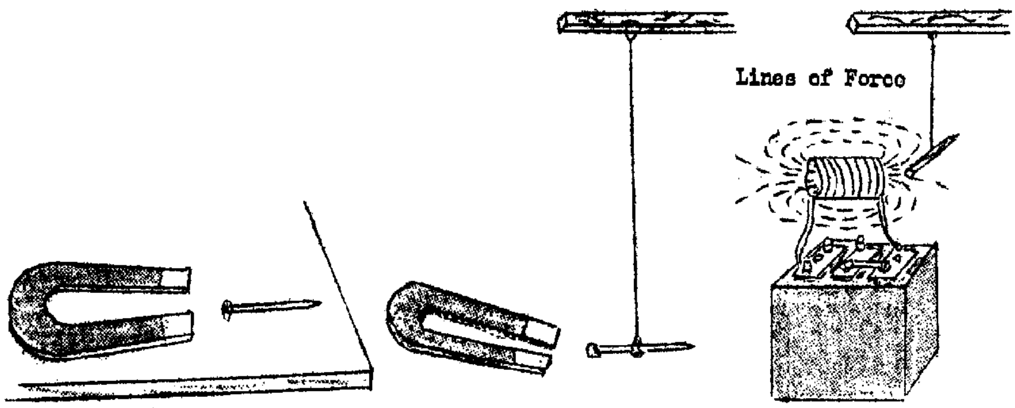

Fig. 10 Fig. 11 Fig. 12

Now you might take some wire and make it into a coil somewhat like the one of Fig. 12. If you then connect the ends of this coil to a battery, current from the battery would flow through the coil. This coil, with current flowing through it, would swing the suspended nail just as the magnet swings it. The same kind of force that exists around the magnet exists also round the coil of wire. We say that this force is a "magnetic field" or an "electromagnetic field" and that it consists of (invisible) "lines of force" as indicated in Fig. 12. The coil of Fig. 12 in called an "electromagnet". The two kinds of fields are exactly similar even though one is produced by permanent steel magnet and the other is produced by an electromagnet that has the properties of a magnet only while current flows through it. The nail sly tries to line up with the linen of force which surround it.

ENERGY

The magnetic field around the coil represents "energy" and the charge upon the plates of a condenser likewise represent energy. But before we go on, you must know a little about this thing energy which will be mentioned many and many a time as we talk about the performance of radio parts.

Energy is the ability to do work. There are a good many forms in which we may have energy. some things have energy, or are able to do work because of their position or shape. The weight on the clock in Fig. 13 has energy (will do work) because it can drop and change position. If you twist a rubber band it has energy because of its shape and it will do work as it untwists. The charges on condenser plates have energy because they will do work as the positive charge and the negative charge come together and neutralise each other.

Other things ham energy because of their motion. The spinning flywheel of Fig. 13 contains energy and will do work if connected to some piece of machinery. A heavy weight thrown through the air contains energy and will do work if it strikes some object. The moving field around a coil contains energy of this general nature.

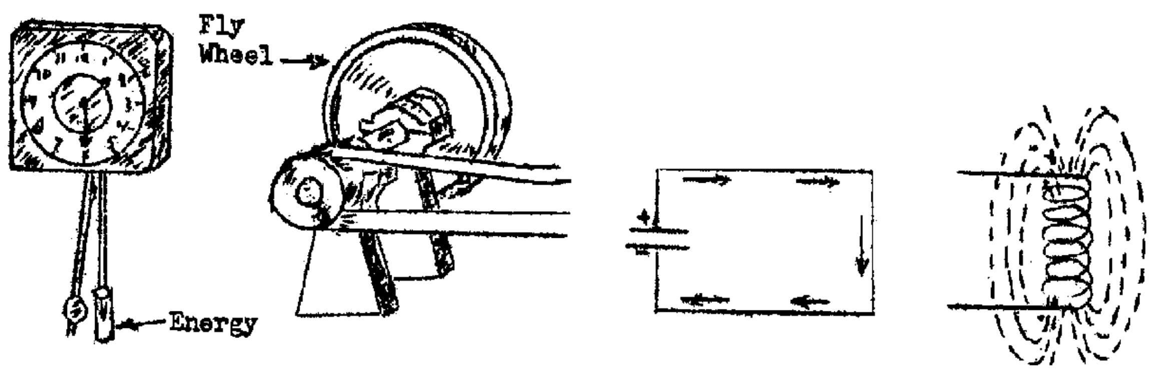

FIGURE 13.

OSCILLATING SYSTEMS

Now we are going to do some things with energy. At the left hand side of Fig. 14 you will see a cross beam, hinged or pivoted at its centre carrying a heavy weight on one end and attached to a coiled spring at the other end. As shown in the left hand drawing, this mechanical system is in balance, the spring is just holding the weight.

Suppose you were to pull the weight down into the position shown in the centre drawing of Fig. 14. This would stretch the spring and it would contain more energy than it contained in the first position. Were you then to let go of the weight the spring would contract and in contracting it would raise the weight as shown in the right hand drawing. In this position the weight contains more energy than it contained in the left hand drawing because it has been raised to a higher position.

FIGURE 14.

Then the weight would tend to drop and in dropping would spring again. So the action would go on, the spring stretching and compressing the weight rising and falling.

With the parts in the positions shown by the centre drawing of Fig. 14, most of the energy of this mechanical system is contained in the stretched spring. Then the spring expends its energy in raising the weight. With the positions shown in the right hand drawing the energy is contained in the elevated weight, which is capable of using its energy to again stretch the spring, The energy oscillates or swings back and forth between the spring and the weight until it finally is used up in overcoming the friction of the moving parts.

OSCILLATING ELECTRIC CURRENT

The most useful arrangement of parts in the whole field of radio is shown in Fig. 15. Look at it carefully. There is nothing more than a coil connected to a condenser. A coil and condenser, connected together, make what is called an oscillating circuit or an "oscillatory circuit". Energy will oscillate back and forth between the coil and condenser until it is finally used up by electrical friction, in other words, by electrical resistance in the conductors used in the circuit and its parts.

The coil and condenser at the left hand side of Fig. 15 contains no energy. Now we will assume that the condenser plates have charged. Then the condenser contains energy. This difference in voltage between the condenser plates will cause current to flow from one plate to the other and in so

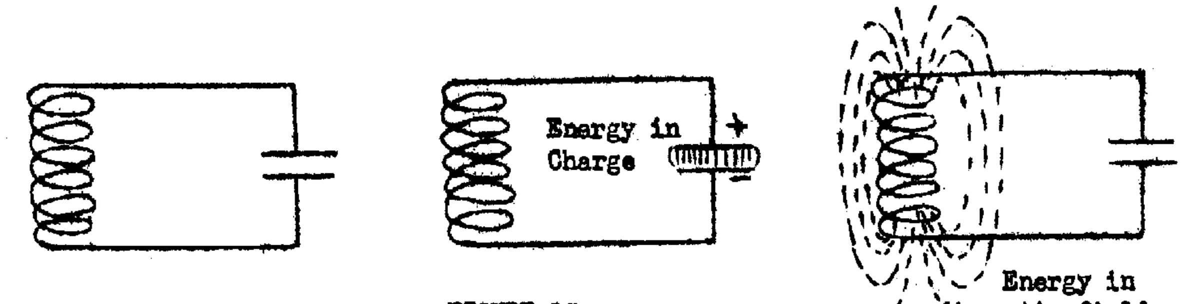

FIGURE 15.

flowing it must pass through the coil.. Whenever current commences to flow through a coil, it rises to the highest value and then falls to zero, there is a rising, and falling magnetic field or a moving field produced around the coil. This field contains energy, low of current from the condenser through the coil will naturally commence at zero, then will quickly rise and will commence to fall again to zero as the voltage difference or electrical pressure between the plates disappears.

The magnetic lines of force which appeared around the coil, due to the current in the coil, will drop back into the coil when the condenser's voltage has been "discharged" and is no longer able to keep the current flowing. As the lines of force drop back through the turns of the coil they generate a voltage in the coil, winding. This voltage produced in the coil causes the flow of current to keep going in the same direction, until the energy, represented by the magnetic field has been all transferred to the condenser as a new charge opposite to the original charge. By the time all of the magnetic lines of force have collapsed back through the turns of the coil to its centre, and have disappeared, all of the energy represented by the magnetic field will have been transferred back into the condenser. As there is now no voltage generated in the coils by the collapsing lines of force, there is nothing to hold the new charge in the condenser so this new charge then exerts itself in producing a current back through the coil in the opposite direction to the original current. This new Current again produces lines of force which again generate a voltage, and so the action keeps going until all the original energy has been used up in the resistance of the circuit. So here, in the electrical system, we have electrical energy oscillating or swinging back and forth between the coil and condenser, very much as in Fig. 14 we had mechanical energy changing back and forth.

PRODUCING VOLTAGE

You will be able to answer the question about getting the energy started just as soon you have learned about another big thing in radio. That big thing is called "coupling". It is the action that enables us to get energy from one electrical circuit over into another electrical circuit even when there are no wire connecting the two circuits. together.

When you were being told about the oscillating circuit, it was said that the lines of force dropping back through the wires of the coil produced a voltage in these wires. That statement is correct - such, an action really does take place. We would like to explain it all to you, but we cannot go that deeply into, things in this lesson. A little further along we will dig into all these things and get to the bottom or them but only just a few of the very beginnings can be crowded into these first lesson.

The first time you have a chance, look inside the electric lighting generator on a motor car. Of course, you know that such a generator produces electric voltage which causes a flow of current to light the lamp and charge the battery. Inside the generator you will see a part that turns around or rotates. This part (called the armature) carries a lot of wires. If you look very carefully you will see that the armature rotates between iron pieces around which are wound coils of wire. These iron pieces are electromagnets.

The electromagnets of the generator produce a field of lines of force. The armature wires are moved through this field and this movement of conductors through lines of force produces the voltage. Any conductor moving through any magnetic field will have voltage generated in the conductor. It is the movement between these two, the conductor and the field, that produces voltage.

One single conductor, such as one strand of wire in our generator would have to cut through one hundred million lines of fore in one second to have one volt developed in it. We seldom come across such strong or concentrated magnetic fields but by using many strands or turns of wire and by making the conductor move through the field, or the lines of force move past the conductor in a much shorter time than one second, we can have quite large voltages "induced" in a coil.

It does not make a particle of difference whether the field remains, stationary with the conductor moving, whether the conductor remains stationary, while the field is moved, or whether both the conductor and field move at the same time. In each case, as long as there is relative movement between field and conductor, voltage is generated.

We have not talked about coupling yet. We had to explain ,about producing voltage by movement of conductors and fields before we could commence with the coupling part. Now that we are able to generate a voltage we can go back all the way to the aerial circuit of Fig. 6.

<u>COUPLING</u>

In Fig. 6 we had an aerial on which voltage changes were being produced, by the radio wave. The aerial circuit is shown in symbols in Fig. 16. The changing voltages on the aerial will cause alternating currents in the coil. When the alternating current is changing from one direction to the other, for just an instant there is no flow either way. Then there is no field around the coil because no current is flowing through it.

Then the current will commence to increase and the lines of force will extend out a little way from the coil as shown by the lines, closest around the coil of Fig. 16. e.g. the current increases, the coil's field will finally, extend way out to the position shown by the outer lines. Now notice carefully that there we have a movement of the lines of force.

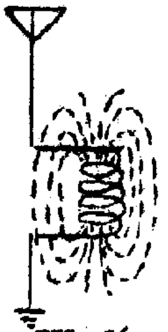

FIG. 16.

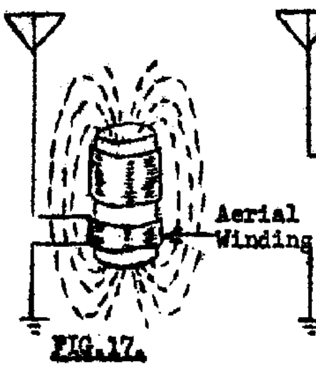

FIG. 17.

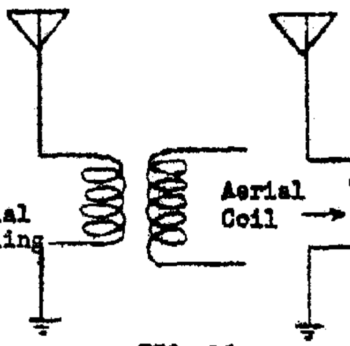

FIG. 18.

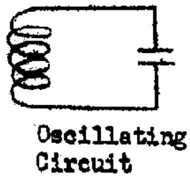

FIG. 19.

In Fig. 17 we have placed the aerial winding from Fig.16 on the bottom of a piece of tubing and on this same tubing have placed a second winding. Now the lines of force produced by the changing current in the aerial wining will pass not only through the aerial winding itself, but also through the other winding as indicated by the line of Fig 17.

The movement of the field of the aerial winding, as this field expands and contracts makes lines of force move through wires or conductors which make up the second coil. You know that movement of lines of force through wires will produce a voltage in those wires. Therefore, a voltage is produced in the second coil. The voltage is a form of energy and will produce flow of current if given a chance. So we have started with energy in the aerial winding and have produced voltage or energy in the second coil. There is no wire connection between the coils, but we say they are "coupled". We are transferring energy from one circuit to another by moans of electromagnetic coupling, by means of electromagnetic line of force. The two coupled circuits or coils of Fig, 17 shown in symbols by Fig. L8. You can see it is a lot easier to draw symbols than to draw pictures.

In. Fig. 19 we have added one more part to the ones shown in Fig. L8. We have put a condenser between the ends of' the second coil, and there you have our oscillatory circuit in which energy will swing back and forth. That is how we get energy into our circuit to start with. We just couple the oscillatory circuit to the aerial circuit, the voltage produced in the second coil will charge the condenser, the condenser will "discharge" through the coil and so the action goes on.

<u>RESISTANCE</u>

In explaining the oscillating mechanical system of Fig. 14 it was stated that the energy would continue to swing back and forth until it was used up in overcoming friction in the moving parts. The spring would give back its energy and the coil would do likewise. Those parts do not use up the energy, they just take it and hold it for while. But the pivot bearing takes energy to overcome its friction and that energy is not given back into either the spring or the weight.

In electrical work we have something which corresponds to friction in mechanics. Electrical friction is called "resistance". Resistance changes electrical energy over into heat. There *are* several devices which make use of this ability of resistance to produce heat. The electric lamp turns electric energy into and light. The electric stove and electric flat iron use electric energy to produce heat energy.

In most radio parts we do not want any more resistance than is absolutely necessary. True, there are a few places where resistance really helps us out in controlling the amount of current which will flow through a circuit. But as a general rule we do not want to waste any of the precious energy in heat, we want to save it *to* produce sound.

Every electrical conductor, every wire, every piece of metal, everything through which electricity flows - all have resistance. All of them use up our electrical energy and change it to heat energy which is of no use to us.

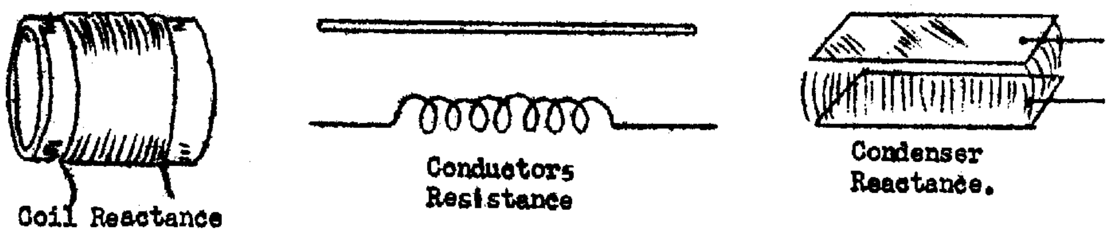

FIGURE 20.

Therefore, in all the circuits we are investigating just now we want as little resistance as we can possibly get. Resistance is reduced by using short connections instead of long ones, by using large wires instead of small ones, and by using material which is a good conductor of electricity.   Copper is the best conducting material that is cheap enough to use for wires and connections.

REACTANCE

In all condensers we have electrical resistance because they are made out of conductors, out of copper wires and other metal parts to carry the current. But in addition to the resistance, these part have another very important electrical quality - they have "reactance" The word itself really tells you its meaning. Parts having reactance are able to re-act. You know what "act" means and you know what the prefix "re-" means about the same as back. So these things act beck. When you twist a spring it reacts by untwisting. When you lift a weight it reacts by falling down again. Remember, as shown in Fig 20, that, coils and condensers have this property of reactance.

I have already explained that energy put into a coil will produce a magnetic field around the coil and this field will then return the energy to the coil. I have also explained that energy put into a condenser produces a charge on the condenser plates and this charge will then give back the energy. These are the actions taking place in Fig. 15.

Even though the coil and condenser will return their energy to us, it requires an effort to get energy into them in the first place. Even though a spring will untwist and return energy, you have to do work to twist the spring to begin with. Even though an elevated weight will do work as it drops, it takes work or energy to elevate it in the beginning. Coils and condensers oppose rise and fall of current through them.

This means that they oppose flow of alternating current through them because of their reactance. The amount of opposition offered to alternating current by a coil or by a condenser is measured in a unit called the “ohm”. We say that a coil has a reactance of certain number of ohms and we say that a condenser has a reactance of a certain number of ohms. So here we have one common measuring stick that applies to the action of both coils and condensers - we can measure both of them in ohms.

BALANCING THE REACTANCES

The next thing we are going to figure out is how to let the tiny amount of energy coming down through the aerial coil of Fig. 19 produce the greatest possible amount of energy to oscillate back and forth in the oscillating circuit coupled to the aerial coil. Of course, you will say that we must reduce the resistance of the oscillating circuit so that. the energy will not disappear in the form of heat. You are exactly right - we will reduce the resistance. That is the first step. Then we will work on the reactance of the coil and the condenser.

If you pull down on the weight in Fig. 14 and then let it go, the spring will make the weight bounce up and down, or, oscillate, at a certain rate of speed -- so many oscillations Per second. Were you to change the amount of weight or were you to change the strength of the spring, the oscillations would be at different rate.

They would be either faster or slower. We get a similar effect in the coil and condenser. For any one size of coil and one size of condenser the electrical oscillations will take place at a certain frequency or at a cretin rate of speed. If you change the size of the coil and use the same condenser, the frequency will be different. If you change the condenser and use the same coil, again the frequency will change.

For each particular frequency there is a right combination of coil and condenser. When you get this right combination it becomes very easy for the electrical energy to oscillate back and forth at that frequency. With the right combination for certain frequency you would find that the reactance of the coil and the reactance of the condenser were alike Then the two reactances balance each other and the result is just as though there were no reactance at all. Then we find the greatest possible flow of current back and forth and we have done everything possible to prevent loss of energy.

To assist the maximum possible flow of current at any particular frequency, we generally use an adjustable or variable condenser or an adjustable coil so that the two reactances can be made exactly equal so as to encourage the strongest oscillations of current. We will see how this is done in the next lesson.

WHAT WE HAVE DONE SO FAR.

Here are the highlights, of this lesson, the things you must remember; we have an alternating current in, the aerial coil. This current produces lines of force which get energy over into an oscillating circuit. The energy swings back and forth between the coil and condenser in the oscillating circuit. This circuit will receive the greatest possible amount of energy when the reactances of the of the coil and condenser are equal and when the resistance is low.

EXAMINATION QUESTIONS -- No.2.

1. What is the name of the instrument in the broadcasting station which changes sound into electrical impulses?

2. What is the name given to 1000 cycles?

3 What kind of electric current flows in the aerial circuit?

4. What is the name of the electrical instrument which consists of two metal plates insulated from each other? What is its purpose?

5. Does the magnetic field around the coil contain energy?

6. what two important electric devices are needed for an oscillating system?

7. How is energy transferred from one oi1 to another which is coupled to it?

8. Does it make any difference whether the lines of force move or one of the coils moves in order to have the lines of force generate voltage?

9. What electrical property is like friction?

10. What in the real meaning of the term “reactance”? What radio parts possess this property?

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LESSON NO.3.

CHANGING ELECTRICITY INTO SOUND.

The energy that comes into your receiver by way of the aerial is so small hat the force of a falling feather would be tremendous in comparison. Yet before we are through with it, the tiny impulse is going to control sounds so loud that they could be heard by a thousand people from one loud speaker.

Now you can see why it is exceedingly necessary to guard every particle of power against loss and why we work so hard to carry every bit of energy through from one receiver part to the next without losing efficiency in between.

SELECTING A FREQUENCY.

In the previous lesson I said, "Notice the carrier's frequency remains unchanged, it is only the voltage that is altered." That is the key to the whole problem of selecting one station to listen to.

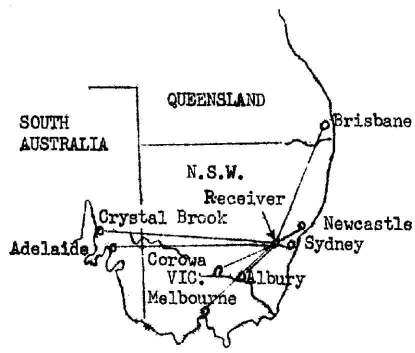

Figure 1.

Suppose you have a receiver located somewhere as shown by the map in Fig.1. There are powerful radio transmitters in Sydney, Brisbane, Melbourne, Adelaide and all those other cities. Right near you is one of the strongest stations - the one in Sydney, Say it is eight o'clock in the evening. Every station is on the air with all its power. How are you going to listen to a programme from Melbourne for half an hour and then change over to a programme from Brisbane, or even choose the one particular programme you wish to hear, from the many Sydney stations.

The only thing that makes radio reception possible under these existing circumstances is the fact that different stations use different frequencies for their carrier waves. A Melbourne station may use a frequency of 800,000 cycles (800 kilocycles) and a Newast1e station may use a frequency of 1,200,000 cycles (1,200 kilocycles) per second. We will now see just how it is possible to se1ect either one and exclude the other

We will make the selection by working with the coil and condensers in the oscillatory circuit.

COIL REACTANCE CHANGES WITH FREQUENCY.

In Fig. 2 you will see three coils. They are exactly alike in every way. If you were to send current at a frequency of 800 kilocycle through such a coil you might find its reactance to be 1000 ohms. Raising the frequency to 1000 kilocycles would raise the reactance to 1250 ohms, and raising the frequency to 1200 kilocycles would raise the reactance to 1500 ohms. Then the reactance of this coil at Melbourne station's frequency would be 1000 ohms and at the Newcastle station's frequency would be 1500 ohms.

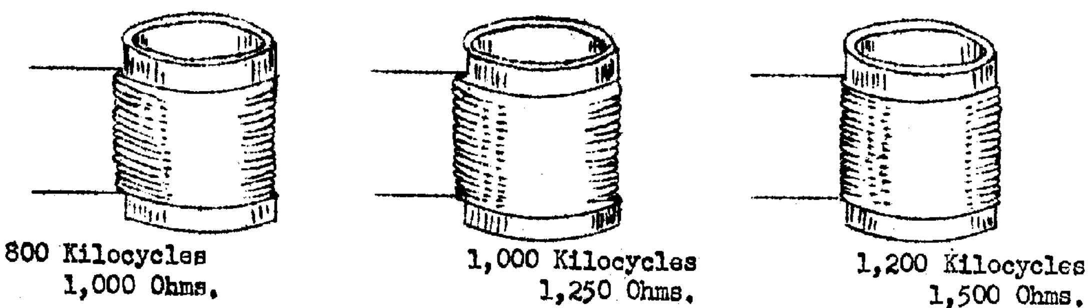

Figure 2.

CHANGING THE CIRCUIT'S REACTANCE.

You saw in Fig. 2 how a coil's reactance changes with frequency. Looking at

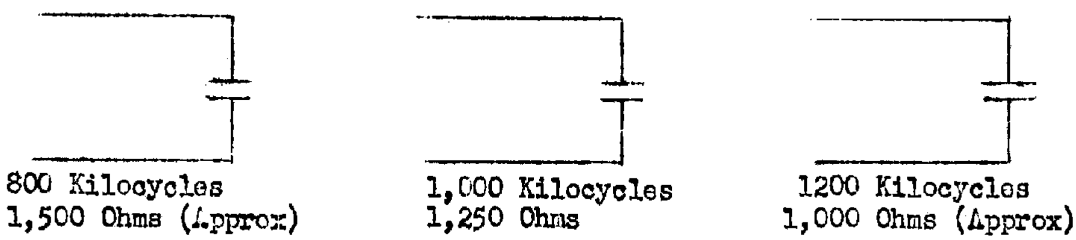

Figure 3.

Fig.3 you will see that a condenser's reactance also changes with frequency. But here is an important difference, The coil's reactance gets greater and greater as the frequency gets greater, but the condenser's reactance works just the other way around. The condenser's reactance, gets smaller and smaller as the frequency increases.

Fig. 3 shows the same condenser working at three different frequencies. At a frequency of 800 kilocycles the reactance is it is 1250 Ohms, and at 1200 kilocycles the reactance is approximate 1000 ohms. Compare these reactance's for the condenser with the reactances for the coil in Fig. 2. Notice that the coils' reactance increases with the frequency and the condenser's reactance decreases with the frequency,

Take a coil just like the one shown in Fig. 2 and connect it with a condenser like one in Fig. 3 which has a reactance of 1250 ohms at a frequency of 1000 kilocycles as in Fig, 4. Now we have an oscillatory circuit. There is the most energy in an oscillatory circuit and the greatest amount of current will flow back and forth between the coil and condenser when their reactances are exactly equal. Now in this circuit at which of the three frequencies will the oscillating current have the greatest amount of energy? At the 1000 kilocycles, of course, because at this frequency the reactance of the coil is exactly the same as the reactance of the condenser and as we saw earlier, would tend to cancel the other.

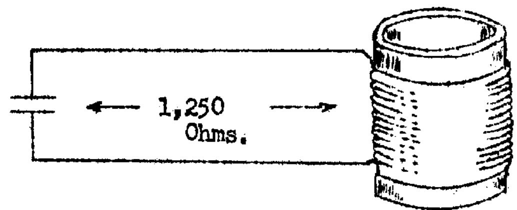

Figure 4.

It would be possible to take a circuit like that in Fig. 4, apply a certain frequency to it and then change the condenser for one that would equal the coil's reactance at this frequency. This would be the circuit's most sensitive frequency. It is the frequency to be received. But you know that we do not reach into our radio receivers change condensers when we are tuning.

What we really do is change the condenser without reaching inside the receiver, without taking out one condenser and putting another in its place. We simply use a variable condenser made something like the one shown in Fig. 5.

This variable condenser consists of a number of plates divided into two sets or groups. All the plates in one group are connected together and all those in the other group are connected together, but the two groups are insulated from each other. This amounts to the same thing a our two plate condensers as you see in Fig. 6.

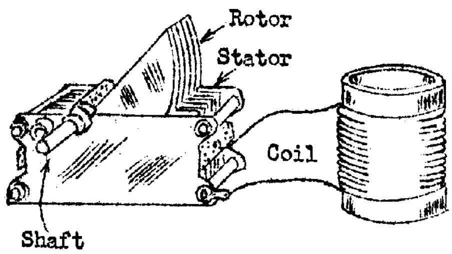

Figure 5.

At the left hand side of Fig. 6 are the two plates of a large condenser. The top plate is marked "A" and the lower one is marked "B". Over at the right we have divided one large "A" plate into three smaller "A"p1ates, all connected together. Similarly we have divided the single large plate into three smaller "B" plates and connected them together.

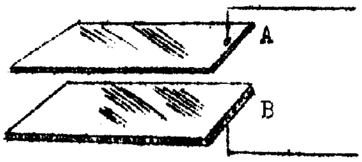

Figure 6.

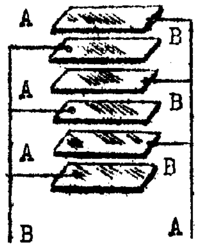

Figure 7.

By sliding the "A" plate out from between the “B” plates we will lessen the effect of the condenser. The further apart the plates are moved the smaller will be the capacity of our condenser. Getting the plate further apart is just the same thing, electrically, as using smaller plates. The variable condenser of Fig. 5 is made so that the plates marked “Rotor” move out from between those marked “Stator” when you turn the shaft. This changes the effective capacity of the condenser and thereby changes its reactance.

The coil ad the variable condenser of Fig. 5 are shown by symbols in Fig. 7. All we have done to show that the condenser is variable, is draw a curved arrow to represent one set of p1ates. The arrow indicates that the condenser's value can be varied while it is in use.

Turning the shaft of the variable condenser so that the condenser's reactance is made equal to the coil’s reactance at the frequency to be received is the operation called “tuning”. The tuning dial on a receiver operates the shaft of the tuning. condensers which move the condenser plates in or out.

RESONANCE.

To the coil shown in Fig 5, we will add or couple, an aerial coil as in Fig.8. The aerial coil catches some of the carrier waves' energy, gets it first, so we call it the “primary” coil or winding. The other coil gets the energy second, so we call it the “secondary” coil or winding. To the secondary winding is connected a variable tuning condenser.

We will say that you want to receive a broadcast station transmitting on a carrier frequency of 1000 kilocycles per second. If the secondary coil of Fig,8 were like the coil of Fig. 2 it would have a reactance of 1250 ohms at this frequency of 1000 kilocycles. Then you would take hold of the shaft of the tuning condenser and turn this shaft slowly until the plates were in such position that the condenser's reactance would be 1250 ohm at the frequency of 1000 kilocycles. Just as the condenser plates Come into the right position you would have the greatest possible energy and current in the secondary circuit. This current would then be at the frequency of 1000 kilocycles.

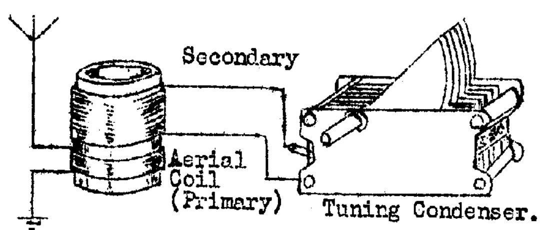

Figure 8.

Now supposing you turn the condenser plates in either direction away from this position. The reactance of the coil and condenser will no longer match for a frequency of 1000 kilocycles and there will be very little current produced in the secondary winding by that frequency.

All this time, the serial and the primary winding are being affected by all the radio waves from all the stations on the air. Look back at Fig. 1, and you will
see what I mean. As you turn the variable condenser's plates you are continually changing the condenser's reactance, and before you turn the plates very far you will find that the coils reactance and the condenser's reactance will again match on another frequency of some other station. Then you would have maximum energy at a new frequency coming from the other station.

When a coil reactance and a condenser's reactance match or are equal to each other for a certain frequency we say that the circuit (coil end condenser) is "resonant" for that frequency. when a circuit is resonant at a given frequency, it will carry the greatest possible current at that frequency. All other different frequencies will then produce vary little, if any current in the circuit.

Now we are able to pick out the carrier wave of any station we wish to hear. All we have to do is tune our osci1ltory circuit to resonance at the desired stations frequency of carrier wave This carrier wave along with its modulations, will come in very strongly, while all the other stations will be so weak that we will not hear them if we have a first class receiver.

WHAT CAN WE HEAR

Vibrations of the air cause our ear drums to vibrate and are distinguished by our brains as sounds. Things. which vibrate at a low frequency or low rate, such as the strings of a bass viol in an orchestra, affect our ears as low pitched sounds, while those at high frequency or high rate of speed affect our ears as high pitched sounds. Very few people can distinguish, as sound, vibrations at a rate or frequency below fifteen per second or higher than a rate of fifteen thousand per second. The frequencies of a1l vibrations between 15 per second and 15,000 per second are called "audio frequencies" because they are audible as sound.

The very lowest frequency at which any Australian broadcast station at present sends out its carrier wave is 540,000 cycles per second - so we do not have a chance of hearing anything at this frequency. What. we have to do is separate the carrier frequency and the modulation which was put on it in the fist lesson. We will save the modulation and listen to it, but will get rid of the carrier.

THE DETECTOR

When you learned about THE modulation of the carrier wave, you were shown the effect in a drawing like Fig. 9. This is a picture showing how the a1terting currents behave in the aeria1 circuit. Our first step in getting rid of the carrier frequency is to cut off or rectify one part of the wave or alternation, leaving an effect like that in Fig. 10.

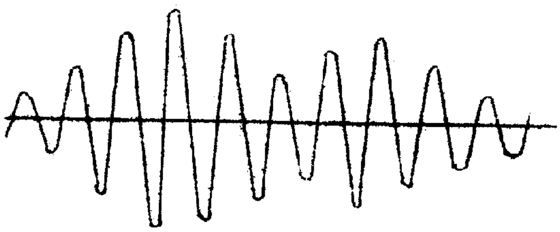

Figure 9.

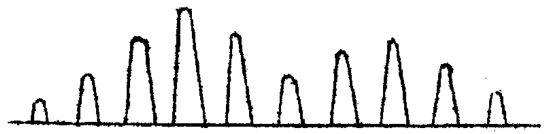

Figure 10.

One of the easiest ways to do this is with a "crystal detector" shownn in Fig. 11. The crystal. a piece of the mineral called galena, is mounted in cup and connected to one wire terminal. Resting lightly on the surface of The crystal is a small, sharp wire point called the "cat whisker". The "cat whisker" is connected to the other wire terminal of the detector. The symbol for a crystal detector is shown to the right in Fig. 11.

Figure 11.

Electric current will flow across the contact between cat whisker and crystal in one direction, but not in the other. Consequently, if the current shown in Fig. 9. is applied to the crystal it will cut off one half of the alternations giving the current the wave form shown in Fig. 10.

The type of crystal detector shown at the left of Fig. 11 is an old fashioned type in which the cat whisker had to be probed on to many spots on the crystal's surface to find a "sensitive" position. The modern type of crystal detector, used in many modern radio and television receivers has permanent contact between the cat whisker and germanium. or silicon crystal and is called a "germanium diode" or "silicon diode".

If you take a whole lot of small current impulses in rapid succession like those of Fig. 10 their average effect will be a gradual rise and fall of current as shown by the broken line in Fig. 12. Taken by itself, this gradual rise and fall look like the line at the bottom of Fig 12, and this is the kind of a rise and fall of voltage we had in the microphone at the transmitter.

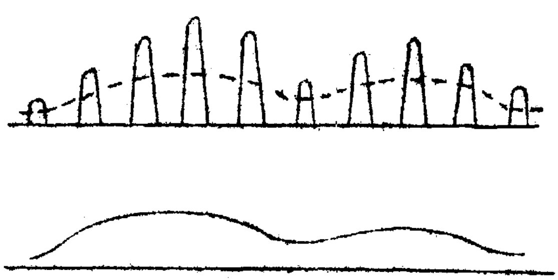

Figure 12.

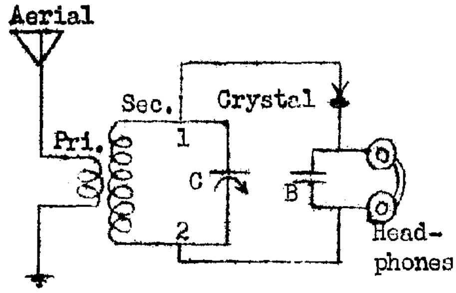

Figure 13.

Now we will take the circuit of Fig.8, change it over into symbols, add a crystal detector and pair of headphones, and we wil1 have Fig. 13. As the current swings back and forth in the oscillatory circuit composed of the secondary winding and the tuning condenser "C", the voltage between these points "1" and "2" rises and fa1ls. The changing voltage between these points will send current through the line containing the cryptal and the headphones. The pulsations of current shown at the top of Fig. 12 are still radio frequency. In order to make use of this pulsating current it must be changed over to a. slowly rising and falling current, like that at the bottom of Fig. 12, representing the audio frequencies or sound. To do this we connect the small "bypass" condenser "B" in Fig. 13, across the headphones. The action of this condenser is like a storage tank - it stores up energy which it receives in the form of pulsations, and allows it to flow out steadily. When a pulsation of current comes through the crystal, some of it goes into the con-denser to charge it up and the rest goes through the headphones. When the current through the crystal stops for an instant this condenser discharges itself by producing a flow of current through the headphones, until another pulsation comes along from the crystal to charge the condenser again. So you see that the condenser allows a steady current through the headphones like that shown at the bottom of Fig. 12, even though it comes in the form of pulsations from the crystal.

PRODUCING SOUNDS.

The inside of a headphone looks somewhat like Fig. 14. Current from the radio circuit flows through the two wires and through the coil which is wound around the small permanent magnet. Between the end of this magnet and the thin, flexible steel diaphragm there is a very small air gap. The permanent magnet always pulls the diaphragm downwards. As more current flows around the coil (during rises of signal voltage) the magnet's strength is changed then as the currant decreases, the magnet's strength is again changed. This changing strength of the magnet changes the pull on the diaphragm with the result that the diaphragm vibrates according to the current and voltage changes described in Fig. 13 Since these are the same kind of changes that came from the transmitter microphone, the headphone reproduces the sounds that are spoken into the microphone many miles away.

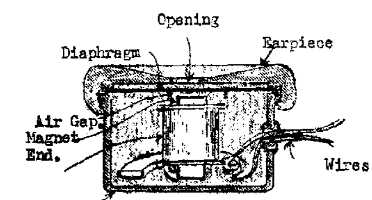

FIGURE 14.

There you have a complete radio system - all the way from the microphone to the headphones - all the way from sound at the transmitting station, through electrical actions back into sound at the headphones.

There is one serious fault to find with the receiver of Fig. 13. It will not produce loud sounds. With the receiver built exactly as shown you could get headphone reception from stations within about twenty-five miles of your receiver. Twenty-five miles is not, far enough and headphones are not loud enough Now we will correct these faults. Firstly, you will realise that the basic requirements of a radio receiver are (1) an aerial system to change passing radio waves into voltages, (2) an oscillatory circuit to select the one lot of signals we wish to hear, (3) a detector of some sort to pick out the audio signals and discard the carrier wave which has finished its job of carrying the audio frequency sounds through apace, and (a) a headphone or similar device to turn the studio frequency signals back into sounds again.

RADIO TUBES.

One of the most wonderful devices ever produced by man is the vacuum tube or valve, used in radio circuits. Before we were able to get and use vacuum tubes in our sets there was comparatively little public interest in radio reception. But since the tube became available you know what has happened.

If you were able to cut open an ordinary radio tube of the simplest kind, the parts would appear as they are shown in Fig. 15. The outside is a glass bulb similar to a tiny electric lamp bulb.

Practically all the air is removed from this bulb, leaving a vacuum. Then, working from the outside towards the inside we first come to a sheath of thin metal which is called the "Plate" . Inside the plate s coil of wire with a lot of apace between its turns. This wire is called the "grid". Inside the grid is a straight or V-shaped wire called the "filament". The plate, the grid and the filament are called the elements of the tube.

Looking down at the top, the three elements are arranged as in Fig. 16; filament wire inside, grid between filament and plate, and the plate outside. The symbol for this kind of radio tube is shown in Fig, 17. Here again you see the grid between the filament and the plate.

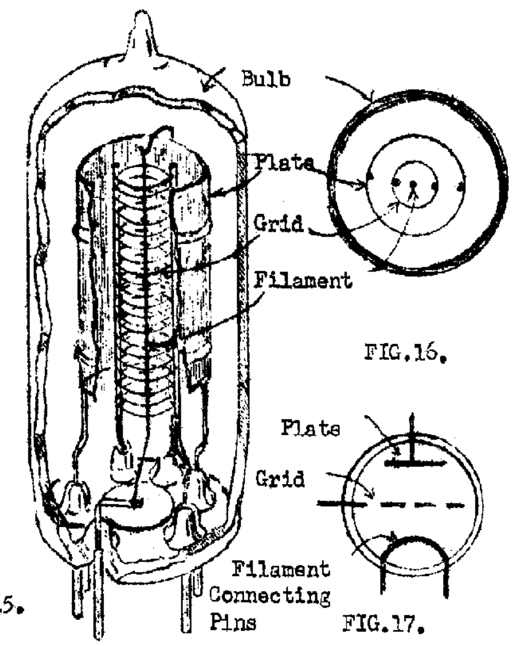

FIG. 15. FIG.16. FIG.17.

THE TUBE AS AN AMPLIFIER

To use one of these radio tubes we connect it up as in Fig. 18. The two ends of the filament are connected to a battery called the "filament battery" or "A" battery. This will make the filament light up and become very hot. Then we connect the plate to a coil and connect the other end of this "plate coil" to the positive side of another battery called the "plate battery" or "B battery".

As explained in Lesson 1, there are always two different ways of thinking about the direction of current flow. The old fashioned idea wan to picture a flow of electric current as something which moved around an electrical circuit from positive to negative.

As a result of professor Thompson's investigations and theories, we now know that actually electrical phenomena are due to the movement of tiny particles called “electrons” which move around the circuit from negative to positive.

It is difficult, at this very early stage in your training, to know whether to describe the action or circuits in terms of the popularly used term “current” which is assumed to flow from positive to negative, or to explain phenomena in terms of “electrons”. As so many people start a course of training such as this with some sort of general knowledge of electricity, those people usually find it more simple, to begin with, to talk about electric current, and to leave discussions concerning electrons until later on in the course. In fact, we will do just this. In our early lessons we will generally talk in terms of current flow and occasionally refer to electrons to keep you familiar with them, but as you proceed into the more advanced lessons you will find that we will concentrate more and more upon electronic action and gradually discard the idea of current flow.

You may say “why not do this right from the beginning?” It is really too big a jump for most people to start right at the outset by dealing only in terms of electrons and flatly contradicting any idea of current flowing from positive to negative. As you read on through this lesson and the remainder, you will find that it is often much simpler to explain some subjects in terms of current flew and others in terms of electron flow and consequently, we will at times use one form of description and other times the other, whichever is more appropriate. This is not bad practice as it will exercise your mind to look at each problem in two different ways, which is just what we have to do in practice because this conventional idea of current, formulated by early scientists, is so firmly impressed in everybody's mind that it is very difficult to just completely discard it and think only in terms of electrons.

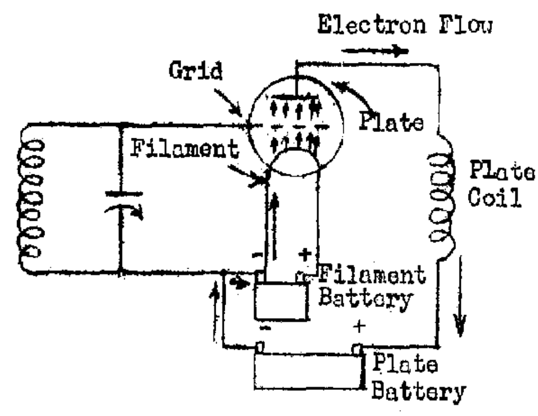

Figure 18.

In Figure 18 we have shown a number Of arrows which indicate the direction of electron flow through the circuit. The application of current from the filament battery to the filament of the valve makes the filament hot and this heat in effect boils electrons out of the atoms of the filament material, thus freeing them in space inside the valve around the filament.. The electrons being negatively charged particles of electricity are attracted by the positive voltage provided by the positive terminal of the plate battery. This positive voltage s across the space inside the valve to the plate and then they move on around the circuit from atom to atom through the plate wire, the wire comprising the plate coil, the wire leading to the battery, and they are pumped internally through the plate battery and pushed out at the negative terminal to replace those electrons which were “emitted” from the filament.

In this way the filament never runs out of electrons but is kept readily supplied by the fact that the plate battery simply acts like a pump sucking electrons in at its positive terminal and pushing them out at the negative terminal to keep them circulating through the valve and through the other parts or the circuit.

The other way of looking at this action is simply to say that the plate battery provides plate current then, because we are talking in terms of "current", we would form a mental picture in our mind of the current starting from The positive terminal of the battery, moving up through the plate coil across to the plate, through the valve to the filament and back to the negative terminal of the battery.

As pointed out In Lesson 1, the real direction does not matter very much as long as we do understand the fact that here is a circulation of electrical charges in the circuit and it does not really matter whether we know for sure whether they travel in a clockwise or anti-clockwise direction. You will see from Figure 18 that whether we Think in terms of electrons moving across from the filament to the plate or in terms of current moving across from the plate to the filament, in either case our electricity has to pass through the grid.

The grid consists of a number or strands of wire with fairly wide spaces in between and the electrons or currant, in passing through these narrow spaces between the grid wires are influenced by whatever electrical charge is supplied to the grid. A positive voltage reaching the grid will increase the number of electrons moving or the value of current, whereas a negative voltage supplied to the grid will reduce the number of electrons moving across the valve, or the current flowing through it.

The grid is connected to one end of the oscillatory circuit in much the same manner as the crystal was connected in Fig, 13. The other end of the oscillatory circuit is connected to the tube's filament. Now the voltage changes produced across the oscillatory circuit act on the grid and filament. First they will make the grid voltage higher than that of the filament, then they will wake the grid voltage lower than that of the filament. In other words, with reference to the filament, the grid becomes alternately positive and negative.

The grid is the more important element in our tube. When the grid becomes positive as in Fig. 19, it helps the electrons leaving the filament to pass cross to the plate, thus making it much easier for plate current to flow. Then as the grid becomes negative as in fig. 20,
it makes it much more difficult for electrons to pass through it and for plate current to flow. As The grid is made positive with reference to the filament, the plate current increases, As the grid is made negative with reference to the filament, the plate current decreases. The grid controls the action of the plate current.

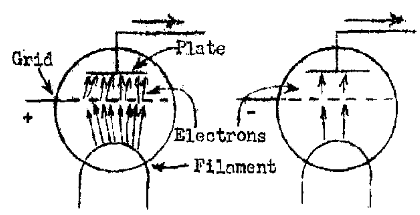

Figure 19. Figure 20.

We will now take our crystal receiver and cut it apart on the broken line of Fig. 21. In between the parts we will connect a vacuum tube as in Figure 22. The voltage changes which were applied to the crystal in Fig, 21 are applied to the tube's grid in Fig. 22. The plate circuit of the tube, or the coil in this circuit is coupled to another coil in a circuit containing the crystal detector and the headphones.

If you were to listen to a certain station on the receiver of Fig. 21, then listen to the same station on the receiver of Fig. 22 you would find the sound from the headphone in Fig. 22 several times as loud as those in the phones of Fig. 21. The tube has “amplified” the signal strength. The increase in strength comes from energy from The plate battery.

A certain voltage applied to the grid of a curtain tube makes itself felt eight times as strongly in the tube’s plate circuit. Such a tube is then said to have an “amplification factor” of eight. Various tube have amplification factors of from three up to over a thousand. That is the number or times They multiply the strength of a signal applied to them. With the circuit or Fig. 22 the voltage’s in the crystal circuit would be eight times as strong as the voltages in the tube’s grid circuit provided the tube had an amplification factor of eight and provided we neither lost or gained voltage in other ways, actually we always lose a certain amount of voltage and the full amplification factor of a tube is realised in practice.

<u>DETECTOR ACTION OF A TUBE</u>.

You probably know that most modern receivers do not make use of crystal detectors. Years ago the crystal detector was displaced by the vacuum tube working as a detector.

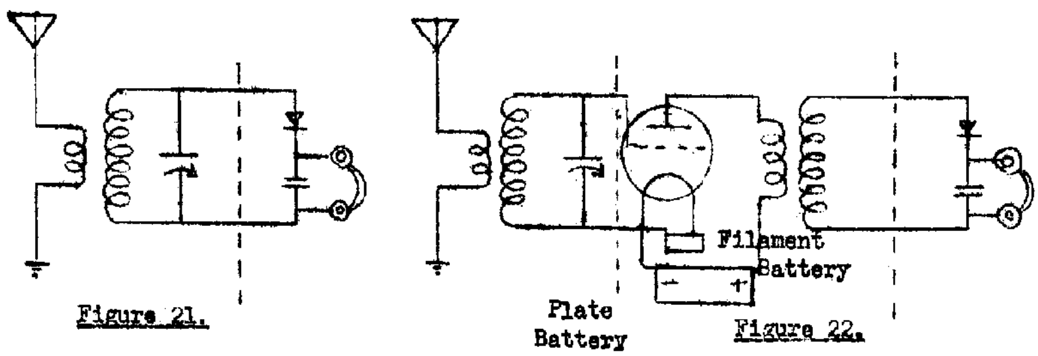

Figure 21. Figure 22.

There is no end to the things such a tube can be made to do and we can use the same identical tube as either as an amplifier or as a detector.

When we use a tube as an amplifier, voltages such as those shown by the curve the on the left hand side of the tube in Fig. 23 will come out of the tube magnified as shown by the curve on the right. The rises and falls of voltage in the amplified signal are exactly similar to the rises and falls before amplification they are greater, that is all. This is The action in an amplifier. In a detector it is different.

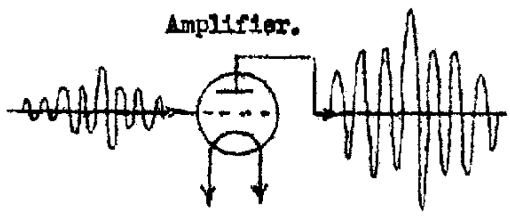

Figure 23

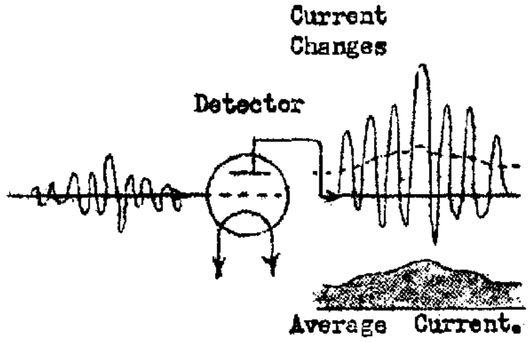

Figure 24.

In explaining Figs. 17 and 18 it was said that increasing the grid's voltage increased the plate current and that decreasing the grid's voltage lowered the plate current. In an amplifier that is exactly true but in a detector we arrange things so that the voltages in the tube's output circuit are not just magnified pictures of the voltages in the input circuit. To use a tube for a detector us may either use a “diode” tube which has just a plate and filament but no grid. A diode tube has exactly he same action as a crystal detector in that it allows current to flow easily in one direction but prevents it flowing in the other direction. most modern radio receivers use diode detectors. Another way of “detecting” signals is to use a tube with a grid and pick such values of plate voltage and grid voltage that increasing the grid voltage will make the plate current increase in proportion - but decreasing the grid voltage will not make the plate current decrease in proportion. We simply fix things so that the plate current can drop only a little, but so that it can still rise an much as the positive grid voltage allows it. Then we get an effect like that in Fig.24. The output current at the right of Fig, 24 is almost the same as in Fig. 12.

Now the increases of current, shown above the horizontal line, are far greater than the decreases of current below this line. The average effect of these current changes, which is produced by the action of the bypass condenser,

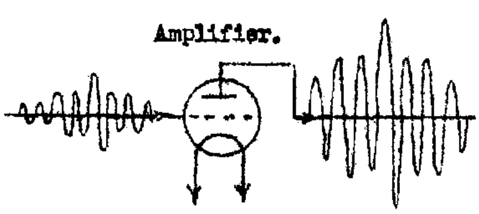

Figure 23

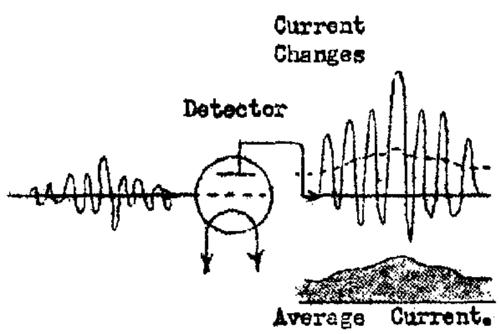

Figure 24.

will be above the line and will be about as indicated by the broken line drawn through the curves. This average current changes in just about the same manner that the voltage changed in the microphone circuit when we were studying the transmitter. So her again we are back with changes that are gradual and that will affect a pair of headphones or a loud speaker.

Again we will take our crystal receiver, as shown in Fig, 25 and this time will remove the crystal detector and substitute for it a vacuum tube detector, This makes the complete receiver look like The arrangement of Fig. 26. Even when used as a detector, the tube does some amplifying at the same time, consequently the sounds from the pones in Fig. 26 will be much louder than those from the phones in Fig. 25.

You will notice in Fig, 26 that we have lettered the filament battery "A"; the plate battery "B" and added another battery. This is merely more of radio's language. We call the battery supplying the filament with electricity the "A" battery; the plate battery, the "B" battery and the grid battery, the "C" battery. You will also notice that we have marked all battery terminals plus (+) or minus (-) in the circuit of the detector tube. The purpose of this "C" battery will be taken up more in detail in a later lesson. We just show it here to make the circuit complete so that you will know where it goes in the tube circuit later on in our lessons on tubes. Notice that we still have a bypass condenser placed immediately after the detector.

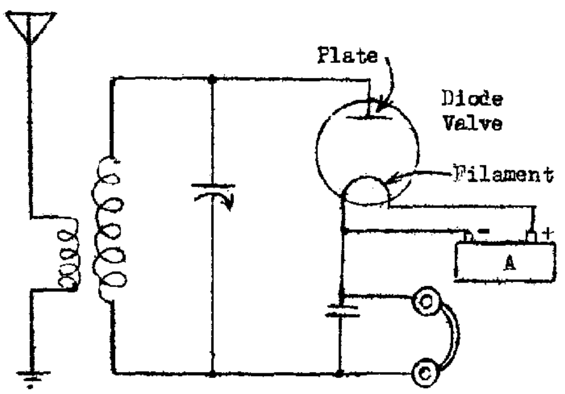

FIG. 27

Only one of the three common ways of using a tube as a detector has been described. This circuit is generally called a "plate rectification" system or else a "grid bias detector" system, because of the manner in which we control the plate and grid vo1tages. There is another circuit which was very popular. It uses a small condenser in the grid circuit and a high resistance connection between the grid and the filament. The second circuit is called a "grid-leak detector" or a "grid rectification" system.

Do not bother learning these names now because we will have more to do with detectors later on.

The third way is to use a simple "diode" tube in the circuit of Fig, 27 which is almost the same as Fig. 25. The diode detector, like the crystal does not amplify at the same time as it detects.

AUDIO FREQUENCY AMPLIFICATION.

You already know that our ears will not respond to vibrations at such high frequencies as come directly from the transmitting station. We have to get rid of these high frequencies and keep only the average rise and fall of current to affect the diaphragm in a head-phone or a loud speaker. The detector only changes the frequency. All the circuits and parts between the aerial and the detector carry the high frequencies of the carrier wave. These frequencies are called "radio frequencies" because they are the frequencies at which the wave is transmitted through space. And as mentioned before, all the audible frequencies are called "audio frequencies." and they are found in the circuits and parts following the detector.

In Fig 22 and again in Fig. 23 the amplifier tube is working in between the aerial and the detector, therefore it is working at radio frequencies. We call a tube in this position a radio frequency amplifying tube. This name refers only to the kind of work the tube is doing, the same tube might be used as a detector or as an amplifier of the audio frequencies. In the latter case we would call it an audio frequency amplifying tube.

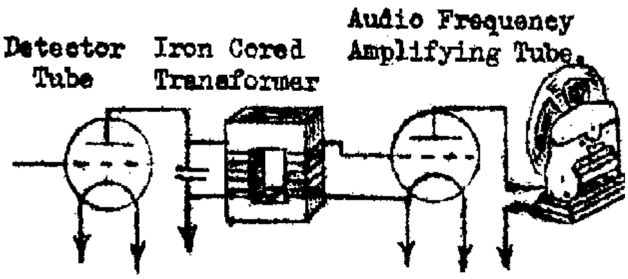

Figure 28.

When we are handling currents at audio frequencies we frequently use the system shown in Fig. 28. Here we couple the plate circuit of the detector tube to the grid circuit of the following amplifying tube through an iron-cored transformer. This transformer has the two windings, plate and grid, or primary and secondary wound upon an iron core.
The currents in the plate circuit magnetise the iron and it then has a very strong magnetic field, a field many times stronger than the field with an air core coupling device like that in Fig.8.

The iron makes a better coupling for a comparatively low audio frequency than we could get with the coil wound on a hollow tube. The audio frequency amplifying tube, working through its iron-core transformer strengthens the signal voltages so that the plate current from the audio tube can operate a loud speaker rather than headphones.

There are other ways of "coupling" audio frequency signals from the detector to the audio amplifier apart from the use of an iron cored transformer. However, we will leave the other methods until later lessons.

<u>A COMPLETE RECEIVER.</u>

Now let us see what we have built up. Our complete radio receiver is shown in Fig. 29 with pictures of all the parts. First we have the aerial and ground connected to the coupler coil with its two windings. The secondary winding is tuned with a variable condenser and this oscillatory circuit is connected to the grid of the radio frequency amplifying tube.

The plate of the radio frequency tube connects to the primary winding of an air-cored transformer. The transformer's secondary winding is tuned with a second variable condenser to provide a second chance of getting rid of unwanted signals, and this oscillatory circuit is then connected to the grid of the detector tube.

The plate of the detector tube connects to the primary winding of the iron-cored transformer with its bypass condenser and the secondary winding of this transformer connects to the grid of the audio frequency amplifying tube. The plate of 9the audio tube connects to the loud speaker. The wires marked "B" all lead to the plate battery.

The filament wires have not been drawn in because They are not important to us now.

When the two tuning condensers are adjusted to make their circuits resonant at the frequency we want to receive what happens? The aerial brings in a very small alternating voltage to the coupler. We will say all the tubes have an amplification

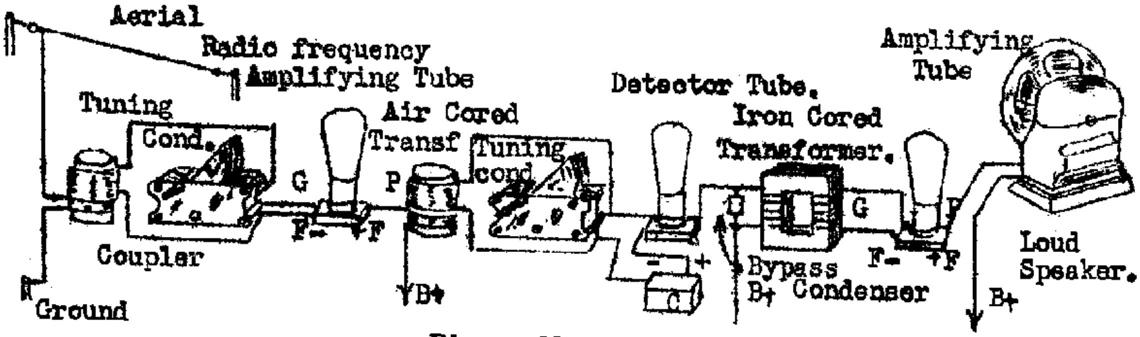

Figure 29.

factor of eight. The radio frequency tube multiplies this signal strength by eight, Then the detector may be assumed to again multiply it by four, and four times eight in thirty two, which represents the amplification so far applied to the signal. The detector really amplifies a little less than an amplifier tube and we say four for its amplification factor just to see what happens. Then the iron-cored audio frequency transformer will give us a little gain in voltage, say three times. So we multiply our figure of thirty-two by three, and get 96 times the original signal strength. Finally, the audio frequency tube again multiplies its input by eight, and we come to the loud speaker with a signal amplified to 768 times the strength in the aerial circuit. We have done this with only three tubes, and you know that many receivers use six or eight tubes, each much more efficient than the simple types we have described hare. Some modern 5 valve sets are capable of multiplying the signal received from the aerial over a million times before it goes to the loudspeaker.

We can show all the parts of Fig. 29 a lot simpler by using symbols as in Fig. 30. This receiver is shown both ways so that you will understand the reason we almost always use symbols to illustrate our radio circuits. Notice the difference between the symbol for an air-cored transformer and the symbol for an iron-cored transformer.

It is important to realise that at the very heart of any radio receiver is a detector. We cannot have a radio receiver without some sort of detector to discard the high frequency carrier wave which has completed its task and pick out from it the lower frequency audible signal which we may hear. Of course, other essentials are some sort of tuning system to enable us to select the one set of signals we wish to listen to and some device such as a loudspeaker or headphones to convert the electrical pulsations back into sound Thus we may again repeat that the circuit of Figure 13 is the simplest basic circuit for a radio receiver.

The performance of a receiver of this type can be considerably improved by providing additional amplifying valves, to boost up weak signals before they reach the detector.

This principally allows the receiver to operate in conjunction with simpler and less efficient aerials or from stations which are situated a greater distance away than is the case with the simple receiver of Figure 13.

If we are dissatisfied with the use of headphones for reproducing the sound, and wish to strengthen them so that they art powerful enough to drive a loudspeaker then it is necessary to introduce audio amplifiers following the detector.

THE FOUNDATION OF YOUR TRAINING

In this lesson and the two before it we have covered the whole field of radio transmission and reception.. We have gone all the way from the microphone in the broadcast station to the speaker in a far away home,

We have paid little attention to details. We have, so to speak, been hitting only the "high spots". You have been given a framework into which you can fit every fact that you get in the lessons to come. Later on, when we talk about a detector, an amplifying tube, a tuning condenser, or any part of the transmitter you will not be wondering just what part that unit plays in radio - you will just fit it into this preliminary outline and will immediately understand its effect on all the other parts and their effect on it.

In these pages you have been studying you often must have thought we were travelling along at a high rate of speed, barely dipping into one subject only to leave it for another. Now you know why we did things that way - so that your structure of radio knowledge would have a secure and complete foundation

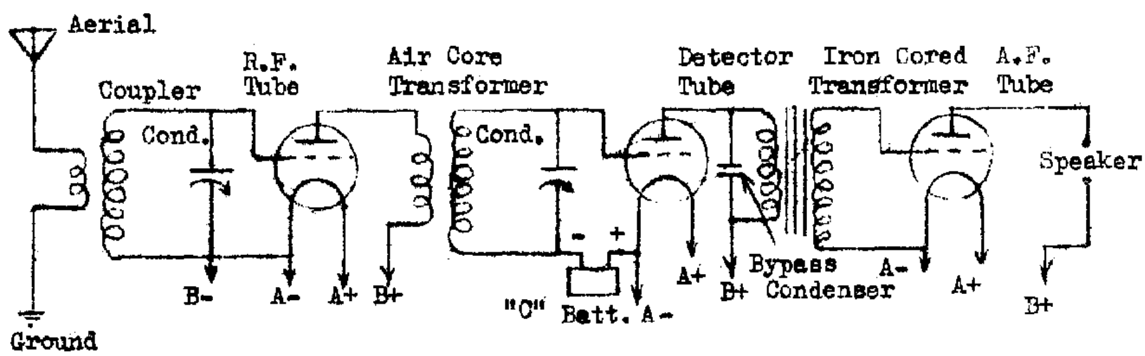

FIGURE 30.

EXAMINATION QUESTIONS - No.3

1. In what unit do we measure reactance?

2. How do you tune a radio receiver?

3. Does condenser's reactance increase or decrease with an increase of frequenqy?

4. what is resonance?

5. Describe the action of a crystal detector.

6. What are the three elements of a radio tube?

7. What does a change in strength of the magnet in a headphone do?

8. To what part of the tube is the A-battery connected? What is its purpose?

9. When The grid of a radio tube is positive, does it increase or decrease the plate current?

10. what is the name of the part between detector and audio amplifying tube in the receiver described in this lesson? What does it consist of?

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Write on one side of the paper only.

Always write down in full the question before you answer it.

Use sketches and diagrams wherever possible. One diagram in many cases is equivalent to pages of explanation.

Remember that you learn by making mistakes; So give yourself an opportunity of having your mistakes found and corrected

Don’t hesitate to ask for further explanation on. any point, we are always ready to help you.

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LESSON NO.4.

ERECTING THE AERIAL

WE are going to assume that you have as your very first job in radio the erection of a first class aerial. This is important work because the performance of the finest receiver that money can buy will be ruined if it is connected to a makeshift aerial.

The sounds which come out of the loud speaker are supposed to be magnified reproductions of whatever the aerial collects from space. A good aerial collects signals that are good to hear, a poor aerial collects more noise than anything else, and some aerials are so very poor that they will not even collect the noises.

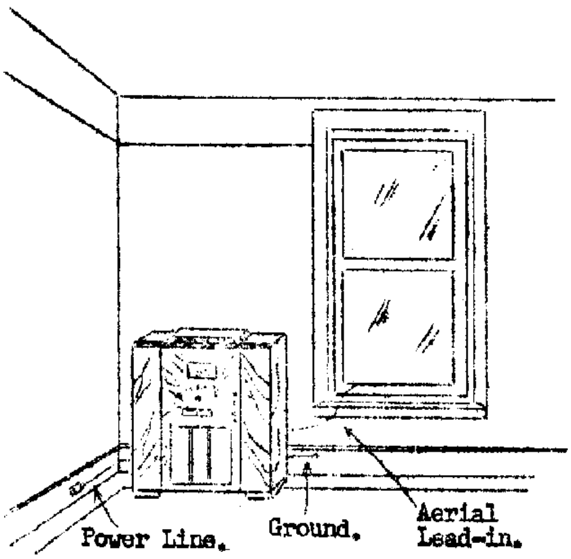


Figure 1.

Supposing you have reached the home or a man who has Just become the proud owner of a modern radio receiver. You are to make the installation for him. Such work is probably one of the most common problems in radio servicing and because it is so common it is often neglected sadly. Handled in almost slovenly fashion. As a result the set owner becomes dissatisfied and critical right in the beginning because the sounds he hears are anything but what the salesman led him to expect.

LOCATING THE AERIAL

Naturally, your very first step will be to decide on the best location for the aerial. Here you must use judgment; weighing the advantages and disadvantages of each possible position, considering the kind of receiver, the personal likes of its owner,

The surroundings of the home and many other things.

The usual type of electric receiver require three connections; one to the aerial, one to the ground and one to the power or light lines for its. electrical supply, as in Fig. 1.

Tine wire connecting the receiver to the aerial is called the "load-in", It must be exceedingly well insulated, securely supported and well spaced from practically all objects along its pathway. As a general rule the lead-in may most conveniently come through frame or ventilator. The set owner may even allow the lead-in to come right through the building wall. The point at which the wire emerges from the building the outside will have a great deal to do with the location of the aerial itself.

The ideal location for an aerial is between the building housing the receiver and some support at a little distance away, as shown in Figure 2. Here the aerial extends right out over the ground with nothing but air between it and the earth.

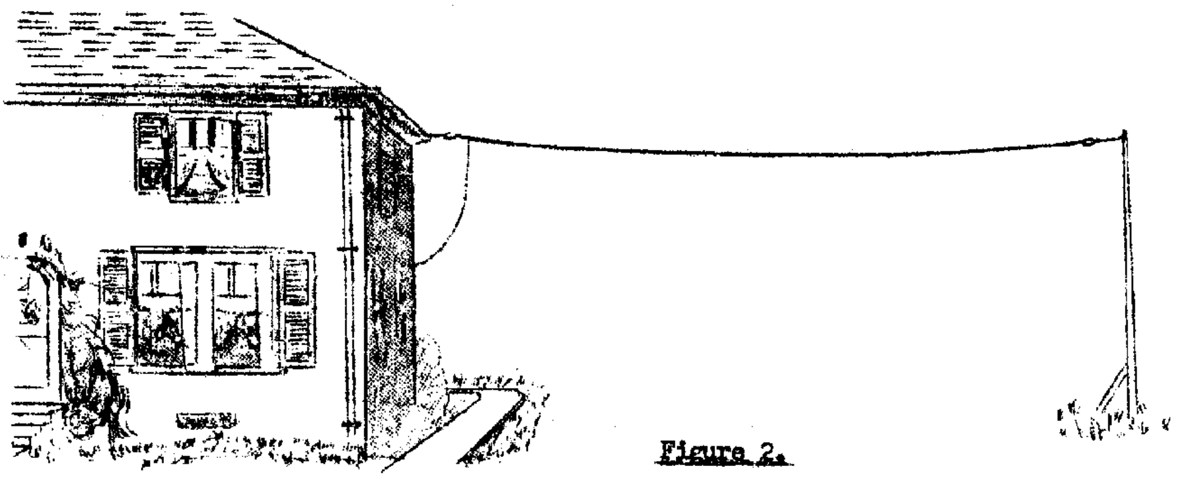


Figure 2.

An aerial or this kind is really a large condenser and between the two plates of a condenser you can't have anything better than air from the standpoint of saving every bit of energy from loss.

Your own knowledge of condensers will tell you that the more miscellaneous objects there are between the plates of this condenser, the poorer the result will be. That just stands to reason. So having placed the receiver inside the home, you go outdoors and look aver the situation - hoping to find a nice clear space over which you can swing the aerial wire.

AERIALS ON ROOFS

In many locations there is not enough clear space around a building to accommodate the aerial. Then you may be forced to choose a location on the roof something like that shown in Fig. 3. Here one wire is strung over the top of the gable to act as an aerial. Such an arrangement is very unsightly. The wire may be partially concealed by running it along the side of the house just under the eaves, This position also being shown in Fig. 3. In a flat roof, like the one shown one in Fig. 4, you can conceal the aerial fairly well.

There is no objection to running the aerial between a building and a tree as in Fig. 5, or between two trees with the lead-in running over to the building. When a tree is used you mat remember that it sways in the breeze and to allow for this movement you must support the aerial at end with a strong coiled spring as shown.

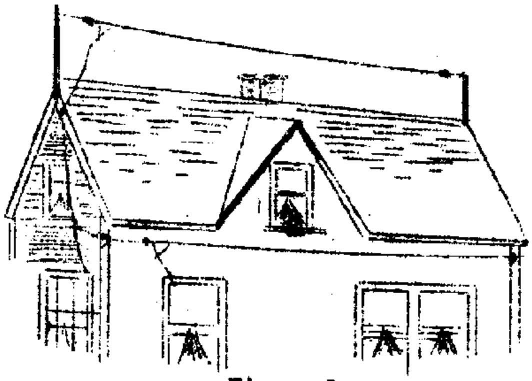


Figure 3.

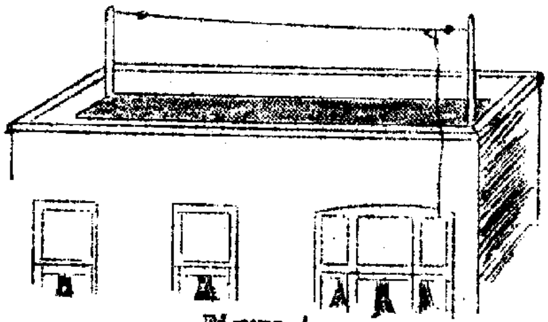


Figure 4.

As you can see in Fig. 6, one end of the spring is attached to a solid support, an aerial insulator is attached on the other end of the spring and the aerial itself is attached to the insulator. Movement may also be taken Up by a weight and pulley arranged as in

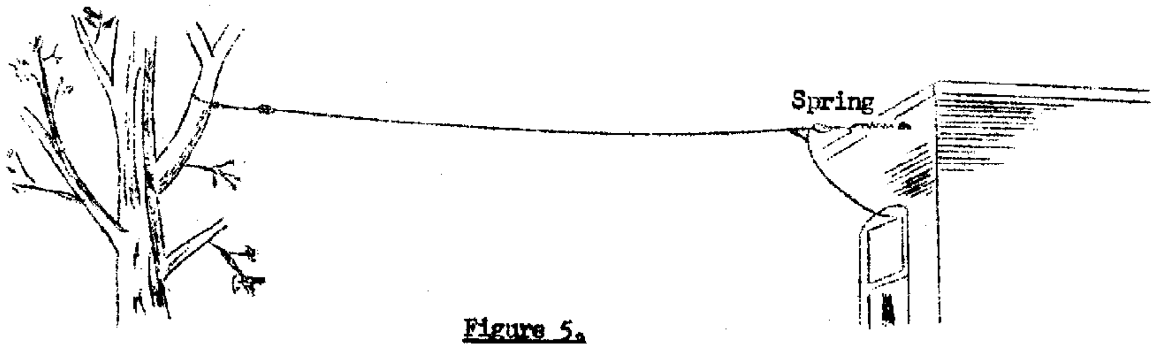


Figure 5.

Fig. 7. The weight will rise and fall as a tree or other moving support sways back and forth. The pulley scheme is not so good because it will squeak with every movement after a little time, and the pulley might jam and cut the wire or rope,

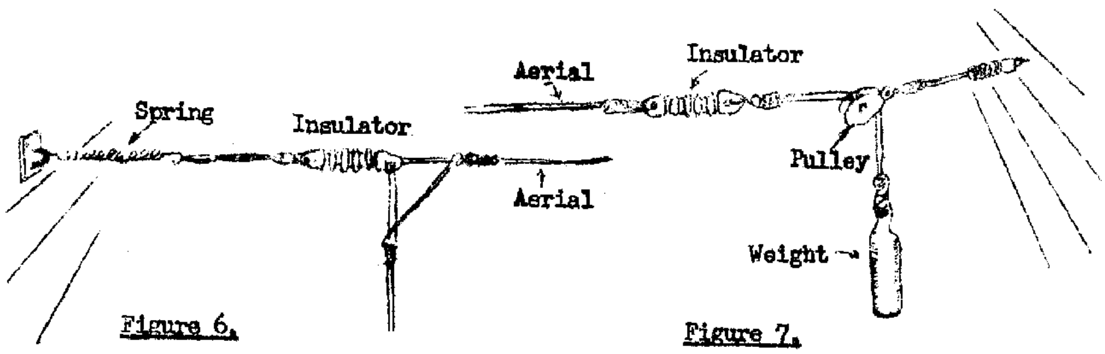


Figure 6. Figure 7.

The previous three pages should not be interpreted as a complete condemnation of the indoor type of aerial. This is so far from our intention because indoor aerials are today undoubtedly in the majority, so far as ordinary radio receivers are concerned. They may also be used, under certain conditions, with television receivers. This apparent paradox obviously needs some explanation and so here it is.

The sound which is herd from the loudspeaker of a radio receiver is a combination of programme material speech or music - and noise. The noise component of the total signal can be classified as noise which is developed within the receiver and noise which reaches the receiver from some external source. External noise may reach the receiver through the power mains or it may be picked up by the aerial-earth installation.

All radio receivers have a certain residual internal noise level due to thermal agitation of electrons in conductors and random emission of electrons from valve filaments and cathodes. Both of these effects produce a steady background hiss quite distinct from the intermittent crackles and scratching noises which may be produced by a fault in some part of the receiver or by external noise signals. Receiver noise is related primarily to the design of the equipment and as there is, generally, little that the serviceman can do to reduce such noise, his major aim should be to ensure that the signals fed to the receiver shall be many times greater than the internal residual noise level.

The strength of the signal fed to the receiver depends upon many factors. Some of the most important of these are the power of the signals radiated from the broadcast station within range of the receiver, the distance between the receiver and transmitters, the geographic location or the receiving equipment, that is, whether it is located at the top of a hill or at the bottom of a valley and the efficiency of the aerial-earth installation The first three factors are, of course, beyond the control of the user of a receiver and whether or not the third one is favourable or not depends upon the person responsible for receiver installation.

If the only signals picked up by a radio receiver's aerial are those actually radiated by the various transmitting stations, aerial installations would present no great problem. However, such desirable conditions rarely exist because invariably there will be some interfering noise signals which will be picked up also with the required radio signals. These noise signals may be due to entirely natural causes such as an accumulation of electrical charges in the atmosphere, or to radiation from power lines and electrical machinery.

The two effects are related in that each is caused by an arc between two points of opposite potential. With natural atmospheric disturbance the spark discharge is manifest in its most violent forms during an electrical storm, it is then visible as lightning and audible as severe intermittent crackling from the loud-speaker of a radio receiver. One can do nothing towards alleviating noise due to natural atmospheric without impairing the quality of received programme material.

Noise due to “man-made” disturbances commonly emanates from certain types of electric motors due to sparking between brushes and commutator, faulty switches in industrial or household electrical installations or thermostats in refrigerators or household electrical irons. All those devices can create what is, in effect, a miniature lightning flash, the audible result of which is much the same noise created by the natural lightning flash. Like the natural static discharge the spark causes radio frequency energy to be radiated either directly from the point where the arc occurs or from the power mains wires to which the equipment is connected. The greater part of the interfering noise is due to the latter effect.

In the case of a good outdoor aerial installation erected well in the clear, away from, and preferably at right angles to, overhead power lines and with as much height as possible, very little of this “man-made” interference is picked up by the horizontal section of the aerial and so a favourably high signal to noise ratio is likely to result, except when the level of atmospheric disturbance is high. There can be no doubt then that a good outdoor aerial will always provide the best signal to noise ratio. However, erection of an outdoor aerial of adequate height and length is not always possible, particularly in congested metropolitan and suburban areas. The flat-dweller is at a particular disadvantage in this regard, although, at first sight, it may seem that he would actually have an advantage over people forced to use an aerial little above ground level because an aerial erected on the roof of a tall building, such as a modern block of flats, has apparently satisfied one cardinal specification for a satisfactory aerial installation, namely, height. The aerial would certainly have considerable height in relation to the surface of the earth, perhaps in excess of 100 feet, but this does not necessarily make the installation a good one because the electrical or effective height of the aerial may be no more than a few feet. Why?

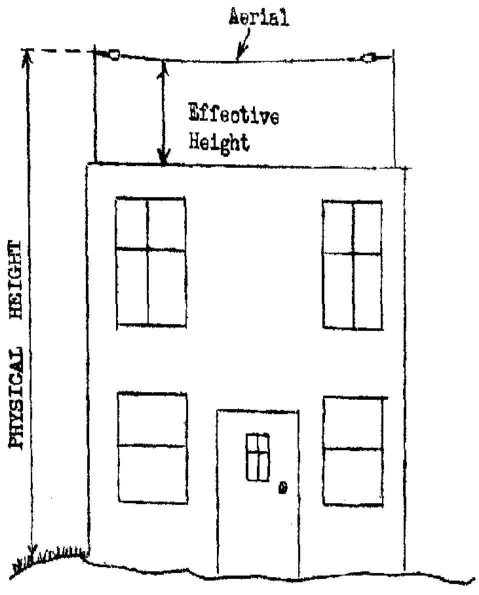


FIGURE 8.

The height of an aerial corresponds to the distance between the plates of condenser. One plate is the aerial wire, the other plate is the ground. In Figure 8 the ground is, in an effect, carried right up to the roof of the building because of the metal reinforcement which is characteristic of many. modern buildings. The actual ground in the earth is connected to the roof by the metal girders which form the framework of the building. Therefore, considered electrically, the roof is the ground so far as the aerial is concerned. The physical height of the aerial is its distance up in the air above the earth's surface. The effective height -the height that really counts - is the aerial's distance above the nearest conductor that is connected to ground, in This case the roof.

if there is a tree under an aerial the effective height is lowered because the moisture in the tree makes it a fairly good conductor and it raises the electrical ground up towards the aerial. Any other conducting materials or objects under the aerial have a similar effect.

In congested areas, therefore, there is little point in relying upon an outdoor aerial which trust, of necessity, be limited in length and height, It is for this reason that one rarely sees an outdoor aerial for broadcast reception in city and suburban locations. An indoor type of aerial is by far the most commonly used. One can be certain that the signal to noise ratio will be no worse than with an inefficient outdoor aerial. It may, in fact, be slightly better,

The degree of electrical noise picked up by an indoor aerial is likely to be greater than that received by a highly efficient outdoor aerial, because the indoor aerial must invariably be run near to electrical wiring within a house. It will, as a consequence, more readily be affected by interfering noises radiated by the electric wiring. However, so strong is the signal radiated by most present day broadcast stations that the ratio of signal to noise is still perfectly satisfactory in all but highly industrialised areas whore the considerable amount of electrical machinery used may create an excessively high noise level. The major points to be observed when installing an indoor aerial are discussed in the next lesson.

THE GROUND CONNECTION

It was mentioned earlier that a radio receiver's aerial acts as one plate of a condenser with the ground as the second plate, Although this statement was originally made in reference to an outdoor aerial, it is equally true with aerials of the in-door type and so one should take just as much care with the ground connection when an indoor aerial is used as when we are installing one of the outdoor types. The Standards Association Wiring Rules specify “Permanent earthing conductors shall be of stranded copper and shall not be smaller than 7/.029” diameter”(which means 7 strands of No, 22 gauge copper). There shall be insulated cables, the insulation being 600 megohm grade.” As indicated above, this specification applies whatever type of aerial is used.

KINDS 0F GROUNDS.

The ground which you really desire to reach as directly as possible is permanently moist earth. Your ground connection must attach to some good conductor, usually a piece of metal, that runs down into such moist earth. The most convenient ground connection in most buildings is a cold water pipe coming in from the water mains. Within practical limits there is no better ground than such a water pipe. Your connection should be made to the pipe as near as possible to its entrance into the building.

All kinds of pipe joints introduce more or less resistance - the reason for making the connection close to the street service pipe is to keep on the right side of joints. A connection made to hot water pipes, gas pipes or drain pipes often will prove quite unsatisfactory because there are too many joints before any conducting path reaches moist earth.

Should The building have no water service from supply mains you can make a good ground connection by dropping a copper wire down into a well or into the bed of a stream or any body of water. Failing to find any easily reached body of water, you will have to drive a pipe down into the earth and drive it deep enough to reach moisture.

IRON PIPE GROUNDS

Permanently moist earth may be found at any depth between one foot and eight feet below the surface. Nothing will be gained by driving the lower end of the pipe down further than the point at which it reaches moisture. On the other hand, it is necessary that you get the pipe down as far as the permanent moisture or you won't have a good ground during dry weather.

There is no easy way of knowing how deep to drive a pipe. For a good job in ordinary locations you can use a galvanised pipe about six feet long and drive it down until only about six inches remain above ground. This isn't such a hard Job because you don't need to use a large pipe. If the ground is fairly soft and contains but a few rocks, a pipe three-quarters of an inch in inside diameter is strong enough. Iron pipe is always specified by its inside diameter. To prevent splitting the top of the pipe, have the end threaded and screw a coupling or a cap on as far as

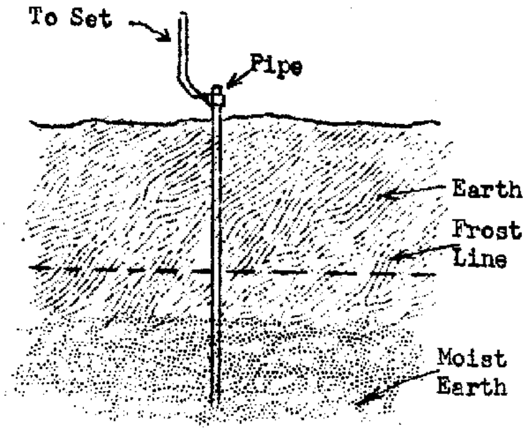


FIGURE 9.

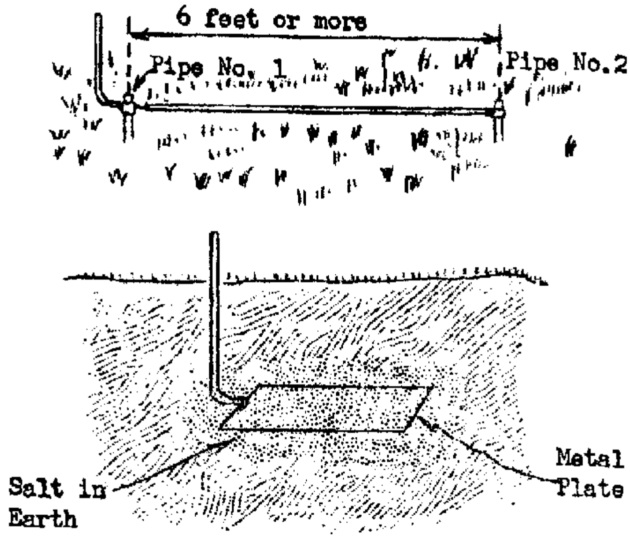


FIGURE 10.

it will go. Any *size* pipe is good enough as an electrical conductor. Nothing will be gained by running a copper wire down inside the pipe.

In addition to going down to permanently moist earth as indicated in Figure 9, your ground pipe must extend below the frost line or the depth to which the earth freezes in cold weather, if you are in a climate where this may happen.

It is possible that you will get better results by using two pipes connected together in place of a single pipe. When you use more than one pipe have them at least six feet apart as in Figure 10, otherwise The two won't be appreciably better than one.

If, for any reason, it is difficult to drive a pipe deep enough to make a good ground, you can bury a steel or iron plate several feet below the ground surface as shown in Figure 10. After you dig the hole, throw in a liberal quantity of rock salt, then a little earth, some more salt and then place the metal plate. Cover the plate with mixed salt and earth for two or three inches before finally covering it with the plain earth, the salt attracts and holds moisture around the plates.

The best connection to a buried plate is that made by having the end of a large copper wire welded to the metal of the plate. If this cannot be done, bolt the end of the wire on to a cleaned spot of the plate and cover the joint with a quantity of hot pitch or tar.

An iron pipe ground will give best results when driven into ashes, refuse, rubbish or old dumps of any kind. Good results will be had when the pipe is in loam clay or shale which is free from gravel and stones. Sand, stone and gravel make poor grounds because they don' t hold moisture and the greater the percentage of these in the soil the poorer will be the ground.

THE GROUND CLAMP

The attachment of the ground lead to the pipe or other metal part serving as the ground Must be made with considerable care because this attachment will always be in an out-of-the-way place and in a place quite likely to be damp. Dampness causes oxidisation or rusting of the metal and radio currents pass through oxides with the greatest difficulty.

A soldered joint would be best, but it is practically impossible to solder to a cold water pipe without first draining the water. Even then it is difficult because the pipe carries away the heat about as fast as it can be furnished. The best connection that may be made conveniently is secured with a ground clamp

You can see two styles of ground clamp in Figure 11. The one at the left is simply a metal band fitting around the pipe. The outer surface of the pipe mast be thoroughly cleaned with a file or coarse sandpaper until bright metal shows. The inner surface of the clamp must be similarly cleaned. After the clamp is in place the joint between it and the pipe should be liberally covered with varnish or tar to keep out the moisture.

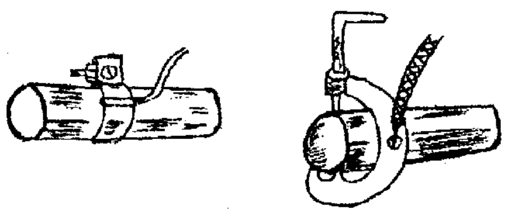


FIGURE 11.

A more positive kind of ground clamp is shown at the right hand side of Figure 11. This clamp has three sharp points that dig into the metal of the pipe, Two points are fixed and the third is on the end of the screw. Such a clamp is easily applied and is almost certain to reach in to the clean metal9 Even with this type it won't do any harm to cover the points with varnish or tar to exclude moisture. Any kind of ground clamp will require re-tightening every few months.

AERIALS FOR VERY HIGH FREQUENCIES

In the previous lesson you were introduced to an effect called “resonance” which occurs when equal amounts of inductive and capacitive reactance are present in a circuit. Under such conditions a circuit will be resonant at the frequency where equality of reactances occurs.

With most tuned circuits you are likely to encounter in the first three sections of the course, tuning is carried out by using known values of inductance and capacity, one, usually the capacity, being variable. With such an arrangement we say that the circuit is tuned by “lumped” values of inductance and capacity. In addition to “lumped” inductance and capacity one will invariably be aware of other small values of inductance and capacity scattered throughout a circuit. Capacity may exist between wiring and a metal chassis, between coils and a shield which encloses them, and between the internal elements of a valve. These are called “stray” capacities and in a well designed circuit are kept to a minimum. There are, however, other values of inductance and capacity which are inevitable and cannot be eliminated.

The distributed capacity and inductance, as they are called, can exist between individual sections of even a straight conductor or wire. The reason for this is explained in our Television Receiver Servicing Course, which may be taken on completion of this Radio Service Course.

When an alternating voltage is applied to circuits in which the inductive and capacitive constants are distributed rather than “lumped”, oscillatory current circulates in the form of a wave motion which is similar in every way to the wave which is radiated by a broadcast station and like it, has the velocity of light. If the alternating voltage is applied to a single conductor, the wave which is propagated along the conductor will be reflected at the far end and travel back to the starting point where reflection may again take place. If only a single pulse is applied to the conductor the resultant current wave will travel back and forth along it, suffering some loss at each reflection until it eventually dies away. This reflection is similar to the effect of a sound wave being reflected from a hard surface, such as the wall of a room. The sound “bounces” off the reflecting surface and travels back towards its starting point.

You have already learned that an alternating voltage or current has frequency. As the wave motion mentioned above is of an alternating nature, it too will have frequency. In addition it has another property to which we do not normally refer when speaking of ordinary alternating voltage or current, namely wavelength. This property is discussed in some detail in the next lesson and so we shall not make further reference to it here beyond stating that the wavelength of an alternating wave motion is the distance measured between two succeeding peaks or two succeeding troughs.

Now returning to the alternating wave motion along a straight conductor, when the length of the conductor is equal to half the wavelength of the alternating wave propagated along it, the reflected wave will arrive back at the starting point just as the next cycle of current is about to commence, if we continue to apply an alternating voltage through the conductor. Under these conditions we say that the conductor is resonant at the particular frequency where its length is equal to half the wavelength of the disturbance. The voltage and current distribution along the half wavelength conductor is shown by Figure 12. The current impulse travelling along the line A to B has a minimum value at the staring point, rises to its peak value when one-quarter of the distance has been travelled and then falls to the minimum value again at B. Reflection occurs at this point and the reflected wave will travel back to A. The wave due to reflection at B is indicated by dotted lines in Figure 12.

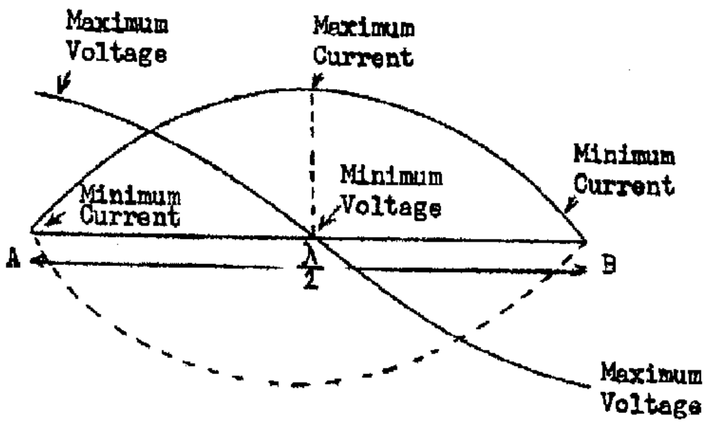


FIGURE 12.

Reflection will again occur at A and this time the reflected wave will be travelling along the conductor together with the third half cycle or current which has commenced to flow at exactly the same time.

We say that the two currents are in phase with each other and so their two values will add together.

If an A.C. meter is placed in the exact centre of the conductor it will register a maximum reading. On the other hand if it is placed at either A or B it will give a zero reading.

Because current is surging back and forth along the line at a certain frequency we may think in terms of electrons starting at one end, rushing down to the opposite end, and, after a momentary pause, returning to their starting point.

When the electrons pause at either end of the line, their velocity is zero and so the current flow at this point will also be zero. Having started on their journey the electron velocity will increase steadily until it reaches a maximum at the centre of the line. Thereafter the velocity decreases at the same rate, reaching zero during the pause at the opposite end of the line, Thus we have maximum flow of current at the centre of a line and minimum flow at either end.

As the electrons pause at alternate ends of the line preparatory to reversing their direction of travel, we will have a condition whereby a large number of electrons will be congregated at one end while a relatively small number will be present at the opposite end of the conductor. At this instant there will, therefore, be a maximum difference of potential between the ends of the conductor. At its centre where we have neither a maximum nor minimum number of electrons there will be no difference of potential. In other words there will be a maximum difference of potential between opposite ends of the conductor and zero voltage at The centre.

When a conductor conforming to the conditions set out above comes within the influence of a radio wave having a wavelength, which is twice the length of the conductor, a greater amount of energy will be generated in the conductor than by a transmission having any other frequency. In other words The conductor is resonant at one particular frequency. This is precisely what would happen if we made the length of an aerial wire equal to the half wavelength of a particular transmission. The aerial would be tuned to that particular frequency. This does not mean that the aerial would receive one station to the exclusion of all others because the tuning effect would be very broad for reasons which will become apparent as you proceed with your studies. This, however, is not the reason why such an aerial would be impracticable for receiving stations within the medium wave broadcast band, a station having, for instance, a carrier wave frequency of 1000 kilocycles. The major drawback is the physical size of an aerial designed to be resonant at this frequency. The wavelength corresponding to a frequency of 1000 kilocycles is approximately 300 metres, that is, nearly 1000 feet. The length of a half wave aerial designed to operate at 1000 kilocycles, therefore, would be 500 feet, an inconveniently large size, even for country districts, and so for reception of medium wave transmissions we compromise by using the greatest length of aerial that can be conveniently employed.

Resonant aerials conforming to the half wave length dimension are quite feasible for reception of stations operating at a high carrier wave frequency because in this case the wavelength of the transmission will be comparatively short. The wavelength of a 30 megacycle carrier wave would be between 30 and 40 feet. This places the half wavelength at between 15 and 20 feet and so installation of an aerial designed to be resonant at a frequency of 30 megacycles would not be a difficult matter even in comparatively congested areas. It the higher frequencies used by television transmitters and frequency modulation broadcasting stations, the problem becomes even less acute. For instance, an aerial designed to he resonant at the centre of a band of frequencies allotted to frequency modulation broadcasting stations in Australia, namely 88 to 108 megacycles, would have a total length of only about 4 feet.

The method of installing resonant aerials conforming to a half wavelength dimension differs from that followed with the more conventional types used for reception on medium frequencies. With half wave V.H.F. aerials an earth connection does not play the significant part it does with the more conventional type of aerial-earth installation. With the V.H.F aerial both ends of the aerial coil primary winding are connected to the aerial as shown by Figure 13. For maximum signal pick-up, the broad side of the aerial faces towards the particular station one wishes to receive.

Connection of a half wave resonant aerial to a radio receiver is not merely a matter of running two separate wires from the aerial to the radio receiver as may appear from Figure 13. The lead-in from aerial to receiver is a very special type of cable having a characteristic impedance of approximately 72 ohms.

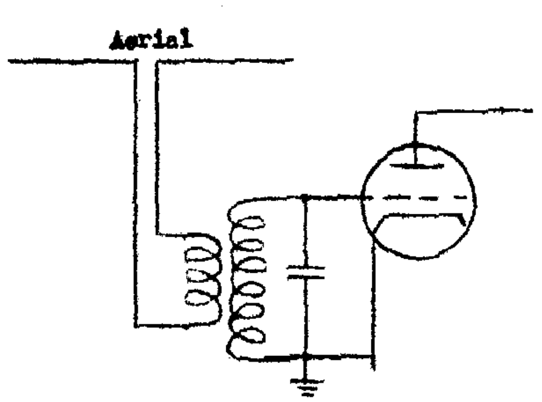


FIGURE 13.

This impedance of 72 ohm has nothing to do with the actual resistance of the conductors but is related to the distance separating the two leads from each other and the diameter of each lead. This means that whether the lead-in is 1 foot long or 20 feet long its characteristic impedance will still be 72 ohms for a particular spacing and wire diameter. Our Course dealing with The servicing of Television and Frequency Modulation Receivers covers this subject in detail and explains why the lead-in, cables should have this particular value of impedance.

The running of the lead-in from aerial to receiver should be arranged with some care. The leads should not come. closer than about 6" to large areas of metal, particularly where such such metallic objects are grounded. Particular care should be taken to ensure that the lead-in cannot flap about due to wind agitation and consequently suffer abrasion due to contact with rough surfaces. These precautions, of course, also apply to the running of a lead-in from an ordinary out-door aerial of the type discussed in the early part of this lesson.

The lead-in may be held away from walls and other objects and at the same time prevented from flapping about by means of stand off insulators of the type indicated by Figure 14, The manner in which these insulators are used is shown by Figure 15.

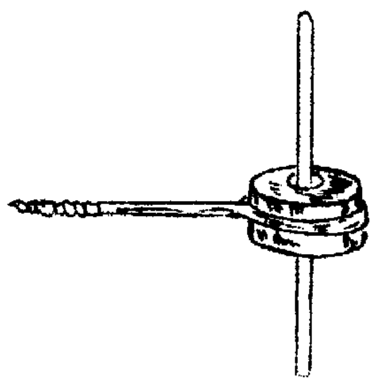
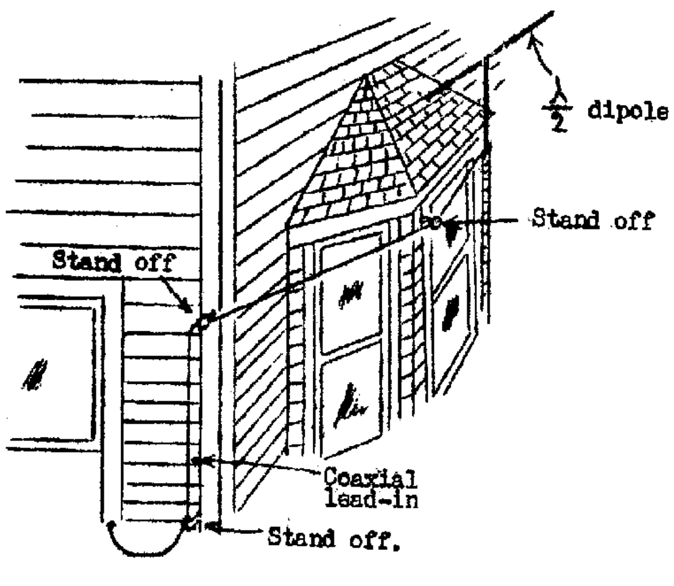


FIGURE 14.



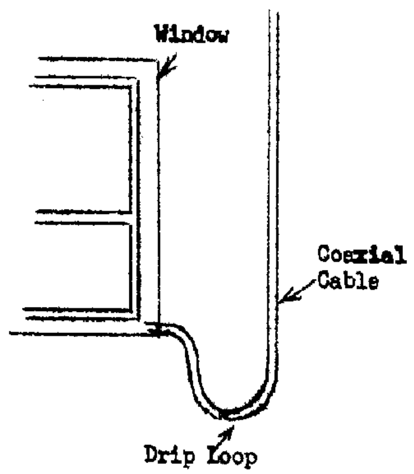


FIGURE 16.

The lead-in may enter the house through a ventilator or through a hole in the lower section of a window frame. In either case a loop should be left in the cable as shown by Figure 16 to allow rainwater to drip outside the house rather than be conveyed inside along the lead-in cable.

SOLDERING.

There can be no doubt that the ability to make a good soldered joint must be rated as a most essential accomplishment for the radio and television serviceman.

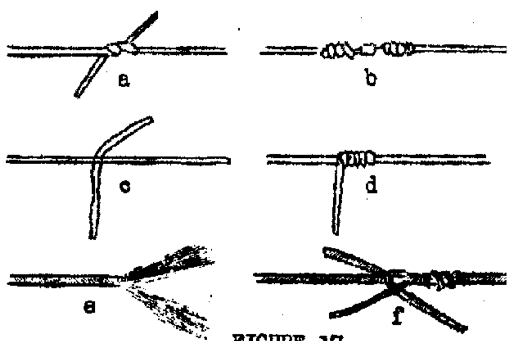
A radio or television receiver constructed without the use of soldered connections would be entirely impracticable. Even though it may perhaps be coaxed into working at first, before very long crackles and noises would interfere with reception and the receiver would soon become inoperative. It is essential for all the connections in a radio receiver to be soldered and consequently it is most important for you to learn the art of soldering efficiently and quickly.

The reason for the widespread use of solder in radio receiver construction is the fact that the amount of electricity which will flow in any circuit is dependant upon the resistance of the paths through which it has to flow Most metals have a fairly low resistance and if their surfaces are perfectly clean, merely clamping them together will initially cause a low resistance path so that normal values of current can pass through the connection. However, all metals in contact with the air will eventually have a film of oxide formed on their surface. This oxide is, in the case of iron, called rust. Other metals also have a film which is not always as apparent as in the case of rust on iron but nevertheless exists to some degree. The oxide films on metals are normally fairly good insulators of electricity and consequently would increase considerably the resistance to the path of electricity and reduce the current to a lover than the correct value. Eventually the thickness of the oxide film may become so great, as the result of moisture in the atmosphere, that in a radio circuit it may completely prevent current from flowing. This may happen even though the oxide film may only be a fraction of a thousandth of an inch in thickness and hardly noticeable to the eye.

The use of soldered connections is not so important in high voltage circuits, such as those used for electric power and lighting, because the high voltages used are strong enough to cause any oxide film to break through and for the current then to be able to flow directly from one metal surface to the other. With receivers, however, some of the signal voltages are only a few thousandths or even millionths of a volt in strength and these low voltages are not enough to drive electric current through an oxide film of any appreciable thickness. The film will form even on pieces of metal which are fairly tightly clamped together, due to air getting in between the surfaces and corroding them. One certain way of ensuring a permanent connection of low resistance between two pieces of metal is to exclude any possibility of air reaching the surfaces across which the current has to flow and at the same time bridging the gap between the two pieces of metal with a third metal, solder, which is itself a good electrical conductor.

Solder is not a very strong metal and consequently should not be relied upon where a great deal of mechanical strength is required. It is always preferable to make a strong mechanically see joint before the solder is applied. By mechanically secure joint we mean one that you can't twist or pull apart after it is made. To commence making a joint between two wire ends you cross them as at “a” in Figure 17. Then you wrap the ends around as at “b” in this illustration. To connect the end of one wire to some point along the length of another one, you start as at “c” in Figure 17 and end as at “d”, Stranded wire may be handled as already explained or you may divide the strand into two groups as at “e” in Figure 17. Place the two wire ends together so that the split of one wire engages the split of the other. Then, as at “f”, twist one group of strands around in one direction and twist the other group from the same wire in the other direction around the second wire.

In making a wire joint ready for soldering, it is assumed that the surface of the copper is absolutely clean. To make sure it is clean, use a knife blade and scrape away every particle of enamel, or any other insulation and of copper oxide until the whole surface to be soldered is bright and shining. This cleaning should always be done before the joint is twisted together. Do the cleaning even though the wire is brand new. Then, after the ends are twisted into place, again scrape the outside of the joint or rub it with a piece of sandpaper. Thorough cleaning of the two surfaces to be soldered is the most important factor in making a good soldered joint.



SOLDERING MATERIALS. FIGURE 17.

Soldering is most easily done with a good electric soldering iron of liberal size. The copper tip extending out from the heating element of the iron should be from three-eighths to one-half inch in diameter and should extend about two inches from the heater. A tip shaped as shown in Figure 18 is best for wire soldering. If you can't use an electric iron, just as good work can be done with one heated by a blow lamp, but it is more troublesome to care for the torch. In heating an iron with the torch, keep the tip of the iron in the blue part of the f1ae as in Figure 19.

If you get the tip into the yellow flame a coating of soot will be will have to be cleaned away thoroughly before the deposited on the copper and soldering operation.

Wire solder or strip solder is easier to use than bar solder. Resin-cored solder will make it unnecessary to use a separate flux but it is generally easier to make a clean neat joint with the plain wire solder. Above all, never use acid-core solder because joints made with it will surely corrode and cause high resistance after a time. Most soldering pastes contain materials which cause corrosion therefore don't use any of them unless you can be certain they contain neither acid nor salts of any kind. The purpose of any flux is to remove the oxide from the metal just as you are ready to solder, leaving the copper ready to unite with the solder. The safest and most generally satisfactory flux for radio work is plain resin. You can get resin in powdered form or in crystals and keep a small supply in a tin dish or a can cover as you do your work Another method of using resin is to dissolve it in methylated spirits until it forms a thick paste. This paste should be kept in an air-tight container when not in use, to prevent the methylated spirits evaporating and the paste drying up.

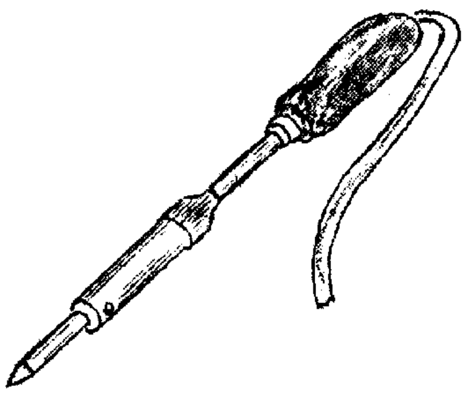


FIGURE 18.

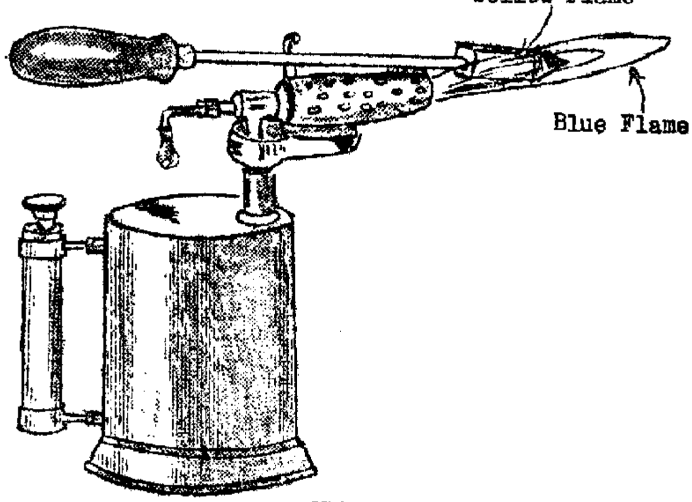


FIGURE 19.

PREPARING THE SOLDERING IRON.

If the tip of the soldering iron isn't of the approximate shape shown in Figure 18, use a file and make it that way. Then clean the tip for a distance of half an inch back from the end by filing it down all around until you see nothing but clean, bright copper everywhere, Then polish the cleaned surface with emery cloth or sand paper. Finally, heat the iron just as though you were ready to solder.

When the iron gets good and hot touch the tip to the resin flux and while doing this, rub the end or tip of the iron with solder, The solder will flow over the cleaned portion of the tip and leave a bright coating there. This process is called “tinning” the iron. After an iron is used for a long time it will need to be re-tinned.

File off the tip and perform the operation in the manner just explained. While you are doing soldering job you will notice that the tinned tip gets dull or blackens in spots. To remove this coating, rub the hot iron on a piece of heavy cloth which you can keep handy for the purpose.

You can tell when an iron gets hot enough by touching the tip with a piece of wire solder. A properly heated iron will cause the solder to flow like water the instant the two touch. An iron that is too hot will blacken rapidly at the tip, while one that is just right will remain quite bright or will show just a faint brownish tinge or film over the bright tinning. An iron too hot will hurt its own surface and will require cleaning and re-tinning, but an iron not hot enough will fail to make a good joint. Therefore, keep the iron hot,

SOLDERING A JOINT.

Now that you have a mechanical joint, well cleaned, and have a properly shaped iron, well heated, you are ready to apply the solder.

When using wire solder, first heat the joint by applying the iron to it, then drop on a little of the resin flux The resin will smoke. Hold the hot iron underneath the joint until the wires get really hot. Then, as in Figure 20, dip the end of the wire solder into the resin and touch it to the joint. If things are properly heated, the solder will flow down into the joint, completely filling the spaces in and around the wires. It is very important to apply the heat long enough to do this because unless each of the metal surfaces is heated to the melting point of the solder, the solder will not "wet" the two surfaces and a "dry" joint will result. The ultimate effect of such a joint will be internal corrosion and high resistance between the two surfaces and this can create a considerable amount of trouble in any radio or television receiver. A "dry" joint can also result if contact between the two surfaces to be soldered is not firmly maintained until the solder applied to the work has cooled sufficiently to set hard One further word of warning. Do not attempt to solder wire or any other metal to aluminium While this can be done, very special techniques and materials are involved, and it is better left to experts in this field.

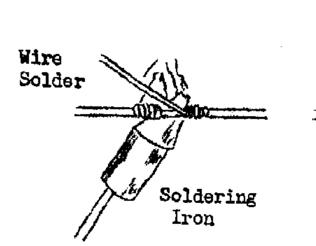


FIGURE 20.

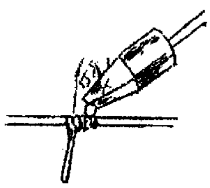


FIGURE 21.

If you are using bar solder instead of the wire form you first heat the joint and apply a small amount of resin flux just as before. The easiest way to apply the solder is to have a quantity of resin in on side of a flat tin dish and a piece of solder in the other side of the same dish. Then you touch the tip of the hot iron to the resin and quickly move it over and touch the solder. The solder will melt and some of it will stick to the tip of the iron. With the least possible delay move the iron with its drop of molten solder over to the joint as in Figure 21, and slowly rub the iron tip over the top of the wire joint As the wires get hot the solder will run down around them and complete the joint. The purpose of soldering an electrical joint is to provide a good conducting medium between two parts carrying electricity and to prevent oxide from forming on the surfaces and increasing the resistance of the joint.

I think we can best conclude this lesson by summarising the rules for successful soldering.

(1) The iron must be clean and well tinned.

(2) The two surfaces to be joined must be thoroughly cleaned of all forms of oxide film so that both surfaces of metal are bright and shining.

(3) The correct amount of flux is that which will completely evaporate during the soldering operation without leaving any surplus remaining.

(4) The soldering iron must be left in contact with the work long enough to enable both surfaces to be joined, to be heated to a temperature higher than the melting point of solder, about 450 or 460 degrees F., So that the solder flows readily from the iron and spreads evenly over both surfaces. If the iron is not left in contact with the work long enough to heat each surface sufficiently, the solder my be pasted onto the work but it will be found later that the solder will peel off easily when given a slight pull. This is known as a “dry joint”.

(5) When the solder has run freely onto the work and the soldering iron is removed, care should be taken not to shake or disturb the work or the solder until it has had time to cool and solidify. If the work is shaken when the solder is in the p1stic state, before it finally sets hard, a bad connection will often result as the solder will not effectively grip the wire it surrounds.

EXAMINATION QUESTIONS - NO. 4.

l Why may an inefficient aerial-earth installation completely ruin the performance of even the bo of radio receivers ?

2. If an aerial wire isi 100 feet above the level of the earth and 10 feet above the roof of a reinforced concrete building, what is its electrical height ? Explain the reason.

3. Which brings clearer reception, an outdoor or an indoor aerial ?

4. Would you always choose an outdoor aerial when installing a radio receiver ? Explain.

5. Is it practical to use a resonant aerial for reception of stations operating within the band 525 kc/s to 1605 kc/s,? Explain.

6. How would you connect a resonant half-wave aerial to a receiver ? Give a diagram.

7. How far from a building wall would you carry a lead-in wire?

8. what are the four most important points to consider in running a ground from the set ?

9. How deep would you drive an iron pipe to be used for a ground connection ?

10. What is the safest kind of soldering flux for radio work? Why ?

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Use sketches and diagrams wherever posib1e. One diagram in many cases is equivalent to pages of exp1anation

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LESSON NO.5

DESIGN AND INSTALLATION OF SPECIAL AERIALS

The aerial you studied in the other lesson on this subject is the most common type of all. Its circuit consists of an overhead wire, connected to the lead-in, then to the first coil in the receiver, and from there to the ground connection. All these parts are shown in Fig. 1, both in pictures and in symbols.

This form of aerial is often called an “L-type” or an “inverted L-type” because its general shape, with the lead-in at one end, resembles an inverted capital letter “L”. The lead-in is generally, but not always, connected to one end of the aerial. Sometimes, as in Fig. 2, the lead-in is connected near the centre of the aerial's length. This arrangement makes what we call an aerial of the “T-type”; because the aerial and lead-in resemble the capital letter “T”.

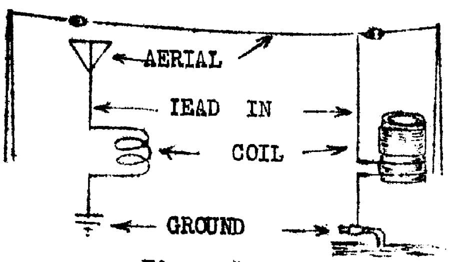

Figure 1.

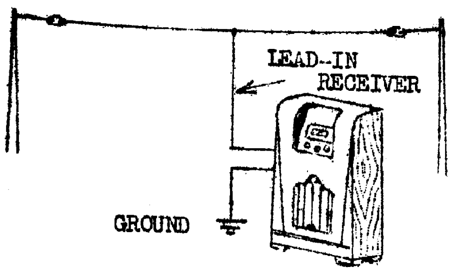

Figure 2.

All the aerials referred to so far have used a single overhead wire. Sometimes, when there is not sufficient space to accommodate a single wire aerial of the required length, we resort to the use of two or more parallel wires instead of the single wire. Then we have a multiple wire aerial.

The separate wires of such an aerial are all of the same length and are spaced at least two feet apart by means of spreaders. The spreaders are pieces of hard wood about one inch square with. small holes bored through them. A spacing of two feet is required in order that this aerial may have greater signal collecting ability than a single wire of equal length. There is very little advantage in spacing greater than two feet. A two-wire aerial is shown in Fig. 3 with the lead-in attached at one end. In Fig.4 you can see a three-wire aerial with the lead-in attached near its centre.

A two-wire aerial having each wire of the same length as the one wire of a single aerial will collect a stronger signal than the signal wire, but the signal will be nowhere near twice as strong. Likewise, the three wire aerial will collect more signal than the two-wire type, but it will not collect fifty per cent more. Multiple wire aerials are generally between fifteen and thirty feet in over-all length.

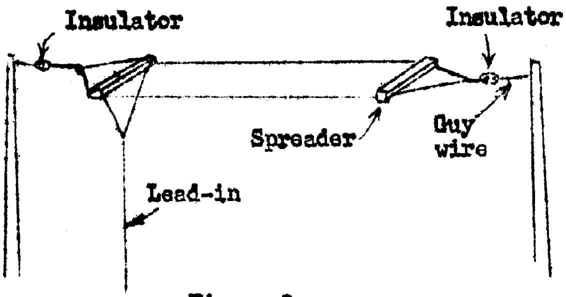

Figure 3.

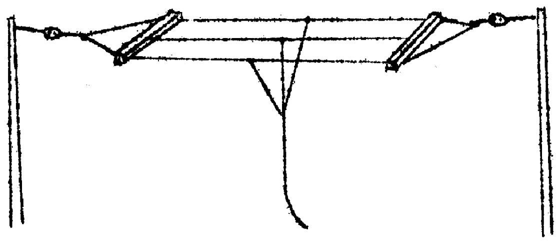

Figure 4.

Because modern receivers require such a small amount of aerial signal for satisfactory operation, it is very seldom necessary, oven in country districts to obtain the equivalent of a single wire more than fifty feet long, but this can be done with a two-wire aerial about thirty feet long or with a three-wire aerial twenty feet long. All of the wires in the multiple aerial are connected together by the lead-in attachment.

The wires may be attached to the spreaders by either of the methods shown in Fig.5. At the right the wire is passed through the hole in the spreader and wrapped once around the wood, At the left the aerial wire does not pass through the hole in the spreader but is fastened by a second short piece of wire which passes through the spreader and is wrapped around the aerial wire. There is no need for insulation between the wire of the aerial and the wood of the spreader because all the aerial wires are connected together anyway.

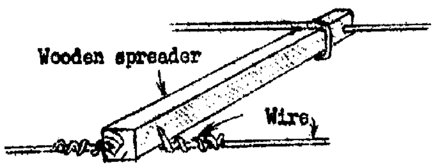

Figure 5.

IS A GROUND CONNECTION NECESSARY?

In the last lesson, it was pointed out at some length, that the aerial and ground connections act as the two terminals of a source of voltage or "generator" which supplies the weak signal voltages necessary to operate a receiver. The last lesson also explained the normal path of current surging to and fro between the aerial and ground and passing through the aerial coil of a receiver on its way. This circulating current then generates voltages in the secondary winding of the aerial coil, which are responsible for the sounds we hear from the receiver's loudspeaker.

It would appear from the foregoing that if the ground wire were detached from a receiver operated with an aerial only, the circuit would be broken, current would cease to flow and the receiver would fail to work. Despite this, you have possibly seen numerous receivers, particularly those which function from alternating power mains, operating without a ground wire and found That they work quite loudly. The reason the receivers are able to operate is shown in Figure 6. In the case of an ordinary receiver operating from the alternating power mains, power from the mains is converted into suitable voltages for the valves by means or a power transformer. A power transformer is something like the iron cored audio transformer described in Lesson 3. It consists of a primary winding of copper wire wound around the centre leg of a set of iron laminations but insulated from these laminations by means of a good quality insulating material to prevent the power mains voltage jumping straight from the primary winding to the core.

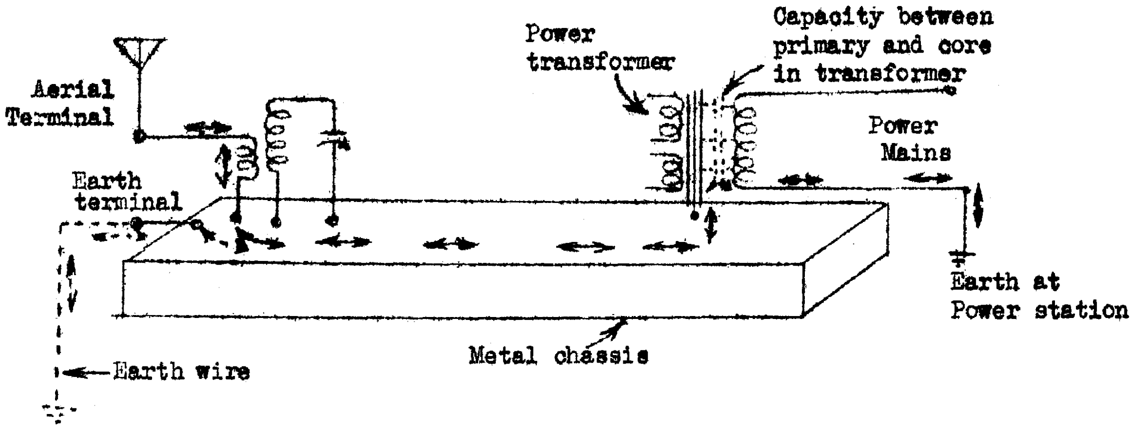

Figure 6.

Over the top of the primary winding is another layer of insulating material and then, in turn, come additional windings to supply power to the various valves in the receiver although the primary winding is insulated from the iron laminations, both the primary winding of copper wire and the laminations are conductors and because they are separated by an insulating material they form a small condenser effect which allows radio frequency current to pass through.

If we connect an aerial to the aerial terminal of the receiver, as shown in Figure 6, radio frequency current can pass from the aerial down through the aerial primary winding to the metal chassis. Because there is no ground wire on this receiver, there is no metal path to earth for the radio current so instead it passes from the metal chassis to the iron laminations of the power transformer, which are bolted on to the chassis and then through the capacity effect between the laminations and primary, into the primary winding and then through the power mains wiring to ground at the power station or at some intermediate point where capacity of other electrical appliances provides an easy path for the radio frequency current to reach the earth.

Although an actual ground wire is not connected to the receiver illustrated in Fig. 6, radio frequency current can nevertheless circulate through the aerial coil, finding its way ultimately to ground at some remote point, and this enables the receiver to work just about as loudly whether it has an earth wire actually connected to it or not, In fact, in some areas the receiver may actually have light1y stronger signals reaching its aerial coil when operated without the ground connection because the power main wires are high and well insulated from the earth and in themselves act as quite an effective aerial so that there is a strong voltage difference between the receiver's aerial and the power mains wiring. Connecting a ground wire to the earth terminal of the receiver in these cases would reduce the loudness of signals slightly. This may lead you to conclude that it is better to operate, power main receivers without an earth wire rather than with one. However, their are other factors which we must take into account in deciding whether an earth wire should be used or not.

One of the first of these factors is safety. Although the insulation we have described, between the primary winding and iron core of a, power transformer is always tested in good order in a new receiver, it is always possible for the insulation to deteriorate due to heat and age and possibly to ultimately break down. If a ground wire is not connected to the radio chassis then it is possible for the voltage from the power mains to reach the metal chassis of the receiver, should the insulation fail. This in itself may not be dangerous because radio chasses ore normally enclosed in wooden or plastic cabinet However, without an earth wire connected to the chassis the power mains voltage would be able to pass through the aerial primary winding reach the aerial terminal and then also reach the aerial lead attached to this terminal and it might be possible for someone to come into contact with this wire and at the same time and receive an electric shock. For this reason it is safer to use & ground wire. If a short circuit should develop in a power transformer when ground wire is used, the heavy current flowing to ground will "blow" the power fuse so that no danger will exist.

There is a second reason which makes the use of a ground wire desirable on power mains operated sets. From Figure 6 you can see that the current which circulates through the aerial coil is that resulting from the voltage difference between the aerial itself and the power mains wiring. At various points along the power mains there are all sorts of electrical devices not only n the building in which the radio receiver operates but also in other buildings up and down the street. Various machines, particularly those employing electric motors with carbon brushes, or thermostats, produce forms of electrical interference which can be converted by the radio receiver into annoying "crackles" and "bangs" from the loudspeaker. The current disturbances responsible for these noises, like radio signals, can travel from the power mains, through the capacity in the power transformer, to the metal chassis, and then from the chassis through the aerial coil to the aerial. As a result we have not only radio signal current passing through the receiver's aerial coil but also surges of current originating from the power mains. These surges of current are quite weak and are not dangerous in way but when amplified by the valves in the radio receiver can result in annoying buzzes and crackles from the loudspeaker.

By connecting an efficient earth system to the earth terminal as shown at the left hand side of Figure 6, in dotted line, the noise voltages will, in many instances, be diverted away from the aerial coil and will not be heard to the same degree from the loudspeaker. This provides an improvement in "signal to noise ratio" which makes listening more enjoyable.

When the earth wire is attached to the earth terminal, there is a complete and easy path for radio signal current, from the aerial, through the aerial coil in the receiver, to chassis and then down to the ground itself, without this current having to circulate back through the power transformer and power main wiring. In the case of radio disturbances originating in the power mains wiring, although these small amounts of energy may find their way through the capacity in the power transformer to the receiver chassis, instead of them continuing through the aerial coil to the aerial they will also pass through the ground wire to the earth and will thus be diverted away from the aerial coil and will not be effective in generating "noise" signals.

From this explanation you will realise that in many districts the attachment of an earth wire to a power mains operated receiver may not make the signals any louder but may make, noise disturbance much weaker therefore providing more enjoyment as a result of the improved signal to noise ratio.

GOUND WIRES FOR BATTERY OPERATED RECEIVERS.

In the case of radio receivers which operate from batteries and which consequently have no connection to the power mains, there is no possibility of radio current from the aerial circulating through the aerial coil and continuing on to ultimately reach ground unless a good ground wire is attached to the earth terminal of the receiver. For this reason it is most important, in the case of battery operated receivers, to have An efficient earth system as this plays just as much part in determining the strength of signal current flowing through the receiver's aerial coil as does the aerial itself.

Of course, there are some battery operated receivers which have a self-contained loop aerial in which the signal voltages are directly developed within the loop coil itself. In strong signal areas, these receivers do not require any external aerial or ground wire. You will find a more complete description of this type of aerial in the latter pages of this lesson.

In the case of mobile installations such as in motor cars and aeroplanes, the ground terminal of the receiving equipment is connected to the metal body of the motor car or of the aeroplane and the large metal surface takes the place of an actual connection to ground in forming the second plate of a condenser of which the aerial itself is the other plate. You will remember from the last lesson, that in an ordinary installation the aerial and ground connections form two condenser plates widely separated in space and that the passing radio signals generate a voltage between these two conductors. The same principle applies in the case of mobile installations with the aerial and car or aircraft body acting as the second condenser plate. Thus no actual connection to the earth itself is necessary.

COUNTERPOISE.

In a few rare cases, particularly when attempting to use battery operated receivers in districts where it is difficult to get a satisfactory ground connection, you can apply the principle used in motor cars and aircraft even in household receivers. These conditions may exist when the earth is exceedingly dry and sandy, where the receiver is located where there is only rock beneath it or when the receiver is in an upper floor of a high building. In such cases we may employ a counterpoise as illustrated in Figure 7. You will remember that it is necessary to form a large condenser consisting of widely spaced conducting surfaces. If we cannot use the earth itself as one of the conducting surfaces, then we can erect an aerial wire as high as possible end erect another wire underneath it and parallel to it to form the second plate of the condenser. This second wire is called a “counterpoise”.

The counterpoise nay consist simply of a single wire placed directly underneath the aerial or even two or three wires spread a little apart.

It is desirable that the wire employed for a counterpoise be insulated wire similar to that employed for a receiver “lead-in”.
The wire itself may in many instances be tacked under the floor of a building or, in the case of an outdoor aerial, parallel with and directly under the aerial itself. Of course, in this case it must be erected high enough to allow people to walk under as it would be likely to trip people if placed only a foot or so above the earth's surface.

Another possible arrangement is to use 3/.036 or 7/.029 copper wire covered with P.V.C. type plastic insulation and bury thin wire a foot or so under the surface of loose sandy soil. This would have the effect of making what would normally be soil of very poor conductivity into a good conductor and would provide a satisfactory form of combined counterpoise and earth system for a battery operated receiver.

The signal strength from an aerial and a good earth around will be much greater than from the same aerial and any counterpoise. The only reason for using a counterpoise is inability to install the usual kind of ground. It is seldom necessary to go to the trouble of erecting a. counterpoise for receivers operating from power mains, because there is capacity in the power transformer which allows RF current to pass between the power mains and the receiver chassis, so that the power mains will act as a counterpoise and will provide quite good reception without there being any connection to the receiver's ground terminal.

NOISE REDUCING LEAD-IN.

In some areas electrical noise or “man made static”, as it is sometimes called, may be very bad and seriously interfere with the reception of broadcast stations. Apart from the noise currents which reach the aerial coil of a receiver in a power mains operated set operated without an earth wire, as described in connection with Figure 6, another way in which the noise impulses, brought into the building by the power mains, can reach the aerial coil is by radiation from the power mains through space to the nearest part of the aerial system, which is the lead-in, and of course are carried by the lead-in to the aerial terminal of the set. This applies even when an earth wire is used.

If the aerial itself can be placed at a good height and well away from the building or power wires carrying interference, so that it will not pick up a strong inferring signal, then we shall have good clear reception of radio signals without any annoying noise or crackles.

The difficulty lies in preventing the lead- wire from picking up the noise signals without seriously affecting its ability to carry radio signals from the aerial to the receiver.

SHIELDED LEAD-IN.

One method sometimes employed to prevent the lead-in wire from picking up the noise signals is to cover the lead-in wire with a sleeve of flexible metal braid The metal braid should be connected to ground and forms complete metal case or shield around the lead-in wire which prevents the noise impulse from directly reaching the lead-in.

The hollow metal braid can be purchased separately and slipped over ordinary

lead-in wire or wire is available with the metal braid already around it. Both the separate braid and the, shielded wire are fairly costly and for this reason, together with the fact that the metal braid being connected to earth is so close to the lead-in wire that it causes quite a considerable loss of radio signals, the system is not very frequently used.

Figure 8 shows the arrangement of a shielded lead-in.

TWISTED PAIR LEAD-IN.

Another simple method for preventing the lead-in wire from introducing interfering noises into the receiver is shown in Figure 9.

In this system, Two pieces of lead-in wire (usually 1/.044 250 volt grade) are twisted together like ordinary electric light flex. At the aerial end one wire is

connected to the aerial wire and the second wire is either left disconnected or can be joined to the wire or rope for joining the two insulators together; this will hold the second wire in place and prevent it from untwisting.

Unless the receiver is already designed to operate with this type of lead-in, an alteration will have to be made to the set. Normally, one end of the primary winding on the aerial coil of a receiver connects to the aerial terminal while the other end connects to earth. An additional terminal should be mounted on the chassis of the set and insulated from it. If there are only 20 turns or so on the aerial primary, it may be possible to make a connection to the centre one thus providing a centre tap. It this is so, the earth end of the aerial primary winding should be disconnected from its normal place in the circuit and connected to the new terminal and the centre tap connected to the earth terminal. We now have two aerial terminals and the earth terminal. The two ends or the twisted lead-in should connect one to each of the aerial terminals while the earth wire is connected to the earth terminal. If it is not possible to make a centre tap connection to the existing primary, it may be a simple matter to rewind the primary altogether to provide a centre tap.

In this system any noise impulses in the vicinity of the lead-in will induce signals in both wires of the lead-in, but these are connected to the receiver in such a way that any signals picked up by one of the lead-in wires will act against and neutralize any signals picked up by the other wire, consequently the noises are not heard from the loudspeaker. Signal voltages induced in the aerial wire by the various broad-casting stations will be conducted by the lead-in wire which connects to the aerial, to the receiver and through one half of the primary, and will of course take the normal path through the set.

Due to the small distance between the two lead-in wires this system is not very efficient in conducting the signals from the aerial to the receiver and so reduces the signal strength by quite a considerable amount.

DOUBLET AERIAL

Figure 10 shows The arrangement of a doublet aerial. It simply consists of a long aerial wire broken at the exact centre and joined by an insulator. Two lead-in wires are also used with this system, one being connected to the inner end of each of the aerial wires.

The lead-in wires used with this system should not be closely twisted together but should be spaced 3 inches apart, crossing each other about every eighteen inches two feet.

To space the lead-in wires correctly and to enable them to cross at the required points, transposition blocks are employed every eighteen inches or two feet along the length of the lead-in.

A transposition block consists of a plastic substance having a shape similar to that shown in Figure 11. One lead-in wire is brought down to the top left hand slot in the block, passed through the slot, diagonally across the back of the block to the bottom right hand slot then through this slot and continue on down to the next block. The second wire comes to the top right hand slot, through this slot, diagonally across the front of the block, through the slot in the bottom left hand corner and down to the next block.

This system, like the last requires that the end of the aerial winding which normally connects to earth, be disconnected and brought to an additional aerial terminal, but no centre tap is needed   Some receivers are wired up with the aerial coil arranged in this manner and require no alteration when used with a doublet aerial.

The principle of operation of the doublet is somewhat similar to that of the last system. Any noise impulses will induce equal voltages in both the lead-in wires and these will counteract one another in the receiver and, so will not be heard, but signals are picked up on the two halves of the aerial and instead of counteracting, add to one another and so are, handled by the receiver.

None of the above systems will produce as strong a signal in the receiver as an ordinary T or L type aerial of similar length, consequently they are generally only used in districts where the amount of electrical noise is very severe.

All of the aerial systems shown so far if over 50 ft. in length or 30 ft. in height, must be protected against damage which may be done by discharge of atmospheric electricity through their wiring and the connected parts in the receiver. Lightning is one form of atmospheric electricity, or electricity generated in the air, but there are lots of other kids of atmospheric electricity as well. The purpose of a lightning arrester is to provide a path through which such electricity, of whatever variety, may escape from the aerial into the earth without going through the receiver or coming into the building containing the receiver.

During an electrical storm, or a thunder storm the air and clouds are heavily charged with electricity. This electricity does its best to escape from above and come down to the earth. Any metal object which is elevated may be in the path of this electricity, and since the aerial is such an object it is necessary that we provide protection. Ordinary electric charges which collect on the aerial flow harmlessly to ground through the aerial circuit of Figure 1, passing through the parts of the receiver. During a storm these charges increase and it is possible that their passage through the receiver may cause some damage - even to the extent of setting fire to things. This is what the lightning arrester prevents. Should an aerial suffer

a direct hit from a lightning flash, no arrester or anything else would prevent serious damage or complete destruction of everything in the lightning's path. This is a rare occurrence and the stroke undoubtedly take place in exactly the same manner and same place whether or not an aerial were there.

The principle of all lightning arresters is shown in figure 12. Two metal points are placed between aerial and ground, which means that they are connected across the first coil winding in the receiver. Radio signals meet the high resistance of the gap between the arrester points and flow around through the coil as usual because of their inability to jump across the gap. But should the aerial suddenly be charged with a large quantity of electricity during a storm, this electricity would not take time to pass around through the coil (being opposed by the coils "reactance") but would instantly jump across the gap. Passage of the electricity across the arrester gap produces a spark or arc.

Immediately such an arc is formed it provides a low resistance path between the arrester points and all the electricity which has collected on the aerial passes through the arrester to ground and does no harm in the receiver. The points in the lightning arrester are placed at such a distance apart that a pressure of 500 volts will cause an arc between theme No radio signal is more than a fraction of one per cent of this voltage and any electrical discharge which might cause damage develops well over 500 volts - so the arrester does its work very easily.

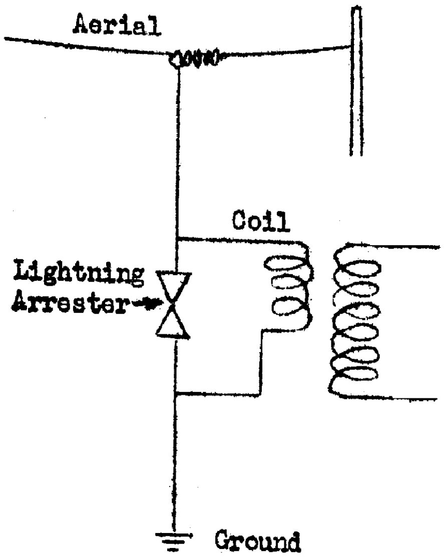

Figure 12.

TYPES OF LIGHTNING ARRESTER.

Some lightning arresters have their points made from carbon spaced apart by a thin sheet of mica around which the electrical discharge takes place when they work. Other types have points formed by small brass or bronze pins extending into a glass tube which is sealed to keep out moisture and dirt which might short circuit the arrangement and form a conducting path between the points, when all the signals from the aerial would go right down into the ground without having to pass through the coil in the receiver.

There are a few kinds of lightning arresters having the points, formed by wires sealed into the end of a glass tube from which the air has been pumped, leaving a vacuum. The electrical resistance or opposition to current flow is much less in a vacuum than it is in air, consequently the points can be kept further apart in the vacuum than in air and still allow he 500 volts to make a spark pass between them.

The construction of one commonly used type of lightning arrester is shown in Fig. 13.

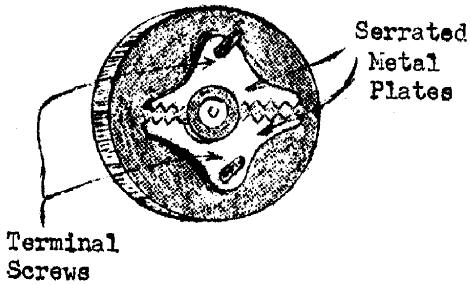

FIG. 13.

This typo consists of two brass plates with serrated edges insulated in a moulded bakelite container. The tip of each serrated edge are exactly opposite one another shown in Figure 13, so that any large voltage can easily jump across the small gap between them.

When this type of arrester is screwed down on flat surface by means of a screw through its centre, the two plate Are enclosed in a moisture proof compartment so that moisture or dust cannot bridge the gap between the plates and allow radio signals to leak away to earth instead of passing into the receiver.

IMPORTANT – FIRE UNDERWRITER'S RULES

it is absolte1y necessary that some form of arrester which has bee approved by the Fire Underwriters be attached to every radio installation having an outdoor aerial over 50 ft. in length or 30 ft. in height. Failure to observe this rule may make it difficult or impossible to collect insurance in case of damage from fire.

The special type of aerials shown in Figures 9 and 10 each require the use of two lighting arrestors. As each system is provided with two lead-in wires, it is necessary to prevent either of these wires from conducting electrical discharges into the building, consequently, a lightning arrester must be connected to each wire and the earth terminal of each arrester connected together and to the ground.

The method of connecting the arresters to the doublet or twisted pair lead-in is shown in Figure 14.

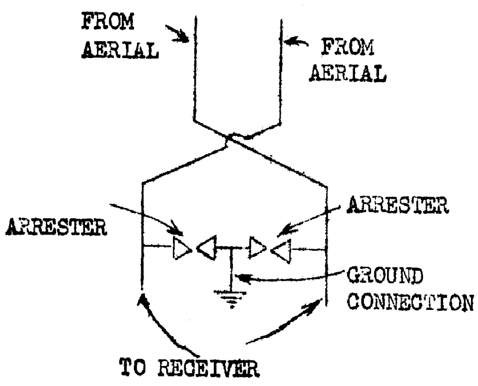

Fig. 14.

TELEVISION AERIALS.
The form, dimensions, principle of and method of connecting television aerials to television receivers differ considerably from similar characteristics for radio reception. Due to the very much higher. carrier frequencies involved for television transmission quite different aerials are needed far T.V. and consequently we will not attempt to deal with them at this early stage OF your course. Due to the quite different types of aerials required for T,V, and radio, it is best to use entirely separate aerials for the television receiver and radio receiver.

INDOOR AERIALS.

We will now consider the case of areas where signals a so strong that an outdoor aerial is not necessary. The next best thing is an indoor aerial - a wire placed within the building and taking the place of the overhead wire in the usual installation. Let me say here that no other form of aerial can compare with the regular outdoor type as a collector of signal energy. All other kinds are less effective no matter what claims to the contrary you may hear about. This does not mean that a receiver mast have an outdoor aerial to do good work. The receiver may be powerful enough to need but the slightest hint of a signal in order to produce satisfactory volume. Then it will do good work with some inefficient kind of aerial. But it will be still more powerful with a good outdoor aerial.

Any form of indoor aerial requires that the receiver be equipped with the same kind or ground that is used when an outdoor aerial is employed. All of the care that is taken with the ground for use in an outdoor aerial circuit must also be taken when the indoor type is used.

An indoor aerial concealed behind a room moulding is shown in Fig. 35. For this kind of aerial, the picture moulding type, we use thin flexible, stranded plastic or rubber covered wire. In running such an aerial, attempt to keep it away from metal piping of any kind, from telephone wiring, from conduits carrying power and light wires from signal bell wires and from all such things. Nearness to any kind of electrical circuit will allow impulses from that circuit to cause annoying sounds to come from the loud speaker when those circuits are in use.

As an alternative to the picture rail when, the wire may be run around the skirting board, near the floor or under the edge of a carpet, but signals in these positions will be weaker than the aerial is higher up.

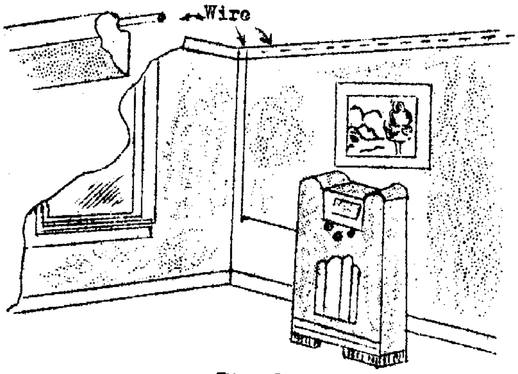

Fig. 15.

The indoor aerial collects less energy than the outdoor kind therefore it is allowable to use a greater length of wire for the indoor job than for the outdoor. Wire at the back of a moulding may be run nearly all the way around one good-sized room, or it may be run through several rooms. It is impossible to run these concealed indoor wires in straight lines, but it is advisable to string them out to the greatest possible length, running through several rooms in line if wire around two walls of one room does not provide sufficient signal strength.

You can use an indoor aerial with any kind of a receiver having three or more tubes. The average indoor job is not half as effective in bringing through the distant stations as a good outdoor aerial.. Therefore, the distance range of an ordinary set will be limited. The quality and clearness of reception will be excellent on nearby stations.

However, if you are working with powerful receiver, with one the newest superheterodyne sets or with any set having five tubes or more, the indoor aerial is very satisfactory even on stations at a distance of many hundreds of miles from the receiver, unless noises transferred to the aerial from the electric power mains are very bad.

Before leaving this matter of indoor aerials, it is very desirable that you provide a first class ground. This will help matters a lot. Also the greater the length of the indoor aerial, the stronger will be the signals it brings in, but the less selective the set will be.

LIGHT AND POWER WIRES FOR AN AERIAL

If you or your customer, should wish to get along without even an indoor aerial there are still simple methods of bringing signal impulses to the receiver. One method makes connection to the lighting circuit wires which come into the building. We will take these aerial arrangements in the order of their excellence. Best of all is the outdoor type, next comes the indoor aerial, then the power or light line type and so on.

If you will stop to consider it you will realise that the electric wires coming into any building meet many of the requirements of an aerial. They are insulated and they extend out into space. Of course, it is out of the question to make a direct connection from these wires to the aerial post of a receiver because their high voltage would send a great rush of current through the coils and other parts and would cause a disastrous fire. We make our connection through a small condenser.

You recall that the effect of an alternating current will pass through a condenser. Radio signals produce alternating voltage and currents in any elevated wire or for that matter in any wire at all that may be in their path. Consequently, you will find radio signal impulses in all light and power wires.

One method of extracting the high frequency radio signals from the power mains wiring but at the same time safely holding back the low frequency power mains voltage is to employ & small condenser with a capacity of about .0005 mfd. connected as shown in Fig 16.

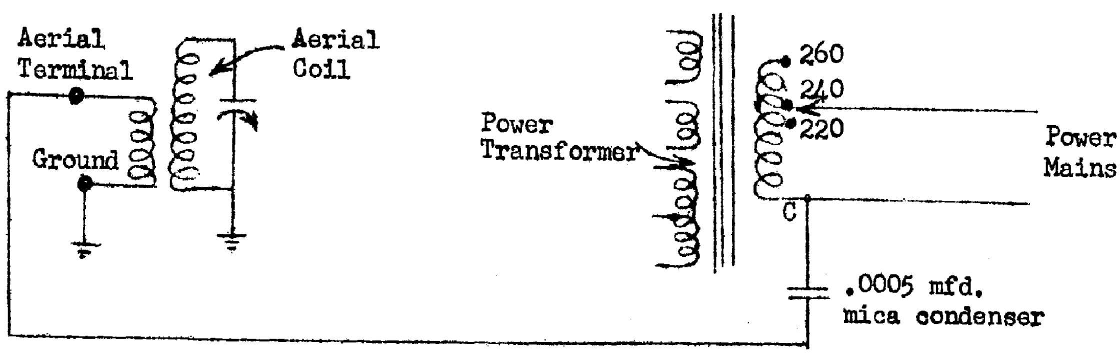

Figure 16.

The reactance of . .0005 mfd. condenser to the radio frequency of one megacycle per second is only about 300 ohms and this value is not sufficient to appreciably restrict the radio frequency current. At the power mains frequency of 50 cycles per second however, the reactance of the same condenser increases to a value of about six million ohms and this is sufficient to hold back any dangerous current at the power mains frequency itself.

Unfortunately, it is not an easy matter to install a condenser a shown in Figure 16. This work would require removing the radio chassis from its cabinet so as to give access to the point where the power flex is connected to the terminals of the power transformer One could then solder one end of the .0005 mica condenser to one of the two wire loads in the power flex at the point where the flex solders to the power transformer connections. The other end of the condenser would then be connected through a length of hookup wire to the aerial terminal.

Fortunately, there is a much simpler way of extracting radio signals from the power mains, without the work of soldering a condenser into position as shown in Figure 16. In Figure 17, you will notice that we make use of the stray capacity inside the power transformer, to couple our radio signals from the power mains through to the metal chassis of the set, as described earlier in connection with Figure 6. The only thing which looks different about Figure 17 is the fact that we have connected a ground wire to the aerial terminal of the receiver instead of to the ground terminal. Nothing is connected to the earth terminal of the set.

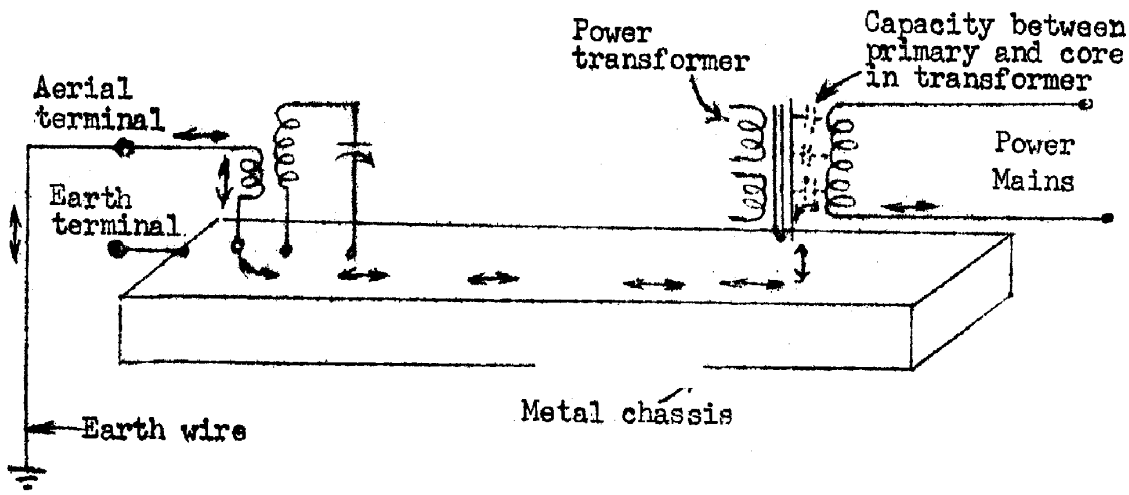

Figure 17.

In Figure 17 you can see that any radio frequency energy present in the power mains wiring can find its way through the stray capacity in the power transformer to the transformer's core and then though the bolts which hold the transformer to the chassis, to the metal chassis itself. The radio currents then pass through the metal chassis to the earth end of the aerial primary coil and pass through this coil to the aerial terminal. From here they are able to pass through the earth wire itself to ground so that there is a complete circuit through which radio frequency current may flow to and fro.

This arrangement works quite well and is very easy to apply to any receiver by simply connecting an earth wire to the aerial terminal in place of the aerial wire.

The earth wire should preferably connect to a water pipe or earth pipe driven into ground as explained in Lesson 4, although in some cases good results can be obtained by connecting the earth wire back to the earth pin in a three-pin power point.

The disadvantage of the arrangement shown in Figure 17 is that by depending upon the radio frequency voltages picked up in the power mains for our signal and encouraging radio frequency energy from the power mains to flow through the aerial coil, by connecting the earth wire to the aerial terminal, we will also have any electrical, noise impulses, produced by power operated equipment, flowing through the aerial coil as well as the radio signals and consequently the signal to noise ratio is not as good as when a separate aerial and earth wire are used in the conventional manner.

LOOP AERIALS.

All of the aerials described so far have been suitable for connecting to the aerial terminal of an ordinary type of receiver. Because of the size and awkwardness of installation of these aerial systems there have been many attempts to reduce the aerial to a size small enough for it to be fitted inside the radio cabinet. Some receivers have been fitted with e short length of wire fitted to the back of the cabinet but these are usually not very satisfactory,

The most practical form of small aerial is to enlarge the first tuning coil to such a size that it picks up broadcast signals and is then known as a “loop aerial”, This system is most commonly used in small battery operated portable receivers so that the receiver may operate without the necessity for any other aerial or for an earth wire, in the case of battery operated sets an earth connection, is only needed to complete the normal aerial circuit so that when a loop aerial is used, neither an external aerial or earth wire is needed.

The greater the length and, height of a loop aerial, within reasonable limits, the greater will he the voltage developed in it by signals from a certain broadcasting station so designers endeavour to make the loop aerial coil as large in size as possible. Figure 18 shows an oval shaped loop aerial, wound on a piece of insulating material and intended to be attached to the back of a radio cabinet. in an endeavour to obtain the largest possible size, and consequently efficiency, many portable receivers have a shallow groove cut around the inside of the wooden cabinet. The loop aerial coil is wound in this and the whole cabinet is then covered with leatherette or fabric so that the aerial is not visible. This is illustrated in Figure 19.

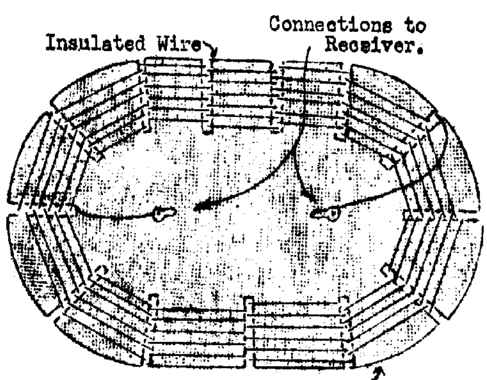

Fig. 18.

The number of turns of wire used to form the loop aerial is fairly critical, because the inductance has to be just right to be tuned by the tuning condenser to the range of broadcast frequencies, Figure 20 shows the way in which the- loop aerial is connected to the tuning condenser and to the grid of the first valve. Because of

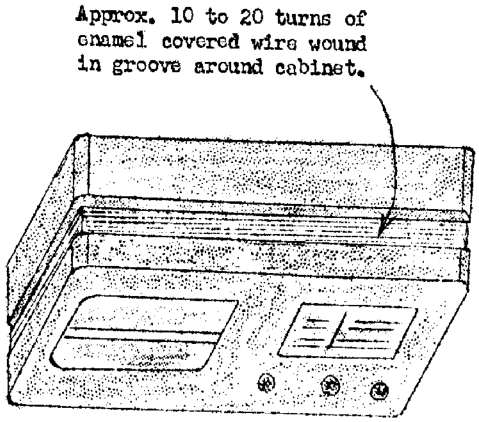

Figure 19.

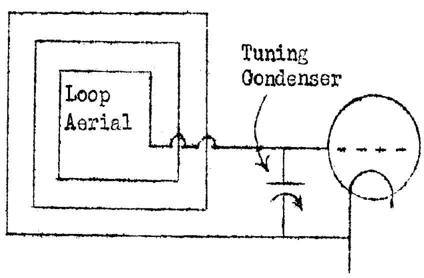

Figure 20.

the large size of the aerial only a small number or turns is needed. Usually the number varies from about 20 down to 10, the larger the size, the fewer the turns. As it is difficult to obtain just the right amount of inductance in the loop aerial, some manufacturers wind a few turns less than the correct number and then add an additional small coil called a “loading coil” as shown in Figure 21. The adjustable iron core enables the total inductance of the loop and loading coil to be set to the correct value.

STRAP AERIAL

In some very small portable receivers, the size of the case is too small to permit winding an efficient loop aerial around it.. One solution to this problem is to provide a carrying strap which may be placed over the users shoulder. This strap is usually made of a double thickness of leather or plastic material with a single length of wire contained between the two thicknesses of material. This single turn loop has far too little inductance to be directly tuned as shown in Figures 20 and 21 and so is connected to a suitable primary winding on an aerial coil as shown in Figure 22.

DIRECTIVE EFFECT.

All loop aerials are highly directive, that is, they will hardly respond at all to signals received from the two directions faced by the broad surfaces of the loop but they will be most sensitive to signals from a direction towards which the edges of the loop arc pointing.

In Figure 23 if we are looking down from above, on a receiver containing a loop aerial, good reception will be received from stations lying in the direction A or B, moderately good reception will be obtained torn stations in directions C, D, or E and hardly any signals will be obtained from stations in directions G or H. As a result, it is desirable to turn a receiver, containing a loop aerial, until the loop points approximately in he direction of the station

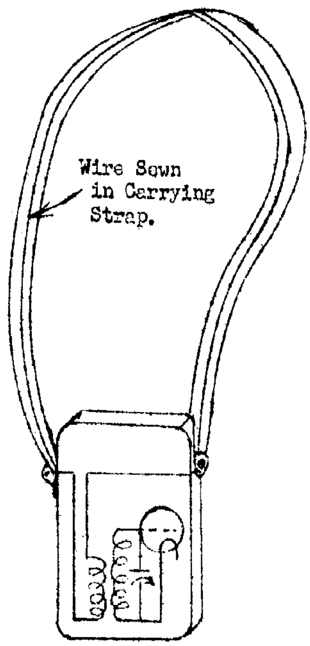

Figure 22.

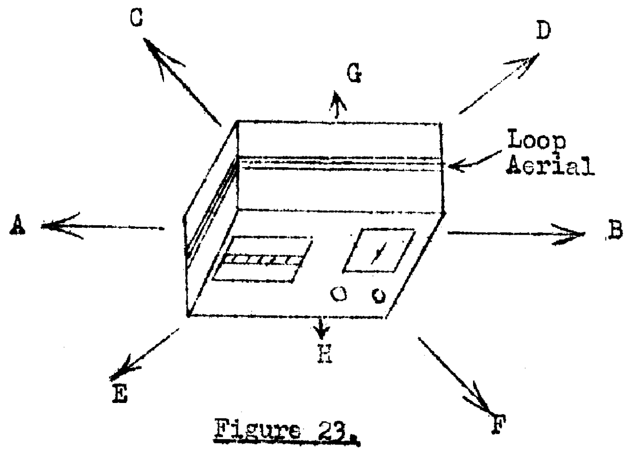

Figure 23.

it is desired to listen to, This is done by turning the receiver until the sounds from the loudspeaker are as loud as possible.

Loop aerials are not as sensitive at picking up signals as an outdoor or indoor aerial and earth system but with a sensitive set will generally provide a range of about 50 miles, most sets fitted with a loop aerial are provided with an aerial and earth terminal as well, so that an ordinary aerial and earth can be connected if it is desired to receive weak signals from distant stations.

LOOPSTICK AERIALS

In order to provide efficient signal pick-up in a device smaller than the conventional loop aerial shown in Figure 13 or 19, and more efficient results than with the Strap Aerial shown in Figure 22, the aerial shown in Figure 23 has been devised. This consists of a length of compressed powdered iron particles formed into a rod about eight inches long and three-eighths of an inch in diameter. Wound over one section of this "ferrite" rod is a coil of wire which becomes the tuning coil for the grid circuit of the first valve in the receiver, just as the loop aerial forms the tuning coil in Figure 20.

The powdered iron particles used in the rod on which the coil is wound, will carry magnetic lines of force many times more readily than the air and consequently even though the coil winding shown in Figure 24 is much smaller than the one shown in Figure I8 or 19, the magnetic lines of force passing to and fro in the rod spread through the centre of the coil and generate voltages in the coil winding comparable with those produced in quite a large loop aerial similar to the one shown in Fig.19.

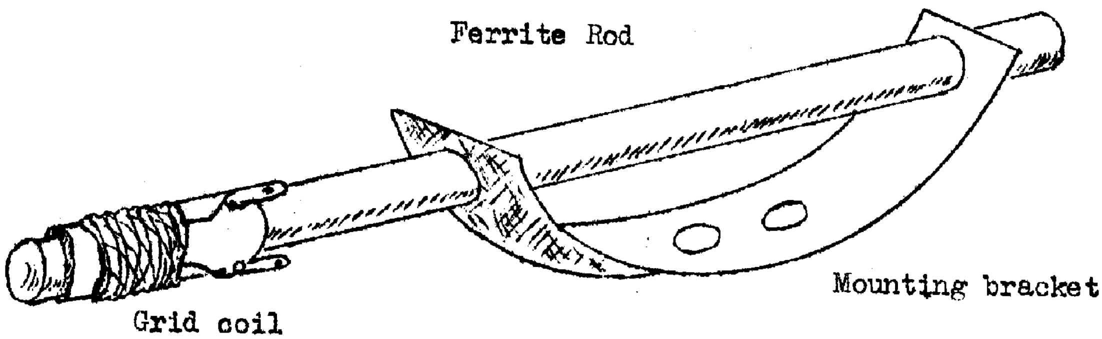

Figure 24.

The loopstick aerials are not only fitted in many modern portable receivers but also in quite a number of power mains operated table model and small sets. Their use save the necessity for any external aerial and earth connections although once again, their efficiency does not compare with that of a moderate sized outside aerial and ground connection.

Like loop aerials, the loopstick type of aerial has marked directional properties. The principles governing the directional pattern are the same as with the loop aerial in that reception is weak when transmitting stations lie in a direction which is broadside on to the coil winding and strongest reception is obtained from stations which are edge on to the coil winding. Due to the long iron core rod, which is threaded through the coil, the broadside direction from the coil winding is the direction in which the rod points. Therefore, the long rod or material should be set broadside to the direction from which it is desired to receive signals.

In employing any receiver equipped with a loop aerial or loopstick, it is desirable to rotate the aerial to determine the direction from which signals are loudest and to leave the receiver with the loop set in this direction.

RATIO OF SIGNAL TO STATIC

Every aerial will have two kinds of electric currents induced in it, or rather it will have induced in it currents from two different sources. One source is the transmitting station which you desire to hear. The other source is the combination of all the electrical disturbances in the air. The most troublesome disturbances are those coming from electrical apparatus and electric power mains.

To make a practical illustration of conditions, say that the strength of the atmospheric disturbances may be represented by the number 10, That number will indicate the loudness of the noises caused by static, then it is perfectly evident that a signal which produces a strength of 8 will be hoard with great difficulty. A signal with a strength represented by 12 will be heard louder than the static noises, but will not be very enjoyable. If 20 represents the signal strength from the station to which you tune, the reception will be fairly satisfactory.

Now you can see that it is not just the strength or signal that counts in obtaining good reception, it is the proportion of static that comes in with the signal or the ratio of signal to static.

When we talked about the outdoor aerial you will recall that it was said that the ratio in a high and long aerial is more favourable than in a short and low aerial. It was also said that thin ratio is more favourable with the outdoor aerial than with the indoor type. The disturbances from the arrangements shown in Figures 16 and 17 may be quite bad, as the light wires sometimes carry quite strong disturbances.

In choosing the type of aerial you are going to use for a given installation, you should take this signal-static ratio into account. If you are working with a modern, powerful receiver you often can use one of the simpler forms of aerial in a good district. Upon first making an installation you can put up a temporary indoor aerial, let the owner use it for a few days, then find out whether he is satisfied. If he is content with the reception, than you have saved him the expense of the outdoor aerial. If he complains that he cannot hear enough distant stations, it will be time enough to erect the outdoor aerial.

FREQUENCY AND WAVELENGTH

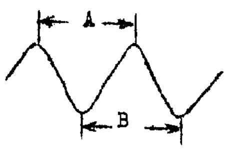

Fig. 25.

In The first lesson you will recall that I told you about the radiation of waves from a transmitter. The distance from either the crest or trough of one wave to the crest or trough of the wave ahead of it is called the length of the wave or the wavelength. If we represent radio waves an in Fig. 25 the distance between the crests, distance "a", or the distance between the troughs, distance "b", is the wavelength.

Wavelength is measured in a unit called the metre. This is the unit. of length in the French, or metric, system of measures. One metre is equal to 39 37/100 inches, almost exactly 39 3/8 inches.

All radio waves travel away from the transmitter with the approximate speed of light, about 186,000 miles in a second. Changing this speed to metres, it comes out that the speed of radio waves is 299,820,000 metres in a second. In round numbers you can say that the speed of radio waves is 300,000,000 (three hundred million) metres per second.

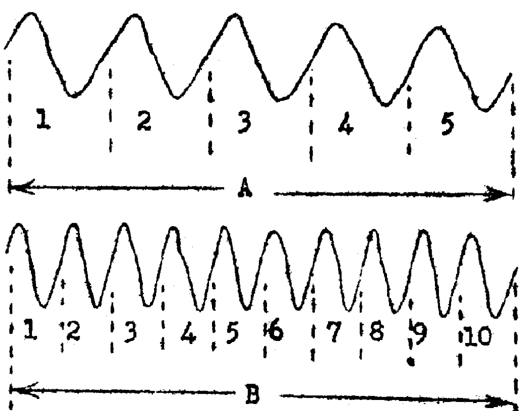

Figure 26.

Now look at Fig. 26, Within the distance "a" there are five complete waves. Within the distance "b" (which is the same length as "a") there are ten complete waves. The length of the waves at "a" is greater than the length of the waves at "b", The waves at "b" are coming from the transmitter more frequently than those at "a", consequently the frequency at "b" is greater than the frequency at "a".

From Fig. 26 you can see that the longer the waves or the greater the wavelength, the less will be the frequency.

Also the greater the frequency, the shorter the wavelength. They go opposite to one another. As one goes up the other goes down. Since the number of waves corresponding to the frequency must be contained within 300,000,000 metres (because the frequency is the number emitted in second) you can always find the length of one wave, or the wavelength, by dividing 300,000,000 by the number representing the frequency. Likewise, if you know the wavelength you can divide 300,000,000 by this wavelength and find the frequency. Of course, to get accurate figures you could use the number 299,820,000 instead of 300,000,000. If the frequency is in kilocycles (1000 cycles) you use 300,000 instead of 300,000,000.

In the earlier day of radio we always referred to the carrier wave as being of so many metres wavelength. That is no longer considered good practice. Nowadays we make it a rule to talk about frequency in place of wavelength. You can always change one to the other by performing the division as given above.

DATA SHEETS

A you progress with your radio studies there will be many kinds of information which you should have handy. This relation between frequency and wavelength is the first information you should have on hand. To save you the work of making all the divisions, the work is done for you and is given on a "Data Sheet". Frequencies are given in kilocycles, thousands of cycles. Here at the end of this lesson is the first one of these sheets. Many more will come with your future lessons. Preserve them carefully because at the end of your course they will provide you with an invaluable reference of the kind of information you use daily in your work.

DATA SHEET.

FREQUENCY AND WAVELENGTH. (broadcast Band)

Frequency In Kilocycles.	Wavelength In Metres.	Frequency In Kilocycles.	Wavelength In Metres.	Frequency In Kilocycles.	Wavelength In Metres.
1600	187.6	1230	243.8	860	348.6
1590	188.5	1220	245.8	850	352.7
1580	190.0	1210	247.8	840	356.9
1570	191.0			830	361.2
1560	192.5	1200	249.9	820	365.6
		1190	252.0	810	370.2
1550	193.5	1180	254.1		
1540	194.8	1170	256.3	800	374.8
1530	196.0	1160	258.5	790	379.6
1520	198.5			780	384.4
1510	199.0	1150	260.7	770	389.9
		1140	263.0	760	394.5
1500	199.9	1130	265.0		
1490	201.2	1120	267.7	750	399.8
1480	202.6	1110	270.1	740	405.2
1470	204.5			730	410.7
1460	205.4	1100	272.6	720	416.4
		1090	275.1	710	422.3
1450	206.8	1080	277.6		
1440	208.2	1070	280.2	700	428.3
1430	209.7	1060	282.8	690	434.5
1420	211.1			680	440.9
1410	212.6	1050	285.5	670	447.5
		1040	288.3	660	454.3
1400	214.2	1030	291.1		
1390	215.7	1020	293.9	650	461.3
1380	217.3	1010	296.9	640	468.5
1370	218.8			630	475.9
1360	220.4	1000	299.8	620	483.6
		990	302.8	610	491.5
1350	222.1	980	305.9		
1340	223.7	970	309.1	600	499.7
1330	225.4	960	312.3	590	508.2
1320	227.1			580	516.9
1310	228.9	950	315.6	570	526.0
		940	319.0	560	535.4
1300	230.6	930	322.4	550	545.1
1290	232.4	920	325.9		
1280	234.2	910	329.5		
1270	236.1				
1260	238.0	900	333.1		
		890	336.9		
1250	239.9	880	340.7		
1240	241.1	870	344.6		

All broadcast stations are given an assignment of a certain frequency in kilocycles on which to transmit their carrier wave. These frequencies are spaced 10 kilocycles apart. The above table includes all broadcast frequencies in use for regular receivers. The wavelengths given are all the result of dividing 299,820,000 by the frequency in cycles. In speaking of wavelength it is customary to mention the nearest whole number to the decimal given; thus we speak of 316 metres instead of 315.6 metres.

EXAMINATION QUESTIONS

1. Will an aerial having three parallel wires each 30 feet long, bring in signals three times as strong as a single wire 30 feet long ?

2. How far apart should you space the wires in a multiple wire aerial ?

3. What is the advantage of a doublet aerial system ?

4. Between what two wires do you connect a lightning arrester ? Explain its purpose.

5. Should a loop aerial be set broadside to or lengthwise towards a station it is desired to receive ?

6. Assuming a set to be sufficiently sensitive and selective, what limits the weakest signal which can be satisfactorily received.

7. Do you use a ground with an indoor aerial ?

8. Which collect the more static noise, a "power mains" aerial or a doublet aerial? Why ?

9. For best reception with a "4" tube set would you use an indoor or outdoor aerial? Why ?

10. Which has the greater or longer wavelength, a frequency of 780 kilocycles or one of 1110 kilocycles ? Work out these wave lengths.

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Always write down in full the question, before you answer it.

Use sketches and diagrams wherever possible. One diagram in many cases is equivalent to pages of explanation.

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LESSON NO.6

THE OPERATION OF CONDENSERS AND THEIR PART IN RADIO.

We might y in all truthfulness that every radio receiver and every transmitter is made up of four principal kinds of parts - condensers, coils, resistances and tubes. All the other parts, such as tuning dials, switches, panels and all the rest are there only because they allow you to control the operation of the receiver.

WHERE CONDENSERS ARE USED:

Possibly you think of condensers as used for tuning the receiver and do not think of these useful units as entering into many other portions of this work. Just to give you an idea of how much the average radio set depends upon its condensers, a circuit diagram of a very small and simple all-electric A.C. operated receiver is shown in Figure 1. This particular circuit is not currently used by radio receiver manufacturers but it still enjoys considerable popularity among beginner home constructors, because of its comparative simplicity. Although this circuit represents a very small type of receiver there are no less than 13 condensers used in it. From this you can judge what important parts condensers are in modern receivers, not only for tuning the receiver to the various stations, but for many other purposes as well.

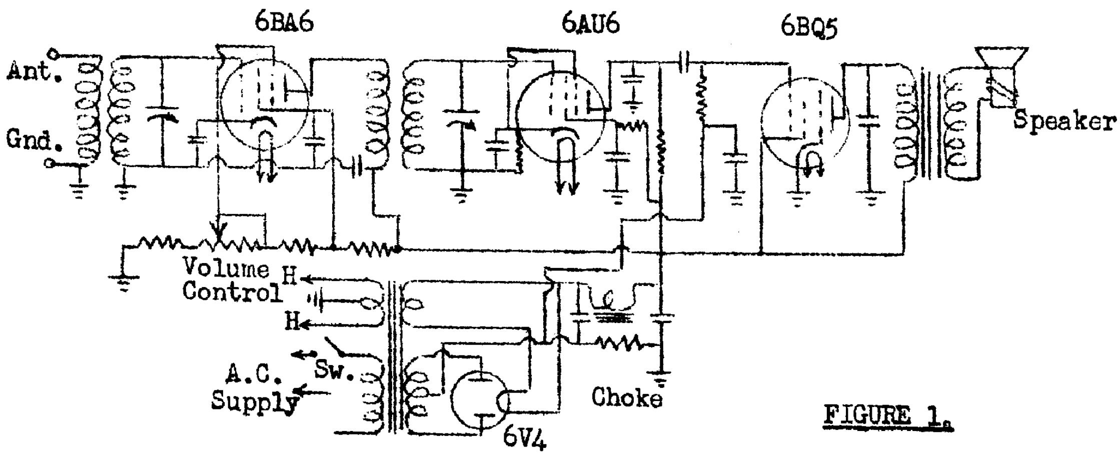

FIGURE 1.

Commencing at the left hand side or aerial end of the diagram in Figure1 we first of all have the first tuning condenser, a variable condenser of course. Between the "cathode" of the first tube, a "variable-mu" tube, and ground we have what is called a "cathode by-pass" condenser. The cathode is that part in an A.C, heater tube which takes the place of the filament in the ordinary tube which operates from an "A" battery. Then to the right of the first tube there is a condenser from the "screen-grid" of this tube to ground, and then another from the bottom of the air-core transformer primary also to ground. These are called the screen and plate by-pass condensers respectively.

Across the secondary of this air-core transformer is another variable tuning condenser. Actually this one and the one nearest the left of the circuit diagram are "ganged", or connected mechanically so that they both turn together as you move the tuning dial All modern sets have their tuning condensers ganged in this way. The next condenser to the right is the "detector cathode bypass" condenser. Just to the right of the second tube, which is a pentode detector tube, there is a "detector screen bypass" condenser, and just above it is the "detector plate bypass" condenser - the condenser which works with the detector tube and which serves to smooth out radio frequency pulsations from the detector output.

Continuing to the right is the "coupling" or "blocking" condenser between the plate circuit of the detector and the grid circuit of the audio frequency amplifier. Below this and further to the right we have yet another bypass condenser, this one is known as the "grid decoupling" condenser. The third tube is the audio frequency amplifier, and this particular tube is called a "pentode" because it has five elements or parts in it. From the plate of this tube to ground is another condenser which is put there to improve the tone quality, and is called a "tone corrector". Right at the bottom of all you have followed so far is the "power unit" or the part which supplies all the tubes with their power from the alternating current power lines The tube in this part of the set is called the "rectifier tube". It has two plates and a filament, and it changes the A.C. from the power or light socket into a pulsating or unsteady D.C. current to supply the plates of all the other tubes. In the bottom right hand corner of the diagram there are two more condensers. These are called "filter condensers", and their purpose is to "smooth out" or filter the uneven pulsating current from the rectifier and deliver it to all the min tubes as a steady unvarying direct current.

Remember we are going through this receiver just to show you how many different condensers are used in a modern set - don't attempt to memorise the names given or spend time studying the circuits, because we will have plenty of all that later on

<u>KINDS OF CONDENSRS</u>:

All condensers used in radio may be divided into two classes, variable condensers and fixed condensers. Variable condensers include all those whose capacity or condenser effect may be changed or varied while the condenser is in use. Fixed condensers include all those whose capacity is determined when they are built and in which the capacity cannot be changed afterwards.

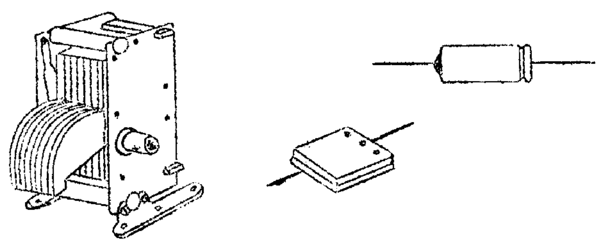

FIGURE 2.

Variable condensers, similar in a general way to the kind shown at the left in Figure 2, are used for tuning and for various other jobs where the capacity must be changed to let us secure the desired effect while the recover is in operation.

Two kinds of fixed condensers are shown at the right hand side of Figure 2, The smaller one has mica for the dielectric between its plates and is called a mica condenser.

The larger one has paper as its a its dielectric and is called a paper condenser. Both thee styles, mica and paper, are used quite generally throughout a receiver. The mica style is used where only a very small capacity is needed because large mica condensers are expensive and bulky. The paper style is used where more capacity is required than can be had economically in the mica type. The paper condenser contains more capacity within a given bulk or size than does the mica condenser, and the cost of paper condensers is much less than for mica condensers of the same capacity.

In this radio work you will come across a certain word quite often, especially in connection with condensers. The word is “electrostatic”. It refers to anything pertaining to electricity which is not moving, to electricity at rest as you find it in a charged condenser.

When the two plates, or the two kinds of plates, in a condenser are charged we have in the dielectric or space between the plates what is called an electrostatic field. This field is indicted in Figure 3 as existing in the dielectric. The electrostatic field consists of electrostatic lines of force which are somewhat like the magnetic lines of force existing around a magnet.

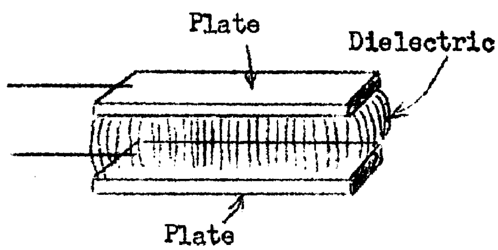

FIGURE 3.

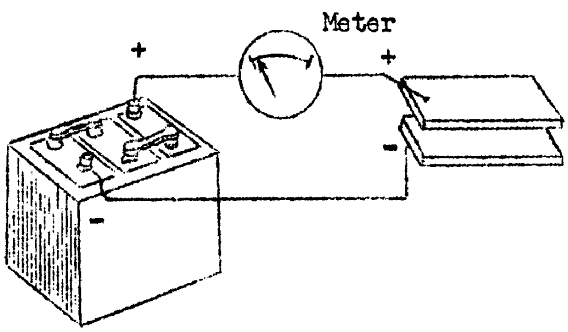

FIGURE 4.

THE CONDENSER CHARGE:

If you were to connect the two plates of a condenser to the two terminals of a battery as in Figure 4 and have in one of the wires a very sensitive ampere meter or ammeter to indicate flow of electric current, you would find that electricity did actually flow between the battery and the condenser. To understand the reason for this flow of current it is necessary to refer to that section of Lesson No. 1 dealing with Electron Theory and Atomic Structure. You will recall that all matter consists of a large quantity of individual atoms of a particular material and that each atom comprises a tiny solar system whereby the positive nucleus, the heaviest part of the atom, is surrounded by one or more planetary electrons The planetary electrons, which are negative particles of matter, rotate about the positive nucleus in much the same fashion as planets of our own solar system rotate about the sun.

Any material which exists in solid, liquid, or gaseous form is matter and, as a consequence, will consist of innumerable atoms, each with its negative and positive charge. The dielectric material placed between the plates of a condenser is no exception. It may exist in solid (mica or paper), liquid (a special type of oil), or gaseous (air) form. When there is no difference of potential between the condenser plates, planetary electrons will rotate on a normal orbit in the manner indicated by Figure 5. For the sake of simplicity only one planetary electron is shown for each positive nucleus. In actual fact the only atom which exists in thin simple form is the gas hydrogen. With any of the commonly used dielectric materials there would be several planetary electrons for each atom of the particular material.

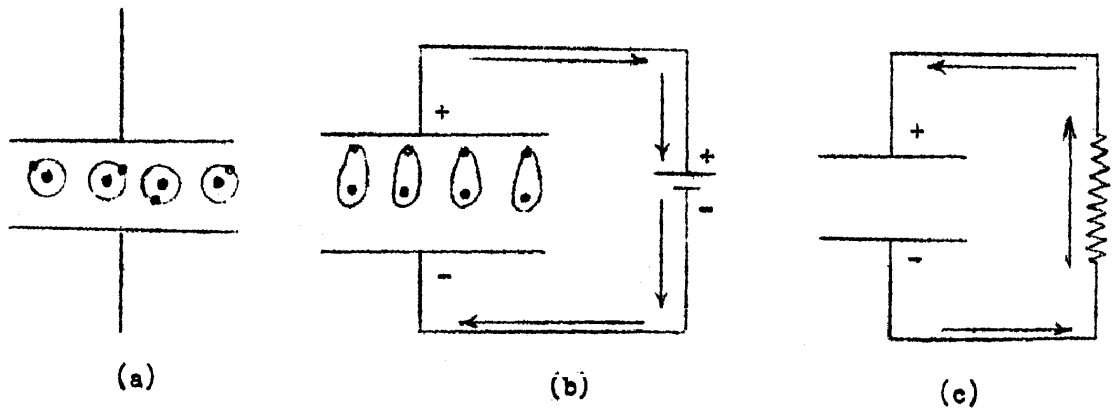

FIGURE 5.

If now the condenser plates are connected across a source of voltage so that the upper plate is connected to the positive terminal of the voltage source, and the lower plate is connected to the negative terminal, the electrons in the dielectric material atoms will try to obey the natural electrical law which states that points of unlike polarity are attracted towards each other while points of like polarity are repelled from each other. Because the dielectric material is always a very good insulator, electrons cannot move right through the material from one side to another as they can in a good conductor of electricity. Nevertheless, they will try to move through the material and in doing so will be diverted out of their normal orbits.

As a consequence of the combined effects of attraction and repulsion a condition of strain will be set up within the dielectric such that electrons are pulled towards the positive condenser plate and repelled by the negative condenser plate, while the positive nucleus will be drawn towards the negative plate and repelled by the positive plate. The effect is indicated by Figure 5(b)

Because a movement of electrons constitutes a flow of electrical current, the displacement of electrons within the dielectric material is responsible for a flow of electrical current within the dielectric. It must be clearly understood, however, that electrons do not move right through the dielectric from one plate to another and so out into the external circuit in which the condenser is connected. The flow of current continues only for as long as electrons in the dielectric are taking up their new positions. Immediately they have reached the limit of strain which is dictated by factors to be discussed later, further movement ceases and, as a consequence, displacement current in the dielectric ceases to flow.

Now there is a fundamental electrical law which states that electrical current cannot accumulate at any point in a circuit. The practical manifestation of Kirchoff's Law, as it ii called, creates what, at first sight, may appear to be a contradiction of the previous statement that current does not flow right through dielectric materials from one plate of a condenser to the other. This contradiction is, however, apparent only and cannot be sustained when the operation of a con-denser is carefully examined.

When a condenser is connected to a voltage source as in Figure 5(b), electrons in the upper plate of the condenser will be attracted by the positive pole of the battery and so will move around the external circuit from the upper condenser plates to the battery. On the other side of the battery, electrons are repelled by the negative battery terminals towards the lower plate of the condenser, and so will be moved around the circuit towards that point. Because the upper plate of the condenser is now deficient in electrons, it is said to have positive polarity and will cause the electrons in the dielectric material to be attracted towards it. similarly the lower plate of a condenser, having a surplus of electrons, will be of negative polarity, and so will repel electrons in the dielectric material and, at the same time, attract the positive nucleus of dielectric material atoms. The movement of electrons around the external circuit and within the dielectric material will continue only until the dielectric atoms are strained to their limit. When this state is reached, electron movement throughout the circuit and in the dielectric will cease and the condenser is said to be charged, If the source of voltage is now removed the condenser will remain in a charged condition. With a perfect condenser stored in a completely evacuated container, the charged condition would be permanent. Because even the very best of insulating material does not have infinitely high resistance there is, inevitably, some leakage of current through the dielectric material. For similar reasons there will be some external leakage between the terminals of the condenser and the combined effect of the various leakage paths will be to slowly discharge the condenser over a period of time, Even so, a good quality condenser, in first class condition, will hold a charge for several weeks,

If the terminals of a charged condenser are connected together, either directly or through a certain value of resistance, the surplus of electrons on the negatively charged plate will, by virtue of the external circuit be able to return to the positively charged plate and so make good its deficiency of electrons. when sufficient electrons have left the negative plate, the lower plate in Figure 5(b), to bring the number of electrons on the upper plate to their initial figure, a state of equilibrium will exist and there will now be no difference of potential between the two plates, electrons in the dielectric will no longer be under strain and so will return to their normal orbits. The condenser is then said to be discharged. The rate at which a condenser charges and discharges is dependent upon its capacity and the amount of resistance in series with it. This question of a condenser's time constant will be discussed in more detail in later lessons.

The small amount of current which flows during charge or discharge, and which quickly drops to zero, is called the displacement current or the dielectric current.

The amount of current which flows depends on four things. In the upper part of Figure 6 a small battery of low voltage is connected to the condenser plates. In the lower drawing we have a large battery of high voltage. There will be a greater flow of current with the higher voltage, the more the voltage the greater the amount of current.

In the upper part of Figure 7 we have small condenser plates and in the lower drawing we have larger plates. The larger the condenser plates the more current will flow on to them with the same voltage applied. In the upper part of Figure 8 the plates are separated by a considerable space and in the lower drawing the plates are very close together. The less the separation, the more current will flow, the size of the plates and the applied voltage remaining the same. The kind of dielectric materiel between the plates also has an effect on the amount of current which will flow.

Now you see that more current will flow with higher voltage, with larger plates and with less separation between the plates. Less current will flow with lower voltage, with smaller plates and with more separation between them. We are assuming that there is no change in the kind of dielectric between the plates.

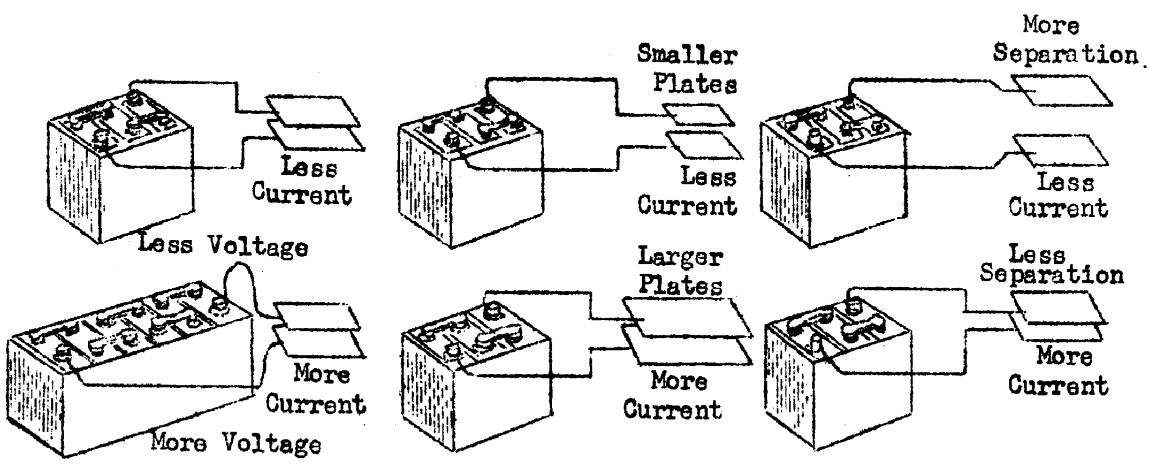

FIGURE 6. FIGURE 7. FIGURE 8.

The ”charge” of a condenser is the amount or electricity it will hold. The unit of measurement for condenser charge is the “COULOMB”. One ampere of current flowing for a period of one second represents one coulomb of electricity. If the difference of potential between the plates of a condenser having a capacity of one farad is one volt, the condenser's charge would equal one coulomb. You now know that this amount depends on four things, but, in any given condenser, the kind of dielectric, the size of the plates and their distance apart remain the same.

In a fixed condenser these three things never change and in a variable condenser they will not change unless you move the plates. Then we can say that the amount of current flowing from the battery into the condenser depends on the voltage applied to the plates of any given condenser.

The voltage comes from outside the condenser but the other three things are within the condenser. The size of the plates. Their separation and the kind of dielectric between them all work together to determine what we call the “capacity” of the condenser. Large plates, small separation and certain kinds of dielectrics increase the capacity and make the condenser able to take a greater charge with a certain applied voltage. Small plates, great separation and other dielectrics reduce the condenser's capacity and allow it to take a smaller charge with the same applied voltage. Always remember that the applied voltage does not affect the capacity of a condenser. It affects only the condenser’s charge.

MEASURES OF CAPACITY.

The capacity of a condenser is measured in a unit called the “Farad”. A condenser having a capacity of one farad would be exceedingly large, entirely too large for any of our radio work. Therefore we use fractions of a farad as the practical units for speaking about condenser capacity.

One of the common units of capacity is the microfarad. Micro means the one millionth part of, so a microfarad is the one millionth part of a farad. This is the unit generally used in speaking of fixed condensers of the paper dielectric type. For tuning condensers and for the small mica dielectric condensers we need a still smaller unit in many cases, so we use the micro-microfarad. As you would guess, this means the millionth part of the millionth part of a farad, or, the one millionth part of a microfarad. Some time ago the prefix “pico” was adopted in Continental countries *as* a substitute for micro-micro. This practice has now spread to other parts of the world including Australia, so that it is customary now to refer to a small capacity condenser, say 0.0005 microfarad, as 500 picofarads rather than 500 micromicrofarads.

The tuning condenser at the left hand side of Figure 2 would probably have a capacity of about 420 micro-microfarads. The small mica condenser in the centre of that illustration might have a capacity of about 1000 micro-microfarads. The paper condenser at the right hand side of Figure 2 probably would have a capacity of one tenth or one half microfarad. There are still other measures of capacity, but none of them are used in practical radio work.

KINDS OF DIELECTRIC:

Three kinds or dielectric have already been mentioned - air, mica and paper. Air is the dielectric used in tuning condensers. It is also the dielectric for the aerial, which you will remember is a large condenser.

There is only one thing used as a dielectric with which a condenser will have less capacity than with air between the plates. That thing is a vacuum or the absence of air. All other materials used as a dielectric increase the condenser's capacity.

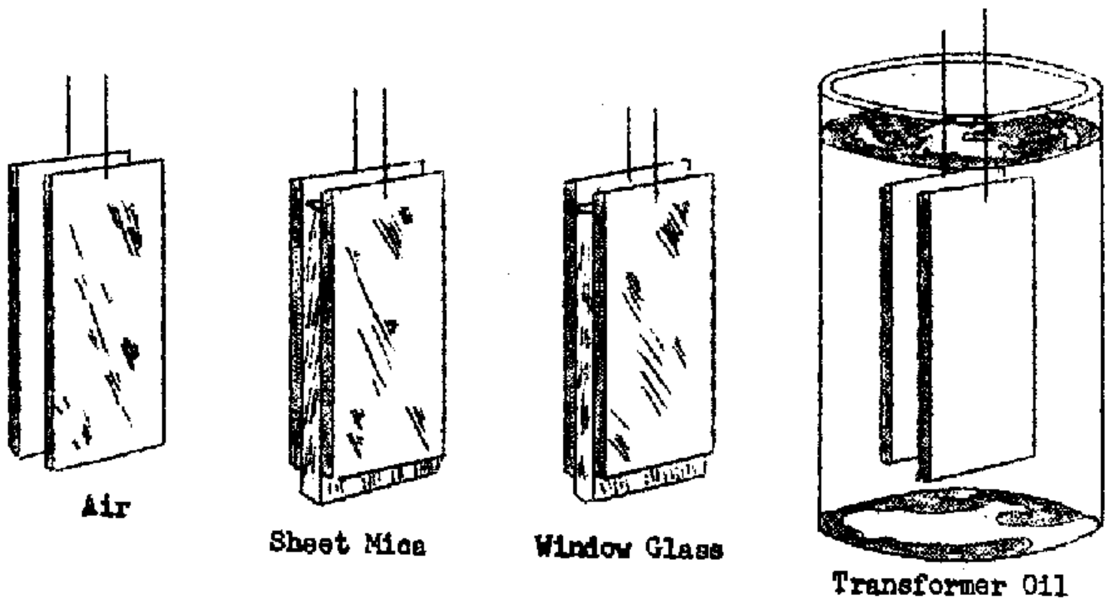

FIGURE 9.

The very interesting experiment illustrated in Figure 9 might be performed with various dielectric materials. We will assume that the condenser plates shown at the left are found to have a capacity of 2 micro-micro-farads when the dielectric between the plates is air. Were you to use mica for the dielectric, filling the space between the plates with this mineral substance, and were you to then measure the capacity you would find it somewhere around 10 micro-micro-farads. That word micro-microfarad is a long one, so we abbreviate it to “mmfd”, or even “mmf”. The abbreviation for picofarad is “pf”.

Then to continue the experiment, supposing you removed the mica and substituted a piece of window glass. Measuring the capacity again, you would find it to be about 15 mmfds. You might even make a test with liquids by immersing the condenser plates. Should you Use the kind of oil used for large power transformers you would find the capacity of your condenser to be about 5 mmfds.

You find that various kinds of dielectric materials multiply the capacity of the condenser by certain amounts as compared with its capacity when air is the dielectric. The number by which the capacity is multiplied is called the “dielectric constant” of the material. For example, you found that the capacity of the condenser in Figure 9 was increased from 2 mmfds, with air to 10 mmfds. with mica for the dielectric. Theretoroe the dielectric constant of the mica is 5, because 2 is multiplied by 5 to get 10.

Similarly, the dielectric constant of the glass is 7½ because the original capacity, 2, is multiplied by 7½ to give 15, the capacity with glass as dielectric.

This property of dielectrics by which they increase the capacity of a condenser allows us to make very small condensers with quite large capacities. The dielectric constant of paper used in fixed condensers is about 2½. This paper can be had in very thin sheets, one-half thousandth of an inch being a commonly used thickness. Consequently, the condenser plates can come very close together - and you know that bringing the plates near each other increases the capacity. So we have plenty of capacity in small space due to the small separation between plates ant to the multiplying action of the paper. The same effects are secured with mica, but since the dielectric constant of the mica is even greater than that of paper, the capacity of the mica condenser is still higher. However, mica cannot be made as thin as paper, so it would require a large condenser to get a capacity of say, one microfarad, in a mica condenser.

HOW ALTERNALTING CURRENT EFFECT PASSES THROUGH A CONDENSER:

All through these lessons you have been told that the effects of alternating current will pass right through a condenser. Since the dielectric is an insulator and since you know that electricity cannot continue to flow through an insulator, or for that matter can hardly flow through an insulator at all, you must wonder how alternating current performs this apparently impossible thing.

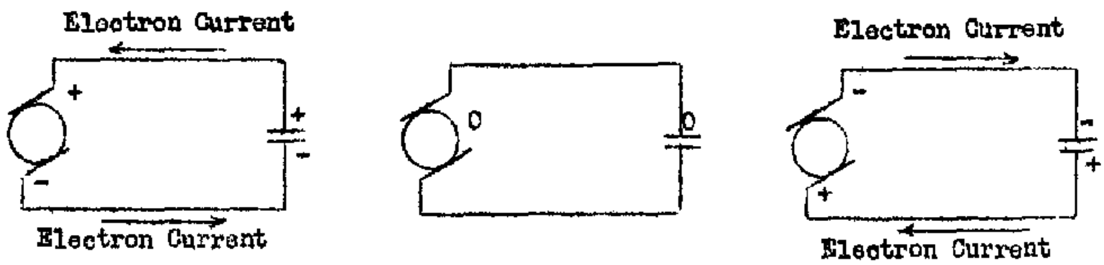

FIGURE 10. FIGURE 11. FIGURE 12.

To begin with, look at the diagrams in Figures 10, 11 and 12. Here we have a condenser connected to an alternating current generator. In Figure 10 the generator polarity is such that the upper brush is positive. As a consequence, electrons will be attracted away from the upper condenser plate towards the positive terminal of the generator. At the same time, electrons are moving from the lower brush, which is negative, on to the lower plate of the condenser. In other words, the generator is charging the condenser in such a manner that the top plate of the condenser is positive and the bottom plate negative.

As the generator continues to run, the potential difference between its terminals drops to zero as shown in Figure 11. That's the way alternating current acts, first rising to its highest voltage in one direction, then falling to zero, and immediately afterward rising again to its highest voltage but in the opposite direction.

As the potential difference increases in the other direction, the conditions will be as in Figure 12. Now the generator polarity has been reversed. The upper brush is negative while the lower brush is positive. The movement of electrons will, therefore, be in an opposite direction to that shown by Figure 10. Electrons will flow from the lower plate of the condenser to the positive terminal of the generator and from the negative terminal of the generator to the upper plate of the condenser. Once again the condenser will be charged but with an opposite polarity to that indicated by Figure 10.

No current actually flows right on through the dielectric of the condenser. First the top plate receives a charge, then the bottom plate receives a charge. The current alternates back and forth in the wires, first flowing one way as the condenser is charged one way, then reversing and flowing the other way as the condenser's charge is reversed. So alternating current flows in this circuit containing a condenser just as it would flow in a circuit composed entirely of conductors. Of course, not as much current can flow with the condenser in the circuit as though it were replaced with solid wires, but a certain amount of current actually alternates back and forth. The amount of current that can flow in this circuit containing the condenser depends on the size or capacity of the condenser.

Now you can see how alternating current acts through a condenser. The condenser plates simply charge and discharge, first in one direction, then in the other and the current alternates back and forth in the wires included in the circuit.

<u>HOW THE DIELECTRIC WORKS:</u>

The action of a condenser can be made still clearer to you by going back to our old friend the water, and using another analogy or comparison of actions in water and electricity.

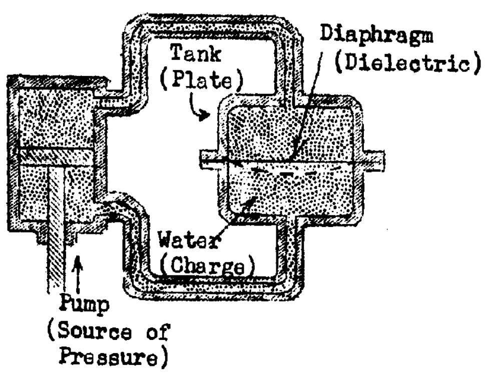

FIGURE 13.

In Figure 13 you will see a water pump connected to a tank which is divided into two parts by a diaphragm or partition across it. The pump, the pipes, and the tank are filled with water. The diaphragm is made of thin, flexible rubber. The two parts of the tank correspond to the two plates of a condenser. The diaphragm corresponds to the dielectric. The two pipes correspond to two wires. The water corresponds to the electricity.

to revert to the older conventional idea of electrical current flowing from a point of high or positive potential to a point of low or negative potential. Now let us see what happens when the pump is set into operation.

As the Pump's piston is pushed upward, in the direction of the arrow along the piston rod, water will be forced over through the upper pipe into the upper part of the tank. The diaphragm stretches downward just as it is shown in the broken lines. The top tank becomes charged with more water and the water in that tank is under increased pressure. The diaphragm is placed under strain by this action.

In a condenser the top plate would be charged with an excess of electricity, the electricity would be under increased electrical pressure, or voltage, and the dielectric of the condenser would be placed under an electrical strain.

On the reverse motion of the pump plunger or piston the action in the tanks would be reversed. Water would flow out of the top tank and into the lower tank. The diaphragm would then be stretched in the other direction and the water in the lower tank would be under increased pressure. Similar things happen in the condenser. The lower plate accumulates an excess of electricity, and the dielectric is again placed under a strain.

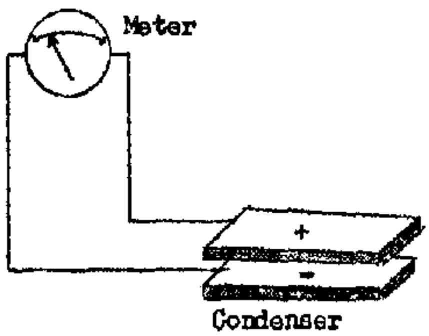

FIGURE 14.

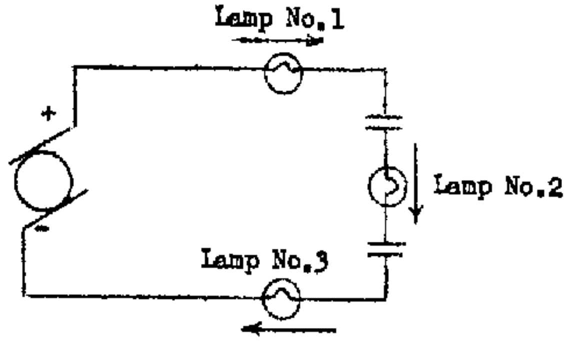

FIGURE 15.

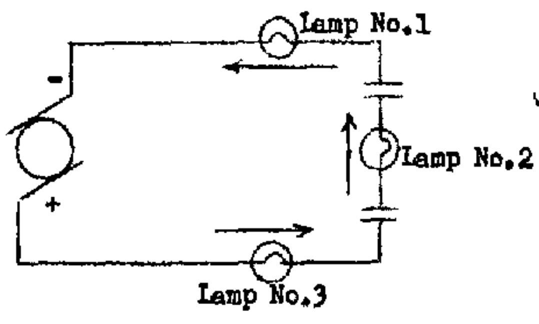

FIGURE 16.

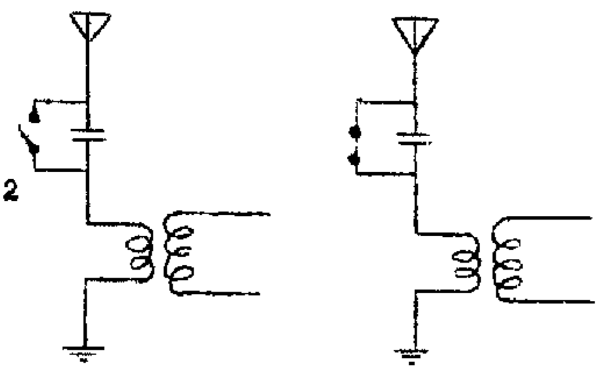

FIGURE 17.

Supposing with the diaphragm in the strained position of Figure 13 you were to release the pump piston - what would happen? The diaphragm would force water out of the tank and would draw water into the lower part of the tank. The tension or strain of the rubber in the diaphragm would do that. As the diaphragm came to the straight across position (shown in full lines) it would no longer be under strain, no more pressure would be exerted on the water in the top tank and there would be no further flow or water in the piping. Exactly similar actions take place in a condenser. With the condenser charged, one of its plates is at higher electrical pressure than the other plate. The dielectric is placed under electrical strain. If the two plates are connected together through a wire as in Figure 14, an electric meter in the wire or circuit would show a current to be flowing for an instant following the connection. As the voltage difference between the plates dropped to zero, or as the condenser became discharged, the flow of current would stop.

To make sure that you clearly understand the manner in which alternating current will act in a circuit containing condensers, let uso take two condensers and three lamps or meters and connect them to an alternating voltage generator or power mains as shown in Figure 15. This is called a "series" circuit, because any alternating current acting in the circuit will have to act through each of the parts in turn before getting tack to the second terminal of the generator. The lamps by lighting, or the meters by the movement of their needles, will tell us when current is passing.

When the upper brush of the generator is becoming positive, current will flow across through lamp No.1 and into the top plate of the upper condenser. When examining Figure 13, you saw that water, pumped into the upper part of the tank would strain the diaphragm downwards so that an exactly equal amount of water is pushed out of the lower section of the tank to go on around the pipes.

Exactly the same thing happens with the upper condenser in Figure 15. The current flowing into the top plate produces a strain in the dielectric and this causes an exactly equal current of electricity to go on, out of the bottom plate, through lamp No. 2, and into The top plate of the lower condenser. Here the same action again occurs. The dielectric in the lower condenser is strained and forces an equal current to go on, through lamp No.3 back to the negative terminal of the generator.

When the generator's voltage reverses, as shown in Figure 16, the current will simply act in the opposite direction, as shown by the arrows. As the generator produces alternating voltage, the current will act in the direction shown by Figure 15, for a tiny fraction of a second and will then reverse and flow in the direction shown in Figure l6, for a similar period and will then repeat over and over again, flowing firstly one way and then the other with each cycle of alternating voltage.

As the current is just as strong in any one part of the circuit as at any other part, the three lamps would light just as brightly as one another or three meters, if used, would all give the same reading as one another. Naturally, because of the opposition of three lamps and two condensers, a rather high voltage will be necessary to make enough current flow to light the lamps. The larger the capacity of the condensers, the greater the amount of current which can act through them and the lower will be the voltage needed to make any lamps light. The flow of current in Figures 15 and 16 can, of course, be readily modified to conform to the modern conception of electron movement from negative to positive. You will find it good practice to do this. It will help you to develop flexibility of thought.

AERIAL CONDENSER:

In some simple receivers there is included between the aerial terminal and the aerial coil a small condenser, often having a switch to cut it out of the circuit if desired, as in Figure 17. Placing a condenser between the aerial and the receiver has a very peculiar effect. As far as all electrical circuits are concerned, such a condenser shortens the aerial. You learned that a short aerial brings in less energy, makes the reception clearer and makes the receiver more selective, better able to pick out one station without interference from others. The aerial condenser does exactly the same thing. It allows less power to come to the set, but makes for clearer reception and greater selectivity.

The less the capacity of the aerial condenser, or the smaller this condenser, the greater will be its, effect in shortening the aerial system and the more selective the receiver will be. The larger this condenser or the greater its capacity, the less effect it will have.

The purpose of the switch around the condenser is to prevent the condenser from having any effect at all on the reception while the switch is closed. At the left hand side of Figure, 17 the aerial condenser is shown with the switch open. Then the radio currents have to pass through the condenser on their way into the receiver.

At the right hand side of Figure 17 the switch is shown closed. Now it is so much easier for the radio currents to flow through the metal of the switch that practically none of them flow through the condenser, and it is just as though you had a continuous metal path or a wire between the aerial and the coil in the receiver. We say that the condenser is "shorted out" by the switch because the switch provides a path that is easier to follow, or "shorted", from the electrical standpoint.

Now let us see just what this aerial condenser really amounts to. The left hand drawing in Figure 18 shows the aerial, the aerial condenser "C", the first coil in the receiver, and the ground. The centre drawing illustrates the fact that the aerial and ground are really the plates of a big condenser. The right hand drawing shows aerial-ground condenser marked "A-G" and the aerial condenser "C" both in the one electrical circuit or line. So here we really have two condensers connected in "series".

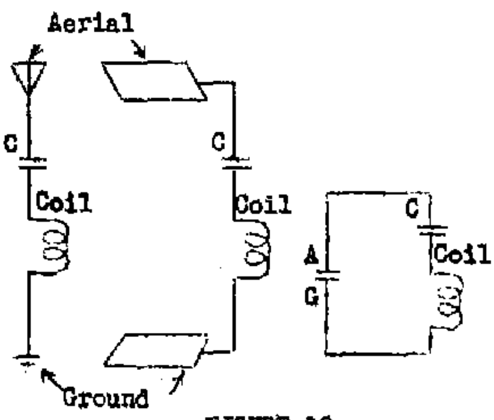

FIGURE 18.

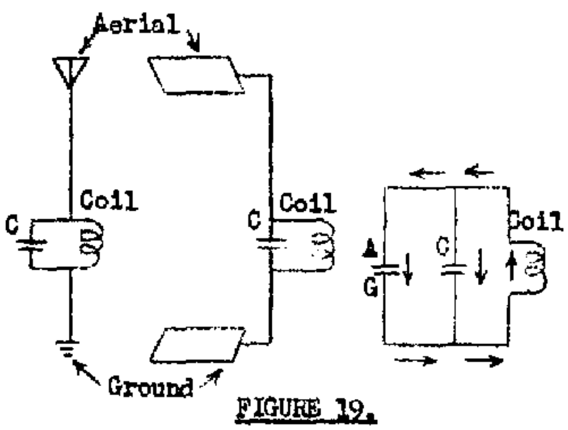

FIGURE 19.

SERIES CIRCUITS:

A series connection is a connection or circuit in which all current passing through any one part in the connection or circuit must also pass through every other part in the circuit. At the right hand side of Figure 18 you can see that every bit of current passing through one of the condensers must also pass through the other one and through the coil as well. Therefore, this is a series circuit.

The total capacity or the combined capacity effect of two condensers connected in series is to make the capacity of the combination less than the capacity of either one or the condensers taken alone. Remember this fact; it is very important in radio work. Remember that you can reduce the capacity of a circuit by placing more condensers in series with the other condensers already there.

PARALLEL CIRCUITS:

Connecting the aerial condenser in series with the aerial, as in Figure 18, has the effect of lessening the capacity of the whole aerial system. There is another kind of connection by means of which we can increase the capacity of the aerial system. This other connection is called a parallel connection or parallel circuit.

At the left hand side of Figure 19 is shown an aerial condenser "C" connected in parallel. The centre drawing shows how the aerial and ground "plates" would appear with the aerial condenser. Over at the right the aerial and ground are shown as a small condenser "A-G" and the aerial condenser "C" connected in parallel with it.

A parallel circuit is a connection of parts made in such a way That current will divide between them, part of the whole current of the circuit flowing through each of the parts connected in parallel. Supposing the circuit at the right hand side of Figure 19 was an oscillatory circuit, like the ones explained in the earlier lessons. Current starting out from the coil would flow through both condensers, following the paths shown by the arrows. Part of the current will flow through condenser "C" and the rest will flow through condenser "A-G". Also, if these condensers were charged, the currents which they would give forth upon discharge would combine or join together and then flow through the coil. Remember that with parallel connections, the current will divide or will combine, part going to or coming from each of the parts in the parallel circuit.

EFFECT OF AERIAL CONDENSER IN PARALLEL:

The effect of the aerial condenser connected in parallel, as in Figure 19, is quite different from the effect of the same condenser connected in series. Connection of the condenser in parallel acts to lengthen the aerial system (electrically).

This effective lengthening of the aerial does not make any material change in the amount of power brought in, or in the clearness of reception or in the selectivity of the receiver. What the parallel condenser does actually do is to change the tuning of the aerial circuit. The circuit with this condenser in it will be resonant or will tune at a different frequency than were this condenser omitted.

Parallel aerial condensers are not used on ordinary present-day receivers used for ordinary broadcast reception.

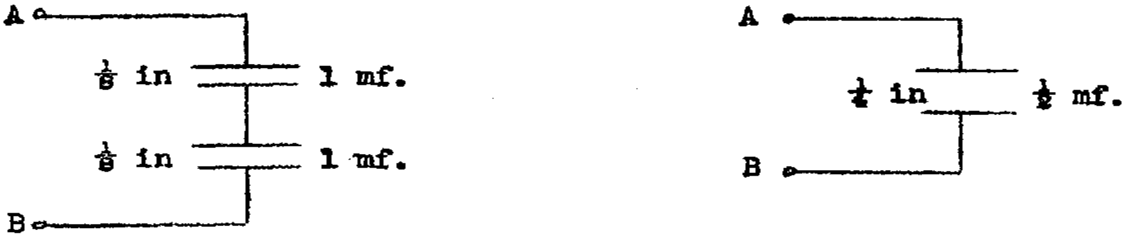

FIGURE 21.

You have learned that when condensers are connected in series, the combined capacity is less than either of the condensers alone; also that when connected in parallel the combined capacity of two or more condensers is greater than either alone. But just how much is the capacity increased or decreased.

CONDENSERS IN PARALLEL:

You know that the capacity of a condenser increases as you increase the area of the plates - twice as much plate area gives twice as much capacity. When you connect two or more condensers in parallel as at the left in Figure 20, you are really adding the areas of all the top plates together, and also adding all the bottom plates together. This gives a plate area equal to all the separate areas added together, as shown at the right in Figure 20. Therefore, the combined capacity will also be equal to all the separate capacities added together, as also shown in Figure 20. So now you have a simple rule to remember - "To find the combined capacity of a number of condensers in parallel, add all the separate capacities together".

CONDENSERS IN SERIES:

The thicker the dielectric of a condenser, other things remaining the same, the less will be the capacity - twice the thickness or twice the distance between the plates will give half the capacity. Supposing you had two condensers, both the same size and both having one-eighth inch spacing between plates, connected to the top plate of the bottom condenser, and these two plates are then the same thing electrically. The bottom of the top dielectric is in electrical contact with the top of the bottom dielectric, and the result is that there is really one-quarter inch or twice the thickness of dielectric between the two connections "A" and "B", as shown at the right of Figure 21.

FIGURE 21.

The dielectric being twice as thick, any voltage on one plate will have less effect on the other plate and the capacity will only be half as much; that is, if the two condensers were 1 mfd. each, the combined capacity would be ½ mfd. Then to find the combined capacity of two or more equal condensers or capacities in series, divide the capacity of one condenser by the number connected in series. Thus, if four 8 mfd. condensers were connected in series, the combined capacity would be 8 divided by 4, or 2 mfds.

For unequal condensers in series, the exact amount of combined capacity is not so easy to calculate. We will deal with this in a later lesson, but for the present remember that when condensers are connected in parallel, the combined capacity is greater than the greatest single capacity; but when connected in series, the combined capacity is always less than the smallest single capacity of the combination.

ELECTROLYTIC CONDENSERS:

Previously it was stated that mica was used as a dielectric only in condensers of very small capacity and that when we want a larger capacity than can conveniently be obtained with mica dielectric we use paper. Now there is also a limit to the maximum capacity available within reasonable physical dimensions when using paper as a dielectric.

A paper dielectric condenser having a capacity greater than about 1 microfarad tends towards bulkiness and also becomes very costly. When we consider that a modern receiver operated from A.C. or D.C. power mains may use condensers of up to 32 mfd. capacity while the vibrator power supply unit employed with many radios operating in country districts may incorporate filter condensers having capacities up to 500 micro-farads, the provision of condensers having the required capacity seems to present a first class problem. However, our difficulties are easily overcome by the electrolytic condenser.

Whereas the condensers with which we have so far dealt consist of two metal plates separated by a dielectric The electrolytic type has one plate of metal called the anode, while the other plate is a liquid or semi-liquid called the electrolyte. dielectric is a thin oxide film formed on the surface of the anode.

In one form of construction, the anode, which is a rod or cylinder, sometimes pleated, of chemically pure aluminium, is placed centrally in an aluminium can, while the space between the anode and can is filled with the liquid electrolyte. The anode is insulated from the can be means of a rubber bushing. The protruding end of the anode serves as one terminal of The condenser while the oTher connection is made to the metal can.

The principal reason why we are able to obtain large capacity within a comparatively small physical space with this type of condenser is the extreme thinness of the dielectric. You will remember that one of the factors governing the capacity of a condenser is the distance between the plates, and that the smaller the spacing between plates, the greater will be the capacity.

Because the oxide film which is formed on the surface of the anode during manufacture is so very thin there is very little space between the plates or the condenser and so we have increased capacity without undue increase in the physical size of the condenser.

All electrolytic condensers do not use a free liquid as the second plate. Some of them have the electrolyte suspended in an absorbent material such as linen or blotting paper. Although this latter type is sometimes called a dry electrolytic, the term "dry" is in this case, purely comparative. The liquid electrolyte is there, even though it is not free to move about.

Another very great advantage which the electrolytic condenser has over those using a mica or paper dielectric is its ability to withstand slight overload without suffering permanent damage. All condensers when they are made are rated to withstand a certain maximum voltage between the plates. You may have noticed condensers bearing the figures "400 volts working" after the capacity. This indicates that the maximum voltage which can be continuously applied to the plates is 400 volts. If this voltage is exceeded for any length of time the dielectric will break down and the condenser plates will be short circuited.

In the case of mica or paper dielectric condensers a breakdown of this nature is permanent and the condenser is of no further use. However, if a condenser of the electrolytic type is overloaded, provided that the overload is not too great, no permanent damage will result. If the cause of the overload is removed and the condenser is allowed to operate at a voltage below the normal working figure for a short period, the punctured dielectric will heal and the condenser will be as good as ever.

Unlike ordinary condensers, employing mica or waxed paper as the dielectric, electrolytic condensers must only be connected in a circuit in which direct voltage is present and the connections must be such that the anode is connected to the positive side of the circuit whilst the electrolyte is connected to the negative side, consequently in testing electrolytic condensers, care must be taken to see that the testing voltage is applied correctly, if misleading indications are to be avoided. Assuming that a battery is being used for testing an electrolytic condenser, the positive terminal of the battery should be connected to the anode of the condenser while the negative terminal of the battery should be connected to the electrolyte. In the case of the "wet" type of condenser the anode connection protrudes through the centre of the end of the can, while connection to the electrolyte is made via the can itself. With electrolytic condensers of the semi-dry type two leads are usually provided for connection to the plates. It is normal to have a red lead connecting to the anode while a lead of some other colour, usually black, connects with the electrolyte. Alternatively, one end of the container may be coloured red to indicate the positive connection, whilst the other end is uncoloured or coloured black.

A final point may be mentioned in regard to the wet electrolytic condenser and that is the necessity for always mounting in an upright position. When in operation, a certain amount of gas is generated in the condenser which normally escapes through a rubber covered vent in the top of the can. If the condenser is mounted in such a position that this vent is covered by the electrolyte, the pressure of gas set up within the can will force some of the liquid from it and the useful life of the condenser will be greatly reduced. Because of the fact that the electrolyte in the semi-dry type of condenser is not a true liquid such precaution is not necessary when using these. Care must always be taken with both types of condenser to ensure that they are not subjected to excessive heat. If they are mounted in close proximity to components which normally radiate a great deal of heat, such as rectifying valves, power transformers and so on, the life of the condenser will again be greatly reduced due to excessive evaporation of the electrolyte.

The appearance of both wet and “dry” type electrolytic condensers is shown in Figure 22.

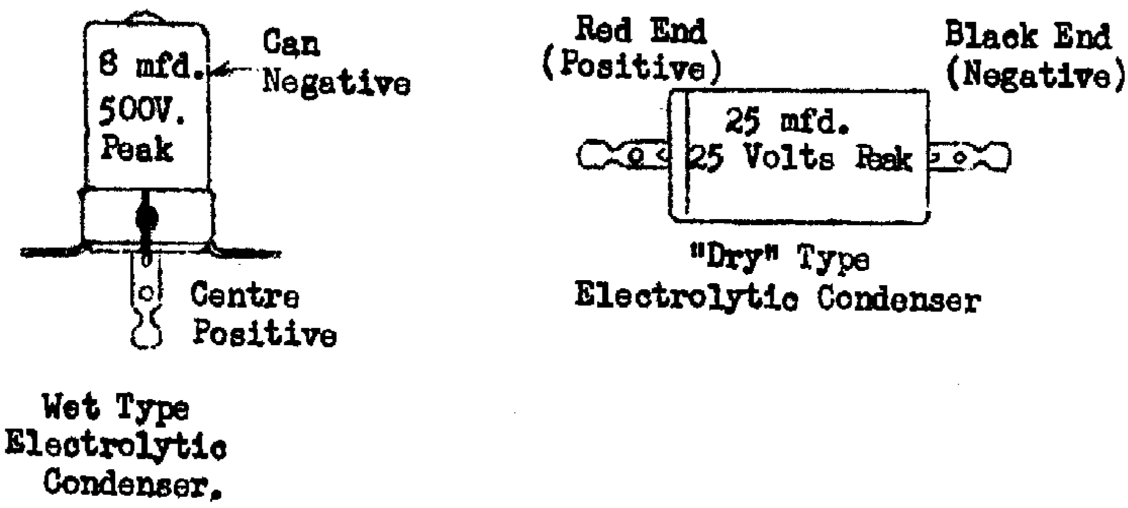

FIGURE 22.

CHECKING UP ON YOUR PROGRESS

Let Us see what you have accomplished in this lesson. You learned that condensers of one kind or another are used all over the set and also in the power unit. Those condensers include those with air as the dielectric, others with mica dielectric and still others using paper. Then you found that the capacity of a condenser is affected by three things:

(1) the size of the plates,
(2) the distance between the plates, and
(3) the dielectric constant of the material between the plates.

You also learned that the amount of electricity or amount of charge taken by a condenser depends on the condenser’s capacity and on the voltage applied. The farad is the unit in which capacity is measured, but for radio work we make our measurements in microfarads (mfds.) and in micro-microfarads (mmfds).

One of the most interesting things you have learned from this lesson is that certain kinds of dielectric increase or multiply the condenser's capacity several times over. You found out how it is that alternating current flows in a circuit even when a condenser is in the circuit. Also, during your investigations of aerial condensers you learned about series and parallel connections of condensers. Finally, you have been given some preliminary details of electrolytic condensers.

You have certainly covered a lot of ground - plenty for one lesson. Before you answer the examination questions, you should go right back to the beginning and read these pages over once more. You will be astonished at how much easier it will be for you to understand the action of condensers during that second reading.

EXAMINATION QUESTIONS – No. 6.

(1) Does electric current flow right through the dielectric or a condenser, from one plate to the other ?

(2) To increase the capacity of a condenser would you use larger or smaller plates ?

(3) Will bringing condenser plates closer together make the capacity greater or smaller ?

(4) Does the voltage applied to a condenser affect its capacity ? Explain.

(5) In what two units do we measure the capacity of radio condensers ? Show their relationship.

(6) If a certain condenser with air as its dielectric has a capacity of 30 micro microfarads, what will be its capacity with a dielectric of mica having a dielectric constant of 6 ?

(7) Is mica used as the dielectric in radio condensers of large or of small capacity ? Why?

(8) Which will allow more alternating current to flow, a condenser of small capacity or one of large capacity ?

(9) To make an aerial electrically shorter, would you use a condenser in series or in parallel with it ? Why ?

(10) If you wanted to get a capacity of 2 microfarads by using a number of 8 mfd. condensers, show how you would connect them.

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NOTE: Write the lesson number before answering the questions.

Write on one side of the paper only.

Always write down in full the question before you answer it.

Use sketches and diagrams wherever possible. One diagram in many cases is equivalent to pages of explanation.

Remember that you learn by making mistakes; so give yourself an opportunity of having your mistakes found and corrected.

Don't hesitate to ask for further explanation on a point, we are always ready to help you.

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LESSON NO.7

RADIO CIRCUIT TROUBLES AND HOW TO CORRECT THEM.

In this lesson we are on the trail of trouble. We are going to find out what goes wrong in electric circuits. A circuit is the path through which the electricity flows in getting to and passing through all the different parts we use. Radio circuits are made up of coils, condensers, resistances and the wires or other metal parts which connect THEM together.

All radio circuits are what we call "closed circuits", or at least they are closed circuits as long as they are working correctly. A closed circuit is a pathway through which it is possible for either direct current or alternating current to flow from the source of voltage around through any parts contained in the circuit, and then back again to the voltage source. If the pathway is not complete all the way around we have an open circuit, and, unless it is opened, on purpose, an open circuit means trouble.

A closed circuit for direct current is illustrated in Figure 1. Here we have a battery furnishing current for the filament of a radio tube and a switch in one of the lines between the battery and the tube. Electrons will flow from one terminal of the battery over to the tube, through the tube's filament, to the switch, through the switch, and then back to the other terminal of the battery.

The current then passes through the battery itself, and once more comes out of the left-hand terminal.

This circuit of Figure may be opened by opening or turning off the switch; it might also be opened by one of the wires becoming disconnected, or breaking, by one of' the terminals breaking, by a wire breaking or by the tube's filament burning out. Should this circuit be opened at any point, not a bit of current would flow in any part or it, The conductors would be full of electricity, but it could not get across the break or open place, and consequently could not move or flow.

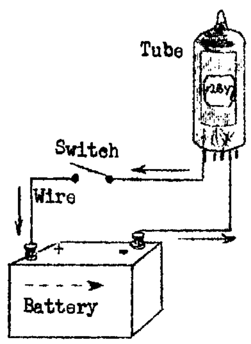


FIGURE 1.

Never forget that it takes but one open place in a circuit to put the whole circuit out of business, and that an open between the tube pin and the negative battery terminal will be just as effective in stopping any current from flowing as an open at any other point.

In the full lines of Figure 2 you have a closed circuit *for* alternating current. Of course any circuit which will carry direct current will also carry alternating current, but here in Figure 2 we have a circuit containing a condenser which would stop the flow of direct current. However, as you know, a condenser allows alternating current to flow in its circuit. This particular circuit carries audio frequency currents between the radio tube, the loud-speaker and power unit.

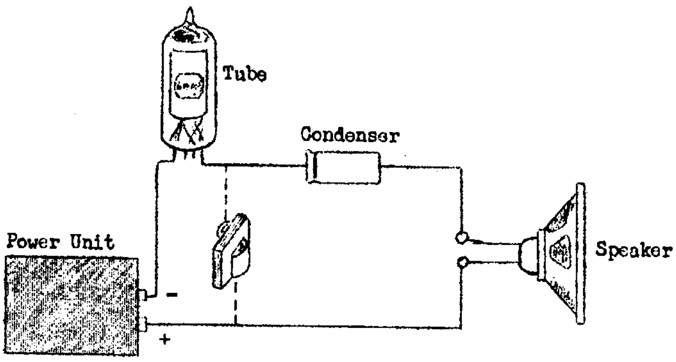


FIGURE 2.

Suppose the audio frequency current at some one instant is flowing out from the bottom terminal on the power unit. It passes into and through the speaker, acts through the condenser, and then goes to the "plate" in the tube. The current then passes across the space between the tube's plate and its filament, enters the filament and goes back into the power unit. This is a closed circuit for alternating current because alternating current can act through every portion of it. It is, at the same time, an open circuit for direct current because direct current cannot get through the dielectric of the condenser. As the direct current for the plate of the tube cannot pass through the dielectric of the condenser, we must provide another path so that the D.C. can flow from the power unit to the plate to enable the tube to operate correctly. The path for D.C. is provided by connecting an iron cored coil called a "choke" between the + terminal of the power unit and the plate of the valve as shown in broken lines in Figure 2. The D.C. will then flow in the plate circuit, which comprises the power unit, cathode-plate path within the valve and the choke, while the alternating signals act through the condenser and speaker.

<u>ELECTROMOTIVE FORCE</u>.

The thing that causes current to flow is called electromotive force. Voltage is electromotive force, and this force is measured by the unit called the volt.

You recall that in the very first lesson you were told that voltages mean electric pressure and nothing else. The abbreviation for electromotive force is “e.m.f.”

electromotive force is produced by batteries, which change chemical energy into electrical energy or e.m.f. This force is also produced by generators which change mechanical energy or motion into e.m.f. There is a third method in which heat energy is changed to electrical energy. This method was used in motor vehicle radio receiver some years ago. The unit employed was called a “genemotor”.

ELECTRIC CURRENT.

When electromotive force or voltage is applied to a circuit, the electrons in the circuit will move, and these moving electrons are, in effect, an electric current. Now this fact is of great importance. A flow of electric current is brought about by a movement of electrons from one point to another in an electrical circuit. The one is, in fact, equivalent to the other. Many people find this difficult to grasp, primarily because of the unfortunate assumption, a long time ago, that an electric current flowed from a point of positive potential to a point of negative potential, an assumption accepted as fact because, at that time, little was known about electricity beyond the appreciation that it did certain things in a certain way. This assumption, or convention, had become so firmly entrenched by the time Professor Thomson published his, now proven, Electron Theory of matter, that the two ideas tended to exist for quite a long time with individual identities They have, in fact, persisted to the present day, which is probably why so many students, while adopting a movement of electrons from negative to positive, cannot rid their minds of the belief that the resulting flow of electric current is a related but entirely separate phenomena which acts in an opposite direction - from positive to negative. So long as you remember that the older conception of current flow is merely a convention and cannot be separated from electron movement, there is no particular reason why you should completely avoid thinking in terms of conventional current flow. This conception is not incomptib1e with theories explaining the operation of radio and electrical equipment, but in this lesson we will concentrate on electron flow from negative to positive in order to get you used to the idea.

In the first lesson you learned that current flow is measured in a unit called the “ampere” and that the number of “amperes” indicates nothing except the flow or the rate at which electricity moves through a circuit. Remember, amperes do not measure the pressure nor do they measure the total quantity of electricity; they measure only the amount of electricity going past a given point in a given length of time.

In terms of electron movement, 6.28 times 10^{18} electrons passing a given point in a circuit in a period of 1 second represents current flowing at a rate of 1 ampere per second.

POLARITY.

Electrical polarity tells us whether one part of a component or a complete circuit is positive or, negative in relation to another part of such component or circuit. While it has become customary to relate polarity to pressure and infer that a point which is of positive polarity is at a pressure higher than that of the earth, and that a point which is of negative polarity is at a pressure lower than that of the earth, we must be careful not to take the inference too far. It is true only if neither side of the component or circuit we are considering is connected to earth or ground. When such condition applies we regard the earth as being "neutral", or without polarity. There are two kinds of polarity, positive and negative. Positive polarity is indicated by the plus sign (+) and negative polarity is indicated by the minus sign (-). Terminals which are positive are often coloured red and those which are negative are often coloured black or green.

Take the batteries in Figure 3, all of which are used in radio. The storage battery is often used for furnishing filament current to the tubes. It has two terminals, one positive and the other negative. The dry cell is also used for filament supply in small sets using very small tubes. The dry cell terminals are not always marked, but the centre terminal is always positive and the outside terminal is always negative. To furnish current for the plate circuits of the tubes we often us what is called a "B-battery", made up of a number of small dry cells inside a case. Such a battery may have only two terminals, one positive and the other negative, but it often will have one negative terminal and several positive terminals, the different positive terminals being of different voltage, some higher than the others.

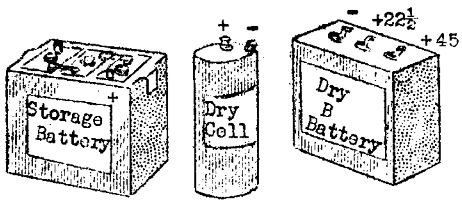


FIGURE 3.

The polarity of direct current remains constant. If, for instance, a potential difference of 6 volts exists across a D.C. circuit, side "a" of the circuit has positive polarity while side "b" has negative polarity, this particular polarity will exist for as long as voltage is applied to the circuit. Even though we may reduce the voltage to 3 volts or increase it to 9 volts, there will be no change in polarity, part "a" of the circuit will till be positive and part "b" will still be negative.

With alternating current we cannot have polarity in the same sense that it exists in direct current circuits. This does not mean that alternating current has no polarity but only that its polarity is periodically changing. At one instant of time one side of a circuit may be positive while the other side will be negative, while at a later instant of time polarity will be reversed. The point in the circuit which was previously positive will now be negative and the point which was previously negative will now be positive. These reversals of polarity take place at a regular rate which depends upon the frequency. The electric mains which supply A.C. power to your homes usually have a frequency of 50 cycles per second. This means that their polarity goes through a complete reversal 50 times each second.

POTENTIAL AND VOLTAGE

In this electrical work we have three words or names all meaning very much the same thing. These three are: Electromotive force, voltage and potential. each, however, has a slightly different meaning from either of the others.

Electromotive force means the pressure or voltage difference existing between the two terminals of a source, such as between the terminals of a battery or the terminals of a generator. E.M.F. is measured in volts,

Voltage, strictly speaking, means the difference in pressure between any point and the earth, assuming that the earth is neutral or is at zero pressure.

Potential means the difference in pressure between two points in an electric circuit. Potential differences are measured in Volts. Interchangeable with potential difference, is the term voltage drop. In figure 4 we have a circuit consisting of a battery as the source of e.m.f, a lamp, a resistance and the wires connecting them together. Now, of course, it is going to take a certain amount of pressure to send the current through the lamp. Consequently, there will be less pressure remaining at “b” than there is originally at “a”. There is a difference of potential, or voltage drop between “a” and “b”, this difference being the amount of voltage it requires to send current through the lamp. The voltage drop from one side to the other of the lamp is the potential difference between the two sides. Likewise, it will take some more pressure to get the current through the resistance, there will be a drop or loss of voltage between “e” and “d”, and this is the potential difference between these two points. The arrows in Figure 4 do not represent the direction in which electrons are moving around the circuit, but rather do they indicate the direction in which voltage drops in the circuit are acting. Point “a” is more positive than point “b” or point “c”, but point “c” is more positive than point “d”. There is no easily measurable voltage drop between point “b” and “c” because the resistance between these two points is negligible.

There is no real need for you to be careful in your use of the words e.m.f., voltage and potential, because very few people are careful in this respect. However, you should understand the exact meaning of each of the words.

Figure 5 shows another circuit; this time we have one unit furnishing plate current, another furnishing filament current, also a radio tube and a transformer in the tube's plate connection. Electrons start out from the negative side of the plate power unit,

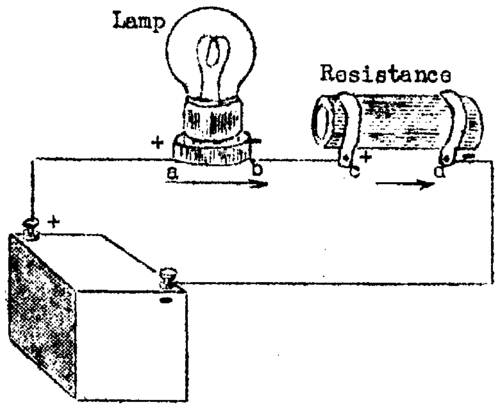


FIGURE 4.

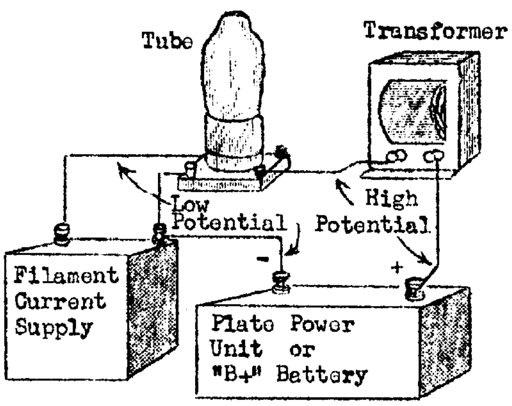


FIGURE 5.

go through the valve or tube and then through the transformer. There is a very great drop of voltage in the tube, practically all of though pressure disappearing right there. The parts of the circuit which are connected to the high side or positive side of the plate power unit make up what we call the high potential side of the circuit. From the transformer back to the power and filament supply units there is a negligible voltage drop

RESISTANCE TO FLOW OF CURRENT

All materials oppose or hinder the flow of electric current through them. The opposition to flow of current is called the resistance. Here we are going to look into the matter of resistance to flow of both direct and alternating currents. Later on we will investigate other kinds of opposition to the flow of alternating currents, also the effects of what we call "high frequency resistance", which takes into account all the losses of energy which occur during the flow of alternating current at very high frequencies. Resistance which we will now consider is sometimes called "ohmic resistance". It is measured by a unit called the ohm.

The amount of ohmic resistance in anything depends on four factors: (1) The kind of material, (2) the temperature of the material (3) the length of the path through which current flows, and (4) the size around or distance across the path through which current is flowing.
Resistance depends on the kind of material; iron has more resistance than copper, and silver has less resistance than copper. Heat also affects the amount of resistance, a hot metal having more resistance than the same metal when cooler. Heat affects carbon just the other way around, carbon having less resistance when hot than when cold.

At the left-hand side of Figure b are two conductors. A conductor is any material of any part which carries electricity without much trouble or resistance. All metals are good conductors and most of the parts through which we carry direct current are made of metal. These two conductors at the left-hand side of Figure 6 are both the same size around, but the lower one is twice as long as the top one. Therefore, the resistance of the lower one is twice as great as the resistance of the top one because in the lower one the current has to travel through twice the

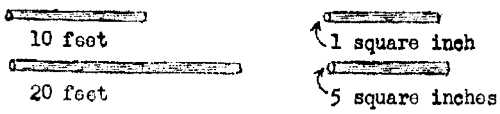


FIGURE 6.

At the right-hand side of Figure 6 are two more conductor. If you cut straight across the top one and measured the space on the cut end you would be measuring the "cross sectional area". The cross sectional area of the upper conductor is 1 square inch and the cross sectional area of the lower one is 5 square inches. Therefore, the lower conductor has but one-fifth the resistance of the top one because in the lower one there is five times as large a path or as free a path through which current may flow. In these comparisons we assume the conductors to be of the same material.

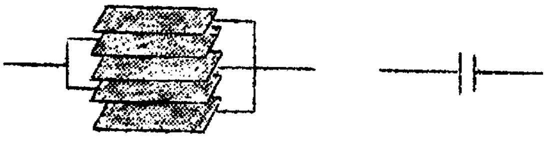


FIGURE 7.

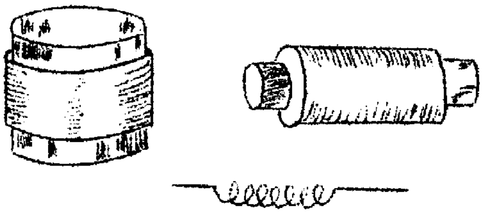


FIGURE 8.

Now remember, the longer a conductor the greater its resistance. Also, the bigger around, or the greater the cross sectional area of a conductor, the less it resistance. Long wires have lots of resistance, short ones have little resistance. Big wires have little resistance and small or thin wires have much more resistance.

All circuits and all parts have ohmic resistance to the flow of either direct current or alternating current. Coil and condensers oppose the passage of alternating currents with their property of resistance, but along with their reactance they always have ohmic resistance as well.

The condenser of Figure 7 may have only a small amount of reactance or opposition to flow of alternating current, but it will have exceedingly great ohmic resistance to the flow of direct current right on through it.

The coils of Figure 8 may have very great reactance to passage of alternating current through them, but since both of them are wound with quite large wire and with not a great length of wire, they will have fairly low ohmic resistance to the flow of direct current through them.

UNITS OF RESISTANGE.

The unit by which we measure resistance is called the “ohm”, as stated above. An ohm is the amount of resistance in a circuit which allows a flow of one ampere of current through it when there is a pressure of One volt. This relation between the ohm, the ampere and the volt is indicated in the circuit of Figure 9.

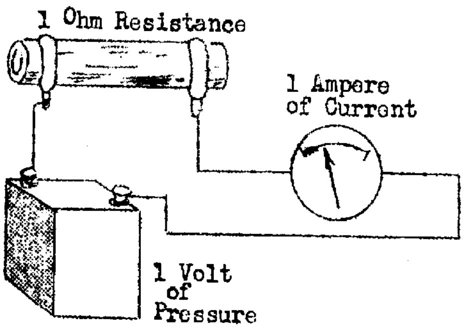


FIGURE 9.

The symbol for ohmic resistance is the letter “R”. Sometimes we use the capital letter “R” and then again we use the small letter “r”. The symbol for electrical pressure in volts is the capital “E” or the small letter "e", standing for e.m.f The symbol for electric current in amperes is either the capital letter “I” or the small letter “i”, standing for “intensity”.

One thousand feet of number 12 gauge copper wire has a resistance of almost one ohm. There is one ohm resistance (approximately) in l27-1/5th feet of ordinary electric bell wire of number 20 gauge size. The standard ohm, or the "international ohm", is the resistance offered to the flow of unvarying current by a column of mercury 106-3/l0th centimetres (41 85/100 inches) high and weighing 14.4521 grams (0.0318 pounds) at a temperature of zero centigrade (the temperature of melting ice). Do not try to remember this definition of an ohm; it is given to you just so you can read a really technical definition.

In radio work we sometimes use parts with so much resistance that we measure it in "megohms". One megohm is equal to one million ohms. Then again we make measurements of resistance so small that we use the "microhm". One "microhm" is the one millionth part of an ohm.

There is one more word to be explained to you now. It is "conductance". If a part has very high resistance it has very low or very little conductance. On the other hand, the conductance is high in a part which has but little resistance. Conductance is measured in a unit called the "mho", which as you see, is o-h-m spelled backwards. You will seldom use the words conductance and mho, but the sub-multiple "micromho", one millionth of a mho, is used very frequently when referring to the mutual conductance of a valve. The precise meaning of the term "mutual conductance" will be explained in later lessons.

METERS FOR RADIO W0RK.

You will realise by giving the matter a little thought that practically any trouble in an ordinary electric circuit will make some change in the current, in the voltage, or in both current and voltage. To detect these changes we make use of two principal kinds of meter. One is the voltmeter, which measures differences in potential or voltages. The other is the ammeter which measures the rate at which current is passing through a circuit, that the umber of amperes. In radio perhaps we use a milliammeter more often than an ammeter. The milliammeter is a meter arranged so that it measures milliamperes. A milliampere is the one thousandth part of an ampere. We are often dealing with currents so small that it is most convenient to measure them in milliamperes.

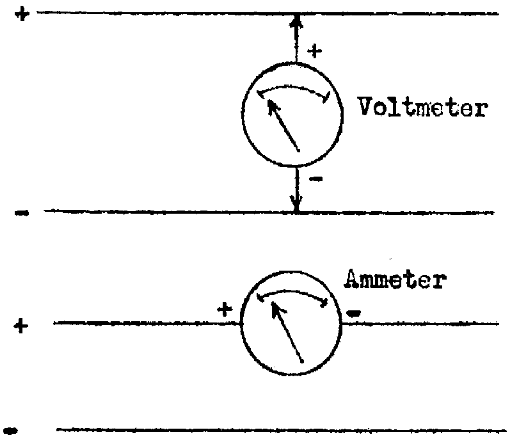


FIGURE 10.

In using a voltmeter it is always your intention to measure the difference of potential or voltage between two points in a circuit. Therefore, you simply touch the leads from the voltmeter to the two places between which you desire to measure the voltage, as the left-hand side of Figure 10. Voltmeters for measuring direct current have their terminals marked "+" and "-" or "Pos" and "Neg", standing for positive and negative. It is important that you touch the positive meter lead to the positive side of a circuit and touch the negative lead to the negative side. Connected in this manner, the voltmeter - pointer will move across its scale and come to rest at the number corresponding to the number of volts difference between the two connections. If you connect a voltmeter the other way around, the pointer will move in the wrong direction, off its scale, and you will not get any reading. You are no more likely to burn out a meter by connecting it backward than by connecting it the right way; the worst you can do is to give the pointer such snap that you bend it slightly.

In using a voltmeter you need not remove any wires or disconnect any wires. You just leave everything as it is and touch the meter's lead to the two points between which you are to make the measurement. Remember this about not taking off the wires.

You use an ammeter in the manner shown at the right-hand side of Figure 10. With an ammeter you want to measure the rate of flow of current through a circuit, therefore you must let all current flow through an ammeter. To do this you have to open up or break the circuit, which will leave two ends. Then you connect the ammeter in between these two ends so that the circuit is again closed, but is closed through the ammeter.

Ammeters and milliammeters for direct current are also marked positive and negative on their terminals. You should connect the positive terminal to the positive end of the circuit, sometimes called the high potential side of the circuit, a legacy from the days when it was believed that electric current actually flowed, like water, from a point of high pressure to a point of low pressure. The negative terminal of the meter is, of course, connected to the other side of the circuit which has been broken to admit the meter. In this way electrons will flow through the meter from its negative terminal to its positive terminal

USING THE VOLTMETER

The very first thing you must do in getting ready to use a voltmeter is to make sure the meter will stand the amount of voltage you intend measuring. That is, make sure that the voltage difference between the points at which you are going to connect the meter is no higher than the highest voltage shown on the meter's scale. If the voltage is much higher than the meter is designed to measure, you are quite sure to wreck the meter.

The most generally useful meters, either ammeters, milliammeters or voltmeters, have several different “ranges”. That is, they are made with several positive terminals and one negative terminal, also with several scales on the one dial, as in Figure 11. Here is a meter with which the pointer may be made to move all the way across the dial with 10 volts, or with 25 volts or with 250 volts, or with 1000 volts The terminal marked “Neg” is connected to one point and one of the other terminals connected to the other point. If you are measuring between points where you are sure the voltage is not more than 10 volts, you can make connection to the 10 terminal. The pointer in the position shown would then be indicting 5-volts. Were you to use the -volt terminal the pointer would be reading 12.5 volts. Were you using the 250-volt scale the meter would be reading 125 volts with the pointer as shown. You just count along from one marked position on the scale toward the next one, reading the scale which corresponds to the terminal you are using.

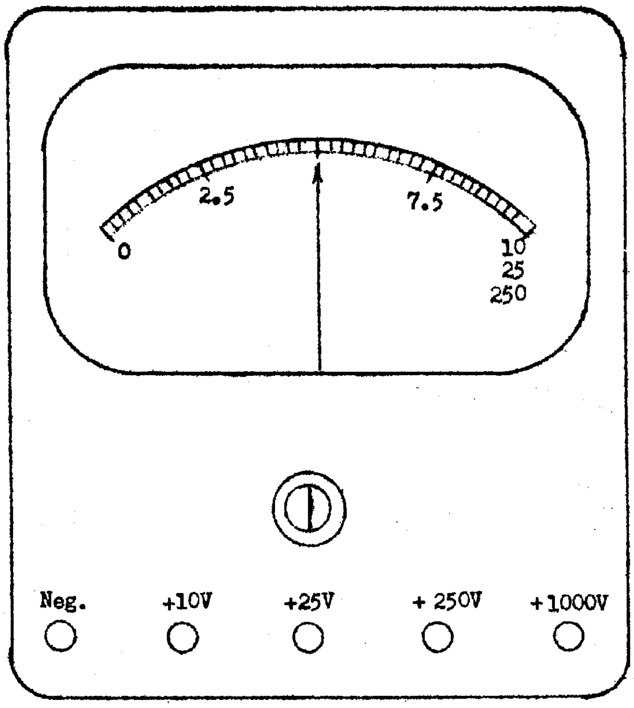


FIGURE 11.

You will notice that although there is a terimna1 marked 1000 volts there is no actual 1000-volt range marked on the face of the meter. When you use multi-range meters you may find that there are more provided than are actually marked on the meter face. Although there is no actual scale marked up to 1000 on the meter in Figure 11, there is a 10-volt range provided. What we have to do is read the voltage on the l0 volt range and multiply the reading obtained by 100. We multip1y by 100 because 1,000 is 100 times 10, and with the needle at any point along the 10 volt range the actual voltage will be 100 time the reading indicated by the needle. For instance, if we connect to the negative and + 1,000V. terminals, and the needle points to 7 on the 10-volt range, then the actual voltage would he 100 times 7 or 700 volts. With the needle in the position shown in Figure 11, it is reading 5 volts on the 10-volt scale, but the actual voltage is 100 times 5 or 500 volts.

Another way we could determine the reading on the 1000 range would be to read the voltage on the 250-volt range and multip1y by 4 instead of 100. The needle in Figure 11 is indicating 125 on the 250 volt range and multiplying this by 4 would give us 500 volts, the same as before.

The way to find out what is safe to do on a circuit when you do not know the approximate voltage is to start with the highest scale first. This reading will give you some idea of the actual voltage. Then, if the voltage is small enough you can drop to one of the lower scales.

In Figure 12 is shown a voltmeter being used in several different positions. In the position marked “A” you would be measuring the vo1tge drop through the transformer. In position “B” you would be measuring the voltage from the “plate” terminal of the tube to the filament "-" terminal of the tube; in other words, you will be measuring the voltage applied to the tube's plate In position "C" you would be measuring the voltage applied to the tube's filament circuit. Notice how the polarity of the meter terminals is observed in making these connections.

USING THE AMMETER OR MILLAMMTER.

In Figure 13 the same circuit is shown as used in Figure 12, but here using the current instead of the voltage. Notice that the wires are disconnected from their terminals and the meter connected between the terminal and the wire end which

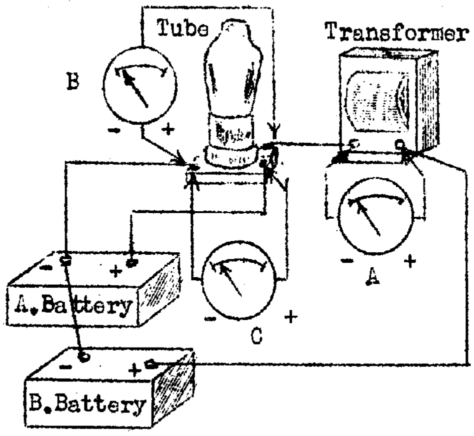


FIGURE 12.

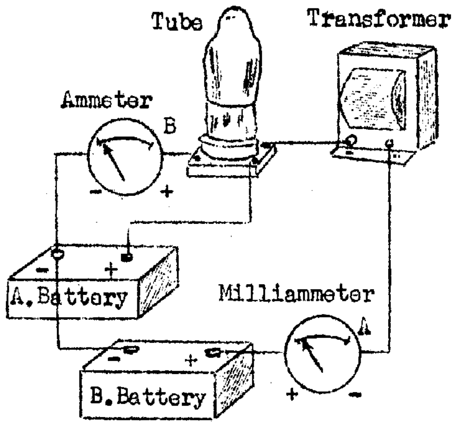
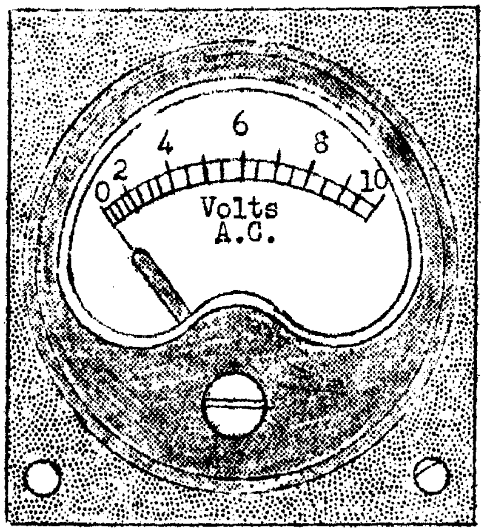


FIGURE 13.

was removed. In position "A" you would be measuring the current in the tube's plate circuit. This current would be small, consequently you would be using a milli-ammeter. In position "B" you would be measuring the current flowing to the tube's filament, and since this current is generally a fairly large fraction of an ampere, you would be using the ammeter.

Certain type of meters, both voltmeters and ammeters, will measure only direct current. If they are used on alternating current circuits, their pointers will always remain at zero. Other meters are designed especially for use with alternating current circuits. You generally will find the face of a meter marked as to whether it should be used for measuring direct current or alternating current, The kind of alternating current meters generally used in radio service work will also measure direct current, although the measurement may not be as accurate as with a regular direct current meter.

With A.C. meters you do not pay any attention to polarity because there is no long term polarity in A.C. circuits, for reasons explained earlier in this lesson. If you apply an alternating current meter to a direct current circuit, try it both ways around. The higher reading, should there be a difference, will usually be more nearly correct than the other one. On A.C. meters having more than one range



An A.C. Voltmeter.

FIGURE 14.

you will find one terminal marked with both the plus sign and a minus sign or with the letter "C". The letter "C" is an abbreviation for "Common". This terminal is treated as the negative terminal when used on direct current circuits. Another way of telling an A.C. meter from a D.C. meter is that most A.C. meters have the gradations or divisions of their scales crowded together at the low end, near zero, and spread out near the top of the scale while D.C. meters have their graduations evenly paced over the whole scale. These differences are shown in Figures 11 and 14.

You may have seen a serviceman dig into a case of trouble with a voltmeter equipped with a couple of long wires. He touches the ends of the wire here and there during a few moments of work, then states quite confidently "the plate load for the audio frequency amplifier is open circuited", or perhaps, "the screen bypass condenser on the intermediate frequency amplifier is short circuited". Now, neither the resistor or condenser at fault provides any external indication that it is actually faulty, so how can the serviceman be so certain that his diagnosis is correct simply because he measure the potential difference between various points, or in other words, measures the voltage drop between those points.

To help you understand the principles involved let us take a simple filament circuit as shown by Figure 15. If the circuit shown is complete, electrons will flow away from the negative terminal of the battery, through the switch, then through the

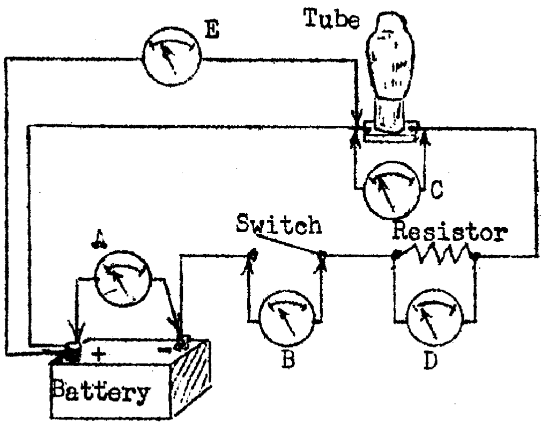


FIGURE 15.

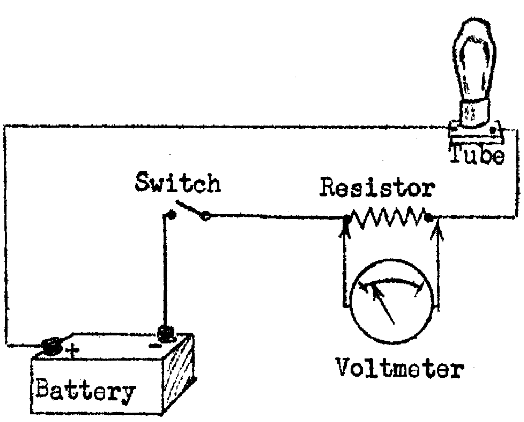


FIGURE 16.

resistor and finally through the valve filament to the positive terminal of the battery. A resistor, incidentally, is a device which has a known mount of resistance and can be used for controlling the amount of current flowing in a circuit or to create a certain voltage drop between two points.

Now test this circuit. Place the voltmeter at "A" and touch the two battery terminals. If the meter shows full battery voltage you know the battery is without fault. Now you move the voltmeter to "B" and touch the two sides of the switch. The switch should make a good connection of practically no resistance, so there should be practically no voltage drop through the switch. If the meter shows no movement of its pointer, indicating no voltage drop, you conclude that the switch is in good working order.

Next you move the meter to position "C" and touch the leads to the two filament terminals of the tube. The meter reads about 1.4 volts. Well, this kind of a tube is supposed to have 1.4 volts across its filament, so you know there is nothing wrong here. Then you change the meter to position "D", connecting it across the terminals of the resistor. The meter reads about 0.1 volt. Now let us see: the battery measured about 1.5 volts, the tube was taking 1.4 of those volts, and here we have the other 0.1 volt across the resistor. Then the resistor must be alright.

Finally, you might move the voltmeter to poition "E", touching one of its leads to the positive terminal of the battery and the other lead to the positive filament terminal on the tube. Since a wire of the kind used between these points should have exceedingly low resistance, your meter will show but the slightest movement of its pointer, hardly enough to see at all, indicating practically no voltage drop and a good wire and good connection.

These tests showed the circuit and the parts in it to be in good condition. Of course you might have gone on and tested across the ends of the wires between battery and switch, between switch and resistor, and between resistor and tube.

Now look at Figure 16. Here you have exactly the same circuit as in Figure 15 - but now something is the matter - the tube filament won't light up. You would proceed with the same tests you used before, first testing the battery which would show correct voltage. Then you would get no voltage drop across the switch, showing it too to be alright. Testing the tube filament would show no voltage. Then you would test the resistor and here you find that the meter reads full battery voltage. That shows that the resistor is open circuited, that is, the wire in the resistor has broken, that no current is flowing through it, that you are getting the full voltage drop of the battery at this one place.

Just think for a minute. With the meter placed as in Figure 16, one side connects through the tube filament and the long top wire to the positive side of the battery. The other side connects through one wire, the switch, and another wire to the battery's negative terminal. With the resistor open, probably burned out, there is nothing between the voltmeter leads in the position occupied by the resistor - at least there is no electria1 connection. Across the ends of such an open point you will always find the full voltage of the source. That shows an open circuit.

This is a good way of locating open circuits or defective parts. You simply get the wrong voltage drop across them. But there is one serious fault with this method it falls down when there is more than one open circuit, or more than one open point in one circuit. In Figure 16, supposing the resistor had actually been burned out, making an open point. But supposing too that the switch had been out of order, broken in such a way that it also made an open point. With no current flowing in the circuit because of the open resistor, you would get no voltage drop across the switch because you cannot get a drop of voltage without current flowing. Then you would have concluded that the switch was in order, yet it was not.

OTHER METHODS OF LOCATING OPEN CIRCUITS.

Now there is Shown in Figure 17 a test method that will locate any number of open points one after another provided you fix them as you come to them. You might say, "If this way is better, why how the other one ?" There are several reasons; first you should understand all test methods; second, it is sometimes very much quicker to use the other method than the one which will be described now

In Figure 17 we have the same circuit we had in Figures 15 and 16. You take the voltmeter and attach its negative lead to the negative terminal of the battery at "1". You are going to leave that lead in that place all through this test. The first stop is to touch the other voltmeter lead to the positive terminal of the battery. You should find normal full battery voltage₃ indicating that the battery is fresh.

Now you flow the circuit away from the positive terminal of the battery, reaching first the terminal on the tube socket at "2". Here you touch the positive lead from the meter. If the wire and the connections are good the meter will show full battery Voltage. If you get no reading it shows that there is an open circuit in the wire between the positive terminal of the battery and the filament terminal of the tube.

Next, at "3", you touch the other filament terminal of the tube socket with the meter lead. If you get no reading the tube's filament is burned out or If you obtain a reading, continue with the tests.

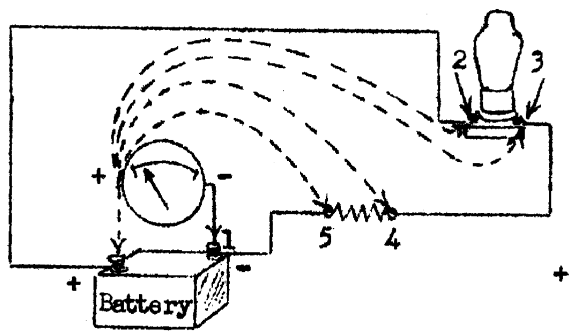


FIGURE 17.

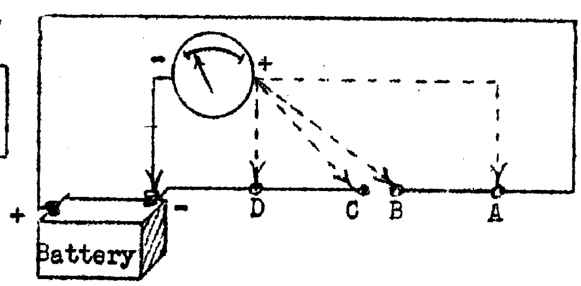


FIGURE 18.

Now you follow the circuit and come to the resistor. Touching, at “4”, the end nearest the tube (which you just left), you may get no voltage reading or a full battery voltage. No voltage reading shows an open circuit in the wire between the tube and the resistor. Full battery voltage shows an open circuit between battery negative and “4”. Then you go on, touching the other side of the resistor at “5”. No reading here but full voltage reading at “4” shows a burned out or broken resistor. If, at this point, you still get full voltage reading, it shows that there is an open circuit in the wire between the negative terminal of the battery and the resistor.

In this test, just what have you been doing? You have been bridging across one after another in the whole circuit. You will see this more plainly in Figure l, where there is shown only the battery, the meter and several points along a circuit. Of course, this really amounts to the same thing as the circuit of Figure 17.

In Figure 18 you can see the open circuit between “B” and “C”. Supposing the positive meter lead is touched to “A”. Electrons can flow from the negative battery terminal through the meter to “A”, and back through the long wire to the positive terminal of the battery. The meter will, as a consequence, read full battery voltage.

Now touch the meter lead to “B” in Figure 18. Because current is prevented from flowing back to the battery by the break between “B” and “A”, there will be no loss of voltage caused by any resistance between “A” and “B” and consequently the meter reading at “B” will also be full battery voltage,

Next you touch the mete lead to “C” but because of the break between “C” and “B”, electrons cannot make their way from the negative terminal of the battery through the circuit back to the positive terminal of the battery, and so the meter will give no reading. You see, as soon as you have passed the open point in the circuit, you have no reading on the meter.

The rule is this: Working away from the battery, when you get no reading, an open circuit exists between the point then being touched end the last one at which a reading was obtained.

Of course, a test at point “D” would also show no reading.

SHORT CIRCUIT AND GROUNDS.

A short circuit is an accidental connection from one side of a circuit to the other side somewhere between the source of voltage and the part operated by the circuit. A short circuit is shown in Figure 19. Current normally should flow from the battery, through the resistor and valve filament, and back to the battery. But between the battery and the tube the two wires are touching each other. Electrons will follow the path shown by the arrows, leaving the battery, passing from one wire to the other, through the short circuit, and going directly back to the battery.

The resistance of the short circuit or the “short” is so low that little current will go on and pass through the resistor and the tube's filament. The battery will be rapidly discharged, but the tube will not light.

It is harder to locate a short circuit than to locate an open circuit because to find the short you really have to get rid of it, separate the shorted parts, before you can find it. That sounds almost impossible, but it is not.

A "ground" is one variety of short circuit. The short circuit shown in Figure 19 is between the wires. In Figure 20 is shown a ground. The ground occurs between a wire and some metal part through which current may flow. In many radio devices the metal framework or the metal brackets are used to carry current for one side of the circuit usually for the negative side of a direct current circuit. Then the metal is spoken of as a "ground", and it forms the grounded side of the circuit.

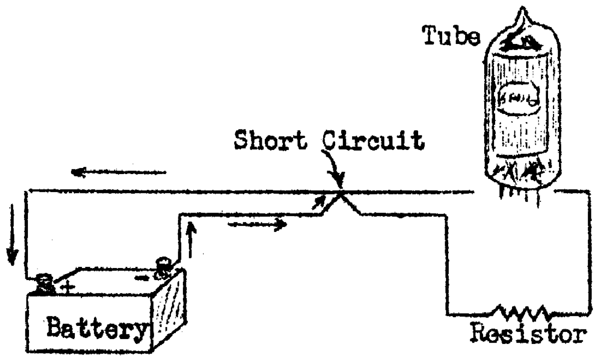


FIGURE 19.

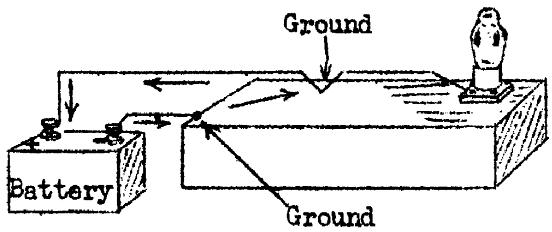


FIGURE 20.

In Figure 20.the negative terminal of the battery is connected to the metal base. The wire between the positive side of the battery and the tube is touching the metal or is "grounded" where marked. Then the battery current flows through the wire to the metal chassis, then returns through the ground to the battery without ever reaching the tube.

Here we are speaking of the kinds of grounds which cause trouble. These might be called accidental grounds. Then there are also intentional grounds such as the attachment of the negative battery line to the ground connection in Figure 20. Both kinds of connections are grounds, but one is the kind we want while the other we do not want.

<u>LOCATING TROUBLE IN ALTERNATING CURRENT PARTS</u>.

In locating a case of trouble there is no difference in general rules whether the circuits and parts are carrying direct current or alternating current. We have looked for open circuits in direct current circuits containing a battery as the source of voltage. Direct current work was selected because the circuits for this current are generally more complicated than those for alternating current - they may have switches, rheostats, and other parts which are not used in alternating current tube circuits.

The chief difference between direct current circuits and alternating current circuits is that a battery forms the source of voltage for the D.C. parts and a transformer for the source for the A.C. parts.

In testing with alternating current you use the A.C. type of voltmeter, whereas for direct current circuits you use D.C. type of meter. All the tests in Figures 12 to 20 might be applied equally well to alternating current circuits. In place of the battery there would be a transformer; that would be the only difference. Of course, in the A.C. work you pay no attention to polarity, for reasons explained earlier in this lesson.

LOCATING SHORT CIRGUITS OR GROUNDS

We are going to do the work on shorts and grounds by illustrating with alternating current circuits. The filament or heater circuit for an A.C. tube is illustrated in Figure 21. The power line or light circuit is connected to one side of a transformer. A transformer is simply a device for changing one alternating current voltage to another alternating current voltage. Here we are stepping down the power line voltage to a lower voltage suitable for the tube. Some alternating current tubes have filaments exactly like those used for D.C. tubes. Others have what we call a “heater” which is placed inside a part corresponding to the filament in other tubes. Wires are connected between the heater terminals or the filament terminals of the A.C. tube and the transformer. Wires carrying alternating current in a receiver or in any radio parts are generally twisted together because this helps to reduce the tendency of the device to hum.

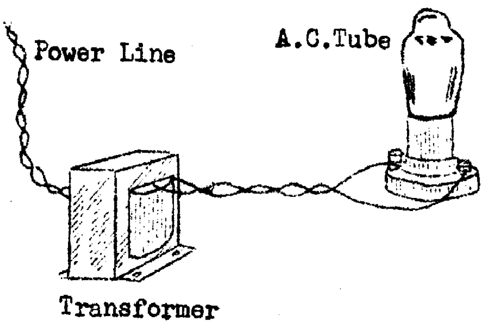


FIGURE 21.

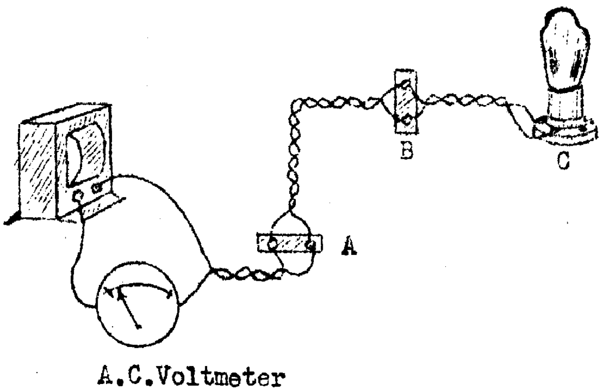


FIGURE 22.

Now we will locate the short in the A.C. circuit of Figure 22. The first thing to do is disconnect one of the wires at the transformer, connect it to one of the terminals of an A.C. voltmeter and connect the other meter terminal to the point on the transformer from which you removed the wire. Since there is a short somewhere in the circuit, current will flow through it. The current passing through the short circuit will now have to pass through the voltmeter and the meter's pointer will show a voltage reading.

This connection of the voltmeter prevents further damage from resulting because it reduces the flow of current to a very small amount. A voltmeter has a very high resistance and only a little current will flow through it even with full voltage applied to its terminals. A voltmeter takes just enough current to move its pointer.

Of course, you roast remove any tubes or dial lamps which might be connected to the wiring, otherwise the current passing through the tubes or lamps will move the pointer and you will not know when you have found the short circuit.

Having connected the voltmeter, you commence opening up various points in the circuit. First you would take a wire off the junction post marked “A”. If the meter's pointer drops back to zero you have not yet located the short. If the meter still continues to read voltage the short circuit is between the point at which you have disconnected the wire and the transformer. Then you can go on and remove a wire at “B”. If the pointer drops to zero you will have to go on still farther, but if the voltage reading remains you know the short is between the point from which you have now disconnected the wire and the last point where you opened the circuit. You could go on still further and take one of the wires off the tube socket, indications would be the same as before.

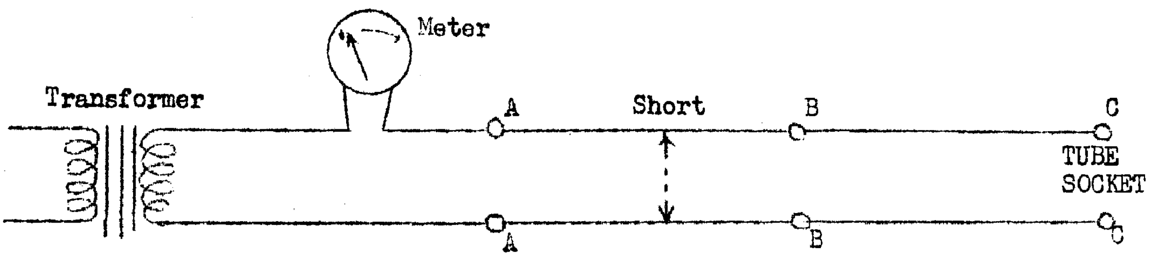


FIGURE 23.

Now, let us see just what you have been doing. In Figure 23 you can see how the circuit in Figure 22 would look if you straightened it out. Supposing there is a short where the wires are joined by the broken line arrow. If you disconnect a wire at “A” you have opened the circuit containing the transformer and the meter; consequently no current will flow and the meter’s pointer will drop to zero. You go on and take off a wire at “B”. Now you have not opened the circuit because current will still flow from the transformer, through the motor and through the shorted place in the wires. The meter's pointer will continue to read voltage.

Notice that as soon as you have passed the short, working away from the transformer or battery as the case may be, then the voltmeter will continue to read voltage. Until you reach the short, each opened connection will stop the current and make the meter read zero. So the rule is: The short exists between the first place at which the meter continues to read voltage and the last place at which the meter dropped back to zero,

Having once located a short circuit or an open circuit as existing in a certain part or in a certain section of the wiring, you just make a careful examination of that particular portion to find the exact point of the defect.

INDICATIONS OF SHORTS AND OPENS.

Either a short circuit or an open circuit will put out of action all parts in a circuit when they are in the line shorted or opened. For example, a tube will go out with either kind of trouble because with either kind the tube is prevented from getting enough current to operate it.

With a ground or a short circuit the wires will get hot and generally will smell hot. The transformer or battery will be badly overloaded. The battery will rapidly become discharged and the transformer will get very hot, will burn out a fuse or may burn out its own windings. When a short occurs, open the circuit near the battery or transformer just as quickly as you can get it open.

An open circuit is, usually, not so harmful as a short. It stops operation of the part or parts in the line, but that is about all although in some cases it may cause a harmful rise in voltage, a circumstance which will be discussed in a later lesson.

WHAT TO DO WHEN BATTERY IS DISCHARGED OR TRANSFORMER BURNT OUT.

In all the tests shown so far you have been using the battery or the transformer already in the circuit as your source of testing voltage. But supposing a bad short or ground has completely discharged the battery or has put the transformer out of business, what then?

The easiest way and one of the surest ways to get reliable indications from your teats is to put another battery in place of the discharged one or in place of the burned-out transformer. All you need is two dry cells connected together in series as in Figure 24. In as much as the only current they have to furnish is enough to operate your voltmeter, these two cells will last a long time. They will give three volts pressure, and this is plenty for all these circuit tests Do not forget to put the testing, voltmeter in circuit before you connect up the battery.

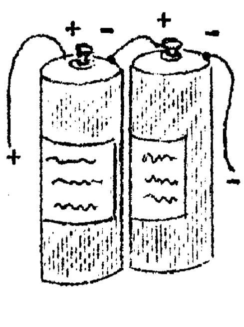


FIGURE 24.

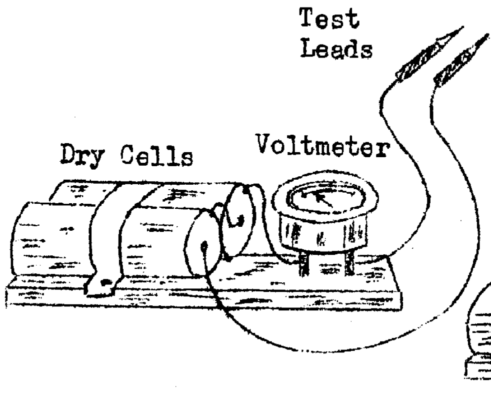


FIGURE 25.

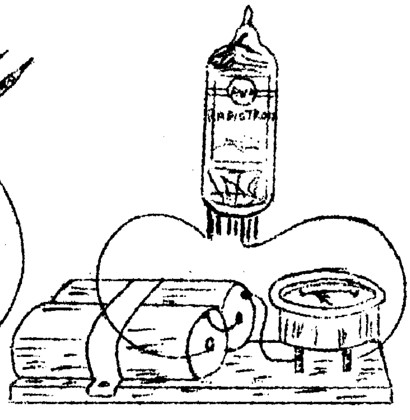


FIGURE 26.

A CIRCUIT TESTER.

The two dry cells connected to a voltmeter will make one of the handiest circuit testers you ever saw. The hook-up is made as in Figure 25. Connect the negative terminal of a voltmeter to the outside terminal of one cell, connect the centre terminal of this cell to the outside one of the other cell, attach a long test lead to the centre terminal of the second cell and connect another test lead to the tester's positive terminal. Instead of using the two large cells shown, you can use a 4½ volt torch battery or radio "C" battery as these are easier to carry about.

Connecting the two teat leads to any two parts will show whether there is a conducting path between them. For example, in Figure 26 the leads are connected to the two filament pins of a radio tube. If the filament is good the meter will read about three or 4 ½ volt, the voltage of the two cells or battery. If the filament is bunt out the meter will show zero voltage, indicating an open circuit. The three or 4 ½ volts pressure will not hurt any radio parts, because with the voltmeter in the circuit you can never get more than a few thousandths or an ampere or a few milliamperes through it.

The circuit tester or "continuity tester" as it is called, will test for a continuous conductor anywhere you touch the two leads, but until you are better acquainted with all radio circuits, you had better use a tester of this kind only for testing parts that are disconnected from all other parts and wires or which are removed from a radio set. The reason for this advice is that several wires are hooked to most things so that they are included in many circuits. With the tester you would not know which of the circuits you are testing.

MULTIMETERS.

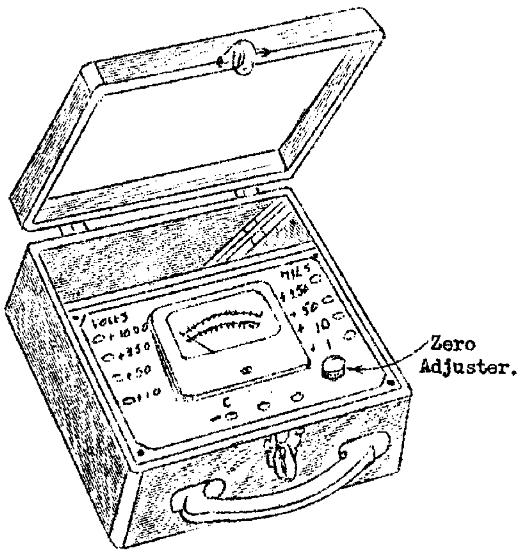


FIGURE 27.

Meters are extremely useful instruments for adjusting receivers and locating faults, and are really a necessity to anyone undertaking service work. Rather than purchase separate voltmeters and milliammeters it is considerably less expensive to purchase or make a "multi-meter" which can be used to measure both voltage and current. In addition, most multimeters contain a built-in battery so that they can be need as continuity testers and also to measure resistance in ohms. You will realise that a combined meter like thin is far more convenient than a number of separate meters.

One type of multimeter is shown in Figure 27. This meter is provided with four separate ranges for measuring voltage. These ranges are 10 volts 50 volts, 250 volts and 1,000 volts.

The terminals which are used when the meter is to be connected as a voltmeter are at the right-hand side of the panel. The ranges are 10, 50, 250 and 1,000 volts. The terminals for D.C. current measurement are at the left-hand side or the panel and range from 1 milliamperes to 250 milliamperes. The three terminals at the bottom of the panel are employed when the meter is used for continuity testing or for measuring resistance. The centre and left-hand terminals are used for measurement of resistance up to 100,000 ohms. The left-hand terminal is also the negative terminal for all voltage and current ranges. The centre and right-hand terminals are used for measurement of resistance up to 100,000 ohms. The knob in the lower right-hand corner of the panel is used for adjusting the needle to the zero position on the resistance ranges when the test prods are directly connected together. Before using the meter to measure resistance, the terminals or test prods should be directly connected together. The zero adjustment knob is then turned until the needle rests on the end of the ohm's scale marked "0". If an unknown resistance or circuit is then connected to the terminals the needle will indicate its resistance.

An enlarged view of the meter scale is shown in Figure 28. The ohms range is the one printed around the top of the scale, while the volt and milliamp ranges re marked below the scale.

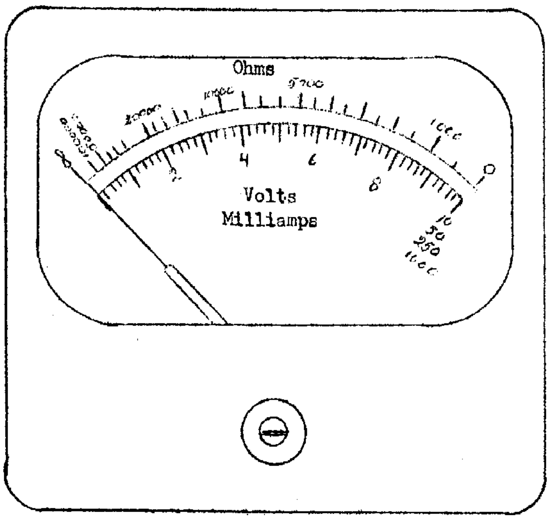


FIGURE 28.

Two most important points you should renumber when using voltmeters or milliammeters are these: First, always select a meter with a range you know to be higher than the voltage or current you intend measuring. Second, voltmeters are connected to any two points in a circuit between which you wish to determine the difference in potential. Ammeters or milliammeters must always be connected in the circuit in which you wish to measure the current flowing.

EXAMINATION QUESTIONS – No. 7.

(1) will current flow in any of the parts of an open circuit? Why?

(2) Does the dielectric in a condenser always make an open circuit seeing that it is an insulator? Explain your answer

(3) Mention the three common names of electrical pressure,

(4) Which has the greater resistance, a thick wire or a thin one, both being of the same length and of the same material? Why?

(5) Write down the letters which stand (1) for voltage, (2) for current, and (3) for resistance.

(6) Can you measure D.C. voltages with an A.C. voltmeter?

(7) To measure the voltage drop in a resistor, to what two points would you connect a voltmeter?

(8) If you find a battery completely discharged, would you look for an open circuit or for a short circuit? Why?

(9) With the positive terminal of the voltmeter in Figure 17 connected first to point 2 and 3, what reading do you get at each of those points, assuming the tube's filament short-circuited?

(10) In using the continuity tester described in this lesson, does the meter remain at zero with a closed circuit or with an open circuit between the test leads?

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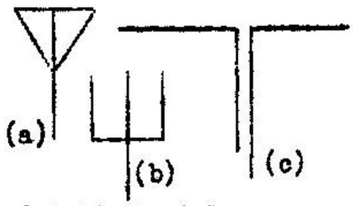
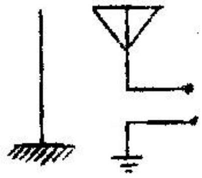
LESSON NO. 8

HOW TO READ THE LANGUAGE OF RADIO ENGINEERING IN WIRING DIAGRAMS.

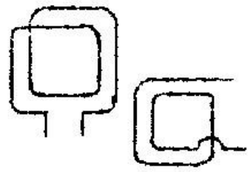
You have looked at radio receivers, have looked inside them and know just haw the parts appear. You also have looked at wiring diagrams and you know that a wiring diagram is certainly no photograph of a receiver. Yet to an engineer or to a first class radio man the wiring diagram is really a picture of the set and it shows things far more clearly than they can be shown by any photograph.



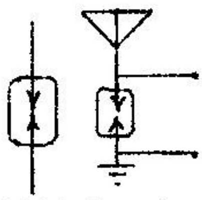
Outside Aerials.
FIGURE 1.



Ground Symb
FIGURE 2



Loop Aerial.
FIGURE 3.



Lightning Arres
FIGURE 4.

We are going to find out how to look at one of these diagrams and make it answer a11 kinds of questions in which you are interested. while performing service operations. First of all, let's see just what kind of parts go into the make-up of a modern receiver and its power supply. We have the aerial and ground system, We have many different kinds of coils. There are condensers of various types and there are numerous resistors. Then come the wires and the switches. Into all this we put different kinds of tubes. Finally we add the loud-speaker. With some sets we also find a few other parts: batteries, meters, gramophone *pick-ups* and so on.

Each different type of all these receivers and power unit parts can be represented in a diagram by its “symbol”. The symbol is a simple sign of some kind which stands for the thing you wish to represent. A symbol shows more than a picture of the outside of a radio part because the symbol lets you see just how the electrical circuits get through the part. With a picture of the outside you can fallow the wiring up to the terminals, but there you have to stop. With a symbol you can follow right into the device, whatever it may be, and out the other side.

AERIAL SYSTEMS

Although a substantial measure of standardisation has been achieved with most circuit symbols, there are still a few where several alternative symbols exist. However, there is enough resemblance between the several symbols to allow of easy recognition. When one encounters a non-standard symbol for a particular component. Figure 1(a) shows a commonly used aerial symbol, while at (b) an alternative is shown. Figure 1(c) represents a high frequency dipole used with FM receivers and same T.V. sets.

Associated with most aerial systems there is a corresponding ground which forms a return path far radio frequency signals. Figure 2 shows the combined aerial earth system with the earth symbol at the lower part of the diagram. To the left of the combination symbol appears an alternative ground symbol which is frequently found in circuits of Continental - European origin.

The symbols for a loop aerial or coil aerial as shown by Figure 3 are easy to recognize because they show the wires just as they are arranged on a loop.

The lightning arrester symbol is shown in Figure 4, Over at the right hand side we have represented an aerial and ground with a lightning arrester between them and with wires running over to the receiver.

COILS AND TRANSFORMERS WITH AIR CORES

A plain air-core coil is indicated by the symbols in Figure 5. this is the kind of coil used in filters operating at radio frequencies and, sometimes, as the inductance in a radio frequency tuned circuit. This does not mean that the air core coil is found only in radio frequency circuits. On the contrary, this type of coil is frequently used in audio frequency dividing networks associated with multiple loud-speaker installations employed with high quality sound reproducing equipment.

If an air-core coil is arranged so that a connection may be changed to use more or less of the turns in the coil we call it an adjustable inductance or coil and use the symbols of Figure 6 with the small arrowhead indicating the adjustable connection.

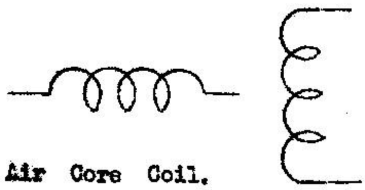


FIGURE 5.

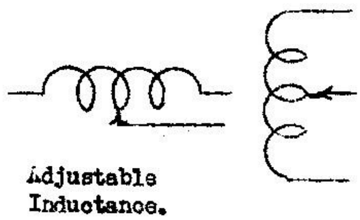


FIGURE 6.

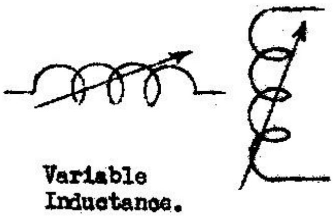
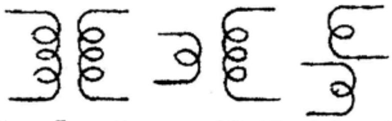


FIGURE 7.

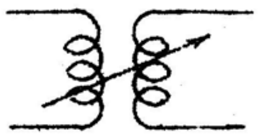
When an air-core coil is built in such a manner that its inductance is continually variable or changeable while the coil is working in the set we call it a variable inductance and the symbols for this arrangement are those of Figure 7. This long arrow drawn right through a symbol always means that the part may have its value changed while the receiver or other radio device is in operation.



Air Core Transformers with Fixed Coupling.
FIGURE 8.

Symbols for air-core transformers or "couplers" are shown in Figure 8, All of these diagrams stand for two coils wound an one former or else on two separate formers which are in line with each other or close to each other so that there is coupling between the two coils. With coupled coils the relative positions of the symbols representing individual windings does not necessarily indicate their true physical position in relation to each other. For instance, the individual coils representing the two windings of the transformers in Figure 8 may be wound side by side on their common former or one winding may be wound over the top of the other, insulated wire being used, of course, to prevent short circuit between the two windings. A11 of the symbols in Figure 8 indicate that the coupling between the coils is fixed and not adjustable or variable.

Variable coupling between air-core coils is now extremely rare, although it was Commonly used in receivers manufactured 20 or more years ago, For the sake of completeness we have included a symbol for this type of coil. Another reason for its inclusion is that, strangely enough, current American practice is to use the symbol shown by Figure 9 for modern coils with variable inductance tuning by means of a movable magnetic core. The operation and application of this type of coil is, of course, discussed in detail in later lessons.



Air Core Coils. Variable Coupling.
FIGURE 9.

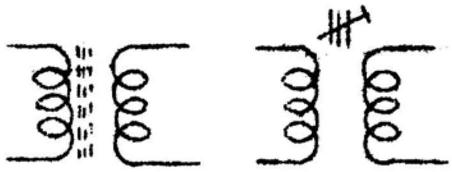


FIGURE 10.

At one time all transformers for use at radio frequencies were of the air-cored type. This does not mean that the transformers had nothing but air inside their windings, it means that no magnetic substance, such as iron or steel, was used inside the coils. Most air-cored coils were wound around a circular former made of some insulating material such as bakelite or specially treated cardboard.

Modern practice is to wind coils directly on to a magnetic core material or where facility for varying inductance is required on to a former having good insulating properties into which may be screwed "slugs" of magnetic material. The magnetic core materials used in such applications consist of special amalgamation or "mixes", using various kinds of plastic or ceramic materials as a base. One well-known material pioneered by the Philips organisation is known as "Ferroxcube". The presence of such a core is shown by the symbols illustrated in Figure 10. The one at the left is frequently used to indicate a radio frequency transformer having a non-adjustable magnetic core. The core is indicated by broken parallel lines to distinguish it from the laminated core used in audio frequency coils. The diagram on the right of Figure 10 indicates that the amount of magnetic material within the core may be varied. This variation is achieved usually by tapping the inside of the coil former and screwing into it a threaded slug of the appropriate magnetic material. By screwing the slug into or out of the coil interior, the inductance of the coil may be changed. Sometimes the symbol for the movable iron core is shown at each end of the transformer to indicate that the inductance of both coils nay be changed by screwing a slug into each end of the former.

Intermediate frequency transformers used in superheterodyne receivers of pre-World War 2 manufacture were mostly of the air-core variety with both windings tuned by small adjustable condensers. As intermediate frequency transformers operated only one frequency, usually 455 k.c. in modern receivers, it is only necessary to vary the capacity of their tuning condensers between very small limits. Once adjusted they are not touched again unless realignment becomes necessary. The symbol at the extreme left-hand side of Figure 11 shows one of the older air-core intermediate frequency transformers with variable capacity tuning. Those transformers are generally mounted in metal cans to shield them from interfering fields. The metal can when used is represented by a broken line around the symbol for the device which it shields as shown by *the* diagram.

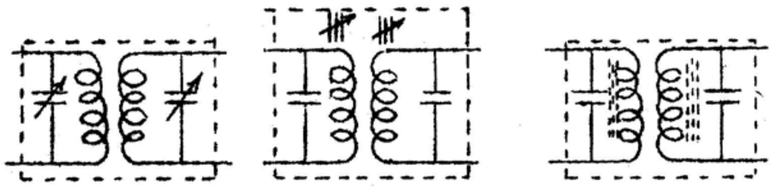
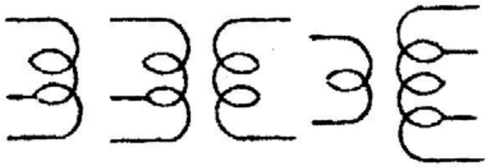


FIGURE 11.

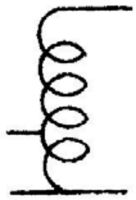
Intermediate frequency transformers, like radio frequency transformers, are now provided with facilities for varying in their inductance over a small range. With this type the tuning condenser across each winding has fixed capacity. The symbol for this particular type of transformer is shown at the centre of Figure 11. The fact that both windings are tuned by permeable slugs is indicated by the three short parallel lines traversed by an arrow, at the top of each coil symbol. Sometimes the adjustable iron core symbol is shown at the top and bottom of the coil, sometimes as shown at the right of Figure 11.

Sometimes for special purposes we use coils or windings with “taps” brought out at several points. For instance, you may find a 50-turn coil with a tap at the 10th turn from one end and another at the 25th turn. Then we use symbols like those in Figure 12. Of course, in a symbol you don't attempt, to draw as many turns as are used in the coil itself otherwise you would have a hard tine showing an audio trans former with 20,000 turns. However, sometimes the relative size of the coils symbolising a transformer indicates whether one winding has more or less turns than the other. This is shown by the symbol at the right of Figure 12. In this case the tapped winding has more turns than the non-tapped winding on its immediate left. This is also apparent with the transformer symbols shown at the centre and right of Figure 15. With the centre symbol the three windings at the right each have a lesser number of turns than the winding *on* the left of the iron core symbol. On the other hand, the transformer symbol at the right of Figure 15 would indicate a similar number of turns on each of the two larger windings while the small winding showing a single loop at the bottom of the diagram would have a smaller number of turns than either of the other two.



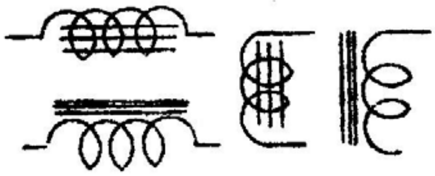
Tapped Coils.

FIGURE 12.



Auto Transformer.

FIGURE 13.



Iron Core Inductance.

FIGURE 14.

In most transformers we have two separate windings but there is one kind of transformer with one continuous winding which is called an "auto-transformer". Its symbol is shown in Figure 13. Once in a while you will find aerial couplers or radio frequency couplers using auto-transformers.

IRON <u>CORE COILS AND TRANSFORMEFS.</u>

An iron core, consisting of a number of sheets of iron or steel, is indicated by several straight, parallel lines. To show a simple coil winding with an iron core we use the symbols of Figure 14. Those symbols indicate such things as audio frequency coupling chokes and power unit filter chokes. You can see that they are exactly like the air-core coils with the iron-core lines added.

The iron core used in coils for handling audio frequencies, or for use in the power unit, are not like the iron cores used in R,F, and I,F. transformers. These iron cores consist of sheets of iron or steel called "laminations". The laminations may be about one fiftieth of an inch in thickness and sufficient are used to make up a thickness of between half an inch and four inches, depending upon the application of a particular unit.

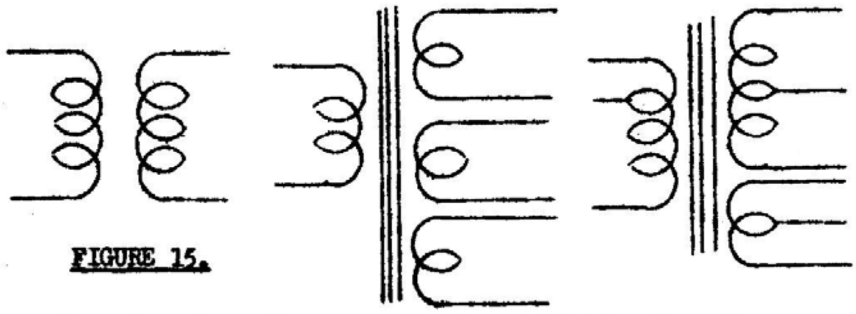
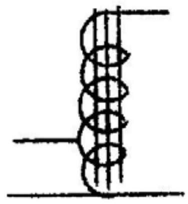


FIGURE 15.

Iron Core Transformer and Tapped Winding Transformers.



Auto Transformer with Iron Core.

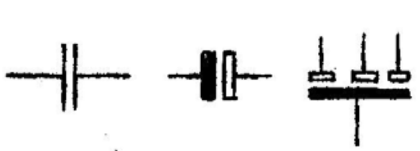
FIGURE 16.

A transformer with two windings and an iron core is shown by the left hand symbol in Figure 15. This is generally the sign for an audio frequency transformer, but it also may indicate any other simple transformer such as one for furnishing filament or heater current to tubes. The other two symbols in Figure 15 indicate transformers with one primary and two or more secondary windings as you will find them in power supply transformers. The right hand symbol in Figure 15 shows a power transformer with a tapped winding and two secondary windings, each secondary having a centre tap. Many power transformers have as many as five or six secondary windings all delivering different combinations of current and voltage to suit the tubes attached to them.

An iron core auto-transformer is indicated by the symbol in Figure 16.

CONDENSER SYMBOLS.

A fixed condenser of any kind, any condenser which is not variable in its capacity is indicated by the symbols of Figure 17. The one at the left is the standard symbol far all non-polarised condensers. This takes in all types having a dielectric of either treated



Fixed Condensers.
FIGURE 17.

Variable Condensers.
FIGURE 18.

paper, mica, oil, or ceramic. The centre symbol in Figure. 17 is most commonly used to indicate an electrolytic condenser. This is a polarised type and must be connected into a circuit the right way round to avoid damage to itself and associated equipment. With this symbol the heavily shaded rectangle represents the negative plate of the condenser while the unshaded rectangle represents the positive plate. In some circuits the symbol for an electrolytic condenser is similar to the one shown at the left of Figure 17 but with positive and negative polarity markings to show which way the condenser is connected into the circuit.

In present day radio and television receivers and audio frequency amplifiers, considerable use is made of multiple condensers. Those are units containing several capacitors in a single container. Although multiple condensers are principally of the electrolytic type, this method of manufacture is also applied to condensers of the non-polarised type. A symbol at the right of Figure 17 shows a multiple electrolytic condenser containing three separate units, A common negative connection is used as shown by the long shaded rectangle, while the individual capacities are shown as separate unshaded rectangle, representing the positive plates.

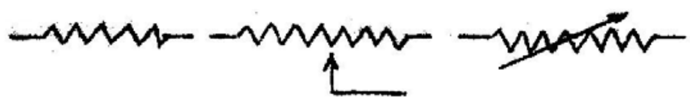
Through the years the symbol for a variable condenser has undergone a number of changes, but finally standardisation has come in the form as shown by the symbols of Figure 18. Variable condensers are principally of two types, those used for continuously variable tuning over a particular band, the medium wave broadcast band for instance, and those whose capacity can be adjusted only through a narrow range. Those latter types are commonly called trimming condensers and they are used principally to “trim” a tuned circuit by bringing its total distributed capacity to a desired figure. The symbol for a “wide band” tuning condenser is shown second from the right in Figure 18. The fixed plates are represented by the heavily shaded rectangle while the moving plates are represented by the curved line with arrowhead.

In the average radio receiver there are at least two condensers of this type, both of which are operated from a single tuning control. The technical term for this type of condenser is a “tuning gang” or a “ganged” condenser. To indicate that the condensers are “ganged” and therefore operated by the one tuning control, the moving plates are connected by a broken line as shown at the right of Figure 18. “Ganged” condensers are not necessarily close together in a complete circuit, on the contrary, they are usually placed at some distance from each other an the printed circuit diagram but as long as the moving plates are joined by the dotted or broken lines, there is no doubt that the two sets of moving plates are joined mechanically and will both move together.

The two symbols at the left of Figure 18 represent the previously mentioned “trimmer” condensers of the semi-adjustable type. The condensers are termed semi-adjustable because, unlike the main tuning condenser, they are adjusted, not by a knob on the front panel of the receiver, but by a screw driver-like instrument called an alignment tool. The symbol at the left is the one most commonly used, although the one shown second from the left *is* often soon, particularly in circuits of English origin.

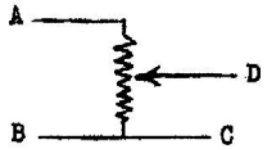
RESISTOR SYMBOLS.

The symbol for a plain fixed resistor of any kind is shown at the left in Figure 19. The centre symbol of Figure 19 represents a resistor with m sliding contact arm, such as may be used in series with any line to control voltage and current flow. Another way of showing a variable resistor is with the symbol at the right hand side of Figure 19.



Fixed and Adjustable Resistors.

FIGURE 19.



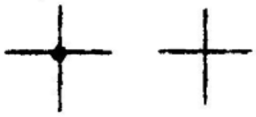
Potentiometers.

FIGURE 20.

Quite often in radio work we use a voltage dividing device called a “potentiometer”. The symbol for which is shown in Figure 20. There is a steady flow of current and a consequent drop of voltage between paints “A” and “B”. The current and voltage to be used in another circuit are taken off between point “C” and the sliding contact “D”. By moving “D'' it is possible to apply any desired voltage to the circuit connected between “C” and “D”. A potentiometer is commonly used in radio receivers as a volume control, The component controls the signal voltage delivered by the receiver's detector to the audio frequency amplifying stages and so varies the loudness of the sound hoard from the loud speaker.

CONNECTING PARTS TOGETHER.

Of course, you know that wires forming electric circuits are shown by straight and curved lines. When two or more wires are joined we indicate the fact with a dot at the junction of the wires as shown at the left of Figure 21. If two or more lines cross without any dot at the point of apparent physical junction, this indicates that there is no electrical connection between these particular wires. This is shown at the right hand side of Figure 21, Some circuit draughtsmen, to avoid any possibility of error, use the “loop-over” effect shown in Figure 22 to



Wires Joined.

FIGURE 21.

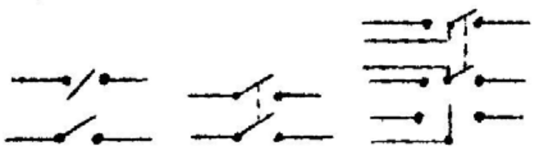
Wires Crossing Without Joining.

FIGURE 22.

show that there is no electrical connection between two wires which have crossed over on the circuit diagram. This scheme is sometimes used even when the dotted junction for joined wires is employed but sometimes where "loop-over" is used to indicate no-connection, the junction of wires even without any dot at the junction is accepted as satisfactory indication that electrical connection exists. In reading circuit diagrams, therefore, one should be alert to this possibility. A safe rule to observe is that, if no dotted junctions appear at any point in the circuit but the "loop-over" method is used to indicate no-connection, one may be certain that all crossing of wires other than where a "loop-over" exists, indicates electrical connection.

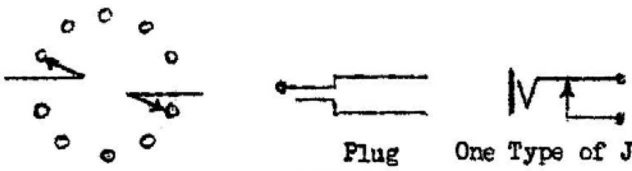
SWITCHES.

Switches which May be opened And closed are shown by the symbols in Figure 23. On the extreme left are two types of single pole single throw switches. These types are used primarily as on-off switches. They simply make or break a circuit as required. In the centre is a double pole single throw switch symbol. This is also a simple on-off type of switch but it may be used to break both sides of one particular circuit or one side of two entirely different circuits. This type is sometimes used in battery-operated receivers where one pole is used to make or break the valve filament circuit while the other pole is used to make or break the high tension battery positive lead. At the right hand side of Figure 23 are two examples of double throw switch symbols. The top one is a double-pole double-throw type while the bottom symbol represents a single pole double throw type.



Switches.

FIGURE 23.



Plug One Type of Jack.

FIGURE 24.

Many switches used in modern equipment are of the rotary or so-called wafer type. Those switches come in a variety of multiple contact arrangements, and are too numerous to illustrate individually. The example we have chosen is a two pole 5 contact type. This is commonly known as a two by five type. As you can see from the diagram at the left hand side of Figure 24. this particular component will allow two circuits to be switched to five different positions. Switch symbols are comparatively simple and once you arc familiar with the basic types as illustrated here, multiple types become more or less self explanatory.

A “jack” is a device far making rapid connection between circuits and, perhaps, at the same time bringing about other circuit changes by causing the insertion of a plug into the jack to make or break a number of separate circuits. You may have seen a telephone switchboard operator using these components. A jack plug is shown at the centre of Figure 24 while the jack with which it is used is shown at the right hand side of Figure 24. The jack shown is a double contact type and insertion of the plug will connect a circuit terminating in the plug to a circuit connected to the jack, at the same time the plug will push upwards the top contact on the jack and disconnect it from the centre contact. Like switches, jacks come in a variety of types but, if you are familiar with a basic type as illustrated by Figure 24. you should have no difficulty in analysing the more complex types. Jacks are very rarely seen on radio receivers, although they are not infrequently found on amplifiers either of the public address type or for high quality reproduction of recorded music.

VALVE SYMBOLS.

We are fortunate that the position with valve symbols is comparatively simple. A few years ago the situation was bordering on the chaotic because of the lack of agreement among technical draughtsmen regarding the manner in which even a simple valve such as a triode should be symbolised, in fact some of them must have spent many a sleepless night trying to figure out additional and even more confusing ways of drawing the symbol for this one particular type, - not forgetting the dozens of other typos of valves to which they could devote their attention. Today the position is quite straightforward. So straightforward, in fact, that once you are familiar with the now standard symbols for the diode and triode valve, no difficulty will result in figuring out the function, in a circuit, of the multiple electrode types such as tetrodes, pentodes, octodes etc., whether they exist singly or in combination.

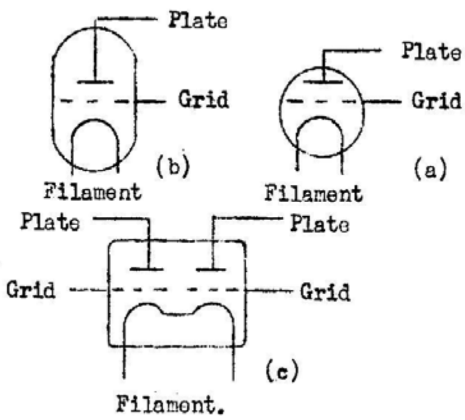


FIGURE 25.

Figure 25(a) shows the now standard method of symbolising the directly heated or filament type triode, so far as the disposition of electrodes is concerned. There is still a little latitude regarding the shape of the valve envelope. Some circuit draughtsmen show the envelope as a true circle as at (a) in Figure. 25, while others prefer the semi elliptical shape as shown by Figure 25(b). The filament is generally shown as an inverted “U”. the grid appears as a broken line, while the plate is in the form of a heavily shaded rectangle. In some cases the plate may appear as a single comparatively thin line, but this is unimportant, Figure. 25(c) shows a common method of depicting a twin-triode valve, that is, two triode valves in a single glass envelope.

Figure 26(a) also shows a triode symbol but with a slight difference. This variety is known as an indirectly heated, or just heater, typo valve. The heater when it

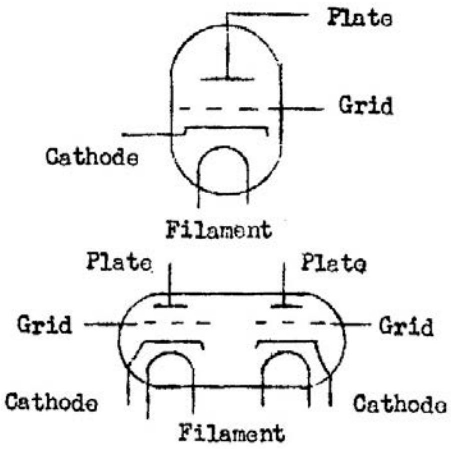


FIGURE 26.

is shown has generally the same form as the filament in a directly heated type, that is, an inverted "U" shape. The symbol at Figure. 26(a) is still a triode in spite of the apparent addition of a fourth element. The important thing to remember here is that the heater is not an element in the same sense Filament that cathode, grid and plate are elements. The sole function of the heater is to bring the cathode to the temperature required for adequate emission of electrons. It is not directly associated in any way with the valve's "signal" circuit although sometimes due to faults within the valve it may contribute unwanted signals in the form of Filament "hum" and other forms of noise. Because of the "inert" nature of the heater, it is not customary, in drawing a circuit diagram, to include the complete heater circuit as is necessary when the circuit employs directly heated filament type valves. Some circuits, in fact, do not show the heater at a11, its presence is implied by the use of a cathode.

At (b) in Figure 26 another symbol for a twin triode valve is shown. As you can see as well as being of the heater type it is also drawn in a somewhat different manner. This particular symbol is used when each section of the valve is functioning in different parts of a circuit. The valve is shown as two separate units by simply splitting the envelope in half and placing each section in its appropriate portion. If, in a particular circuit diagram, a valve so treated was labeled "V5", one part would be shown as V5A and the other as V5B.

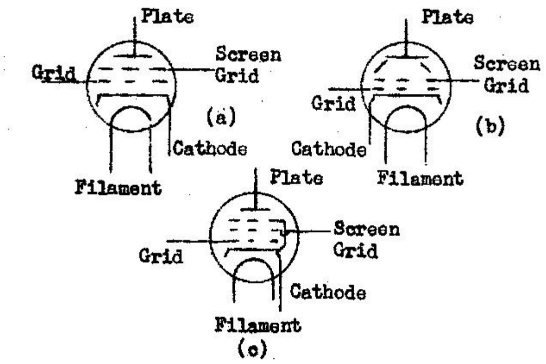


FIGURE 27.

As we stated earlier in this lesson, the ability to recognise a simple triode symbol gives one the key to recognition of the more complex typos of valve because they are, after all, merely extensions of the basic triode. for instance, look at Figure 27(a). This symbol represents a "screen-grid" tetrode, a type of valve introduced during the mid 1920s, which remained in popular use as a radio frequency amplifier for several years. The symbol is equivalent to that of a triode with an *additional* grid located between the plate and the first grid. This type is no longer used

In present day receivers, but one is still likely to encounter older equipment in which they are employed. There is, however, a type of tetrode which is widely used in modern radio and television receivers called a “beam” power tetrode, or simply beam tetrode. The symbol for this latter type is frequently the same as that used for the older “screen-grid” tetrode, but occasionally it is shown as in Figure 27(b), with two short diagonal lines near the plate to represent, the “beam” forming plates. Although in practice the “beam” plates are normally connected to the cathode, usually internally, where they appear as a symbol they are generally left “floating”.

There is yet another alternative for illustrating a “beam” tetrode (Figure 27(c)). This is exactly the same as the symbol for a pentode valve but some circuit designers prefer to use it because, in spite of its four elements, the “beam” tetrode behaves very like the five element pentode. This state of affairs would appear to open up a fine field for complete and utter confusion, but in reality it does not. Because first of a11 “screen-grid” tetrodes and “beam” tetrodes belong to different decades. There is little likelihood of both types appearing in the same circuit diagram, Secondly, the location of the valve symbol in a circuit diagram gives more than just a clue to the function of the valve which it represents, and thirdly, when either type is used in the power output stage of a receiver or amplifier, the manner of connecting it into the circuit is the same, so that it really does not matter whether one thinks of the valve as a tetrode or a pentode. That is all we need say about these two types at present. In later lessons you will learn much more about valves, Their Function and Application, and how apparently similar types may differ one from the other.

MULTI-ELEMENT VALVES.

The symbol for a pentode valve differs from that of a screen grid valve in that it has an additional grid in between the screen and the plate. In a pentode the screen is sometimes called an accelerator grid or it may also be called a, space charge grid, an auxiliary grid, or simply a screen. The additional element is called the, suppressor grid. A pentode may either be of the filament type or the heater type.

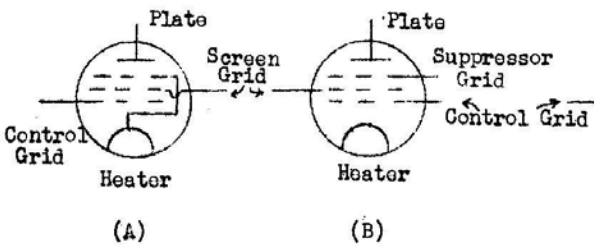


FIGURE 28.

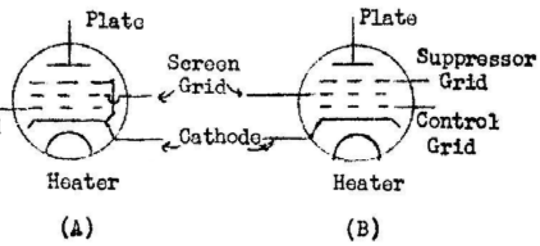


FIGURE 29.

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LESSON NO. 9M1

Everybody is more or less familiar with arithmetic but a little review of this subject is good for any practical man and unless you are sure you can handle it thoroughly, you should go over this lesson very carefully.

Arithmetic may be divided into five parts, namely: Addition, Subtraction, Multiplication, Division and Fractions.

Division may be divided into two classes, Long and Short Division, Fractions may be divided into common fractions and decimal fractions. Fractions are not a mathematical process such as addition, subtraction etc., but are merely an application of these processes to fractional parts of a unit, instead of whole units.

A unit is one complete thing. If one has a number, say 4,326, the 6 will occupy the UNITS place, because it represents the smallest value of the combination. The 6 represents 6 single units. The second figure from the right occupies the ten's place, and means that all figures in that place are multiplied by 10. In this case we have 2 x 10 = 20 + 6 = 26. The third figure from the right represents a still higher value. This number represents a value 10 times as great as the second figure, or 10 times 10 which is 100. This means that the figure occupying that place is multiplied by 100. In this case the figure is 3, which means that 3 is multiplied by 100,which equals 300, The fourth figure represents thousands, and moans that all numbers in this place are multiplied by 1000. In this case we have 4, which means that 1000 is multiplied by 4, Our combination then contains 4one thousands, 3 one hundreds, 2 tens, 6 ones. The total value of this combination is the sum of 4000 300 20 6, which is 4,326 units.

ADDITION.

Addition is probably the simplest of any mathematical calculation. Many errors are made in addition, but these are due to carelessness, as the process is very simple.

The symbol far addition is plus, written (+). This symbol means that the numbers which it connects are to be added together. For example, 3 + 2 means that 2 units are to be added to three units. 3 units plus 2 units equals 5 units.

Where numbers are to be added they are usually written in vertical columns, and the result or sum placed under a horizontal line at the bottom. Thus: 3
2
5

Any number of more than 9 units necessitates the use of two or more figures in expressing it. For example, 22, 46, 89, etc. The process of adding numbers of two or more figures is a little more complicated than adding units, but is practically the same.

For example, one may wish to find the sum of 22 + 33. We will first place the numbers in a vertical column, and draw a horizontal line under them. It will be noticed that the units figures are directly under each other, and also the ten's figures, so that units are always added to units, and tens to tens, etc. We now add the figures in the units column and place the result below the horizontal line. We then do the same with the tens column. This gives us 5 tens, and 5 units, or *55.* Thus: 22
33
55

Larger numbers will involve a little more work. For example, we wish to find the sum of 56 + 98 + 47. First we place our figures in a vertical column as in the previous example. We then add the right hand or units column, and find the sum to be 21. We place the 1, or unit figure, under the horizontal line, but the 2 or tens figure we place to the next column. Adding the second column we find the sum to be 18. To this we add the 2, which we carried over from the units column, and place the total number under the horizontal line, making a total sum of 201.

Thus: 56
98
47
201

For any numbers larger than the above, the process is the same.

Examples for practice:

Add the following numbers (1) 141, 3546, 456, 77 =
(2) 2176, 78,23, 5642, 4357 =
(3) 56714, 3, 2416, 12, 314, 2617, 2312 =

SUBTRACTION,

Subtraction is the direct opposite of addition. Addition is finding the sum of two or more numbers, while subtraction is finding the difference in value of two numbers. The result obtained in subtraction is called the remainder.

The remainder is left, or remains after one number has been subtracted, or taken, away from another. The symbol for subtraction is called minus, and is written (-). Whenever this symbol appears, it means that one of the numbers which it connects is to be subtracted from the other. In subtracting one number from another, the number to be subtracted is placed under the number it is to be subtracted from. The units number of the number to be subtracted must be placed under the units number of the number subtracted from. This must also be observed regarding the figures representing tens, hundreds, thousands, etc.

The process followed in subtraction is as follows. Suppose we wish to find the difference between 366 and 142. First we place the 142 under the 366, in such a manner that like figures occupy places of like value. That is units are placed under units, tens under tens, etc. Having done this we subtract one value at a time, commencing from the units side. We first subtract the 2 units from the 6 units which leaves 4 units, which we place in the units space below the horizontal line. We then subtract the 4 tens from the 6 tens, leaving 2 tens, which we place below the horizontal line. We then subtract the 1 hundred from the 3 hundred, leaving 2 hundred, which we place in the hundreds space below the line. This gives us a remainder of 224. Thus: 366

<u>142</u>

224

In cases where the number subtracted has less figures than the number subtracted from, the figures in the upper row are brought down to the remainder without being changed. For example -- we wish to subtract 122from 26486.

Place the 122 under 26486 as previously explained, Subtract the 2 from the *6, on* the right hand side, which leaves 4. Subtract the next 2, from 8 which leaves 6. After the first three figures are subtracted there *is* nothing left to subtract, so the 6 and 2 are simply brought down to their proper place in the remainder,
giving a remainder of 26364. Thus: 26486

<u>122</u>

26364

In cases where the unit to be subtracted is larger than the unit from which it is to be subtracted, it may be taken from the next figures on the left hand side in the upper row and added to the figure which will increase its value by ten. For example, suppose we wish to subtract 88 from 196. Arrange the numbers as before, 8cannot be subtracted from 6 so we take 1 from the 9 in the tens column, and add it to the 6. This now adds 10 to the 6, making it l6. Then 8 from 16 leaves 8. The 9, however, has had l taken from it, so it is now only 8. Then 8- 8= 0, the second figure in the remainder. There is nothing to subtract from the l, so it is carried down to its place in the remainder, leaving a remainder of 108.
Thus: 196

<u>88</u>

108

Examples for practice:
From 108 take 34 =
Take 7024 from 10000 =
6782 - 5694 =

<u>MULTIPLICATION.</u>

Multiplication is the process of finding the sum of one number taken a given number of times. Multiplication is in reality a short method of addition. For example, if we wish to find the sum of 25 times 36, instead of putting 25, thirty-six times in a column and adding them, we multiply 36 by 25, which gives the same result and is a shorter method.

The result obtained in multiplication is called the product. The number which is multiplied is called the multiplicand, the number which we multiply by is called the multiplier. In the example 20 multiplied by 10 = 200, 10 is the multiplier, 20 is the mult1plieand, and 200 3s the product. The process of multiplication is as follows: First place the multiplier under-the multiplicand, and draw a line under it. Then start multiplying, commencing at the right, and taking one figure at a time. If the result obtained by multiplying one figure is more than nine, put down the unit, and add the “tens” figure to the result obtained from the next figure of the multiplicand. For example, we wish to multiply 143 by 5. First place the number as explained above. Then multiply the 3 by the 5, which is 15, 15 is more than nine, so we put down the 5, and carry the 1 to the next figure. Next multiply the 4 by the 5, which is 20. To this we add the 1, which we carried from the preceding number, which makes 21. We put down the 1 and carry the 2. We then multiply the 1 by the 5, which is 5. To this we add the 2 which we carried, making 7, and the total result is 715.

```
Thus: 143
        5
      ___
      715
```

In cases where the multiplier contains more than one figure, multiply the multiplicand by each figure in the multiplier. Place the first product under the horizontal line, Place the second product under the first result, only place it one space to the left. Do this with each succeeding result. Then draw a line under them, and add them all together. For example, multiply 426 by 324. First place the problem as previously stated. Multiply the 426 by the 4, following the method outlined in the preceding example, This gives a product of 1704. Next multiply by the 2, placing this product under but one space to the left. Than multiply by the 3, placing this product under the second product, and one space to the left. Then draw a line under them and add, which will give you the total product of the two numbers multiplied, which in this example is 138,024.

```
Thus:  426
       324
      ____
      1704
      852
    1278
    ______
    138024
```

Examples for practice:
Multiply 7821 by 15 =
Multiply 1456 by 147 =
Multiply 5235 by 505 =

DIVISION

Division is the process of finding how many times one number is contained in another. For example, if we wish to divide anything into a certain number of equal parts, by division we can determine the exact size of each part. The result obtained in division is called the quotient. The number divided is called the dividend, and the number by which the dividend is divided is called the divisor. Division is the opposite of multiplication, just the same as subtraction is the opposite to addition. To divide one number by another, place the divisor on the left hand side of the dividend and draw a dividing line between them. Then start dividing at the left, dividing one figure at s time. If the first figure is smaller than the divisor, take the first two figures.

If there is a remainder after dividing one figure, carry the remainder on to the next. For example: Divide 12424 by 4. first place the number as explained above, then start dividing commencing at the left. 4 will not be contained in 1, so we consider the first two figures, or 12. Then 4 in 12, three times. Place the 3 above the line and proceed to the next figure which is 4. 4 is contained in 4 once, so place the 1 above the line. 4 will not be contained in 2, so we place an 0 above the line and. carry the 2 to the next figure, thus making it 24. Then 4 is contained in 24 six times, which completes the problem, and gives a result or quotient of 3106.

Thus:

```
   3106
4)12424
```

This process is called short division and is used when the divisor contains only one figure. In cases where the divisor contains more than one figure, a process called long division is used,

Examples for practice:
Divide 6354 by 2 =
Divide 900072 by 4 =
Divide 1134657 by 9 =

LONG DIVISION.

In long division, divide as in short division, with the exception that in long division instead of proceeding to the next figure we multiply the divisor by the quotient, place the result under the dividend, subtract it from the dividend, and divide the remainder by the divisor to obtain the next figure of the quotient, For example, we wish to find how many times 46 will be contained in 1058. First place the divisor, which is 46, a little to the left of the dividend, which is 1058, then draw a dividing line between then, and over the dividend. Then divide 46 into the first three figures of the dividend, which is 105. 46 will be contained in 105 two times. So we place a 2 above the line, Then we multiply the divisor by the quotient (2) and place the result below the 105, 2 x 46 = 92 so we place 92 below 105, and subtract, which gives us a remainder of 13. We next bring down the 8, so we now have a dividend of 138. We then divide the dividend of 138 by the divisor 46. 46 is contained in 138 three times, so we place a 3 above the line in the quotient. Then multiply the divisor 46 by 3, which we just placed in the quotient, and place the result below the dividend 138. 3 x 46 = 138. Place this below the dividend 138, and subtract. 138 subtracted from 138 leaves no remainder, and there are no more figures to bring down from the original dividend, so the problem is complete, and the quotient is 23, which means that 46 is contained in 1058 exactly 23 times. Thus:

```
      23
46)1058
    92
    138
    138
```

Examples for practice:
Divide 20,000 by 125 =
Divide 27,365 by 421 =

FRACTIONS.

A fraction is a part of anything which is less than one complete unit. Fractions may be added, subtracted, multiplied and divided, the same as a whole number can. A fraction represents the number of parts taken. For example, the fraction 4/5 means that the whole is divided into five parts, and the fraction represents 4 parts of those parts.

The figure representing the number of parts into which the number is divided is written below a horizontal line. The figure representing the number of parts represented by the fraction is written above the line. The number above the line is called the numerator, and the number below the line is called the denominator. To add two or more fractions, first reduce them all to the same common denominator. Then add the numerators and, if their sum is greater than the denominator, divide by the denominator. For example, add 2/3 +4/5 +5/6. First find a common denominator. 30 is the smallest number which will evenly contain 3, 5 and 6. Therefore, 30 is the lowest common denominator. Then find 2/3 of 30, 4/5 of 30 and 5/6 of 30. 2/3 of 30 = 20, 4/5 of 30 = 24, and 5/6 of 30 = 25. Then add these numerators 20, 24 and 25 together which will give a fraction of 69/30. The numerator is larger than the denominator, so we will divide it by the denominator. 69 ÷ 30 = 2 9/30. Therefore, 2/3+ 4/5 +5/6= 2 9/30.

LEAST COMMON DENOMINATOR.

The example above contains such denominators that their least common denominator can be seen by inspection to be 30. However, in many eases it will be necessary to find it as follows. Divide the denominator by a number that will equally divide two or more of them, then divide the remaining numbers and quotients by another number that will equally divide two or more of them. Continue this process as far as possible. The least common denominator then is the product of all the divisors and the numbers left. Example:- Find the least common denominator of 8/35, 7/30, 11/45, and 5/80.

5)	35,	30,	45,	80
3)	7,	6,	9,	16
2)	7,	2,	3,	16
	7,	1,	3,	8

Least common denominator = 5 x 3 x 2 x 7 x 1 x 3 x 8 = 5040, which is also the least common multiple.

Examples for practice:
Add 1/2, 2/3, 1/4 =
Add 1/6, 1/8, 3/4 =
Add 1/2, 3/4, 3/8 =

SUBTRACTING FRACTIONS.

To subtract fractions, reduce them to a common denominator and subtract the numerator. For example, subtract 1/3 from 3/4. First we must find a common denominator. The lowest number which will contain both 3 and 4 is 12. Therefore, 12 is the common denominator. Reduce the fractions to fractions having 12 as a denominator. This changes 3/4 to 9/12, and l/3 to 4/12. Reducing fractions in this way does not change their value, as 3/4 has the same value as 9/12. Having reduced them to a common denominator, we subtract the numerator 4 from the numerator 9 which leaves a remainder of 9-4 = 5 or 5/12. Therefore, 3/4 - 1/3 = 5/12.

Examples for practice:
3/4 - 5/16 =
5/7-3/5 =
9/10-4/15 =

MULTIPLICATION OF FRACTIONS.

To multiply fractions, multiply the numerators together, and multiply the denominators together. This will give the product of the fractions. For example, multiply 3/4 by 4/5. All that is necessary is to find the product of the numerators and also of the denominator. The product of the numerators is 12. 3 x 4 = 12. Therefore, the numerator in the answer will be 12. The product of the denominator is 20. 4 x 5 = 20. Therefore, the denominator in the answer will be 20, and the answer is 12/20. Thus 3/4 x 4/5 = 12/20.

Examples for practice:

Multiply 2/3 by 15/16 =
Multiply 7/8 by 32/35 =
Multiply 14/24 by 46/7 =

DIVIDING FRACTIONS.

In dividing fractions invert the terms of the divisor and multiply. For example, divide 7/8 by 2/3. Place the fraction the same as in multiplication, except in the divisor. The divisor, which is 2/3 so inverted, will make 3/2. Then find the product of the numerators and the product of the denominators, as in multiplication. This gives a result of 21/16. The numerator is larger than the denominator, so we divide it by the denominator, which gives 1 5/16 and 7/8 ÷ 2/3 = 1 5/16. Thus, 7/8 x 3/2 = 21/16 or 1 5/16.

Examples for practice:

Divide 5/8 by 3/8 =
Divide 49/65 by L4/39 =

DECIMALS.

Decimals are the same as common fractions, except that they are always expressed in ten, or a multiple of ten. For example, 1/2 would be expressed by .5, which is the same as saying 5/10. This is shown by the decimal point which is a common period placed before the numerator. All figures on the right-hard side of this decimal point are fractional values of ten or some multiple of ten. If there is only one figure to the right of the decimal point, the fraction is expressed in tenths. If there are two figures at the right of the decimal point, the fraction is expressed in hundredths. Three figures expresses thousandths, etc. Thus:

.5 means 5/10

.05 means 5/100

.326 means 326/1000

In adding and subtracting decimals they should always be written so that the decimal points will be directly under each other, otherwise the fractional value will become mixed up with the whole numbers. In adding decimal fractions, place them with the decimal points under each other, and add. For example, add 256.5, 483.75, 746,045, 38.3. First place them with the decimal points directly under each other, then add the same as in whole numbers. Space off as many figures from the right as there are in the number having the largest number of spaces, and place the decimal point at this place. In this problem the largest number of spaces pointed off is three, so we point off three figures from the right and place the decimal point there. This gives a sum of 1524.595. Thus,

256.5
483.75
746.046
38.3
1524.595

In subtracting decimals place them with the decimal points under one another and subtract as with whole numbers. For example, subtract 125.4 from 288.9. First place them with the decimal points under each other. Subtract the same as in whole numbers. Then bring the decimal point straight down to its proper place. This will give a remainder of 163.5 or 163-1,/2. Thus :

288.9
125.4
163.5

In multiplying decimals, multiply the same as whole numbers, and point off as many spaces from the right as the sum of the decimals placed in the multiplier and the multiplicand. For example, multiply 124.62 by 12.4. Multiply the same as with whole numbers, then point off the sum of the decimal spaces in the multiplier and the multiplicand. There is one decimal place in the multiplier, and two in the multiplicand. The sum of 2 +1= 3, so we point off three places in the product, making the answer 3545,288. Thus:

124.62
12.4
49848
24924
12462
1545.288

In dividing decimals, move the decimal point sufficient spaces to the right in both the divisor and dividend to make the divisor a whole number. For instance, if there are two decimal spaces in the divisor it would be necessary to move the decimal point two places to the right to make the divisor a whole number. At the same time it is necessary to move the decimal place in the dividend two spaces to the right. If there are less than two decimal spaces in the dividend, noughts can be added to make up the required number,

Now divide the new divisor into the now dividend until the decimal point in the dividend is reached. Before continuing with the numbers on the right of the decimal point in the dividend, place a decimal point after the portion of the quotient that has already been found. Continue to divide into the dividend and place the resulting numbers on the right of the decimal point in the quotient.

For example, divide 224.112 by 48.72. There are two decimal spaces in 48.72 so that the decimal point has to be moved two spaces to the right to make this a whole number which is 4872. As we have moved the decimal point in the divisor two places to the right we must do the same thing with the dividend which then becomes 22411.2. Divide the new divisor into the new dividend until the decimal point is reached and before continuing with the numbers an the right of the decimal point, place a decimal point after the portion of the quotient already found.

```
          4
4872)22411.2
       19488
        2923
```

Continue to divide into the dividend in the ordinary manner of long division and place the resulting numbers to the right of the decimal point in the quotient.

```
          4.6
4872)  22411.2
       19488
        29232
        29232
```

Here are two other examples worked out for you. Follow through these carefully and make sure that you understand just how they are done.

Divide 14.035 by 3.5 :-

```
        4.01
35) 140.35
    140
     . . .35
          35
```

Divide 966 by 4.2

```
42) 9660
    84
     126
     126
      ... 0
```

At various points throughout this lesson there are examples given for practice. The answers to those examples are set out below. Check through these answers and see how many you have worked out correctly. If you haven't already worked out the examples, do so straight away, before looking at the answers.

141+3546+456+77 = 4220
2176+7823+5632+4357 = 19998
56714+3+2416+12+314+2617+2312 = 64388
198-34= 164
10000 – 7024 = 2976
6782 – 5964 = 1088
7824 x 15 = 117360
1456 x 147 = 214032
5235 x 505 = 2543675
6354 ÷ 2 = 3177
900072 ÷ 4 = 225018
1134657 ÷ 9 = 126073
20,000 ÷ 125 = 160

27.365 ÷ 421 = 65
1/2 +2/3 + 1/4 = 1 5/12
1/6+1/8+3/4 = 1 1/24
1/2 + 3/4 +3/8 = 1 5/8
3/4 – 5/16 = 7/16
5/7 – 3/5 = 4/35
9/10 – 4/15 = 19/30
2/3 x 32x35 = 30/48 or 5/8
7/8 x 32/35 x = 224/280 or 4/5
14/24 x 46/7 = 644/168 or 23/6 or 3 5/6
5/8÷3/8 = 40/24 or 5/3 or 1 2/3
49/65 ÷ 14/39 = 1911/910 or 21/10 or 2 1/10

EXAMINATION QUESTIONS - 9M1.

(1) (a) Add the following numbers:
4926, 3478, 5220, 9651, 4827, 5916, 1324, 5265.
(b) Subtract 38004 from 40001.

(2) (a) Multiply 1856 by 799.
(b) Divide 4434288 by 637.

(3) (a) Add 7/16, 5/12, 5/8, 3/4.
(b) Add 7/18, 8/9, 3/14, 5/7.

(4) (a) Subtract 4/15 from 9/10.
(b) From 3/4 take 5/18.

(5) (a) Multiply 3/8 by 14/27.
(b) Multiply 4/5 by 9/16.

(6) (a) Divide 9/16 by ¾.
(b) Divide 4/5 by 3/10.

(7) Add the following numbers: 6.3, 4.72, 98.46, 54.3, 78.25.

(8) (a) Subtract 18.9 from 47.02.
(b) from .9 take .0482.

(9) Multiply 100.3 by .00405.

(10) Divide 324.8 by 4000.

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LESSON NO. 10

PUTTING ELECTRICITY TO WORK IN THE RADIO CIRCUIT

We often wish to change the amount of current flowing in the various circuits of radio receivers and transmitters. We may want to change or control the current flowing in the filament of a radio tube, we may want to change or control the amount of current flowing in a tube's plate circuit, or we may want to control the amount of current in numerous other circuits to secure results which we desire. We secure this control by means of resistance.

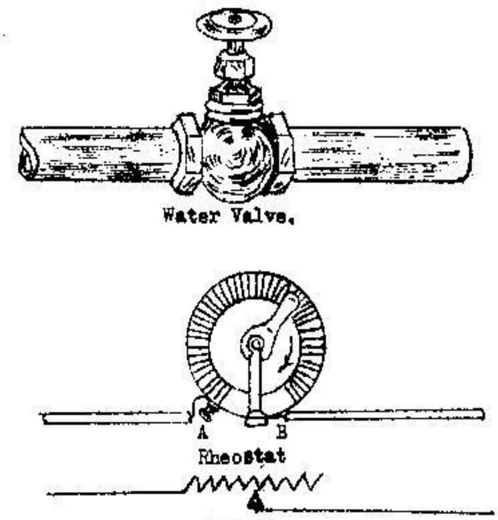


Fig. 1.

In a water circuit the amount of water passing is controlled by a valve as at the top of Fig. 1. The valve, according to its position, offers more or less opposition or resistance to the flow of water. By turning the valve handle the water is regulated.

To control electric current, especially direct current, we use a rheostat which may be made to offer more or less resistance to the flow of electric current just as the water valve resists flow of water through it. As you can see at the bottom of Fig. 1, a rheostat consists of a considerable quantity of wire wound on to a form. An adjustable arm makes contact with the resistance wire. This arm may be turned by means of a knob on a shaft.

If current is flowing from "A" to "B" through the rheostat, moving the arm further around in the direction shown by the arrow will cause the current to pass through more of the resistance wire. Consequently, with more resistance in the circuit, it will be more difficult for the current to flow and less current will pass through wires connected to the rheostat. Moving the contact in the other direction will allow the currant to flow through less resistance and more current will flow. The symbol for a rheostat is shown in Figure 1.

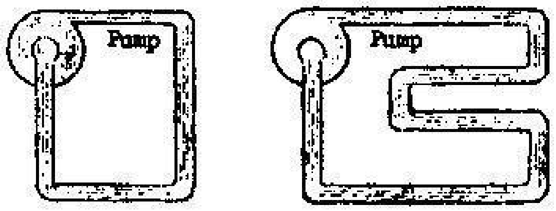


FIGURE 2.

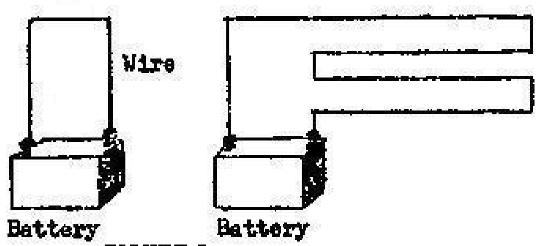


FIGURE 3.

THINGS WHICH AFFECT RESISTANCE.

It is perfectly evident that water driven by the pump through the short pipe at the left hand side of Figure 2 meets with less resistance to its flow than water driven through the longer pipe at the right. Likewise, if the pump is capable of exerting only a certain amount of pressure on the water, less water will be sent through the long pipe than through the short one in a given time.

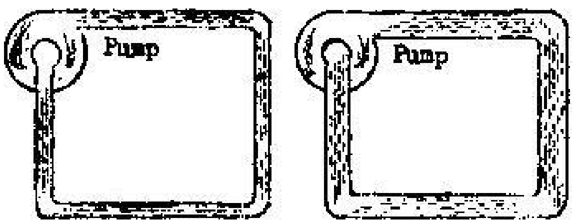


Figure 4.

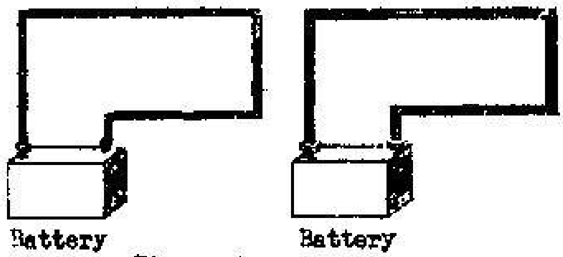


Figure 5.

The same rules apply to the electric circuits in Figure 3. There is less resistance in the short wire at the left than in the long one at the right, and if the voltage is the same in both batteries, less current will flow through the long wire than through the short one.

At the left hand side of Figure 4 there is a water pump forcing water through a very small pipe and at the right hand side the same pump is forcing water through a, large pipe. It is easy to realise that the pump can drive more water through the large pipe than through the small one.

In Figure 5 at the left a battery is connected to a very thin wire and at the right the battery is connected to a large wire, The battery will force more electric current through the big wire than through the small one because the big wire has less electrical resistance than the small wire,

KINDS OF CIRCUITS,

Look at the circuit of Figure 6, Electrons start out from the battery's negative terminal, flows through the valve filament, then through the rheostat, then through the switch and back again to the battery. This sort of circuit is called a “series” circuit because a11 of the electricity that leaves the battery must go through the filament, through the rheostat, through the switch and through every wire in the circuit. The definition of a series circuit says that all the current must go through all the parts.

Now look at Figure 7. One battery is connected to the filaments of three tubes. Trace out the path of current from one side of the battery around through the circuit and back to the battery. This kind of circuit is called a “parallel” circuit because the battery current divides part going through each of the tubes. You can

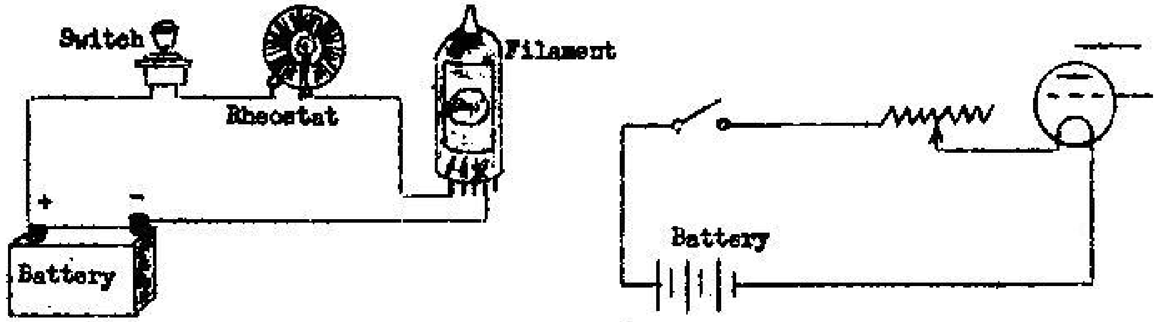


FIGURE 6.

see that the positive side of the battery connects to the positive filament terminal of each one of the three tubes, and the negative side of the battery connects to the negative terminals of all the tubes. You must remember that current divides in a parallel circuit, part taking each of the possible paths.

Notice the circuit diagram drawn out with symbols at the right hand side of Figure 6 and of Figure 7. See how much easier you can trace the circuit in this kind of a

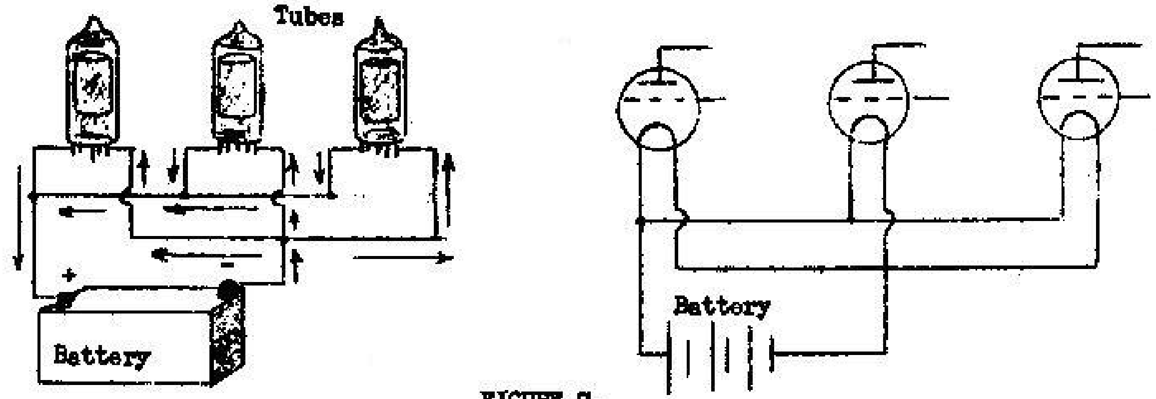


FIGURE 7.

diagram than in the picture kind. The diagram with symbols is often called a “schematic” diagram because it shows the “scheme” of things.

LEARNING WHAT HAPPENS IN A CIRCUIT.

Should you want to know just how much resistance is needed to handle a certain job you certainly wouldn't want to fool around with a lot of different resistances until you located one that worked. Of course if you had an adjustable resistance or rheostat, it wouldn't be so bad but we don't use very many adjustable resistances for control of currant in modern radio devices.

A German scientist, George Simon Ohm, discovered that there is a very definite relation between the number of amperes, the number of volts and the number of ohms in a circuit. He put his findings into a rule, one of the handiest rules we use in radio work, and the rule is called “Ohm's Law”.

Ohm's law says that the number of amperes is equal to the number of volts divided by the number of ohms. We generally use letters to indicate these three electrical values “I” for current in amperes, “E” for pressure or electromotive force in volts, and “R” for resistance in ohms. Then we can write Ohm's Law this ways

$$I=\frac{E}{R} \tag{1}$$

When you write one quantity above a line and write another below the line it means that you are to divide the top one by the bottom one. For example you write:

$$\frac{1}{2}$$

which means that 1 is to be divided by two or divided into two parts, each of which we call one-half. Here are some fractions made in this way and if you divide the top by the bottom you will get the answers given beside the fractions:

$$\frac{10}{2} = 5 \qquad \frac{15}{3} = 5 \qquad \frac{8}{8} = 1 \qquad \frac{81}{9} = 9 \qquad \frac{21}{7} = 3$$

In all these fractions the top is larger than the bottom and the result is a whole number which is equal to 1 or more. If the top is smaller than the bottom, the result will be less than 1 and you have a fraction.

There are two other ways in which we can state Ohm's Law, The first one, the one given above, says that the amperes are equal to the volts divided by the ohms. Another way of saying the same thing is: The resistance in ohms is equal to the number of Volts divided, by the number of amperes; or, in symbols.

$$R = \frac{E}{I} \tag{2}$$

The third statement of Ohm's Law is: The number of volts Is equal to the number of amperes multiplied by the number of ohms, or:

$$E = I \times R$$

When writing “equations” “formulae” like this one the sign of multiplication (x) is omitted. Whenever you see two symbols or letters written next to each other it means they are to be multiplied together. So we write:

$$E = IR \tag{3}$$

Now, in formula (1) we have a statement of Ohm's Law by which we find the number of amperes which will flow in a circuit or in a part of a circuit when we know the resistance in ohms and the number of volts applied to the circuit or part of a circuit. We know the amperes are equal to the volts divided by the ohms.

The second form of Ohm's Law in formula (2) enables us to find out the number of ohms resistance of a circuit or part of it, when we know the number of volts applied and the number of amperes flowing.. We know that the ohms are equal to the volts divided by the amperes.

The third form of Ohm's Law in formula (3) enables us to find out the number of volts which might be acting on the circuit or part of a circuit if we know the number of amperes flowing and the number of ohms resistance. We know that the volts are equal to the amperes times the ohms.

You really must remember Ohm's Law. It is not so hard because all you have to do is remember the arrangement of symbols shown at the left hand end of Fig, 8. Just remember "E" over "I" times "R".

Now from this arrangement of symbols, if you want to find the number of volts, put your finger over the "E" (for Volts) and you road "I x R", so you know the volts are equal to the amperes times the ohms. If you want to find the number of amperes put your finger over the "I" (for amperes) and you read "E" over "R" or the volts divided by the ohms. If you want to find the number of ohms put your finger over the "R" (for ohms) and you see "E" over "I" or volts divided by amperes.
Now we are going to put Ohm's Law to work.

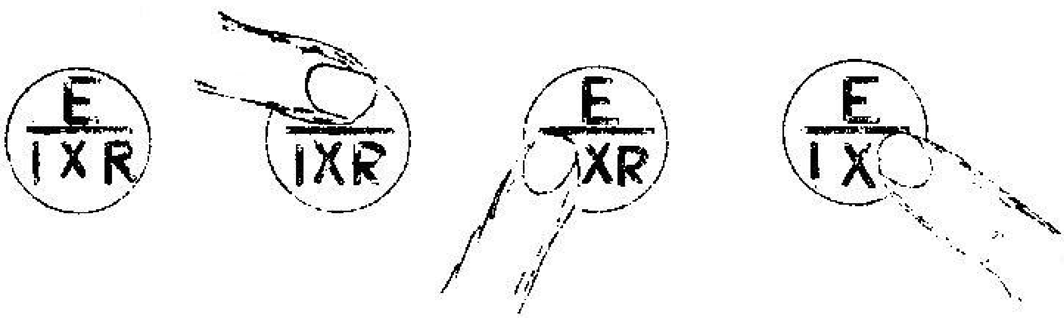


Figure 8.

USING OHM'S LAW
In Fig, 9. neglecting the resistance of the ammeter and the wiring., how many amperes flow in this circuit? Work out your own answer and write it down before you read another word.

We really do neglect the resistance of an ammeter because such an instrument has so very little of it. Also, when wires are fairly short, of good size, and carry only a very small current, we can neglect their resistance, Well, in Fig.4 the battery furnishes six volts pressure and the resistor has three ohms resistance. You know the volts and the ohms - how many amperes? Use fig. 8 put your finger over the "I" (amperes) and you see you must divide the volts by the ohms. The volts (6) divided by the ohms (3) gives 2 as the number of amperes flowing. Was your answer correct?

In Fig, 10 the two heavy wires run to the filament pins of a radio tube and an ammeter connected in one of them reads 1 ampere. A voltmeter connected across the pins reads 6 volts. What is the resistance, in ohms, of the filament? Try this one too, before you read the answer.

Well, you want to find the number of ohms so, using Figure 8, put your finger over the "R" for ohms and you find that you should divide the volts by the amperes. The volts (6) divided by the amperes (1) gives 6 as the resistance of the tube's filament in ohms. How was your answer? In nearly all our radio work we use this very method for measuring unknown resistances. The only other easy way is with an "Ohmmeter" which is an instrument which reads directly in the number of ohms. The tube in Figure 10 in nothing imaginary, it is one of the "50" type in which the

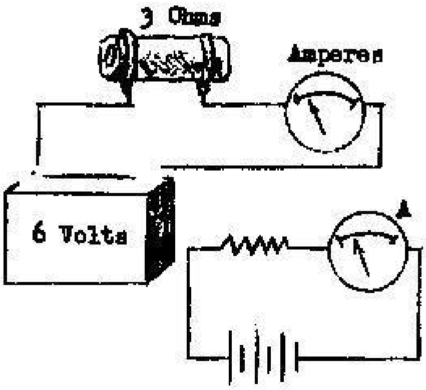


FIGURE 9.

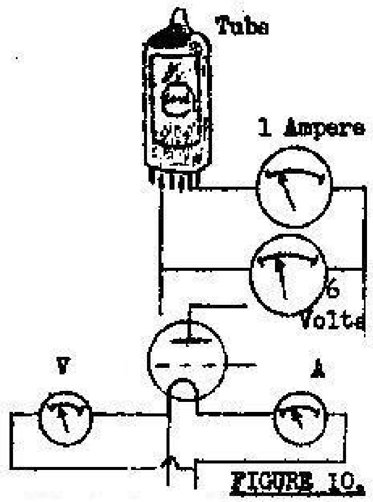


FIGURE 10.

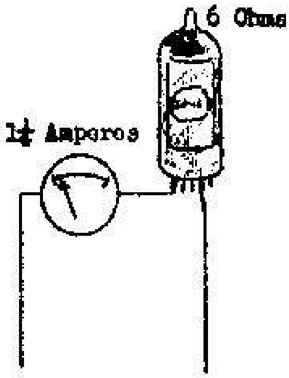


FIGURE 11.

resistance of the filament is really 6 ohms. Now, knowing the filament resistance of this tube, 6 ohms, how many volts must you apply to the filament to make 1¼ amperes flow through it? This 50 tube may be worked with six volts on its filament and a currant of one ampere, but to got the full power it is capable of delivering we have to send 1¼ amperes through the filament.

In Figure 11 we have the tube with its known filament resistance, 6 ohms, and the ammeter reads 1¼ amperes. Calculate the number of volts which must be acting on the filament. Again, using Figure 8, cover the "E" (for volts) and you see that you must multiply the amperes by the ohms. So, 1¼ (amperes) times 6 (ohms) gives as the number of volts needed to get this current through the filament. The "50" tube should be worked on this filament voltage.

There in Figures 9, 10 and 11, you have three practical applications of Ohm's Law. In one you found the amperes, in another you found the ohms and in the third you found the voltage.

In Figure 12 we have a circuit in which the ammeter shows 4 amperes to be flowing. A voltmeter connected across the circuit from "A" to "B" reads 2 volts. There is a "drop" two volts between these points. What is the resistance in ohms of the part of. the circuit between “A” and “B” ? To find the calms we divide the volts (2) by the amperes (4), as shown in figure 8, and we get 2/4. This fraction, 2/4 is equal to ½ or one half, so the resistance of this part of the circuit is one-half ohm.

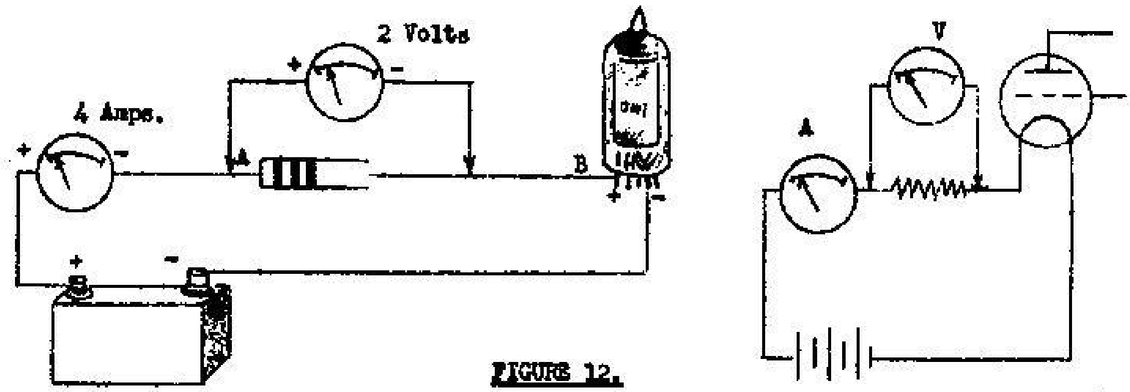


FIGURE 12.

Just to get same practice in using Ohm's Law, calculate the missing quantities in Figures 13, 14, and 15. In Figure 13 the voltage and the resistance are shown; find the currant in amperes. In Figure 14 you can read the voltage and the current; what is the resistance in ohms? In Figure 15 the resistance is given and you can read the current; find the number of volts. The circuits are all different and you will have to work each one separately -- the answer for one won’t help get the others. Now don't read any further until you try for the answers.

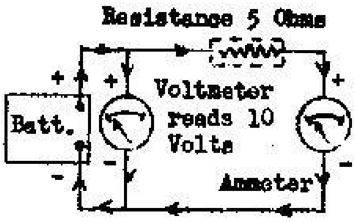


FIGURE 13.

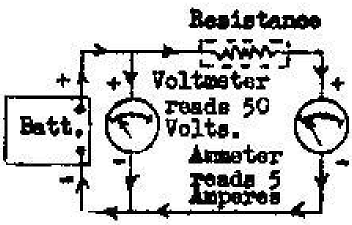


FIGURE 14.

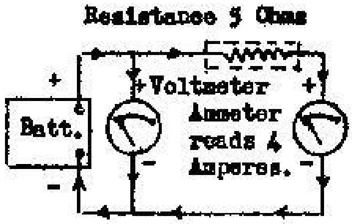


FIGURE 15.

The answers are: Figure 13 -- two amperes. Figure 14 -- ten ohms. Figure 15 - twenty volts. How did you come out? In Figure 13 you should divide 10 (volts) by 5 (ohms) to got 2 amperes. In Figure 114 you should divide 50 (volts) by 5 (amperes) to get 10 ohms. In Figure 15 you should multiply 4 (amperes) by 5 (ohms) to got 20 volts. All these things are shown in figure 8, at least you can work them out with the help of Figure 8.

In Figure 16 you can see a resistor of the kind sometimes used in power units which furnish current to the plate circuits of radio tubes. This resistor is in three sections; one of 5,000 ohms, another of 15,000 ohms, and the third of 10,000 ohms resistance. Then the total resistance from top to bottom, “A” to “B”, must be the total of these amounts, or 30,000 ohms. With a voltmeter you find that the voltage difference between “A” and “B” is 180 volts. How much current is flowing through the resistor?

You know the volts and the ohms. From Figure 8 you divide the number of volts by the number of ohms to find the number of amperes. So you have 180 divided by 30,000. Evidently there is very little current because the fraction, 180/30,000 is a small amount. Small currents are measured in milliamperes, one milliampere being the one thousandth part of an ampere or, the other way around, one ampere being equal to 1,000 milliamperes.

When you wish to get the result in milliamperes, you start off by multiplying the top part of the fraction, the number 180, by one thousand. Then 180 times 1,000 is equal to 180,000. Now for the number of milliamperes, you have:

$$\frac{180,000}{30,000}$$

This means that you are to divide 180,000 by 30,000 and the result is 6 because 30,000 goes into 180,000 six times. Then we have the answer that 6 milliamperes of current will flow through the resistor in Figure 16.

Now we are going back to the "50" tube again, the tube which has a filament with 6 ohms resistance. In Figure 17 an ammeter connected in circuit shows only ½ ampere.

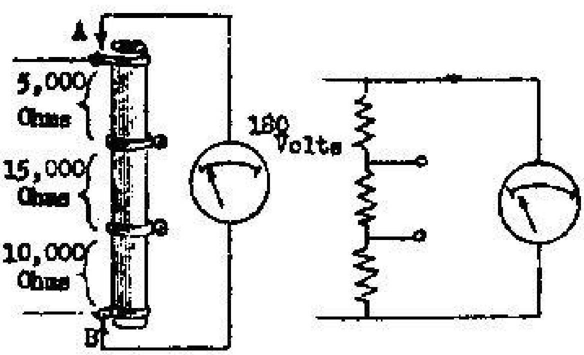


FIGURE 16.

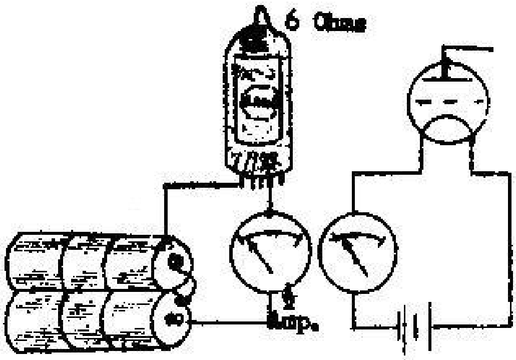


FIGURE 17.

You know the filament's resistance, 6 ohms, and you know how much current is flowing through it. What is the voltage drop across the filament or what voltage would be shown on a voltmeter connected across the filament terminals? From Figure 8 you see that the amperes times the ohms will give the volts. So, ½ times 6 gives the answer as 3 volt acting on the filament.

It is safe to say that Ohm's Law is one of the most useful rules with which a radio man can be acquainted. Radio men use this rule every day in their work -- most days several times over.You should be so familiar with Ohm's Law that you use it as a matter of habit.

To find the current in amperes flowing between any points you divide the voltage difference between the points by the ohms of resistance between the same points. You did that in Figures 9, 13 and 16.

To find the resistance in ohms between any two points you divide the voltage difference by the number of amperes flowing in the circuit between those points. You did that in Figures 10, 12 and 14

To find the volts drop between any two points you multiply the ohms resistance by the current flowing between the points. That's what you did in Figures 11, 15 and 17.

RESISTANCE INSERIES CIRCUIT.

The resistor of figure l6 consists of three parts connected in series, each part having a resistance different from that of the other two. To find the total resistance we added together the three separate resistances. The total resistance of all the parts of a series circuit to current flowing through the whole circuit is equal to the sum of all the separate resistances, and the current through each resistance will be equal to the current flowing through the whole circuit.

In Figure 18 we have a circuit containing a tube and a rheostat, also the connecting wires. The tube is a "71-A" type having a filament with 20 ohms resistance. The rheostat is a 6 ohm unit, that is, its total resistance is 6 ohms. But you can see

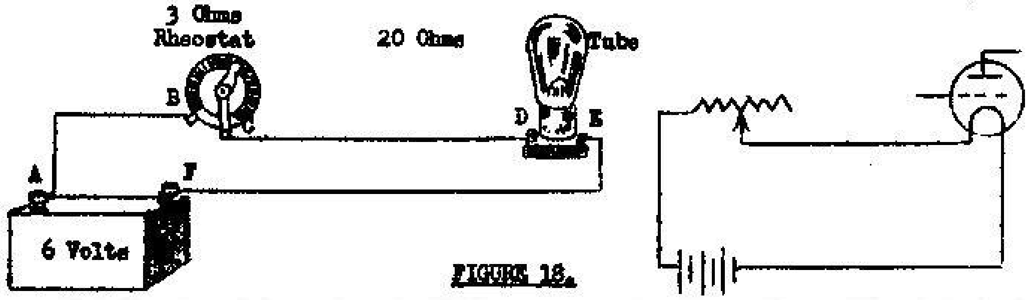


FIGURE 18.

that the rheostat arm is not all the way around. The arm's position lets 3 ohms resistance remain in the circuit. The wires too have some resistance, just for illustration say the wire between "A" and "B" has ¼ ohm resistance, the wire from "C" to "D" has ¼ ohm resistance, and the wire from "E" to "F" has ½ ohm resistance. Let us add up the resistances.

Wire A-B	¼ ohm
Rheostat	3 ohms
Wire C-D	¼ ohm
Tube filament	20 ohms
Wire E-F	½ ohm
Total Resistance	24 ohms.

This is the way you find the total resistance of any series circuit simply add together the resistances of all the parts. If the battery voltage is 6 and the circuit resistance is 24 ohms, how much current flows through the circuit? Divide 6 by 24, giving 6/24 which is equal to 1/4, There is a current of 1/4 ampere flowing in the circuit. This is the current required to operate a "71-A" tube.

PARALLEL CIRCUITS.

At the left hand side of Figure 19 there is a funnel on top of a pipe one inch in diameter and one foot long. At the right hand side the funnel feeds two pipes, each one inch in diameter and one foot long. Through which of these arrangements will water travel more easily? Of course, that's too simple a question to deserve an answer.

At the loft hand side of Figure 20 we have a battery connected to a wire of number 28 gauge size and two feet long. At the right hand side the same battery is connected to two wires as shown, each wire being number 28 gauge and two feet long. These two wires are in parallel with each other. Through which arrangement, one

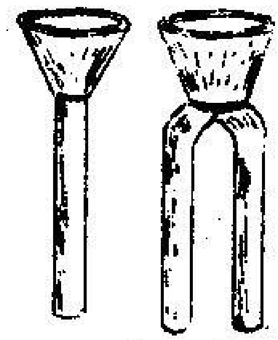


Figure 19.

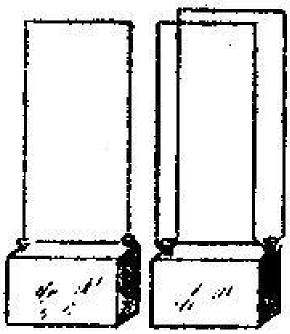


Figure 20.

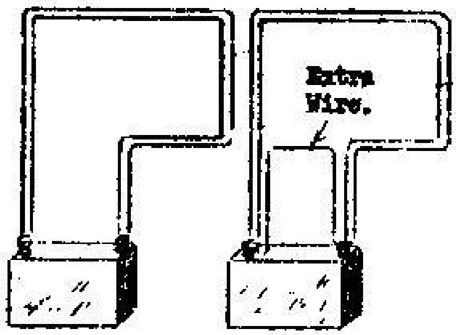


Figure 21.

or two, will the battery current flow more easily ? Through the two wires, of course, because just as much current will flow through the second wire as through the first, and the two will take twice as much current as one. The resistance of two wires in parallel is less than the resistance of either or one alone.

In Fig. 21; at the left, there is a great big wire across the battery. You know that a big wire has but little resistance, consequently carries a lot of current. The resistance (with a given battery voltage) determines the amount of current and if more current flows there must be less resistance

At the right hand side of Fig. 21 them is a very small extra wire between the battery terminals. This little wire will carry a little bit of current, but this little current is in addition to the current already going through the big wire. No matter how small the extra wire, no matter how great its resistance (taken alone) it will carry some current and the two wires together will carry more than the big one alone. Therefore since the two wires carry more current their combined resistance must be less than the resistance of one alone.

If the big wire has a resistance of one ohm and the little one a resistance of 1000 ohms, their combined resistance will be loss than one ohm because the two carry more current than either alone. That is the way resistances work in a parallel circuit.

RESISTANCE OF PARALLEL CIRCUITS.

In Fig-, 22 there are two tubes connected with their filaments in parallel each filament has a resistance of 20 ohms. You know that twice as much current will

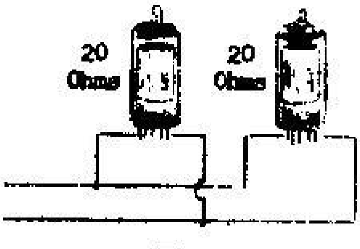


Figure 22.

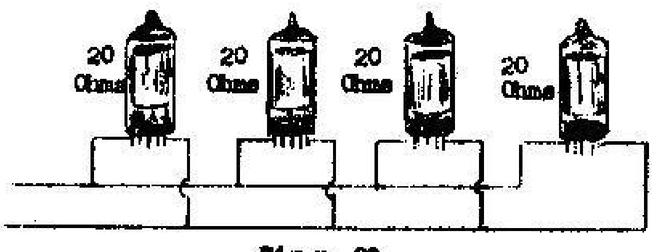


Figure 23.

flow through two tubes as will flow through one because they are just alike. Well, if twice as much current flows, the resistance of the two tubes together must be only half that of one tube. So, to find the resistance, of two equal resistances in parallel, you divide the resistance of one path by the number of paths. That's just what you did.

In Fig. 23 there are four tubes, each having 20 ohms resistance in its filament. If a certain amount of current flows through one of the filaments, four of them will take four times this amount of current. If the four tubes take four times the current taken by one, their combined resistances must be one-fourth that of one tube or 5 ohms. So again you divide the résistance of one path by the number of paths.

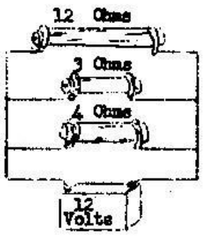


Figure 24.

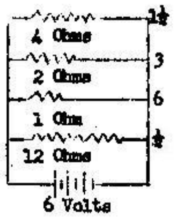


Figure 25.

COMBINING UNEQUAL RESISTANCE

Three different resistances are connected in parallel in Fig. 24. The top one is 12 ohms, the middle one is 3 ohms and the bottom one is 4 ohms resistance. What is their combined resistance? You know it will be loss than 3 ohms because the combined resistance of parallel resistance is always smaller than the smallest one of the lot.

How much current will flow through the top 12 ohm resistor? You have 12 volts and 12 ohms. Divide the volts by the ohms to find the amperes - 12 divided by 12 is 12/12 of 1 amperes passes through this resistor.

Now taKe the middle resistor 3 ohms, the voltage is the same, 12, and dividing 12 by 3 (ohms) gives 4 amperes as the current flowing.

Then take the lower resistor, 4 ohms. Again dividing the volts 12 by the ohms you find that the current is 3 amperes. How much current you altogether?

CURRENTS THROUGH SEPARATE RESISTORS

12-ohm resistor	.... 1 ampere
3-ohm resistor	.... 4 amperes
4-ohm resistor	.... 3 amperes
all resistors	..........8 amperes

Now we will find their combined resistance. From Ohms Law you know that the resistance in ohms is equal to the volts divided by the amperes. You have 12 volts and a total of 8 amperes, and 8 goes into 12 how many times? One and one-half times, so the combined resistance is 1½ ohms. That is one way to calculate the combined resistance with the help of Ohms Law.

Here is another example of this way of working. In Fig. 25 there are four resistors; 4 ohms, 2 ohms, 1 ohm and 12 ohms. The voltage is 6, and this 6 volts pressure acts across the ends of all the resistors. Find the current. It would be a good idea for you to cover the rest of this and work it out for yourself.

Current in 4 ohm resistor ...	6 divided by 4 ...	1½ amperes
Current in 2 ohm resistor ...	6 divided by 2 ...	3 amperes
Current in 1 ohm resistor ...	6 divided by 1 ...	6 amperes
Current in 12 ohm resister ...	6 divided by 12 ...	½ amperes

Total current through all resistors in parallel ... 11 amperes

To find the combined resistance, divide the volts by the amperes. Dividing 6 by 11 gives the fraction 6/11 so the total resistance is six-elevenths of an ohm. The rule for finding the combined resistance of a number of different resistances in parallel by the method just shown is this: Find the current through each resistance by dividing the volts by the ohms; add the currents together and divide the volts by this total current in amperes to got the combined resistance in ohms. The combined resistance of resistors in parallel depends entirely on the resistors themselves - the applied voltage does not affect the resistance in any way at all. For example, in Figure 24 it would not matter whether 12 volts or one volt were applied, the combined resistance would remain at 1½ ohms.

If you wanted to find the combined resistance of several resistances in parallel, but you did not know the voltage acting across them, you could assume any voltage at all, working out the resistances as already explained. You could choose one volt, for example, and still get the same result.

Suppose you did not know the voltage in Figure 24. Then you could imagine for the time being that one volt was applied. Then you would add the current this way :-

Current through the 12 ohm resistor .... 1/12 ampere
Current through the 3 ohm resistor .... 1/3 ampere
Current through the 4 ohm resistor .... 1/4 ampere

Current through all the resistors .... 1/12 + 1/3 + 1/4 amperes

= 1/12 + 4/12 = 3/12 = 8/12 ampere = 2/3 ampere

Now to get the combined resistance we divide the voltage applied, one volt, by the total current flowing., 2/3 ampere. 1 divided by 2/3 is equal to 3/2 -- the fraction 2/3 just turned upside-down. 3/2 is equal to 1½, which is the same combined resistance as we got before. e

Now let's go back and see just what we have been doing to find the combined resistance when we don't know the voltage applied. First. We divide the figure 1 by each of the single resistances, then add the resulting fractions togother. We then divided the figure 1 by the result of this addition, this giving us the combined resistance.

The result obtained by dividing the figure 1 by any number is called the reciprocal of that number. So to get the combined resistance we really added the reciprocals of the separate resistances, and then took the reciprocal of the result, the final result being the combined resistance.
Lot us take the example of Figure 25 and work it out this way. First we add together the reciprocals of each of the separate resistances, like this:-

1/4 + 1/2 + 1/1 + 1/12 = 3/12 + 6/12 + 12/12 + 1/12 = 22/12.

Now we take the reciprocal of 22/12 which is just 22/12 turned upside-down, or 12/22. 12/22 is the same as 6/11, or six elevenths of an ohm. You see, this is exactly the same result as we got working it out the other way.

Remember, to calculate the combined resistance of resistances in parallel by this method, add together the reciprocals of the separate resistances, than take the reciprocal of the result, this being the combined resistance.

One final point - when resistors are connected in series, the value of current flowing through each will be identical and will be the same as the value of current flowing through the complete circuit. The voltage drop across each resistor will be identical only if each resistor in the series circuit has the same value. If the resistors have dissimilar values the individual voltage drops will also be dissimilar. The lower values of resistance will develop a lower voltage drop than the larger values, but the value of current flow through each resistor will still be identical with the value of current flowing through the complete circuit.

When resistors are connected in parallel, conditions, so far as voltage drop and individual current flow is concerned, are reversed. That is, with the parallel connection the voltage drop across each resistor in the parallel network will be exactly the same, but the current flow through each will vary if the resistors have dissimilar values. This last statement is most important. The current flow through each resistor in a parallel connection will be dissimilar only if the values of resistors are dissimilar. Where the value of each resistor is identical, the current flow through each will be exactly the same value, but, - and this too is important - the current flowing through each resistor will be less than the value of current flowing through the complete circuit. If, for instance, four resistors each having the same value of resistance are connected in parallel, the value of current flowing through each resistor will be exactly the same and also equal to one quarter of the value of current flowing in the complete circuit.

HOW TO USE THIS INFORMATION.

The information given in this lesson will prove of the greatest possible value all through your radio work. We have talked a lot about resistances in this lesson. Here is a table giving you the resistances of all the common metals and of carbon. This table will give you an idea of how the resistances of these materials compare with one another.

RE S I S T A N C E S IN OHMS PER MILFOOT.

A “Mil foot” is a piece of material one foot long and having a diameter of one mil or one-thousandth of an inch. This unit is used because it is the unit in which we will later on specify the size of wire and from this table you will be able to calculate the resistance in ohms of a wire of any size, any length and any material

Aluminium	17.0	*Manganin	264.7
Antimony	250.9	Mercury	576.2
Bismuth	.721.9	Molybdenum	34.3
Brass	42.1	*Monel Metal	252.7
Cadmium	45.7	Nichrome	601.6
Carbon	22,000	Nickel	46.9
*Climax	523.7	Palladium	67.2
*Constaton	295.0	Phosphor Bronze	46.9
Copper (soft annealed)	10.4	Platinum	60.2
Copper (hard drawn)	10.6	Silver	9.6
*Excello	533.3	Steel (transformer grade)	66.2
German Silver (18% nickel)	198.5	Steel (Cast)	114.5
German Silver (30% nickel)	294.8	Steel (soft)	95.5
Gold	14.7	Steel (manganese)	421.4
Graphite	4,300.0	Tantalum	93.3
Iron (pure, soft)	60.2	*Therlo	282.9
Iron (cast)	435.0	Tin	69.2
Lead	132.3	Tungsten	33.7
Magnesium	276.7	Zinc	34.9

* Materials marked with this star are mixtures especially for making resistance wires used in various kinds of resistors.

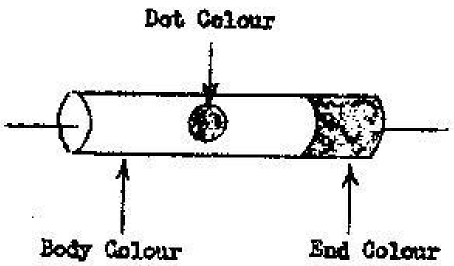
R.M.A. COLOUR CODE RESISTOR CHART

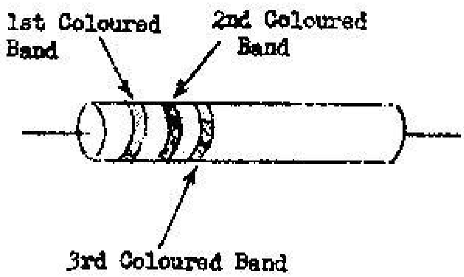
Black	0	Black	0	Black	-
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0000
Green	5	Green	5	Green	00000
Blue	6	Blue	6	Blue	000000
Violet	7	Violet	7	Violet	0000000
Grey	8	Grey	8	Grey	00000000
White	9	White	9	Grey	000000000

EXAMPLE.

A resistor of 250,000 ohms would have a red body indicating that the first figure was 2, a green end indicating that the second figure was 5, and a yellow dot indicating that there are four noughts. Similarly, a 25,000 ohm resistor would have a red body and green end and an orange dot. In this case the dot would indicate that them are only three noughts after the first two digits.

Most resistors nowadays incorporate a fourth band, of colour. This fourth band has no direct relationship to the actual value of resistance, its purpose is to indicate the percentage tolerance under which the resistor has been manufactured. If a resistor has a silver band following the first three, the indication is that the resistor has been, manufactured to a 10% tolerance. This means that the actual value ray be either 10% greater or 10% smaller than that indicated by the first three colour bands. If the colour of the fourth band is gold, the resistor has beer. manufactured to a 5% tolerance. If there is no fourth band then the resistor has been manufactured to a 20% tolerance.





<u>EXAMINATION QUESTIONS – No.10</u>

1. If you know the number of amperes flowing through a circuit and know the number of volts applied across the circuit, how do you find the circuits resistance in ohms?

2. The filament of a tube is carrying ½ ampere when the voltage drop across it is 6 volts. What is the filament's resistance in ohms? Show how you arrive at the answer.

3. The size (cross sectional area) of number 20 gauge wire is practically four times that of number 26 wire. If 1,000 feet of number 26 copper wire (the smaller size) shows a resistance of 32 ohms, what is the resistance of 1,000 feet of the larger wire number 20?

4 With a rheostat set for 5 ohms resistance, 2 amperes flow through it. How many amperes will flow through when the rheostat is set for 10 ohms, all other conditions remaining the same

5. One “35” tube takes 1¾ amperes for its filament. How much current will be needed for four of those tubas in parallel?

6. A wire of number 34 gauge 1000 feet long has a resistance of 120 ohms. What is the resistance of 250 feet of the same wire?

7. If you apply 8 volts across the ends of a resistor through which you want 2 amperes to flow, what must be the resistance in ohms?

8. If You find that 3 amperes flow through a circuit and know its resistance is, 10 ohms, what is the voltage drop through this circuit?

9. One resistor measures 10 ohms resistance. What will be the combined resistance of four of these resistors in parallel? Show working.

10. Three resistors are connected in parallel. One has a resistance of 2 ohms another a resistance of 5 ohms, and the third a resistance of 10 ohms. What will be their combined resistance?

NOTE:- Show all calculations clearly in answers.

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LESSON NO. 11 M2.

SQUARE ROOT

Square root is used a good deal in practical calculations, and it is as well to know how it is done. The product resulting from multiplying a number by itself is called the SQUARE OF the number. If a number is used as a factor three times, the resulting product is called the CUBE of the number. In order to show how many times a number is to be used as a factor a small figure is placed to the right and slightly above the number. This small figure 3 is called an EXPONENT, and shows to what power the number is to be raised. When the figure 2 is used as an exponent, it indicates that the number is to be raised to the second power, or, the square of the number is to be obtained. When the figure 3 is used as an exponent, it indicates that the number is to be raised to the third power, or, the cube of the number is to be found.

Thus 4^2 indicates that the 4 is to be raised to the second power, or, to find the square of 4, which is done by multiplying 4 x 4 and equals 16. Thus 16 is equal to 4 raised to the second power, or, 16 to the square of 4. When the dimensions of a perfect square are known, the area in square units is calculated by finding the square of the length of one of the sides. For example, if a certain plot of land was in the shape of a square and the sides were 100 feet long, the number of square feet in the plot could be calculated by finding the square of the length of one of the sides. Thus, 100^2 equals 100 x 100 which is 10,000 square feet.

A ROOT of a number is one of the equal factors, which equal the number, when multiplied together. If a certain number is multiplied by itself in order to produce another number, the first number mentioned is the square root of the second. The square of 12 is 144 and is found by multiplying 12 x 12. Thus 12 is the square root of 144. If the area of a square is known, the length of one side of the square can be obtained by extracting the square root of the area, Thus if a square yard contained 2000 square feet of ground each side of the yard is 50 feet long, which is found by extracting the square root of 2,500.

This process of finding the square root is merely the reverse of finding the power. The RADICAL SIGN $\sqrt{}$ shows that some root of it is to be taken. The root desired is shown by a small figure called the INDEX which is placed above the radical sign, thus $\sqrt[3]{}$ when no index is shown, the square root is understood.

The following rules are given and explained and if they are carefully followed stop by step, a beginner should have but little difficulty in mastering the method.

Rule 1. Separate the number into periods of two figures each, beginning at units.

Rule 2. Find the greatest square of the left hand period, and place its root for the first figure in the quotient.

Rule 3. Square this root and subtract the result from the left hand period and annex to the remainder the next period for the next dividend.

Rule 4. Double the quotient already found for a partial divisor, and divide the dividend, disregarding the right hand figure.

Rule 5. Annex to the partial divisor the figure last found. Place this figure as the second figure in the quotient. Subtract the product from the dividend and to the remainder annex the next period for the next division.

Rule 6. Proceed in this manner till all the periods have been used and the final result shown in the quotient will be the square root of the number.

Rule 7. If the number is not a perfect square, annex periods of two noughts each and continue the process.

Rule 8. Point off decimal fractions in periods of two figures each beginning at the decimal point, progressing towards the right.

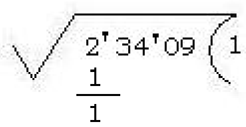
Rule 9. To find the square root of a common fraction, reduce it first to a decimal fraction, or, extract the square root of the numerator and denominator separately.

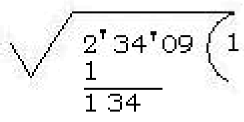
In explaining the rules we will take number 23,409 as an example. Rule 1 says, “to separate the number into periods of two figures, each, beginning at the units”. The unit is the first at the right. Beginning at units, the number should be divided into periods, thus :- 2'34'09. Rule 2 says, “find the greatest square of the left hand period and place its root for the first figure in the quotient”. The left hand period in this case is 2. t should be understood that the left hand period is a complete period, although it contains but one figure in this case. To find the greatest square of 2, means to find the largest number which when multiplied by itself, is equal to, or less than 2. The greatest square of 2 is 1, and it is the only number which can be squared whose product is less than 2. Therefore, the greatest square of the left hand period is 1, and its root, 1, is placed in the quotient for the first figure of the required factor.

√2'34'09 (Quotient

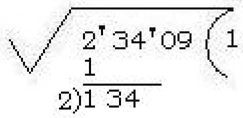
√2'34'09 (1

Rule 3 says, “square this root and subtract the result from the left hand period, and annex to the remainder the next period for the next dividend”. Square this root which is 1, and subtract the product from the left hand period, which is 2, leaving a remainder of 1. To this remainder annex the next period, 34, making a dividend of 134.



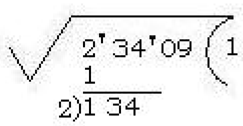


Rule 4 says "double the quotient already found for a partial divisor, and divide the dividend, disregarding the right hand figure". By doubling the quotient 1, a partial divisor is found, which is 2. This partial divisor is placed to the left of the dividend.

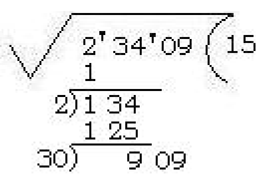


It should be clearly understood that this number is only a partial divisor, and s figure yet unknown is to be annexed before it can be divided into the dividend. By temporarily disregarding the right hand figure in the dividend, the dividend is converted into a partial dividend, and the partial divisor can now be divided into it, to approximately determine the figure which is to be annexed to the partial divisor. By disregarding the figure 4 of the dividend, 134, it is readily seen that the partial divisor 2 is contained in 13 six times, so that the next lower figure, which is 5, is selected.

There is no definite rule saying that the number lower than the quotient, obtained by dividing the partial divisor into the partial dividend, is to be selected. The actual number may be the quotient, one less than the quotient, as in the following example, or in some cases two less than the quotient. Until you have had some experience with these calculations it will be necessary to make a trial, commencing by using the quotient itself and if this is too large using the next lower number, and if the product is still too large the next lower number again.



Temporarily disregarding the 4 Rule 5 says, "annex to the partial divisor the figure last found. Subtract the product from the dividend and to the remainder annex the next period for the next dividend". This 5, which was last found, is annexed to the partial divisor 2, making a complete divisor 25, which is then divided into the complete dividend 134. This 5 is also placed as the second figure in the quotient. Multiply the divisor 25 by 5, as is done in long division, and subtract the product 125, from the dividend, 134, leaving a remainder of 9, to which annex the next period for the next dividend, making 909. Next double the quotient 15, which makes 30, for the next partial divisor.



Rule 6 says, "to proceed in this manner until all periods have been used, and the

final result shown in the quotient will be the square root of the number"

```
√2'34'09 (153          √2'34'09 (153
  1                      1
2)1 34                 2)1 34
  1 25                   1 25
303)  9 09             303)  9 09
                             9 09
```

Rule 7 says, “if the number is not a perfect square, annex periods of two noughts each and continue the process.”

```
√6'24.00'00 (24.9+
  4
44)  2 24
     1 76
489)   48 00
       44 01
        3 99 00
```

In this example the result does not come out even and the plus sign (+) is used to show that there was a fraction left over.

Rule 8 says, “point off decimal fractions in periods of two figures each, beginning at the decimal point and progress towards the right”, as shown below.

```
√.04'66'56 (.216
  04
41)  0 66
       41
426)   25 56
       25 56
          00
```

Rule 9 says, “To find the square root of a common fraction, reduce to a decimal fraction and extract the square root, or, extract the square root of the numerator, and denominator separately”, both methods being shown in to example below.

Find the square root of ¼

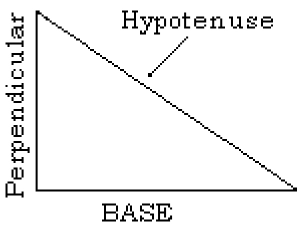
Find the square root of $\frac{900}{3600}$

```
√ .25  (.5
  .25
  00
```

```
√ 9.00 (30        √ 36.00 (60
  9                 36
  00                00

Ans 30
    60
```

A Right Angle Triangle consists of three lines ; a horizontal line which is called the base and is known by the symbol “B”, A vertical line called the perpendicular, which is known by the symbol “P” and a line connecting these two lines called the Hypotenuse and is known by the symbol “H”. The angle at the point whore the Perpendicu1ar and Base meet is always a right angle or a 90° angle. If you know the length of two sides you can find the length of the third as shown below.



Rule 10. The square root of the sum of the squares of the base and the perpendicular is equal to the Hypotenuse.

$$H \text{ equals } \sqrt{B^2 \text{ plus } p^2}$$

Problem. If the base of a right angle triangle is 40 inches long, and the perpendicular is 30 inches long, what is the length of the hypotenuse? By rule 10,

$$H = \sqrt{B^2 + p^2} = \sqrt{40^2 + 30^2} = \sqrt{1600 + 900} = \sqrt{2500} = 50 \text{ inches}$$

Rule 11. The square root of the difference of the squares of the hypotenuse and the base is equal to the perpendicular.

Problem. If the base of a right angle triangle is 40 inches and the hypotenuse is 50 inches, what is the height of the perpendicular? By rule 11.

$$P = \sqrt{H^2 - B^2} = \sqrt{50^2 - 40^2} = \sqrt{2500 - 1600} = \sqrt{900} = 30 \text{ inches}$$

Rule 12. The square root of the difference of the squares of the hypotenuse and the perpendicular is equal to the base.

$$B = \sqrt{H^2 - p^2}$$

Problem. If the perpendicular of a right angle triangle measures 30 inches, and the hypotenuse is 50 inches, what would be the length of the base? By Rule 12.

$$B = \sqrt{H^2 - p^2} = \sqrt{50^2 - 30^2} = \sqrt{2500 - 900} = \sqrt{1600} = 40 \text{ inches}$$

Following are six problems illustrating the method of calculating the square roots of various numbers. These should be carefully followed step by step until you are quite sure you thoroughly understand this method of working.

PROBLEMS.

```
(1)   √ 30'25 ( 55
        25
  105)   5 25
         5 25
           00

(2)   √ 1'18'81 ( 109
        1
  209) 18 81
       18 81
          00

(3)   √ .33'64 ( .58
         25
  108)    8 64
          8 64
            00

(2)   √ 54'76 ( 74
        49
  144)   5 76
         5 76
           00

(3)   √ 1'54.50'49 ( 12.43
        1
   22)  54
        44
  244) 10 50
        9 76
  2483)   74 79
          74 79
             00

(4)   √ .00'00'04'41 ( .0021
             4
   41)    00 41
             41
             00
```

$$H \text{ equals } \sqrt{B^2 \text{ plus } p^2}$$

ANOTHER METHOD OF WORKING SQUARE ROOT PROBLEMS.

If the above method of working square root problems proves difficult, try the method which follows. It is often found when looking at a problem from several angles, misunderstandings are easily overcome. No doubt, the following problem will help.

Find the square root of 55,225.

	5 52 25 (235
	4
40	1 52
43	1 29
460	23 25
465	23 25

1. Begin at the right the numbers into periods of two figures each, because the square of any number having only one digit or figure will not occupy more than two places, and the square of any number having two digits will not occupy more than four places, etc. There will be as many places in the root as there are periods. In the example there are three places in the root.

2. Find the greatest square in the first or left hand period, which is (4), and place Its root (2) as the first figure of the root.

3. Subtract the square (4) from the first period and bring down the next period (52), and annex it to the first remainder (1). This gives a new dividend (152).

4. Take two times the first figure of the root (2) and place it at the left of the next dividend, and annex one nought. This is a trial divisor. Find how many times this trial divisor (40) is contained in the dividend (152). Place the result (3) as the second figure of the root. Also add this second figure of the root (3) to the trial divisor (40). This gives the complete divisor (43).

5. Multiply the complete divisor (43) by the second figure of the root (3), and subtract and bring down the next period (25) and proceed as before until the root is found.

When the number is not a perfect square, annex periods of noughts and continue the root as a decimal. If the trial divisor is not contained in the dividend, annex a nought to the divisor and also to the root and bring down the next period.

To extract the square root of decimals, begin at the decimal point and point off to the right, periods of two figures each, and, if there are whole numbers, also to the left, periods of two figures each, annex noughts if necessary, to make two figures in each period.

<u>EXAMINATION QUESTIONS - MATHEMATICS LESSON-No.11 M2</u>

1. What is the square root of 21609?

2. What is the square root of 5625?

3. What is the square root of 287296?

4. What is the square root of 288369?

5. What is the square root of 56644?

6. What is the square root of 56.25?

7. What are the dimensions of a square room containing 1600 square of floor space?

8. What is a right angle triangle?

9. What are the sides of a right angle triangle called?

10. State the three rules for finding the length of one side of a right angle triangle when the lengths of the other two sides are known.

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NOTE : Write the lesson number before answering the questions.

Write on one side of the paper only.

Always write down in full the question before you answer it.

Use sketches and diagrams wherever posib1e. One diagram in many cases is equivalent to pages of exp1anation

Remember that you learn by making mistakes; so give yourself an opportunity of having your mistakes found and corrected.

Don't hesitate to ask for further explanation on any point, we are always ready to help you.

Write your name and full address at top of paper. If you have made arrangements with the College to have your lessons returned to any particular address - state this at the top of the page.

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LESSON NO. 12

RADIO TUBES - THETR CHARACTERISTICS AND OPERATION.

In one of the early lessons you were told a little about a radio tube or valve. One cannot overestimate the importance of this component because without it, modern radio simply would not exist. The tube as we know it to-day did not happen all at once. No one man invented it all. The beginning came about somewhat as shown in Figure 1. Back in 1884 Edison, the scientist was experimenting. He had a lighted filament inside of a glass bulb from which nearly all the air had been exhausted. Inside the bulb was another wire. This second wire was not heated but was connected to the positive side of a source of voltage and the negative side of that source was connected to the filament.

Edison found that when he connected a current measuring meter between one side of the lighted filament and the negative terminal of the additional battery shown at the right of Figure 1, first breaking the circuit at "X", he obtained definite indication of current flow between the lighted filament and the additional wire inserted into the bulb. As this experiment took place several years before Professor J.J. Thomson stated his famous electron theory of matter, Edison regarded the current flow in the light of what was than known about electricity, that is, he assumed that the current was flowing from the additional wire, across the vacuum, to the lighted filament.

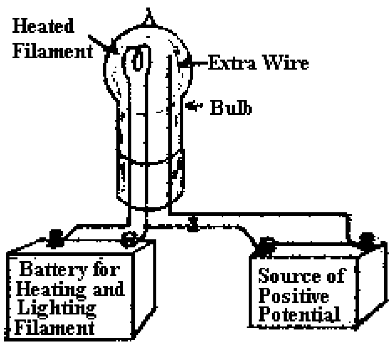

FIGURE 1

In Figure 2, the assumed direction of currant flow is shown by the small arrows. It starts out from the positive terminal of the plate battery, or as we generally call it, the "B-battery". This current then flows to the extra part in the tube, which is shown as a flat metal plate in Figure 2.The current leaves the plate, passes through the space between it and the filament and then flows through the filament. The filament battery or the

“A”-battery” and the “B-battery” are connected together and current which has passed through the plate comes back to the negative side of the B--battery, thus completing its circuit.

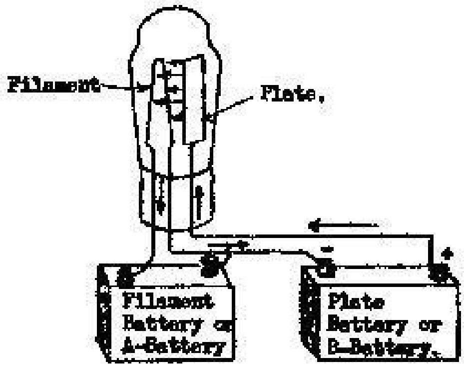

FIGURE 2.

THE TWO ELEMENT TUBE:

The filament is called one of the tube's “elements”. The plate is another element. Consequently we call a tube having a filament and a plate a two element tube, or “diode”. Such a tube is shown in Figure 3.The filament is here a straight wire. The plate is a cylinder of metal placed around the filament. These two elements are connected to pins or prongs on the base of the tube. Tubes of this general type are frequently used as detectors, as they function in much the same manner as a crystal detector.

You will also find that a large proportion of our present rectifier tubes are of the two element type. A rectifier changes alternating current to direct current.

In the two element tube there are two things which we may change in securing a change in the amount of current flowing in the plate circuit. One of them is the voltage applied to the plate, the greater the positive voltage on the plate, or the greater the difference in voltage between the plate and the filament, the more current will flow.

The other thing which we may change is the temperature of the filament. If the filament is cold no current whatever will flow between the plate and filament. As the filament is gradually heated it will reach a temperature at which a little current will flow. More and more heat allows more and more current to flow and as the filament lights up more and more brightly the plate current will increase. After the filament reaches a certain high temperature, the plate current no longer increases in proportion to the heat and beyond a certain point increasing the filament temperature causes practically no further increase in plate current.

Now we add a third element, the grid. This third element is the one which allows the tube to amplify or strengthen radio signals and to do many other remarkable things.

No plate current will flow until the filament is heated. There must be same good reason for this effect. There must be something different within the bulb when the filament is hot than when it is cold.

In Figure 4 we have three pieces of filament wire, greatly enlarged. The one at the left is supposed to be cold, the one in the centre is quite hot and the one at the right is very hot.

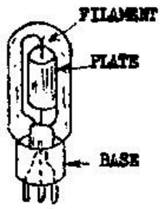

FIGURE 3.

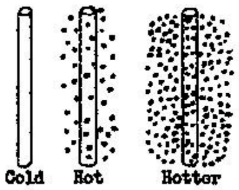

FIGURE 4.

Nothing in particular happens in the space around the cold filament. But around the hot one a very peculiar action is taking place. This hot filament is sending out from its surface the things we call "electrons". The electrons fly out for a little distance, then fall back into the filament. The very hot filament is also sending out or is emitting electrons but it is sending out many more than before it became so highly heated and the emitted electrons travel away from the filament to a much greater distance before they again fall back.

The term "electron" is no stranger to you because it was introduced into the very first lesson. However, you will hear more about it from now on because it plays such an important part in the operation of a radio valve. Thorough understanding of what it is, what it does, will greatly simplify your more advanced studies. In Lesson No.1 we explained in some detail exactly what the "electron" is. In the following paragraphs of this lesson we propose to show you, in even greater detail, exactly what the "electron" does, but first of all here is a brief resume of the earlier discussion on the nature of the "electron".

<u>ELECTRONS</u>:

Of course you know that any common substance may be divided into smaller and smaller particles. Take salt, for instance. You can pulverize the salt as fine as you will and you still have salt. The smallest possible piece of salt would be called a "molecule" of salt.

You could take that molecule of salt and by chemical action you could break it down into two things. One would be the metal sodium and the other would be the gas chlorine. In place of salt you would now have one atom of sodium and one atom of chlorine. For years and years the scientists believed the atom to be the smallest division of matter. They considered that the various kinds of atoms were the materials of which everything was made up by combining the atoms in different ways.

Now we know that the atom is not the smallest thing in existence. The smallest thing is an electron. One or more electrons in combination with what is called a "positive nucleus" form an atom. An electron is electricity itself, it is a particle of negative electricity or is a negative charge.

You cannot possibly realize how small is one electron. If you had a ball or sphere of copper so small that 100,000 of them laid side by side would extend one inch it would be something pretty small. Yet in each one of those balls of copper there would be twenty thousand million (20,000,004,000) electrons.

Hydrogen gas is one of the lightest of all things in weight. It would take two hundred and fifty million (250,000,000) hydrogen atoms in a row to make a length of one inch. And yet every one of those hydrogen atoms would weigh two thousand times as much as an electron. What you should remember out of all this is that an electron is negative electricity.

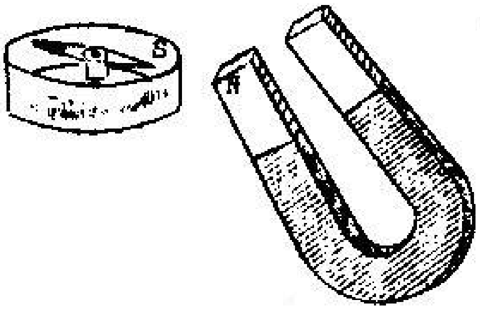

FIGURE 5.

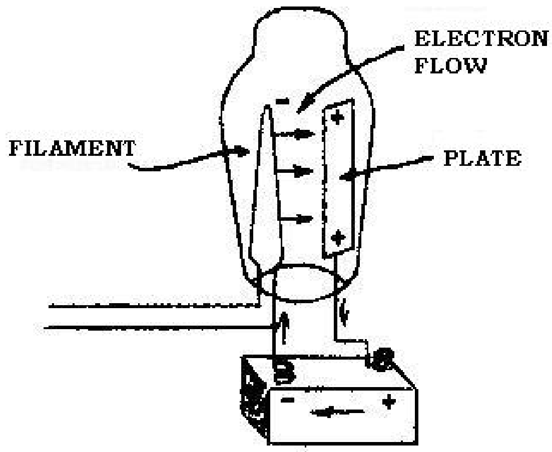

FIGURE 6.

ELECTRON FLOW:

Remember that the plate in a tube is at a higher potential than the filament, the plate is positive and the filament is negative with respect to each other. Any thing which is positive has an attraction for something also which is negative, the positive body exerts an attraction on the negative body and they tend to come together.

When you were younger you probably played with a magnet and a small compass, the kind of compass that tells you which way is north. Then you found that the positive or "North" end of the magnet would attract the negative or "South" end of the compass and that the north end of the compass was drawn toward the south end of the magnet as in Figure 5.

A similar sort of attraction exists between the positive plate and the negative electrons which are emitted by the hot filament. The electrons are negative electricity and are attracted to and are pulled over to the positive plate as indicated in Figure 6. As shown by the small arrows between filament and plate, the electrons leave the filament after being released by the heat, got caught by the plate's attraction and some of them fly across and enter the plate.

The electrons which travel across the space and got into the plate flow down through the wire to the plate battery, go through the battery and than go back into the filament at the connection between plate battery and filament battery.

If you will compare Figure 6 with Figure 2 you will see that we spoke of the electric current as flowing from the plate to the filament, but that the electron flow is from filament to Plate - Just the other way around. It is unfortunate that we cannot think of current and of electrons as flowing in the same direction. The flow of current from plate to filament is what we call a "convention" - it is just an idea, or something assumed to be true by those who first worked with electricity. The fact of the matter is that electrons, which are really negative electricity, pass from the heated filament to the positive plate. We also have to assume, because it always has been assumed, that the current flows in the other direction.

This difference in direction of electron flow and current flow is very confusing. Perhaps you will be able to understand more clearly the action in a radio tube or circuit, if I explain how this apparent contradiction in the direction of flow came about.

In the early days of electricity, scientists knew that for certain electrical actions to occur, there must be a movement of electricity around a circuit. This movement of electricity was called a "Current" of electricity, just as we speak of a movement of water as a current of water. At that stage, they did not know exactly what it was that circulated nor the direction in which it moved. There is no way of seeing the current moving and no instrument was available to definitely show in which direction it moved. As it was necessary to have same way of visualising the action of the current and some way of referring to it, one terminal of a source of voltage was called the "positive" terminal, the other was called the "negative" terminal and current was assumed to flow from positive to negative.

Many years later it was definitely proved that a flow of electricity consists of a movement of electrons around the circuit in the direction from negative to positive, and it is now realised that a movement of electricity really consists of a flow of electrons. Nothing actually moves from positive to negative in an ordinary circuit. As the electrons are negative charges of electricity and similar charges are repelled from one another, obviously electrons would tend to move away from the negative terminal of a source of voltage around the circuit to the positive terminal.

Of course, before the "Electron Theory" was clearly understood, it had become common usage to speak of current as flowing from positive to negative and many text books were written along these lines. Even now, although we clearly understand that a movement of electricity consists of a flow of electrons from negative to positive, most people, in using the word "Current" still conform to the old assumption of a movement of electricity from positive to negative. Many text books also, whenever they employ the word "current" assume the flow from positive to negative but in explaining, valve action it is common practice to refer to the term "Electron Flow" or "Electron Stream" and whenever these terms are employed, the modern conception of electrons moving from negative to positive is used.

From the above, you will have gathered that there is no difference between a current of electricity and the electron flow in a circuit. These are just simply two different terms and two different ways of looking at the same thing. Actually in any ordinary circuit, the only movement is that of the electrons from negative to positive and we only imagine that some force called "Current" is moving from positive to negative
.

The two filaments in Figures 7 and 8 are both heated to the same degree and are bath emitting the same quantity of electrons. In Figure 7 only a small voltage is applied to the plate, say that the plate potential to about twenty volts above that of the filament. The plate has a rather weak attraction for the electrons which form a cloud around the filament and only a few of these electrons are attracted over on to the plate. In Figure 8 conditions are different. The plate voltage is much higher, say it is ninety or one hundred volts, The filament is not emitting any more electrons than before but now the plate exerts a very strong attraction and many more of the electrons are drawn away from the space around the filament, and pulled on to the plate.

Increasing the plate's voltage causes a greater electron flow just as it causes a greater flow of current. You will find this true always; electron flow and current flow obey the same laws and obey them in the same way because they are really the same thing.

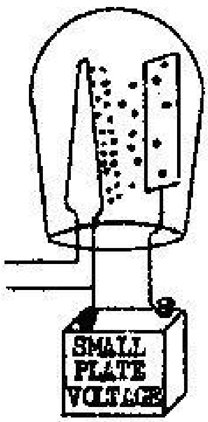

FIGURE 7.

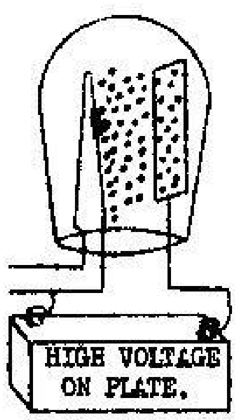

FIGURE 8.

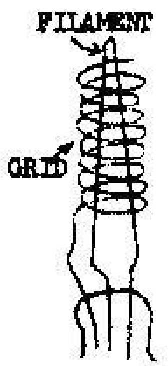

FIGURE 9.

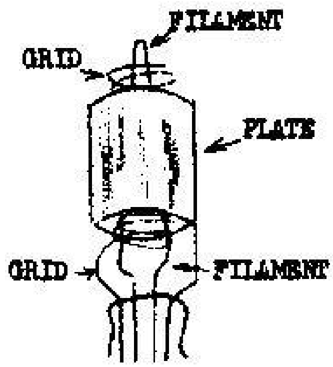

FIGURE 10.

When electrons leave the filament because of its heat, a certain amount of negative electricity has been removed from the filament. Therefore the filament is left more positive than before the electrons left it. Since the filament is then positive with respect to the electrons in the space around it, the electrons that are not drawn over to the plate are attracted by the filament itself and fall back into the filament. The cloud of electrons around the hot filament which are not attracted to the plate is called the “space charge”.

HOW THE GRID CONTROLS THE TUBE’S ACTION:

Up to this time we have been using two elements in our tube. Now we will add a third. In Figure 9 you will see the usual filament and coiled around it another wire, the grid. The grid winds round and round the filament. At its lower end the grid is attached to one of the tube's prongs or pins, but the upper end is left without electrical connection, it just sticks up into space around the filament. In Figure 10 the plate has been put around the outside of the grid so that, from inside, we first have the filament, then the grid and finally the plate. This is the way the three elements are actually arranged within the tube. In order to explain the grid's action it is convenient to show the three elements as in Figure 11. Here again the grid is between the filament and the plate, so this symbol for a three-element tube or “triode” really shows the relative positions of the parts.

Looking back at Figures 7 and 8 you will recall that a space charge of negative electrons exists all around the heated filament. Once this space charge exists around the filament, it makes the emission of more electrons from the filament more and more difficult. Positive and negative things attract each other and it is just as true that things alike in polarity repel each other. That is why the negative space charge repels the emission of any more negative electrons from the filament, and so hinders the flow of plate current. Two negative charges repel each other, or try to keep away from each other. The same thing would be true of two positive charges, they too would repel.

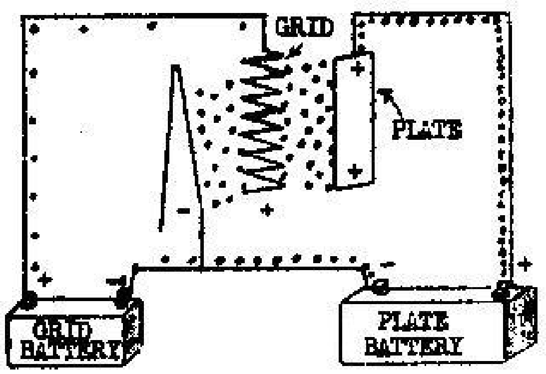

FIGURE 11.

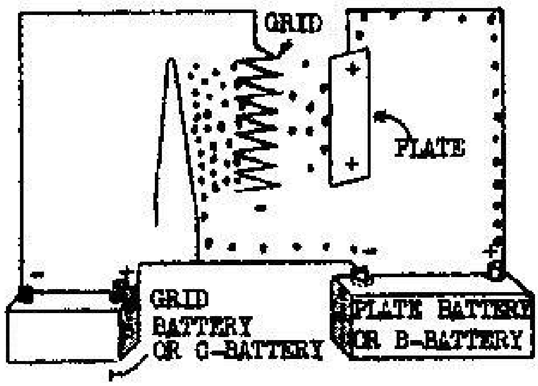

FIGURE 12.

Now look at Figure 11. You see the grid is located right in the midst of the space charge. You can also see that the potential of the grid is higher than that of the filament because the grid is connected to the positive side of a small battery of which the negative side is connected to the filament. Therefore, the grid is positive and the filament negative. Whenever the grid is at a higher voltage than the filament we say the grid is positive.

The positive grid counteracts to some extent the negative space charge. The electrons leaving the filament find fewer negative electrons or a less intense negative space charge to oppose their emission. Therefore, more electrons leave the filament. The positive grid acts to same extent like the positive plate, it pulls the electrons away from the filament and makes it possible for the emitted electrons to fly out further from the filament.

The plate in Figure 11 is held at a positive voltage by the plate battery. The voltage of the plate is very much higher than the voltage of the grid. Once the grid helps the electrons to got further from the influence of the filament, the plate steps in with its still greater pulling power and lots of these electrons are drawn over and on to the plate.

Since the grid is positive it attracts some of the electrons to it, they enter the grid and flow around through the battery and back to the filament. People who have become thoroughly addicted to thinking in terms of the older convention of current flowing from positive to negative will prefer to assume that current flows from the grid battery through the connecting lead to the grid and then across the space within the valve to the filament and from the filament back through the grid battery. However, we consider that the operation of a radio valve is far easier to understand if one thinks always in terms of the "electrons" which are emitted from the heated filament and their subsequent attraction towards any element within the valve which is at a positive potential in relation to the filament.

In Figure 11 the voltage of the grid is positive in relation to the filament, but it is nowhere near as high as the voltage of the plate. The electrons enter the grid and enter the plate in proportion to the voltages of the grid and plate. Inasmuch as the plate has much the higher voltage, it gets most of the electrons and the grid gets only a few. The real purpose of the grid in this case is to make it easier for electrons to get over to the plats when the grid is positive with respect to the filament.

In Figure 11, with the positive grid, there are a great many electrons flowing in the plate circuit and a few electrons flowing in the grid circuit. There is a correspondingly large current flowing in the plate circuit and a small currant flowing in the grid circuit.

Now look at Figure 12. Here the grid is negative. We could say that it is at a lower potential than the filament because the grid is connected to the negative side of the small grid battery and the positive side of this battery is connected to the filament. When a battery is connected in this manner, so that it keeps the grid's potential below the potential of the filament we call it a "C-battery". Now we have a C-battery for the grid, a B-battery for the plate and an A-battery for the filament. In Figures 11 and 12 the A-battery is not shown because we do not reed it for this explanation of grid action.

When the grid is negative with respect to the filament, the grid's action is just the reverse of what it is with a positive grid. Now the negative grid adds its effect to the always present negative space charge and the electrons emitted from the filament find it more difficult than ever to get far from the filament. They meet not only the repelling effect of the space charge but the repelling effect of the negative grid as well.

The result of the negative grid is that only a few electrons get fax enough away from the filament to be attracted to the plate. Of course, a few electrons do got through the grid because the plate voltage is still as high as ever and the plate exerts a strong attraction for the electrons. Now there are comparatively few electrons flowing through the plate circuit and there is a proportionately small amount of plate current.

Because the electrons themselves are negative and the grid is also negative, these two negative charges repel each other. The negative grid keeps the negative electrons from entering the grid and there is no electron flow and no current flow whatever in the grid circuit. When the grid is negative with respect to the filament there is no flow of grid current. This is the condition we want for most purposes.

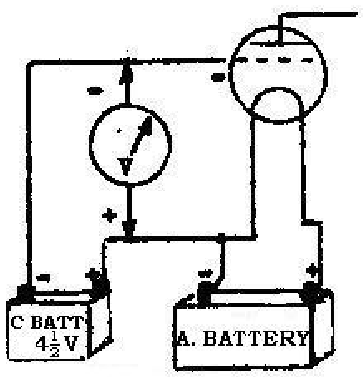

FIGURE 13.

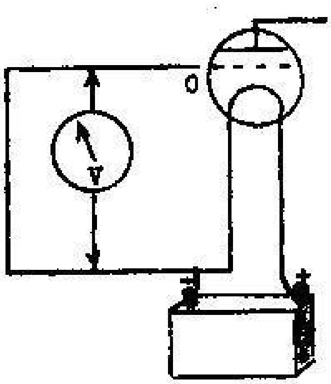

FIGURE 14.

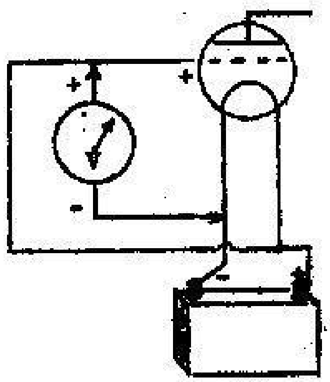

FIGURE 15.

We call the voltage of the grid with respect to the voltage of the negative side of the filament the grid's “bias”. In Figure 11 the grid has a positive bias. In Figure 12 the grid has a negative bias.

In tubes having their filaments operating on direct current the grid bias is the voltage difference between the grid and the negative end of the filament. In Figure 13 there is a C-battery of 4 ½ volts between the grid and the filament. The positive end of this battery is connected to the negative end of the filament or to the end of the filament which attaches to the negative side of the filament battery.

Since the negative side of the C-battery is 4½ volts lower in potential than this battery's positive side and since the grid is connected to this point of lower potential, the grid must be 4 ½ volts lower in voltage than anything connected to the positive side of the C-battery. Then the grid must be 4 ½ volts lower than the negative end of the filament. Here we would say that the grid has a 4 ½ volts negative bias. A voltmeter connected between the grid and the negative side of the filament will show the grid bias.

In Figure 14 the grid is connected directly to the negative side of the filament. Since these two parts are connected directly together they will be at the same potential, there will be no potential difference and we say the grid has a “zero bias”. A voltmeter between grid and negative filament would read zero because there is no voltage difference.

In Figure 15 the grid is connected to the positive side of the tube's filament. This places the grid at a higher potential than the negative end of the filament because, of course, the positive end of the filament is at a higher voltage than its negative end. A voltmeter placed between the grid and the negative end of the filament would now show the grid at a higher voltage than the negative end of the filament and the grid would have a positive bias.

In these drawings illustrating different grid biases the tube is not doing anything in particular. A little later on we are going to give this tube various kinds of jobs, the first of which will be to amplify a signal. The signal will raise and lower the grid's voltage but will not change the bias. We will have to make an addition to our definition for grid bias and say, grid bias is the difference between the grid potential and the potential at the negative end of the filament when no signal is being applied to the grid circuit.

<u>OTHER NAMES FOR TUBE ELEMENTS</u>:

We have been calling the part through which current (in the plate circuit) enters the tube by the name of “plate”. The plate is often called the “anode” as marked in Figure 16. One name is as correct as the other. The plate current leaves the tube by way of the filament and therefore the filament may be called the “Cathode”. The grid has but one name.

In the tubes shown you so far the electrons are emitted from the filament or the cathode, these two names here referring to one and the same part. There is another kind of tube, the, A.C. heater or indirectly-heated type, in which the cathode or electron emitter is separate from the part which supplies the heat. The construction of such a tube is shown in Figure l6.

The plate and grid of the A.C. heater tube are the same as similar parts used in any other tube. But in the A.C. heater tube there is no filament which carries the heating current and at the same time acts as the electron emitter. Taking the place of the filament there are two other parts, a heater element and a cathode element.

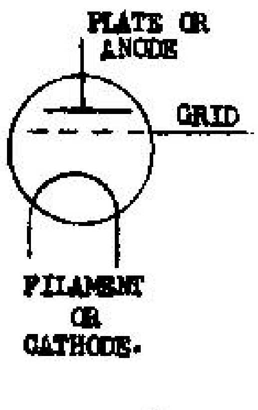

FIGURE 16.

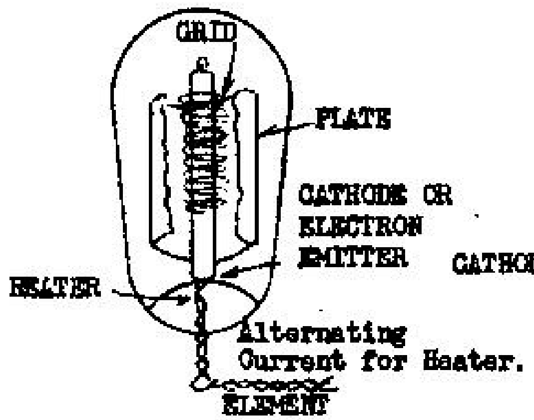

FIGURE 17.

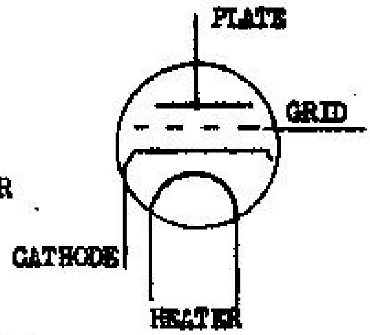

FIGURE 18.

Around the outside of the heater is the cathode, a cylindrical metal surface which is heated and which then emits electrons.

Whereas the tube construction of Figure 17 is designed especially for use with alternating current, it is also possible to use alternating current with which to heat the filaments shown in all the other illustrations. The heater type of tube is less apt to produce hum when used with alternating current than the filament type. There are certain jobs which are performed better by the heater tube and others which are performed better by the filament types. One symbol for an A.C. beater type tube is shown in Figure 18. Other similar symbols are also used. As the heater and cathode are used together to emit electrons they are usually referred to as one element.

THE TUBE'S CIRCUITS:

In the filament type of tube the filament circuit includes the filament within the tube, the battery or other source of filament current and the wires connecting the two parts together.

The plate circuit of any tube includes all the parts through which the plate current flows. One plate circuit is shown in Figure 19. It includes the battery or other source of plate current, it includes any coils or resistances between the source and the tube's plate, it includes the plate itself, the space within the tubs, the filament through which the current returns to the source and all the wires which connect these parts together. In following the plate current from its source all the way around and back again to the source you will have followed the plate circuit.

The grid circuit of a tube includes all the parts between the grid and the filament as shown in Figure 20. This particular grid circuit takes in the grid, then the coil, then the resistor, then the C-battery, then the filament, and it also includes the space within the tube and all the wires used to connect the other parts together. In A.C. heater tubes the cathode takes the place of a filament as far as these circuits are concerned.

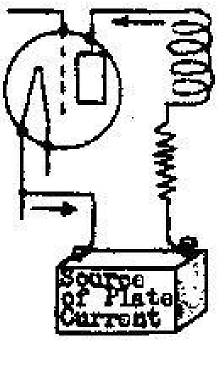

FIGURE 19.

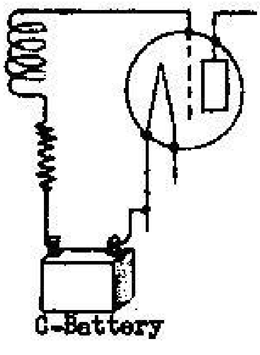

FIGURE 20.

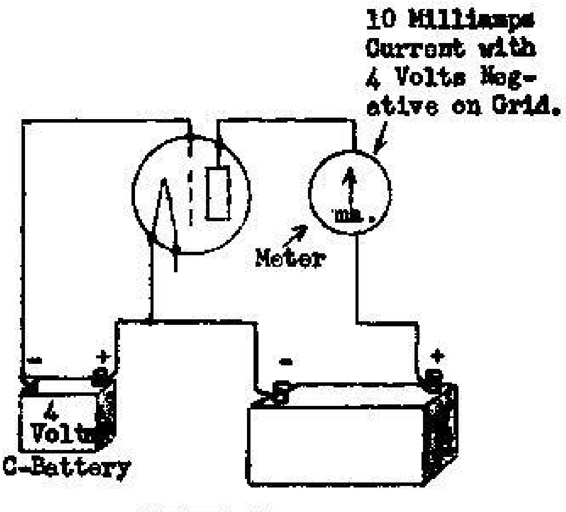

FIGURE 21.

WATCHING THE GRID DO ITS WORK:

In Figure 21 you will see a tube with a 4-volt C-battery in its grid circuit and with a milliammeter in its plate circuit. We will say that the B-battery voltage applied to the plate is such that the 4-volt negative grid bias allows a current of 10 milliamperes to flow in the plate circuit. The word “milliamperes” is a rather long one so radio men generally speak of “mils” instead. Hereafter, when someone speaks of so many mils you will know that the number of milliamperes is meant.

You know that changing the voltage of the tube's grid will cause a change in the amount of current in the plate circuit. You know that the more strongly negative the grid is made the less current will flow in the plate circuit. Of course, making the grid less negative will reduce the repelling action on the emitted electrons, more of them will flow and there will be a larger plate Current.

We are going to change the grid's potential without changing the amount of bias. In Figure 22 you see the same circuit as in Figure 21 with the addition of another small battery, the one marked “extra voltage”. This is a 2-volt battery.

Now look carefully. In Figure 22 the grid is connected to the negative terminal of the extra voltage. The grid was 4 volts negative to begin with because of the C-battery. Now we have made the grid still more negative by this extra 2 volts. So the potential of the grid is now 4 volts plus 2 volts, or 6 volts below that of the negative end of the filament. Making the grid more negative allows less flow of plate current and we find that the milliammeter now reads only 7 mils.

Next, look at Figure 23. We have just the same parts as in Figure 22 but the small battery giving an extra voltage has been turned end for end. Now the tube's grid is connected to the positive of this extra voltage. Does that make the grid positive? No, it does not.

Remember that the 4-volt C-battery is there in the grid circuit all the time. And that the extra positive voltage applied to the grid is really doing is lessening the negative voltage of the C-battery. The 2 volts extra is taken away from the original 4 volts negative bias so that the grid is now only 2 volts below the negative end of the filament in potential. That is, the grid is now only 2 volts negative.

With the grid only 2 volts negative it does not oppose the flow of plate current nearly so much as when it was 4 volts or 6 volts negative and upon looking at the milliameter we find that the plate current has increased to 13 mils.

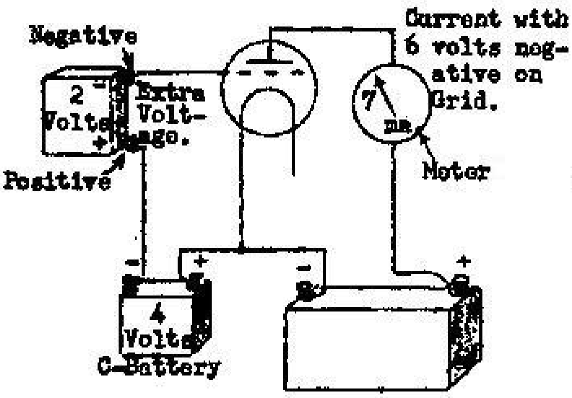

FIGURE 22.

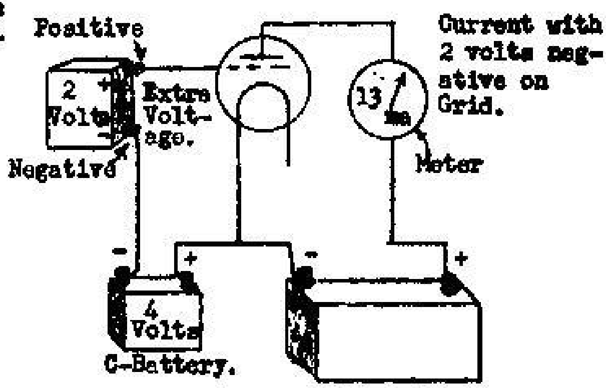

FIGURE 23.

Making the grid voltage more or less negative has changed the amount of plate current flowing. Notice particularly that, because of the C-battery, the grid's potential has always been below that of the negative end of the filament. The grid's voltage has changed, but all the changes have been on the negative side. It gets more or less negative, but it never goes over on the positive side with respect to the filament's negative and. The tube is “worked” with a negative grid potential at all times so that no current will flow in the grid circuit and so that all the electron flow wi11 be in the plate circuit.

From what you have seen in Figures 22 and 23, it is perfectly evident that any extra voltage applied to the grid circuit will cause the plate current to change in step with all changes in the amount of this extra voltage. The illustrations just used brought out the fact that the plats current changes with changes in grid voltage, yet you did not really see a very clear picture of just how much effect the grid voltage had on the plate current. There is a way of letting you see those changes very clearly. It is by moans of “graphs” or curves.

You often have watched the liquid in a thermometer rise and fall with changes in temperature. The liquid changes its length. You could draw straight lines which would correspond to the length of the thermometer's liquid just as they are drawn in Figure 24. One line represents a temperature of 20 degrees above zero, another represents zero, a third represents 50 decrees above zero and the last one corresponds to 20 degrees below zero.

Suppose you started at one o'clock some morning during cold weather and at each hour you drew a line corresponding in height to the height of the liquid in the thermometer at that hour. You might start off with 20 degrees above zero at one o'clock as in Figure 25, then at two o'clock mark off 15 degrees above, at three o'clock make a line standing for 10 degrees above, at four o'clock make one representing zero and so on as the lines are shown all the way through to twelve o'clock.

Anyone looking at Figure 25 could tell exactly how the temperature changed with the changing hours during that time. Still this method is not simple and clear enough. It is only the position of the tops of the lines that counts, so you might draw a line connecting all these tops together. The vertical lines are no longer of any use because the single new line tells the whole story; accordingly we will erase the vertical lines and leave the single line as in Figure 26. We have drawn a graph or curve showing the relation between hours of time and degree of temperature. With only a glance you can tell instantly that the temperature dropped to its lowest paint near the middle of the period, was higher at the beginning and end, and was higher at the end than at the beginning.

Let us draw a graph telling the story of Figures 21, 22 and 23. In Figure 27 the horizontal or cross-wise lines indicate the number of milliamperes from zero (0) up to 15. They are equally spaced and divide the vertical lines into 15 equal parts. The vertical or up-and-down lines indicate the number of volts on the grid from zero (0) at the right down to negative 8 or minus 8 at the left. The three circles are placed where the lines cross for grid voltages and plate currents that we know. Then these three circles are joined by a single line which shows the effect of changing grid voltage on the flow of plate current.

In Figures 21, 2.2 and 23 we took readings with only three different voltages, with2volts, 4 volts and 6 volts negative. Suppose you want to know how many mils will flow with negative five volts on the grid. Look at Figure 27 at the vertical line drawn at 5-volt position. It crosses an imaginary crosswise line at the position for 8½ mils and you can be sure that 4 mils will flow in the plate circuit when the grid is held at negative 5 volts.

There is no end to what you can determine from looking at a graph. A little way back you were told that heating the filament above a certain point would have very little effect on the electron emission or on the flow of plate current. In Figure 28 you are told the same thing in a graph. The temperature of the filament depends on the amount of current you send through it and the amount of current depends on. the amount of voltage you apply to the filament. The more the voltage, the greater the current and the higher tho temperature. Figure 28 shows the relation betwean *the filament emission and the* voltage put on the filament of a certain tuba which normally requires 5 volts to operate it correctly.

The filament emission is measured in the number of ~.~illiampores of current it allows to flow in the plate circuit. With a high plate voltage) the greater the emission the greater will be the amount of plate current. Notice that in Figure 28 there is no emission at all *until* you apply nearly 2 volts to the filament. Th en there

is a very slow increase until you get *to* about ~ volts4 From that point the emission goes up more rapidly *until,* at 5 volts, it begins to increase less rapidly. From h volts to 5 volts the emission increased from *3 to 6 mile or an increase of* 3 mils, But from 5 volts to 6 volts, the same voltage increase, the emission increased only from 6 mile to 7 mils or an increase of only one mil for the same increase in voltage. So you see, increasing the voltage above 5 volts does not

help much with the emission, Dc you also see what a complete picture of the whole process we get from an examination of the graph in Figure 28.

Figure 29 shows a graph of the actual relation between grid voltage and plate current in the ¹¹27" heater type of tube, one of the first indirectly-heated tubes. The plate mi111ampE:ras, from zero to 15, are arranged along the left hand edge. The grid' voltages, from 4 positive down to 12 negative, are shown along the bottom, edge. Zero grid voltage or zero bias is shown in a heavy line.

Ea

N 1

Notice

that the plate current is 9 mils with zero grid bias. With a drop in grid voltege, with this voltage becoming more negative, the plate current drops sharply to a point where the ,rid is 4 volts negative, then drops less rapidly with further d,t,croase of grid voltage. When we get down around
8 volts negative the plate current is not decreasing nearly as rapidly for a given voltage drop as it was when nearer the zero point. When the grid voltage is made positive there is a rapid rise in the plate current. This graph tells you exactly how the plate current acts as the grid voltage is changed. i. graph makes a real picture

of chan4;ing conditions.With the help of graphs you will be able to learn how tubes amplify, how they dsteot, how they modulate a carrier wave, how they act as oscillators or generators of high frequencies, how they rectify alternating current into direct current and how they do a11 the other wonderful things a tube is capable of doing.

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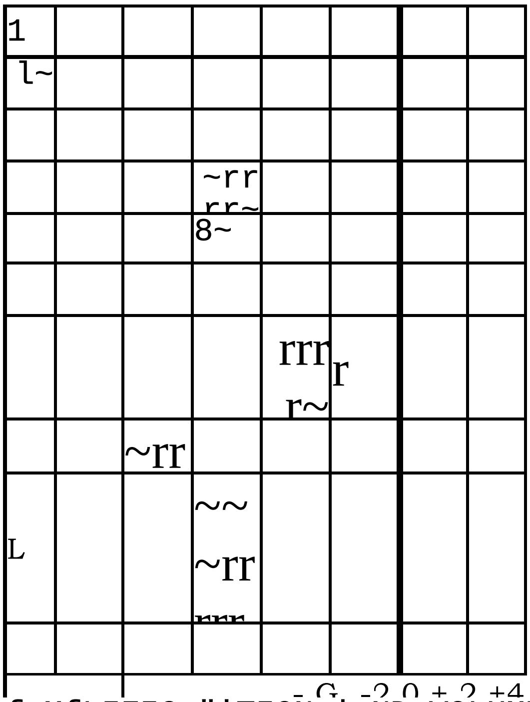

f,MfLIFIC:"'TION i.ND VOLUME;

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Everyone who has heard anything about radio has heard about "amplification", .'nd, of

L.12 - 15.

Grid Voltage. FIGURE 29.

course, everyone has heard talk about "volume". In spite of the fact that many **people seem to think these** two mean the same **thing, they are actually quite diff** erent. Volume is a measure of sound intensity. Loud music has more volume than

faint music. Volume affects the ears directly. If a loud speaker can make the

window panes rattle, it is delivering lots of volume, If you have to get *your* ear

alongside the speaker *to hear* **what is going on, there is not** *much volume.* *Volume*

is sound *intensity.* Amplification is a *measure of how many* **times you multiply the strength of a signal.** If a part of your receiver takes in a signal *having a* strength of 1 volt *and* **then turns out that signal at a strength** of 20 volts, the signal has been amplified twenty times. This is very good amplification. Yet the volume may be so small that you can hardly hear it,

If you tune in a station 1,500 miles away on *an* ordinary receiver$_o$ you may be amp**lifying** the **aerial signal hundreds or thousands of times,** Still., the original strength from *the* aerial may be so exceedingly small that the volume is hardly worth speaking about. On the *other* hand you may take a *signal* from a station *only* three or four miles away, amplify it a comparatively little and get enough volume to drive people out of a room.

tympl3fication is the ability of a receiver or of any radio "amplifier" to multiply the strength of a signal. **Volume is the result of the strength of the incoming signal and the amplification applied** to it.

HOW ii TUBE 1,14

Suppose you had an outfit like *the one shown in* Figure 30. There is an aerial *and* ground with a resistor connected between them. The aerial and of this resistor is connected to the grid of a tube and the ground end is connected through a C-battery to the filament of that tube. In the plate circuit of the *tube,* between the plate

and the B-battery, is a second resistor. Let us see what happcns.

I:erial

Plate
FIGURE 30.
«s you **know, radio signals reaching the aerial cause very small currents to flow** between it and, ground. Carxent coming down from the aerial to the grid cannot flow through the space in the tube **and the tube's filament to the ground** resistor might be measured in millionths of a volt, but just **to explain the action we will say the difference is 1j volts,** This .1f volts is really applied to the tube's grid circuit and the grid becomes less negative than before, You know that increasing the grid's voltage or making the grid less negative, allows an increase of plate current, This increase of plate current will h.ave to pca s through the resistor in the tube's plate circuit,

7 Mils of Plate Current when Aerial Voltage is Positive.

0 0

4 Mils of Plate iCurrent when erial is tegat3.ve.

Grid voltage
when Aerial

is Positive,

Grid Voltage when w©rial is Negative.
C-Battery Voltage,

FIGURE .11₄. FIGURE 3~.

We can "plot" the current changes on a graph, In Figure 31 there is drawn a heavy arrow pointing toward the value of plate current when the aerial voltage is positive. The plate current with the **aerial positive is higher than the current when there is no voltage from the aerial.** You can compare the graph of Figure 31 with that of Figure 29 and see how we use those curvE)s.

In Figure 32 there is another graph on which the heavy arrow points towards the value of plate current when the aerial voltage is negative. **The grid voltage is now brought down below where it stands with no aerial voltage, or with only the C-battery voltage.** In Figure 31 we find 7 mils of plate current due to the aerial action raising the grid voltage, In Figure 32 w© find only 4 mils of plate current **because the aerial action has lowered the grid voltage.**

Now we will. see what this **changing plate current does in the tube's plate circuit.** Of **course, we have shown only one rise and fall of aerial voltage, but as the signal** ***continues to come in,*** the rises and falls follow each other rapidly and the plats current rises and falls just as rapidly,

In Figure 33 w© have the plate circuit resistor carrying the 7 mils of **current while the aerial voltage is positive.** The resistor has a value of 5,000 **ohms and the voltage drop across it with 7 mils of current is 35 volts,**

In Figure 34 w© **havc the plate circuit resistor -^arrying only 4 mils of current while tht aerial** voltage is nogetivo. This reduced curront produces a drop of only 20 volts,

connection because the resistance of the spacc between grid and filament is tremendously great. So the **serial current flows down through the resistor to ground. Here you have current and resistance, consequently, according to Ohm's** law, you must also have voltage drop. It is **true that flow of the aerial current through the resistor causes a voltage drop and at the instant during which current flows downward,** the top of **the resistor is at higher voltage than**
the bottom. The **actual potential difference between the two ends of the**
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LESSON NO. 13.

MATHEMATICS No.3 - ALGEBRA

In Radio work practically all the problems we met can be figured out with simple arithmetic. However, we occasionally find a problem that is difficult to solve by arithmetic, but which can easily be solved by Algebra. Although Algebra is sometimes considered a somewhat difficult study, nevertheless, I am not going to take you into the deeper parts of it, for it will not be used in your Radio work. You will find this lesson just as practical and to the point as the rest of the Course. If after going over this lesson you find it hard to understand, carry on with your course but do not neglect this lesson entirely. I advise you to take this lesson section by section, and spend a few minutes each day or a couple of hours each week reading the one section ever and over again until you understand it. By taking, the lesson in small “doses” in this way, I feel sure you will be able to manage it before long. At the same time, you will not be delayed in your studies because you can carry on with your other lessons.

SIGNS AND SYMBOLS.

The same signs are used to indicate operations as in arithmetic. Thus + is read “plus or add to”; - is read “minus or “take from”; X means “multiply by”; and ÷ means divided by”. Instead of the multiplication sign between two symbols, the multiplication sign is often omitted and the symbols written side by side. For example, instead of writing ; 3 x a x b, we would normally write 3ab. Where symbols are written side by side in this manner. It is intended that they be multiplied together.

Symbols or letters are used to a very great extent in Algebra to represent numbers. When the letter is used to stand far a known number or quantity, a letter from the last part of the alphabet is chosen; while if the value of the letter is not known or an unknown quantity is to be represented, a letter the first part of the alphabet is chosen. The operations are thus performed with these symbols or letters as though they were numbers. However it is permissible to assign numerical values to these symbols when it is desired.
Another important use of symbols is that they enable one to abbreviate ordinary language in the solution of problems. For example:-
Three times a number equals 20 diminished or made less by 5. What is the number.

If we let n represent the number we can write the above statement and the question in the following way;

$$3\,n = 20 - 5$$
$$n = ?$$

The statement 3 n = 20 - 5 is called an equation in algebra and n is the unknown number. Furthermore:

$$3n = 20 - 5$$
$$3n = 15$$
$$n = 5$$ Hence 5 is the number.

This example illustrates the algebraic method of stating and solving a problem.

ALGEBRAIC QUANTIES

In algebra quantities are represented by one or more numerals or letters, or both combined. Thus we say 4XY AND 2A+3. Remember that when no sign is written between a number and a letter, or between two letters, they are always to be multiplied together. Thus 5ab means that 5 is to be multiplied by a and by b.

We dc not know the value of such an expression as 2x + 3y until definite values have been given to x and y. In one problem these symbols may have quite different values from what they have in another problem.

If we let x = 3 and y = 5, then the expression 2x + 3y has a definite value, namely 2x3 + 3x5 or 6 + 15 which, equals 21.

A factor of a product, or an expression is any one of the letters or numbers which multiplied together produce the product. Thus, in the expression 5mn, 5, m, and n are each factors of the expression 5rmn, for if they are multiplied together the result will be the given expression.

An exponent is a little number written to the right and slightly above another number or letter to show how many times it is to be taken as a factor, that is multiplied by itself. Thus, in 3^2, the 2 is the exponent and means that the 3 is to be multiplied by itself two times; namely 3x3 = 9. Similarly 5^3 means that 5 is to be taken as a factor three times, namely, 5x5x5 = 125.

3^2 is read “three squared”, while 5^3 is read “five cubed”.

Likewise a^5 means that a is to be taken as a factor five times, namely :- a x a x a x a x a. Also $4a^2c^3$ = 4 x a x a x c x c x c.

A coefficient is any one of the factors of a product. Thus in 5mn, 5 is the coefficient of m, and m is the coefficient of 5n, and n is the coefficient of 5m. The 5 is called the numerical coefficient while the m or n is called the literal coefficient; because it is a letter while 5 is a number.

Parentheses ( ) are often used to enclose a certain algebraic expression. If two or more numbers or letters are connected by any of the four operating signs and are enclosed in parentheses, the entire expression is treated as a single symbol or a single number. Thus 3(6 + 4) = 3x10 = 30. Likewise 6(x + y) means the sum of x and y multiplied by 6.

Square root in Algebra as in arithmetic is indicated by the sign $\sqrt{}$ The symbol for cube root is $\sqrt[3]{}$ The small figure in front-of the radical is generally called the index of the radical or root, sign.

ADDITION AND SUBTRACTION.

In order to add a number of expressions in algebra, we always place like terms under each other and then add their numerical co-efficients. Similar terms are terms having the same letters in them with the same exponents.

Thus similar terms are in the following manner:

5ac	$9x^2y$	$11\sqrt{a}$
7ac	$6x^2 y$	$5\sqrt{a}$
3ac	$7x^2y$	$2\sqrt{a}$
13ac	22x2y	$18\sqrt{a}$

NEGATIVE NUMBERS.

For certain purposes in algebra it is necessary to use negative numbers. A negative number is one having a - sign in front of it, thus -7, and indicates an "un finished subtraction". Thus the + and - signs are used not only to indicate operations, but also to indicate the kind of number. The + sign is generally always omitted, and whenever a number is written without any sign preceding it, the + is always understood. Thus in making a thermometer a certain point on the stem is taken as zero, and temperatures are marked both above and below this point. Those above are generally called positive temperatures and preceded by a + sign, while those below zero are generally called negative temperatures and are preceded by a - sign. Similarly what a man actually has might be called a positive number, while his debts would be called a negative number and written with a – sign. This illustrates the use of negative numbers.

ADDING POSITIVE AND NEGATIVE NUMBERS.

If several algebraic terms are to be added which all have the same sign, they are written in a column and their numerical_coefficients added up. The same sign is then given to the answer. Thus.

5ab	-6xy
3ab	-3xy
2ab	-4xy
10ab	-13xY

If however, two like terms are to be added and they have different signs, that is, one a positive and one a negative, then we subtract the smaller numerical coefficient from the larger and prefix to the difference the sign of the larger number. This rule is illustrated in the following examples, in which the two terms have unlike signs and are to be added.

7mn	-8xy	10ab
-3mn	+3xy	-15ab
+4mn	-5xy	-5ab

The same principle applies when several positive and negative numbers are to be added. First all the positive coefficients are added and then all the negative coefficients are added, and the difference between the two sums with the sign of the larger is then the coefficient of the sum of all the terms.

SUBTRACTING POSITIVE AND NEGATIVE NUMBERS.

Whenever positive and negative numbers are to be subtracted, we change the sign of the subtrahend (that number which is to be subtracted) and then proceed just as we did In addition. Thus in each of the following examples the second number is to be subtracted from the first. In each case we change the sign of the second number and then proceed according to the rule given above for addition. However, it not necessary to make this change of sign on paper, for we can do so mentally ,and go ahead just as well. For convenience I have shown the changed sign in parentheses.

15mn	8xy	-12ab
(+)-7mn	10xy	(+)-18ab
22mn	-2xy	6ab

In the left hand example the sign of subtraction is - when changed it becomes + as shown within the parentheses. The problem then becomes adding a positive 15 and a positive 7, in the second example the sign of the subtrahend is changed from +to - and then we must add a+8 and a-10 which gives as a sum -2. The right hand example is done in a similar manner.

MULTIPLICATION.

In multiplying algebraic terms there are two steps to perform. Either similar or unlike terms can be multiplied together. The product will be different from either one of the factors. The general rule for multiplication is the following.

First multiply the numerical coefficients in order to obtain the Coefficient of the product. The same letters occur in the product with the exponents equal to the sum of the exponents of the of letter in the factors. This rule is illustrated in the following example.

To multiply 2ab by $3a^2b$ we first multiply the numerical the numerical coefficients and then follow this by letter giving each letter an exponent equal to the sum of its exponent in the factors. The result becomes $6a^3b^2$.

If two terms with like signs (either both + or both -) are to be multiplied together, the sign of the product will be +. But if the signs are unlike the product is -. This is illustrated in the following examples.

$-3mn \text{ x } -4mn = 12m^2n^2$ $\qquad$ $6ab \text{ x } -3a^2b^2 = 18a^2b^3$

DIVISION.

In division there are are two steps to follow as in multiplication. First we divide the: numerical coefficients as in ordinary arithmetic. Then we write the letters, but giving to each an exponent equal to its exponent in the dividend minus its exponent in the divisor.

Thus to divide 12m3 by 3m, we first divide 12 by 3 and the follow the quotient 4 with

with the letter m, but subtracting the exponent in the divisor which is 1 from the exponent in the dividend which is 3. The quotient then becomes $4m^2$.

The rule of signs in division is similar to the rule in multiplication, that is, if two terms with like signs (both + both -] are to be divided, the quotient is 4; but if the signs are unlike, the quotient is -. The following example will illustrate this rule.

To divide $18x^4y^3$ by $-3x^2y$ the quotient is $-6x^2y^2$

REMOVING PARENTHESE.

Often in algebraic work it becomes necessary to remove the parentheses, which enclose certain expressions. When the parentheses are preceded by a + sign (when no sign at all is there the + sign is understood) the parentheses can be removed without making any changes on the terms enclosed. However, when the parentheses are preceded by a minus (-) sign, then the sign of every term within the parentheses must be changed. This is illustrated with an example. Suppose we wish to remove the parentheses in the following example:

$$8a + (6a - 3b) - (7a - 13b + 15) + 10$$

Removing the parentheses and observing the rules just given you we get

$$8a + 6a - 3b - 7a + 13b \quad 15 + 10$$

Combining terms the result becomes:

$$7a + 10b - 5$$

EQUATIONS.

An equation is a statement of equality between two equal numbers or number symbols. It consists of two numbers connected with an equal (+) sign. One is called the left hand and the other the right hand member.

An equation always contains a letter whose value is to be found. This letter is called the unknown.

To solve an equation means to find the value of, the unknown letter. The first step in solving an equation is to collect all the terms containing the unknown on the left hand side and all those not containing the unknown on the right hand side. Whenever a term is taken from one side of an equation to the other, it is necessary to change its sign.

I will now show you how to solve an equation. Let us use the equation

$$5x - 4 = 2x + 17$$

As I said, we transpose the term 7x to the left side and the -4 to the right side, and at the same time change the sign. The equation then becomes:

$$5x - 2x = 17 + 4$$

The next step is to combine terms, and we get

$$3x = 21$$

Lastly, we divide both sides of the equation by the coefficient of the unknown, and we thus obtain the value of the unknown, or x, in this manner.

$$x = 7$$

I will solve another equation for you, according to the same method. Follow the steps carefully.

$$13n + 7\ m = 5n - 17$$
$$13n - 5n -17 -7$$
$$8n -24$$
$$n = -3$$

The solving of equations is often simplified considerably by multiplying or dividing, both side of the equation by the same amount or by changing the signs of both of the equation.

For instance, the equation 8 = 6 + 2 is obviously correct. Supposing we multiply both side of this equation by 3.

$$3 \times 8 = 3(6 +2)$$
$$24 = 18 = 6$$

If on the other hand we divide both side by the same amount say 2.

$$\frac{8}{2} = \frac{6 + 2}{2}$$
$$4 = 3 + 1$$

You will realize that as long as we multiply or divide both side of an equation by the same amount, the answer is not affected. Now let us consider an algebraic equation.

$$3a = \frac{75}{a}$$

Multiplying both sides by "a" $$3a \times a = \frac{75 \times a}{a}$$

$$3a^2 = 75$$
$$a^2 = 25$$
$$a = 5$$

In other cases it may be beneficial to divide instead of multiplying, take the equation. $3ax = 9a$

Dividing both sides "a" $$\frac{3ax}{a} = \frac{9a}{a}$$

$$3x = 9$$
$$x = 3$$

FACTORING.

Factoring is the process of finding those quantities or expressions which multiplied together produce a given number. For instance, the factors of the number 10 are2 and 5, because 2 and 5 multiplied together produce 10. similarly the factors of 25a2b3 are 5 x 5 x a x a x b x b x b

There are many cases in factoring, but I will consider only the simplest one for none of the more complicated ones are likely to come up in your radio work.

The simplest form of factoring is that of determining the factors of a simple number or term, such as 10 or $25a^2b$, as already explained. This form is useful reducing or canceling fractions.

One of the most common processes is that of finding the factors of an expression which consists of two or more terms. These expressions are called polynomials. In this work it is generally not desirable to reduce the expression to the lowest possible factors, but to find the largest factor which is part of each term. This largest factor is called the highest common factor. For instance, in the expression 12 - 18 + 24 the highest common factor is 6, because 6 is the highest number which is a factor of all three terms of the expression. The other factor which, when multiplied by 6, produces the complete expression is 2 - 3+ 4 and is found by dividing 6 into the expression. The two factors could be written:-

$$6(2 - 3 + 4)$$

Now we will find the factors of the algebraic expression:-

$$25a^2b^3 + 15a^3b^2$$

It will be noticed that 5 is a factor of the numerical coefficient of each term, also that a^2 is the highest factor of both a^2 and a3 in the two terms, and that b is the highest factor of b^3 and b^2. Thus the highest common factor of the expression is $5a^2b^2$ a because this is the largest quantity which is a factor of each term.

If we now divide the entire expression through by this factor we will get the two factors of the original expression. These factors are:- $5a^2b^2(5b + 3a)$

The 5b is, of course, found by dividing $5a^2b^2$ into $25a^2b^3$ while the 3a is found by dividing 5ab - into $15a^3b^2$

<u>FRACTIONS.</u>

The expression a/b in which a and b represent numbers is called an algebraic fraction and is read “a divided by b” or “a over b”. A fraction is merely an indicated quotient in which the numerator is the dividend and the denominator the devisor. The numerator and denominator are often called the terms of a fraction. Fractions in algebra are worked according to the same rules as in arithmetic.

The following facts are important to remember.

The numerator and denominator of a fraction may be multiplied or divided by the same number or letter without changing the value of the fraction. To illustrate, let us use the fraction $\frac{2a}{3b}$

We can multiply the two terms of this fraction by 5a and the fraction will still have the same value. The fraction then becomes $\frac{10\ ac}{15bc}$

A fraction is in its lowest terms when the numerator and denominator contains no common factors. The sign of a fraction is the + or - sign placed before the line separating the numerator from the denominator. There are thus three signs to consider, the sign of the fraction, the sign of the numerator and the sign of the denominator. Thus in the fraction $-\frac{+5a}{-7b}$ the sign of the function is -, of the numerator +, and of the denominator -.

In a fraction the sign of both the numerator and denominator may be changed or the sign of the numerator and the sign of the fraction, or the sign of the denominator and the sign of the fraction, without changing the value of the fraction. Thus the above fraction could be rewritten in the following forms and have the same value in each case.

$$-\frac{+5a}{-7b} \qquad -\frac{-5a}{+7b} \qquad +\frac{-5a}{-7b} \qquad +\frac{+5a}{+7b}$$

<u>REDUCING A FRACTION TO LOWEST TERMS.</u>

To reduce a fraction to its lowest terms we must factor both numerator and denominator and then "cancel" the common factors, that is those that occur in both. Thus to reduce a fraction we proceed as shown in the following examples:

$$\frac{12a^2b^3}{15a^3b^2} \qquad \frac{2x2x\not{3}x\not{a}x\not{a}xbx\not{b}x\not{b}}{\not{3}x5xax\not{a}x\not{a}x\not{b}x\not{b}} = \frac{4b}{5a}$$

<u>MULTIPLICATION OF FRACTIONS.</u>

whenever fractions are to be multiplied, we do just as we did in arithmetic, that is, we multiply all the numerators together and all the denominators to get the product. This is illustrated in the following examples:

$$\frac{2a}{3b} \times \frac{4a^2}{5b^2} = \frac{8a^3}{15b^3} \qquad \frac{5x^2}{7y^2} \times \frac{3a}{4b} = \frac{15ax}{28by}$$

<u>DIVISION OF FRACTIONS.</u>

Whenever it is necessary to divide a fraction, the general rule is to invert the divisor and then multiply. This is also illustrated.

Let us divide to expression $12a^3b^3$ by $\frac{2a}{3b}$

According to the rule just given you, we invert the $\frac{2a}{3b}$ so that it becomes $\frac{3b}{2a}$

Then we multiply $12a^3b^3$ by 3b and the answer becomes $36a^3b^4$. But this can be reduced to lower terms, for there are common factors in the numerator and denominator. It then becomes $18a^2b^4$.

Following is a further illustrative example:

$$\frac{24x^3}{15y^3} \div \frac{3x}{5y} = \frac{24x^3}{15y^3} \times \frac{5y}{3x} = \frac{120x^3y}{45xy^3} = \frac{8x^2}{3y^2}$$

A knowledge of algebra, while not essential in radio work will prove to be of considerable use if it can be attained. One of its most useful purposes is in connection with the various formulae found in various lessons throughout the Course. For instance, supposing a formula, is given for finding current when the resistance and voltage in a circuit are known. A knowledge of algebra allows us to change the formula around so that we can find the resistance if the current and voltage are known, or so that we can find the voltage if the resistance and current are known.

Take the formula for current - $I = \frac{E}{R}$ Multiplying both sides of the equation by R.

$$I \times R = \frac{E \times \cancel{R}}{\cancel{R}}$$

$$I \times R = E$$

Divide both sides by I.

$$\frac{\cancel{I} \times R}{\cancel{I}} = \frac{E}{I}$$

$$R = \frac{E}{I}$$

We now have a formula for finding resistance. Again let us start with the same formula.

$$I = \frac{E}{R}$$

This is of course the same as saying $\frac{E}{R} = I$ Now multiplying both sides by R.

$$\frac{E \times \cancel{R}}{\cancel{R}} = I \times R$$

$$E = I \times R$$

Thus we now have a formula for finding voltage.

We will take another example to see how useful algebra can be to us. In the next lesson you will be told about a formula for finding the reactance of a condenser when of the current and the capacity of the condenser are known. This is the formula.

$$\text{Resistance in Ohms} = \frac{159{,}155}{\text{Cycles x Microfarads}}$$

Multiplying both sides "cycles".

$$\text{Reactance x cycles} = \frac{159{,}155 \text{ x } \cancel{\text{cycles}}}{\cancel{\text{cycles}} \text{ x Microfarads}}$$

$$\text{Reactance x cycles} = \frac{159{,}155}{\text{Microfarads}}$$

Dividing both side by "reactance"

$$\frac{\cancel{\text{Reactance}} \text{ x cycles}}{\cancel{\text{Reactance}}} = \frac{159{,}155}{\text{Microfarads x Reactance}}$$

$$\text{cycles} = \frac{159{,}155}{\text{Microfarads x Reactance}}$$

We have now changed our formula around so that instead of finding reactance we can now find the frequency necessary to produce a certain reactance in a condenser of a certain capacity. By similar means we can change the formula to enable us to find the capacity in microfarads if we know the reactance we require and the frequency of the current.

Starting with the same formula

$$\text{Reactance} = \frac{159{,}155}{\text{cycles x Microfarads}}$$

Multiplying both side by microfarads we have

$$\text{Reactance} \times \text{microfarads} = \frac{159{,}155}{\text{cycles}}$$

Dividing both side by reactance

$$\frac{\cancel{\text{reactance}} \times \text{microfarads}}{\cancel{\text{reactance}}} = \frac{159{,}155}{\text{cycles} \times \text{reactance}}$$

$$\text{microfarads} = \frac{159155}{\text{cycles} \times \text{reactance}}$$

The same principles can be applied to practically any of the formulae given in the various lessons, so that even if only one formula is given you will be able to able to change it around and thus make it tell you a number of useful things.

Although there is a great deal more to study in Algebra, this, however as far as is necessary for you to do at this time. It may seem a little difficult at first because it is such a new subject, but if you will study it a little each day in connection with your other work, and I am sure you will master it without serious troubles.

For those of you who have taken Algebra at school this lesson should completely refresh your memories on the subject. For those who have not and still experience difficulty we suggest that in the meantime you carry on with the other lessons in the course as they come to you, but at the same time give an hour or two each week to this lesson on Algebra until you have completely mastered it. If you require a good elementary book on the subject, “Elementary Algebra” Parts 1 & 2, written by Barker & Bourne can be recommended. It gives examples of Algebraic problems for you to work out, together with answers, so that you can check your working. Most well known book-shops stock the book.

EXAMINATION QUESTIONS LESSON 13 M3.

1. Add the following , $4xy^2$ - 2ab + $3xy^2$ + 7ab

2. (a) Subtract -11xyz from 3xyz
   (b) " 18ab from 6abx

3. (a) Multiply $4ab^2c$ by $10abc^2$
   (b) " 2ab by 5axy

4. Divide $12p^2q^5$ by $3pq^2$

5. Simplify the following 6a – (3ab+4a) – (5a +3ab – 15)

6. Simplify the following equation:-

$$18x + 7 - 5 = -4x + 40 + 6$$

7. Find the factors of $20\,x^5\,y2\,c4 + 16\,x^2\,y^3\,c^4$

8. Reduce the following fraction to its lowest terms.

$$\frac{3\,x^3\,y}{12\,x^4\,y^2}$$

9. Multiply $\frac{3x}{4a^2}$ by $\frac{-x^2}{4a}$

10. Divide $\frac{20\,a^2\,b}{15x^4}$ by $\frac{4ab}{6x^2}$

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LESSON NO. 14.

OPPOSING THE FLOW OF ELECTRIC CURRENT.

You have been doing quite a bit of studying on the effects of resistance in various kinds of circuits and have found that resistance is very useful in allowing us to control the amount of current flowing. When you first took up the study of radio, you were told that resistance in electrical circuits corresponds to friction in mechanics. This is true because resistance changes electrical energy into heat, the heat passes away and the energy which produced it is lost as far as the circuit is concerned.

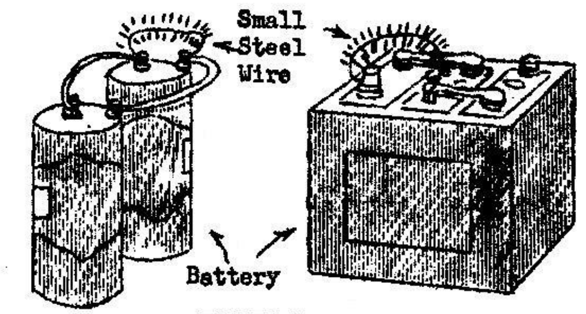

FIGURE 1.

In Fig, 1 is shown an experiment which illustrates the effect of resistance. If you use two dry cells, connected together as at the left, or if you use a single cell of a storage battery such as a radio A - battery or an automobile battery, you will have the source of electric energy. Then get hold of a small steel wire. Steel has considerable resistance. Then connect this wire between the fixed terminals of the car battery as shown in Figure 1. The ends of the wire must be bright and clean.

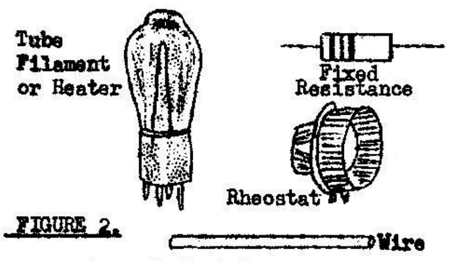

FIGURE 2.

The wire gets hot. Be sure you don't keep hold of it. Then it gets red hot, and finally a dazzling white heat just before the metal in the wire melts and burns apart.

You changed electric energy into heat energy, the heat was radiated into the air and it disappeared never to return. The resistance of the wire changed the form of the energy, it allowed the production of heat and the final result was a loss of electrical energy. Resistance always represents a loss of energy.

Resistance opposes the flow of electric current. In order for the current to get through the resistance, the electricity has to work hard. The work produces heat, Resistance is not the only thing which opposes the flow of electric current.

There is resistance in every part through which electric current flows. Every conductor has ohmic resistance. Sometimes good use is made of the resistance. In Figure 2 the tube filament's resistance is used to make current heat the filament. The flow of current is controlled with the fixed resistor or with the rheostat. A rheostat is another name for a variable resistor used for the control of current flow. But every wire and every other current carrying part also has resistance even though it is undesirable.

It has been said that all conductors have resistance. They have resistance to direct current and to alternating current too. Therefore, even the coil and condensers in Figure 3 have resistance to alternating current or to any other current. Resistance is found wherever there is electric current flowing matter what kind of current,

<u>OTHER WAYS OF OPPOSING CURRENT FLOW.</u>

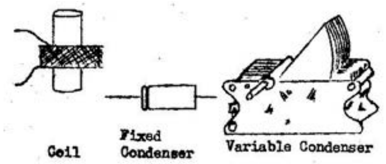

FIGURE 3.

In an earlier lesson you learned that coils and condensers, such as shown in Figure 3. oppose current flow because they have a property called "reactance". You were told that reactance is the ability to "react" or give back energy. Coi1s and condensers absorb energy and hinder the flow of current, but then they give back the energy into the circuits. The effects of reactance were illustrated by showing you a steel sizing which, after being twisted, will untwist and give back energy. You were also shown how a weight may be lifted and then, upon falling will give back energy or do work.

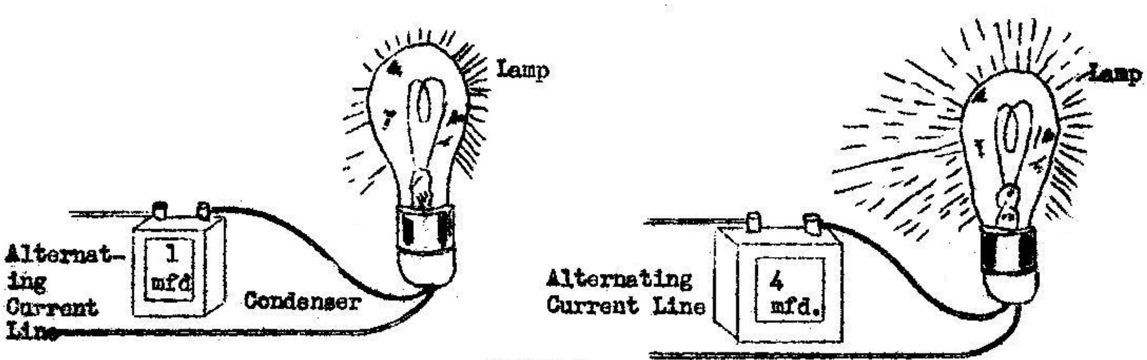

FIGURE 4.

Reactance requires energy to overcome it in the first place, but the energy is then given back. You see there's a big difference between resistance and reactance.

In Figure 4 is shown another simple experiment, this one to show the effect of the reactance in condensers. Over at the left hand side of this picture is an ordinary house lighting lamp connected to an alternating current line with a direct wire on one side of the circuit and with a 1.-microfarad condenser in the other side. The lamp will light, but will light dimly. If the condenser was Left out and a direct connection made as shown by the broken line, then the lamp would light up brightly.

The condenser has a reactance. The reactance makes it difficult for the alternating current to flow to and through the lamp, consequently the lamp lights less brightly with the condenser in the circuit than when there is no condenser. The effect on the brightness of the lamp filament is as though we had connected in series with it a resistor having a value of 3180 ohms. The reactance of a 1 mfd. condenser at a frequency of 50 cycles per second is 3180 ohms. If you wish you may calculate this figure for yourself by using the formula for condenser reactance shown on the next page.

Now look at the right hand side of figure 4. Here we have substituted for the 1-microfarad condenser another condenser having a capacity of 4 microfarads, the reactance of which at 50 cycles per second in approximately 800 ohms. Now the lamp lights up much brighter than with the 1-microfarad condenser. More current must be flowing to and through the lamp with the large capacity condenser. The large condenser has less reactance than the small one and because it has less reactance it is easier for alternating current to act through it. now you can memorise the first rule about reactance in a condenser; MORE CAPACITY – LESS REACTANCE.

In the earlier lesson called "The Operation of Condensers and Their Part in Radio", you learned that alternating current can flow in a circuit containing a condenser by virtue of the fact that as current flows firstly into one plate, where it is stored, it forces an equal amount of electricity to leave the other plate and continue on around the circuit. Then a fraction of a second later the current reverses and flows into the plate from which it previously emerged at the same time causing an equal amount to leave, the plate which it originally entered. Now the opposition or reactance to the current which flows around the circuit from one condenser plate to the other naturally depends on the amount which can be stored in the condenser or on the capacity of the condenser. A large capacity condenser can store a large amount of capacity so that it is easy for the current to flow into and out of the plates. Consequently the reactance of a large capacity is low. A small capacity cannot store a large quantity of electricity so that there is more opposition or reactance to current flow in the circuit. This explains how the rule "MORE CAPACITY – LESS REACTANCE comes about.

In Figure 5 is shown another experiment with a condenser, at the left a small condenser, one with 0,005 microfarad capacity, is connected between the aerial and the receiver. Whether the condenser is placed between aerial and receiver or whether a wire is run directly from the aerial without any condenser there will be practically no noticeable difference in the loudness of the signals. Evidently the condenser has but little reactance.

In Figure 5 at the right the same 0.005 microfarad condenser formerly used in the aerial line is connected between the receiver and the loudspeaker. With this condenser in the speaker line you will hear hardly a sound while with a direct wire to the speaker the loudness is as usual. In this position it is evident that the condenser has a great deal of reactance.

Now you will he told the difference between the condenser connection at the left and the one at the right. At the left the condenser is in a circuit carrying very high frequency, a circuit carrying radio frequency currents. At the right the condenser is in a circuit carrying comparatively low frequency or audio frequency. The condenser is the same in both cases, but its reactance to high frequencies is very little and its reactance to lower frequencies is very great. This condenser lets the high frequency currents through practically without hindrance, yet almost stops the low frequency currents. This gives the second rule for reactance in a condenser MORE FREQUENCY - LESS REACTANCE.

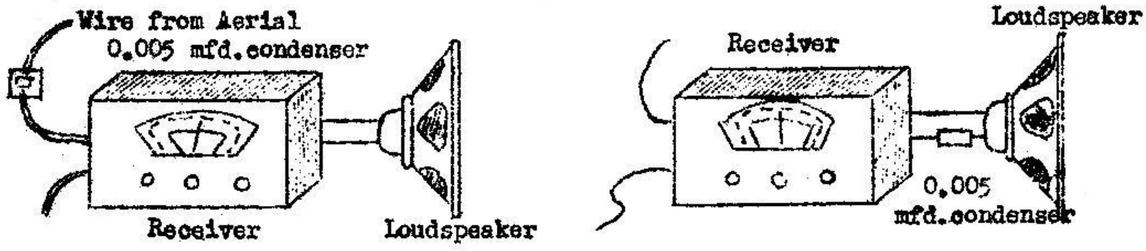

FIGURE 5.

It is very important that you memorise these two rules about reactance. Always remember “more Capacity -- less reactance” and “more frequency -- less reactance”, whenever you are dealing with condensers.

HOW TO CALCULATE A CONDENSER’S REACTANCE.

Anything which opposes the flow of electric current as measured in the unit called an “ohm”. Resistance is measured in ohms and so is reactance measured in ohms. To figure out the reactance of a condenser in ohms you have to know the condenser’s capacity and you have to know the frequency of the alternating current which is to flow through the condenser -- only two things.

Condensers are used in three different portions of a radio receiver, as follows:-
(1) in the radio frequency amplifier, (2) in the audio frequency amplifier, and
(3) in the power supply parts. In those three portions of the set we are handling three classes of frequencies. In the radio amplifier we are handling (1) high frequencies or radio frequencies measured in kilocycles. In the audio amplifier we are handling (2) lower frequencies or audio frequencies measured in cycles. In the power units we are handling (3) very low frequencies or power frequencies also measured in cycles. Three parts of a receiver are indicated in Figure 6.

First we'll take the formula for condensers used in the power supply units and in audio amplifiers where the frequencies are measured in cycles. The condenser capacities are measured in microfarads. Here is the formula:

$$\text{Reactance in Ohms} = \frac{159{,}155}{\text{cycles x microfarads.}}$$

You multiply the number of cycles by the number of microfarads and divide the result into 159,155 which is the constant.

(Special note;- This constant, 159,155 is obtained by dividing 2 Π or 6.28 into one million. In many text books Capacity Reactance formula is shown as

$$\frac{1}{2\Pi FC} \quad \text{or} \quad \frac{1}{CW}$$

where C equals capacity of condenser in farads and W equals (2 Π x F) and F equals the number of cycles per second. As a farad which is one millionth part of a farad.

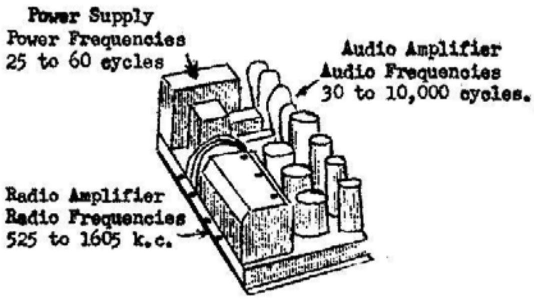

FIGURE 6.

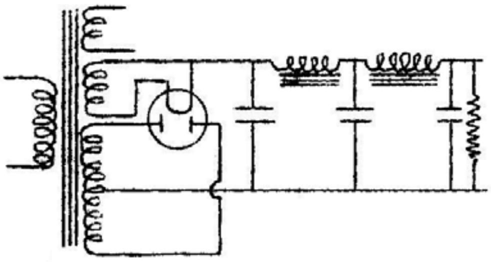

FIGURE 7.

In Figure 7 is a diagram of a typical power unit which contains three condensers of 2- microfarad capacity each. These condensers are acted upon by the power line frequency which in this case is 50 cycles. To find the reactance of each condenser we place these values in the formula as follows:

$$\text{Reactance in Ohms} = \frac{159{,}155}{50 \times 2}$$

$$= \frac{159{,}155}{100}$$

$$= 1591 \text{ (approx.)}$$

In Figure 8 is a diagram for one type of loudspeaker connection. A 2-microfarad condenser is placed between the tube's plate and one of the speaker leads. One of the keys on a piano produces a musical (audio) frequency of 1035 cycles. What is the reactance of the 2-microfarad condenser at this frequency? Again we place known values in our formula tike this:

$$\text{Reactance in Ohms} = \frac{159{,}155}{1035 \times 2}$$

$$= \frac{159{,}155}{2070}$$

$$= 77 \text{ (aprox.)}$$

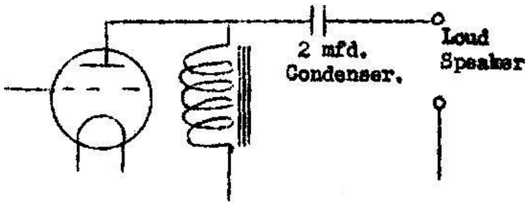

FIGURE 8.

Notice that at a frequency of 50 cycles the 2-mfd, condenser has a reactance of more than 1500 ohms while at a frequency of 1035 cycles the same condenser has a reactance of only 77 ohms. Here you see that the rule “more frequency – less reactance” holds good.

When considering the radio frequency end of the set we are going to deal with frequencies so high they are measured in kilocycles (thousands of cycles) so we will want a formula using kilocycles instead of cycles. We will still measure the condenser capacity in microfarads. Here is the now formula:

$$\text{Reactance in Ohms} = \frac{159}{\text{kilocycles x microfarads}}$$

This looks a lot like the first formula, except that the number above the line is now "159"instead of "159,155".

In Figure 5 we connected a condenser of 0.005 microfarad capacity in the aerial circuit. At a frequency of 1000 kilocycles what is the reactance of this small denser? We will put the known value into the second formula like this:

$$\text{Reactance in Ohms} = \frac{159}{1000 \text{ x } 0,005} = \frac{159}{5} = 32 \text{ (approximately)}$$

The number "0.005" is the same as 5/1000 and when we multiply the number 1000 by 5/1000 the result is 5. So we just divide the number above the line (159) by 5 and the answer is 32 ohms reactance for this condenser.

With this same condenser in the loudspeaker circuit, should the speaker attempt to sound the piano note of. 1035 cycles the condenser's reactance would be more than 30,000 ohms. Here, again you see the working of the rule "more frequency -- less reactance".

THE REACTANCE OF A COIL.

Now that we have finished our investigation of the reactance in condensers we will look into the subject of reactance in coils. Both condensers and coils have reactance or opposition to the flow of alternating current. We will go back to experimenting with the house lighting lamp and connect it as in Figure 9.

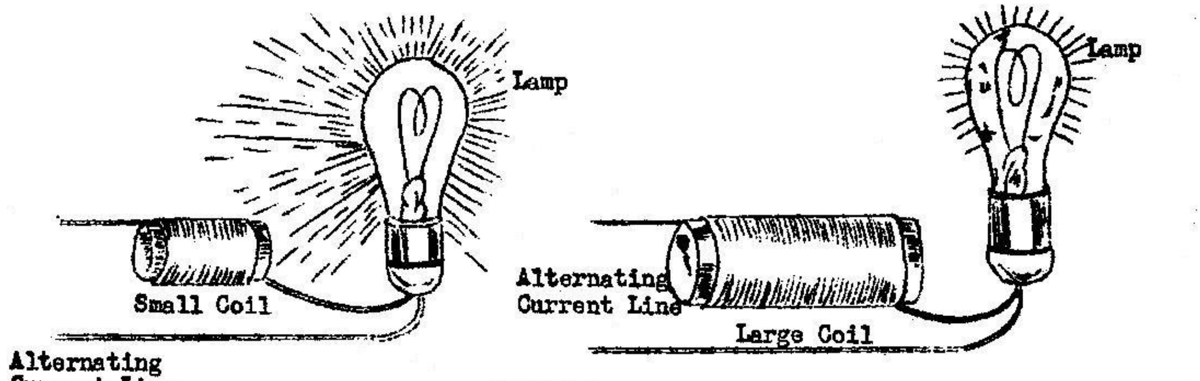

FIGURE 9.

In the left hand illustration we have connected a small coil of wire in one of the two wires carrying alternating current to the lamp. The lamp does not light quite so brightly as without the coil in circuit., but still it does burn quite well. In the right hand picture we have changed coils and are now using a much larger one. The lamp lights very dimly. Evidently the large coil has much more reactance to alternating current than the small one. We can be sure that it is not just the resistance of the coil that dims the lamp because current is coming from the power and light lines through a much greater length of wire than is contained in even the large coil, and the great length of wiring in the outside circuits does not dim the lamp.

In order to explain about the reactance of coils it will be necessary to go back quite a bit and explain first some very important things about the behaviour of a coil when alternating current flows through it.

LINES OF FORCE.

At same time in your life you have probably played with a horse-shoe magnet like those in Figure 10. You found that such a magnet would attract and hold nails and other small objects made of iron or stool, also that the needle of the compass would be attracted towards one of the ends or “pales” of the magnet. It is perfectly evident that some peculiar invisible force exists around the magnet's poles and in the space between them.

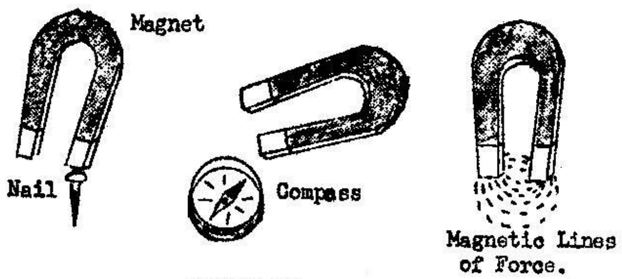

FIGURE 10.

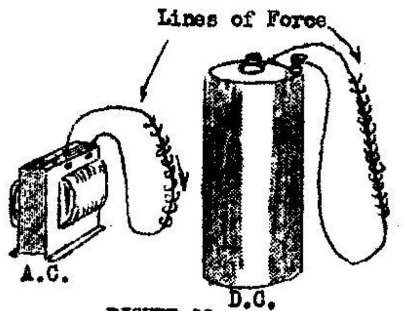

FIGURE 11.

Between the magnet poles there are invisible “lines of force”. The nail tries to come close to the magnet so that it can carry more of these lines. The Compass needle turns so that the lines pass through it from end to end. These lines of force make up what we call the “magnetic field”.

There are similar lines of force around any conductor carrying current. If you have alternating current flowing through a wire, or if you have direct current in the wire, there are lines of force around the wire as indicated in Figure 11.

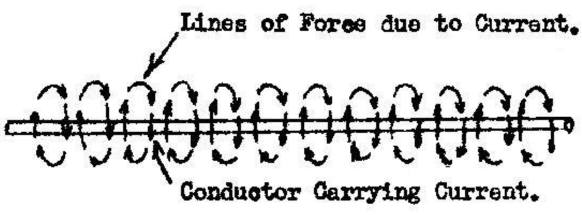

FIGURE 12.

These lines of force have direction, they whirl around in a certain direction. The direction travelled by the lines or by the force which they represent depends on which way the current is flowing in the wire. You can see what is meant in Figure 12. If the current flows from left to right, according to the arrows, the lines would whirl in a clockwise direction as you looked at the right hand end of the wire. If you reverse the direction of the current, the direction of the lines of force will also reverse in direction around the wire.

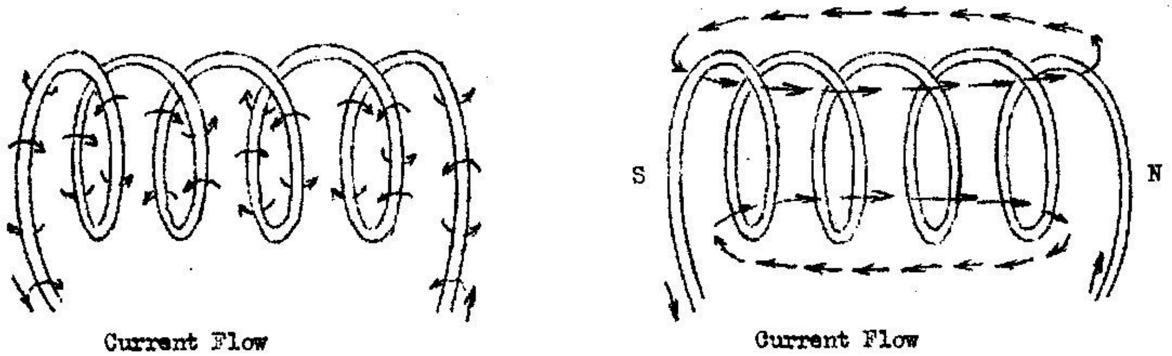

FIGURE 13.

In Figure 13 the straight wire has been formed Into a number of loops or into a coil. Now the lines of force are closer together because you have brought some parts of the wire closer to other parts. The lines still whirl around the wire just the same as when it was stretched out straight. At the left hand side of figure 13 you will see that a11 the little arrows, representing lines of force, are travelling toward the left hand end of the coil while they are on the outside of the coil. What really happens is shown at the right. All the lines on the outside, which are flowing toward the loft, join together and flow along together as shown. All the lines in side the coil likewise join together and flow together from left to right. All the lines of force inside the coil flow in one direction and all those on the outside flow in the other direction. The lines come out of the "IN" end of the coil and go back into the "S" end. Reversing the direction of current flow through the wire of the coil will reverse the direction of a11 the lines of force. Then the lines will go through the coil and around its outside in the other direction. Remember that there are no lines of force when no current is flowing and that there will be the greatest number of lines when the greatest amount of current flows.

Then if we take the coil at the left in Figure 14 and find that the ammeter shows zero, or no current flow, there will be no lines of force or no field around the coil. With a moderate amount of current flowing as shown in the next coil toward the right there will be a field of moderate strength or of a moderate number of lines around the coil. If the current is increased to the maximum amount shown in the centre drawing there will be a strong field or many lines around the coil. Then, decreasing the current as at the next picture will reduce the number of lines around the coil and if the current falls to zero, or stops, as at the extreme right the lines will disappear. This is exactly what happens around a coil carrying alternating current. First there is no field then it increases to its maximum strength or greatest number of lines as the current rises to its greatest flow in one direction. As the current dies down again, the field is reduced in strength and when the current drops to zero there is no field, no lines around the coil. As the alternating current swings the other way, the process is repeated, the field builds up to the maximum number of lines of force, then drops back to nothing again.

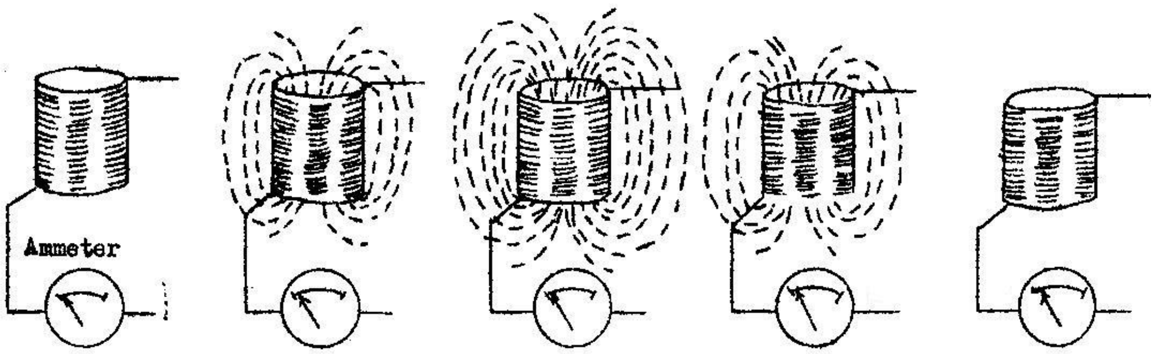

FIGURE 14.

With the action shown in Figure 14, the lines seem to rise out of the coil to spread out as their number increases, and then to drop back into the coil, finally to disappear altogether.

GENERATING ELECTRIC CUIRRENT.

In Figure 15 a hollow coil of wire is connected to a couple of turns of wire around an ordinary magnetic compass. If you were to plunge a bar magnet down into the coil while watching the compass needle, you would see the needle swing to one side. Then as you withdrew the bar magnet from the coil, the compass needle would swing the other way.

You have moved the magnet's lines of force down through the turns of wire composing the coil and the cutting of the lines through the conductor produced a voltage and the electric current in the coil and the wires attached to it. The tiny

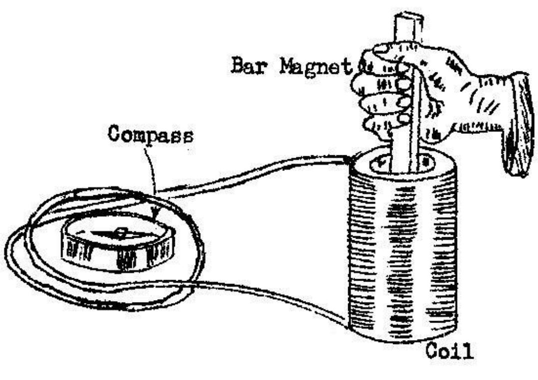

FIGURE 15.

lines of force in the wire around the compass caused its needle to swing. You know that lines of force appear around any wire carrying current, consequently the compass indication of lines of force shows that you have produced a current in the wire around it.

The faster you move the bar magnet into and out of the coil, the more the compass needle will swing or the farther it will swing.The more rapidly the lines of force cut through the coil's conductors the greater is the voltage and current generated.

Exactly the same result could be secured were you to hold the bar magnet stationery and move the coil of wire up and down around the magnet. Any relative movement between the lines of force and a conductor produces a voltage in the conductor

COUNTER ELECTRO MOTIVE FORCE

If you look at Figure 14 you will realise that the lines of force rising out of the coil and falling back into it must be cutting through the coil's conductors. This movement of the lines of force produces a voltage in the coil of Figure 14.

In Figure 14 we had a voltage and current which caused the lines of force to appear in the first place. Then the movement of the lines also produced a voltage in the coil. Therefore, there must be two voltages in the coil -- one being the voltage that produced the lines of force: and the other being the voltage which the moving lines produced.

The second voltage, the one produced by the moving lines of force is called “counter electromotive force”. Electromotive force is just another name for voltage, so we might as well say “counter voltage”. Counter means opposite, or the other way round, so we find that counter electromotive force means a voltage acting in the opposite direction. It is true that the counter e.m.f. acts just opposite to the voltage originally applied to the coil. This action may be illustrated by the steam cylinder and flywheel of Figure 16. The original voltage is represented by the heavy flywheel. As the steam pressure is applied and tries to revolve the flywheel, the weight of the flywheel opposes

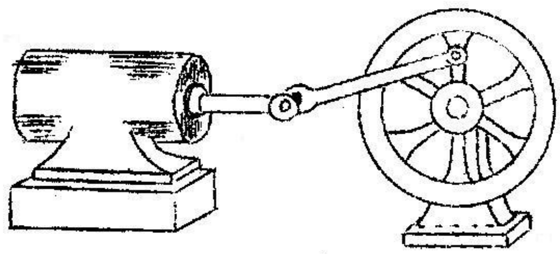

FIGURE 16.

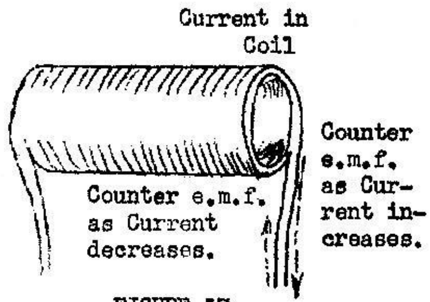

FIGURE 17.

the turning and acts against the steam pressure. Then, as the steam pressure decreases, the weight of the flywheel tends to keep the wheel revolving. A similar action takes place in the coil. While the current in the coil is increasing, or while the lines of force are rising out of the conductors and spreading out, the counter e.m.f. acts against the original voltage. This is shown in Figure 17.

Then, when the current in the coil commences to drop off, the lines of force move the other way, drop back into the conductors. This reverses the polarity of the counter e.m.f. and it tends to keep the current from dying down, tends to keep the current flowing. The counter e.m.f, holds back the current as it tries to increase, then tries to keep the current flowing when it wants to decrease.

It was the counter electromotive force in the coils of Figure 9 which made the lamp burn dimly. This opposing voltage worked against everything that the regular line voltage tried to do. With the coils, and their counter electromotive force, in the lamp's circuit the regular voltage from the supply line was unable to get as much current to the lamp as it could have had the coils been out of the way.

In Figure 18 is shown a curve representing one complete cycle of alternating current such as might pass through the lamp circuit when no coil is included. The current rises to the value marked “8” in each direction. Now supposing we have a coil in the circuit. Then the alternating current may be represented by the curve in Figure 19. The opposing voltage, or the counter electromotive force, holds back the current and it can only rise to the value marked “5” in each direction. That's the way counter electromotive force acts; it reduces the amount of current that can flow in an alternating current circuit.

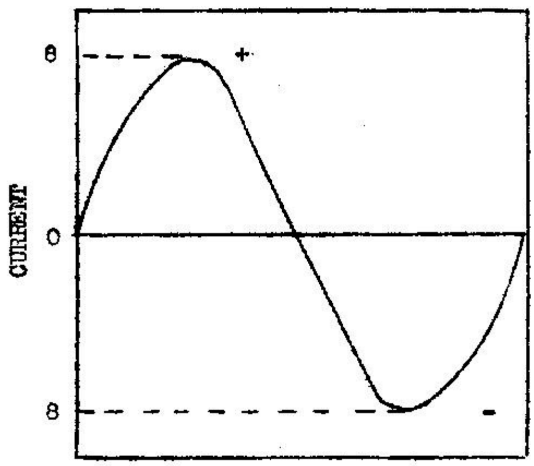

FIGURE 18.

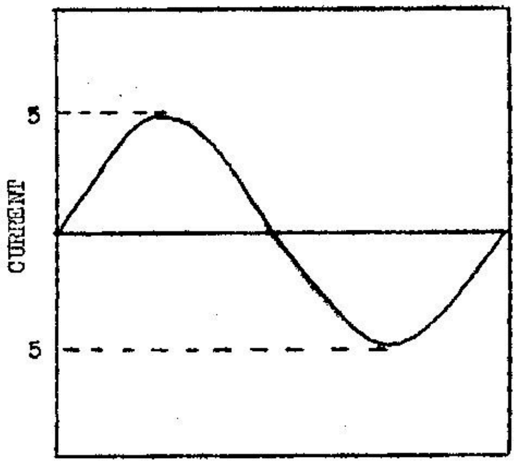

FIGURE 19.

EFFECT OF FREQUENCY ON THE COIL'S REACTANCE

During one cycle of alternating current the current rises to maximum in one direction, falls to zero and increases to maximum in the other direction and finally falls to zero again as indicated in the lower part of figure 20. Were this current flowing through the coil shown at the top of this illustration, there first would be a very strong field, then no field at all, then another strong field, and then no field again -- the strong fields occurring along with the maximum currents.

You have been told that voltage is generated by lines of force cutting through conductors. As the field around the coil of Figure 20 rises out of the coil its lines of force cut through the coil's wires and voltage is generated. As the lines fall back through the wires another voltage is generated. This is the action that produces the counter e.m.f.

The more rapidly the lines rise out of the coil and fall back into it, the greater will be the rate at which the lines cut through the wires and the greater will be the voltage generated. You were told that the voltage generated depends on the number of lines cutting a conductor within a certain length of time. So the faster the lines cut, the greater will be the counter e.m.f. generated. The greater the counter e.m.f. the more the opposition to the action of the original voltage.

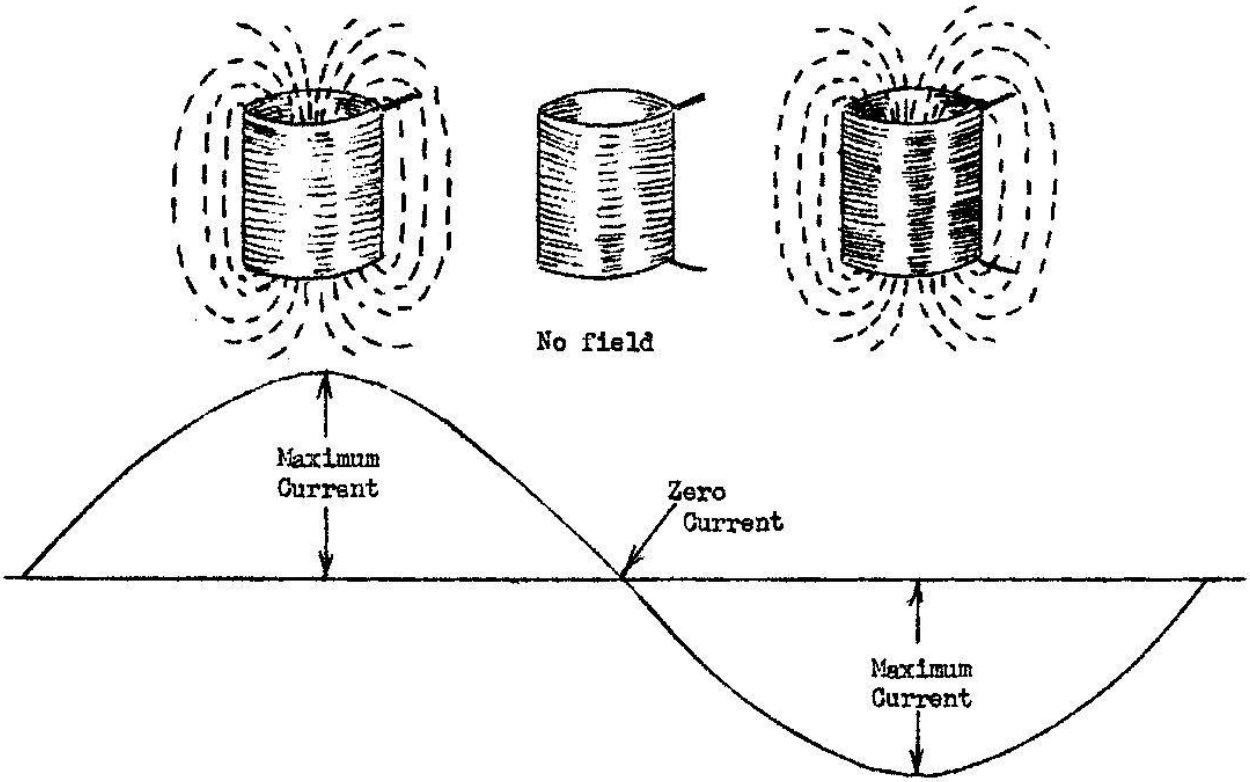

FIGURE 20.

As the frequency of the alternating current increases, the number of times the field rises out of and falls back into the; coil in one second will increase. Consequently the greater the frequency, the greater will be the counter e.m.f. and the more opposition there will be to the original voltage. So you see that increase of frequency increases the reactance of the coil since the opposition to the original voltage is what constitutes reactance.

Now you have the first important rule dealing with the reactance of a coil; M0RE FREQUENCY -- MORE REACTANCE. This is just as important as the rules dealing with a condensers reactance and it is quite necessary that you remember it.

A little farther along you will be given the second rule for a coil's reactance; then you will know two rules applying to condensers and two similar ones applying to coils.
First you will be told about the name used for the ability of a coil to generate voltages in the way that has just been explained.

INDUCTANCE

The property of an electric circuit (such as a coil) by means of which it is able to generate voltage is called "inductance". When a coil generates voltage in itself the property is called "self-inductance". We have just seen how this self-inductance acts in a coil. If the voltage is generated in a different circuit, as is done when two circuits are coupled such as in a transformer, we call the property by the name of "mutual inductance".

The greater the coil's ability to generate a voltage within itself, the greater is the coil's inductance. The amount of inductance possessed by a coil depends on the size of the coil, on the size of the wire, and on the material around which the coil is wound

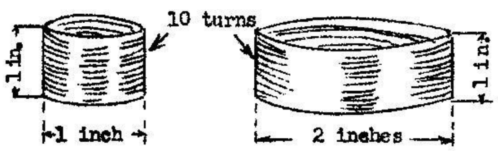

FIGURE 21.

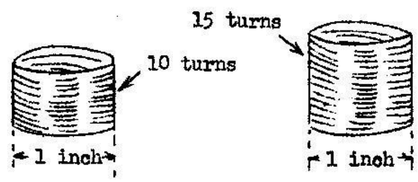

FIGURE 22.

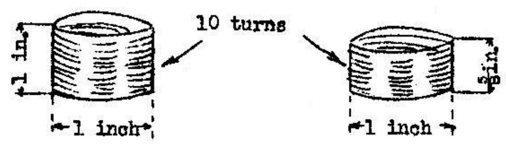

FIGURE 23.

The two coils in Figure 21 have the same number of turns of wire and are of the same length. But the one at the right is twice the diameter of the other one, therefore the right hand coil has much more inductance than the one at the left.

The left hand coil in Figure 22 has 10 turns of wire and the right hand coil has 15 turns of the same kind and size of wire. The two coils are of the same diameter. Because of more turns of the same wire, the right hand coil is longer than the other one. Because of the extra turns the right hand coil has more inductance than the one at the left.

The two coils in Figure 23 have the same number of turns of wire and are of the same diameter. The coil at the left is one, inch long and the one at the right is only 5/8 inch long. Therefore, the effect is more concentrated in the right hand coil and the right hand coil has more inductance than the one at the left.

At the left In Figure 24 we have a coil with nothing but air inside it. The Inductance of this coil is determined by its diameter, its length and the number of turns of wire.

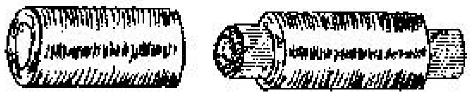

FIGURE 24.

At the right hand side of the illustration we have the same coil but now the space inside is completely filled with iron. Were you to measure the inductance of the two coils you would find that the one with the “iron core” has hundreds of times as much inductance as the one with the “air core”.

There you have the four things which affect a coil's inductance, (l) diameter, (2) number of turns, (3) length of winding, and (4) material inside the coil.

You have learned that the more counter voltage generated in a coil the more it opposes the flow of alternating current through it, or the more reactance the coil possesses. Now you have learned that the coil's ability to generate voltage is called inductance. Then it follows that the greater the coil's inductance, the greater must be its reactance. This is the second rule for coil reactance, MORE INDUCTANCE - MORE REACTANCE. Now you have the two rules for coil reactance to match the two for condenser reactance. You will notice that those two rules for coil reactance are just the opposite to the two for condenser reactance.

HOW TO CALCULATE A COIL’S REACTANCE.

A reactance of a coil is measured in ohms, just as the reactance of a condenser and the resistance of any circuit is measured in ohms. We will always find coils in three portions of any receiver, in the radio amplifier, in the audio amplifier, and in the power supply parts. The coils are handling three classes of frequencies -- radio frequencies, audio frequencies and power frequencies.

In order to figure out the reactance of a coil we must know its inductance and we must know the frequency of the alternating currant which will pass through the coil. The inductance of a coil may be measured in any one of three common units, first comes the “henry” which represents quite a large amount of inductance. The henry is used for inductance measurements of coils having iron cores. Iron-core coils are used in transformers and in chokes for audio frequency amplifiers and for power supply units.

A smaller inductance unit is called the “millihenry” which is the one thousandth part of a henry. Transformer coils and choke coils used in radio frequency circuits may have their inductances measured in either millihenrys or in “microhenrys”. Here is the relation between the three, inductance units:

1 henry = 1,000 millihenrys = 1,000,000 microhenrys.

Now you will be given three formulae used for calculating the reactances of coils when the inductances are given in henrys, millihenrys or microhenrys and when the frequencies are given in cycles or in kilocycles.

$$\text{Reactance in Ohms} = \frac{\text{Cycles x henrys x 1000}}{159} \qquad (3)$$

$$\text{Reactance in Ohms} = \frac{\text{kilocycles x millihenrys x 1000}}{159} \qquad (4)$$

$$\text{Reactance in Ohms} = \frac{\text{kilocycles x microhenrys}}{159} \qquad (5)$$

Another formula is sometimes used for calculating the reactance of a coil:

$$\text{Reactance in Ohms} = 2\Pi fL$$

In this formula the symbol "Π" is culled "pi", and is usually taken as 3,14. The letter "f" represents the frequency in cycles per second and "L" the inductance in henrys. If we multiply 2 by Π as in the beginning, we have a value of 6.28.

Now $\frac{1000}{159}$ works out to be 6.28 and the rest of this formula (cycles x henrys) is the same as the rest of formula 3. Therefore, this formula is exactly the same as formula 3 except that it is written in a slightly different way.

In Figure 25, showing part of a power supply unit, there is a "filter choke" having an inductance of 20 henrys. To calculate the reactance of this choke at a frequency of 120 cycles we will use the formula (3) and fill in the values as follows:

$$\frac{120 \text{ x } 20 \text{ x } 1000}{159} = \frac{2,40,000}{159} = 15,000 \text{ ohms (approximately)}$$

The <u>resistance</u> of a choke such as shown in Figure 25 may be between 200 and 300 Ohms. That would be its resistance to direct current and of course it offers the same amount of resistance to alternating current. Yet, in addition to the fairly low resistance, we find that this choke has a <u>reactance</u> to alternating current of 15,000 ohms. Direct current would flow through this choke quite easily but alternating current would have a hard time getting through because of the great reactance.

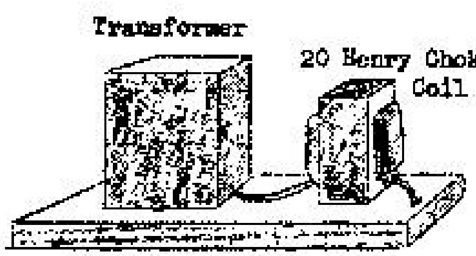

FIGURE 25.

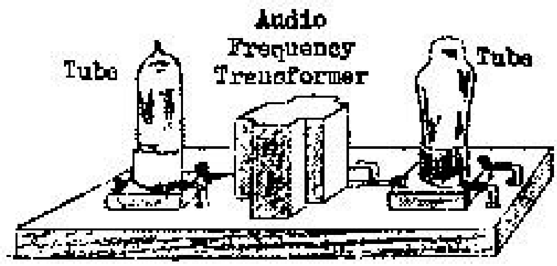

FIGURE 26.

In Figure, 26 we have part of a transformer coupled audio frequency amplifier showing the coupling transformer between two amplifying tubes. Although this arrangement does not conform to modern practice we have included it with a view to providing a simple example of impedance calculation. The same remarks may be made regarding the circuit diagram of Figure 27. This also is not typical of modern practice but has again been included as a concession to simplicity. The primary winding of this transformer has an inductance of 60 henrys. Supposing we are amplifying a musical note having a frequency of 500 cycles, to calculate the reactance of the transformer at that frequency we use formula (3) again and fill in these new values as follows.

$$\frac{500 \times 60 \times 1000}{159} = \frac{30{,}000{,}000}{159} = 188{,}000 \text{ ohms (approximately)}$$

This shows you what very great opposition we have to alternating currents of audio frequencies when our coil has plenty of inductance. The circuits used around a detector tube are shown In Figure 27. On the left of the detector we have a radio frequency transformer in which the secondary coil or winding has an inductance of 170 microhenrys. To calculate the reactance of this coil at a broadcasting frequency of l000 kilocycles we will use formula (5) and fill in the values given:

$$\frac{1000 \times 170}{159} = \frac{1700{,}000}{159} = 1070 \text{ ohms (approximately)}$$

In the case of this radio frequency transformer, we have a very high frequency; of 1000 kilocycles or of 1,000,000 cycles. Yet, because the inductance is very small, being measured in microhenrys, we have only a comparatively small reactance. You can see that the reactance does not depend on the frequency alone, nor on the inductance alone, but on the relation of these two to each other.

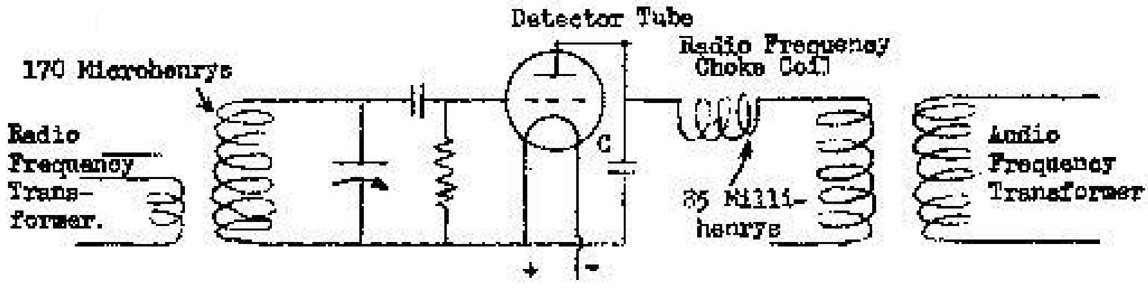

FIGURE 27.

Over at the right hand side of the detector tube in Figure 27 you will se a radio frequency choke coil having an inductance of 85 millihenrys. Let's figure out the opposition or reactance of this coil to radio frequency currents having the frequency of 1000 kilocycles. Here we will use the formula (4) and fill in the values this way.

$$\frac{1000 \times 85 \times 1000}{159} = \frac{85{,}000.000}{159} = 530{,}000 \text{ ohms (approximately)}$$

The purpose of the radio frequency choke coil is to prevent currents at radio frequencies from going over into the audio frequency transformer. You can see that this very high reactance of 530,000 ohms would certainly hold back these radio frequency currents and would force them to pass through the condenser marked “C” in figure 27. The reactance of the choke coil to audio frequency currents from the detector would be very low and these currents would go over into the audio frequency transformer.

We could use the more complicated formulae giving answers which would be slightly more exact, but our formulae here are easy to use and give answers accurate enough for all ordinary work.

In this lesson you have been given five different formulae for figuring out the reactances of condensers and coils. It is not necessary for you to memorise all of these formulae, but it is essential that you know at least one formula for calculating condenser reactance and one for coil reactance.

In all this work we are doing with reactances of coils and condensers, there is one point you should notice especially. We speak of reactance only when alternating currents are being considered. In order that reactance may appear we must have alternating current. There is no such thing as reactance to direct current, once the magnetic field surrounding a coil has reached the limit imposed by the normal resistance to direct current. To explain this last remark, lot us take an example. It is assumed that we have a coil of wire with a resistance amounting to 100 ohms. If to the end of this coil, we apply an e.m.f. of 100 volts, one ampere of current will flow through the coil if the voltage is a direct one. However, one ampere of current will not flow through the coil immediately it is connected to the voltage source. There will be a short lag - only a fraction of a second - but - time lag nevertheless before the current flow reaches its full intensity of one ampere. The time lag is caused by the counter e.m.f. developed within the coil at the instant current commences to flow through it. As with A.C. the counter e.m.f. tries to prevent current flowing through the coil, but immediately the current flow has reached its maximum intensity., one ampere in this case, the field about the coil is no longer moving and, consequently, no longer creating a counter electromotive force within the coil as a result, all reactive opposition ceases until the circuit between the voltage source and the coil is broken. When the circuit is broken, the field surrounding the coil collapses and in doing so creates another counter electromotive force within the coil. This second counter electromotive force endeavours to keep current flowing through the coil and so creates a delay between the time the circuit is broken and the time current ceases to flow. This is the only way in which reactance will affect a D. C. circuit. In effect, reactance is continuously present in an A.C. circuit but only temporarily present in a D.C. circuit.

Resistance is different -- we have resistance to all kinds of currents, to alternating current as well as to direct current. Resistance is due to the size and material of the conductors. Reactance is due to the form of the parts and is greater where the conductors are formed into coils or into condensers. Now you will be told something about the combined effect of reactance and resistance on the flow of alternating currents.

IMPEDANCE.

You learned that every circuit has resistance, or ohmic resistance, to the flow of alternating current and to the flow of direct current. Resistance is always there. Reactance is there only when alternating current flows in the circuit. For the total opposition to the flow of alternating current, for the opposition offered by both the resistance and the reactance combined, we have new name. “impedance”. This is a perfectly natural name because the impedance is the thing which impedes the flow of alternating current. If you know the resistance of a circuit and also know that circuit's reactance, you can figure out the impedance.

Unfortunately we can't just add the resistance in ohms to the reactance in ohms and get the impedance in ohms. You haven't been told before,, but impedance is measured in ohms - just as all other kinds of opposition to current flow are measured in ohms.

It is also unfortunate that the formula by which we figure out the impedance is not so easy to use as the formula for reactance. To figure out the impedance we have to "square" the resistance in ohms, then square the reactance; in ohms, then add the two squares together and extract the square root of their sum. That doesn't sound so very easy. The lucky thing about it all is that you do not often have to figure out the impedance of a circuit. In radio work we can got along by knowing the resistance and reactance separately.

The formula for calculating impedance is very important and should be memorised
It is as follows:-

$$\text{Impedance in ohms} = \sqrt{(\text{resistance})^2 + (\text{reactance})^2} \qquad (6)$$

When you write a number with the figure 2 following it and a little above the line it means that you square the number. To square a number simply means to multiply it by itself. Thus, the square of 2 is 2 times 2 or 4. The square of 10 is 10 times 10 or 100.

Let's take a practical problem. Say you want to know the impedance of a circuit having a resistance of 6 ohms and a reactance of 8 ohms. You use the formula (6) and fill in the values like this:

$$\text{Impedance in ohms} = \sqrt{6^2 + 8^2}$$

The number 6 squared is 6 times 6 or 36. The number 8 squared is 8 times 8 or 64. Adding 36 and 64 we get 100. Then we have to figure the square root of 100. The square root of number is some other number which, multiplied by itself will give you the original number. Now 10 multiplied by 10 gives 100, so the square root of 100 is 10. We find that 6 ohms resistance and 8 ohms resistance in a circuit results in 10 ohms Impedance.

The impedance of a circuit is always less than the sum of the resistance and the reactance. The impedance is always greater than either the resistance or the reactance taken alone
.
Impedance in alternating current circuits measures the whole amount of opposition to flow of alternating current just as resistance alone measures the opposition in direct current circuits. If you know the impedance of a circuit you can use it in all the rules of Ohm's Law in place of the resistance when dealing with A.C. circuits.

EXAMINATION QUESTIONS No.14

1. Does reactance affect The flow of direct current or of alternating current? How?

2. In what units do we measure (1) reactance, (2) resistance?

3. Which has the greater reactance, a condenser of 2 microfarads capacity or one of 6 microfarads capacity? Why?

4. If the frequency of a circuit is increased, does the reactance of a condenser in the circuit go up or go down?

5. Which has more reactance a coil 2 inches in diameter, 3 inches; long and having 60 turns or a coil 2 inches diameter, 3 inches long and having 30 turns? Explain why?

6. Will a coil have more reactance at a frequency of 1,000 kilocycles or at a frequency of 600 kilocycles? Why?

7. In what units can we measure the inductance of a coil?

8. Which has more reactance, a coil of little inductance or one of big Inductance?

9. What two things do you have to know to calculate a condenser's reactance?

10. What do we call the combined opposition to alternating current of both the reactance and the resistance in the circuit? In what units is it measured?

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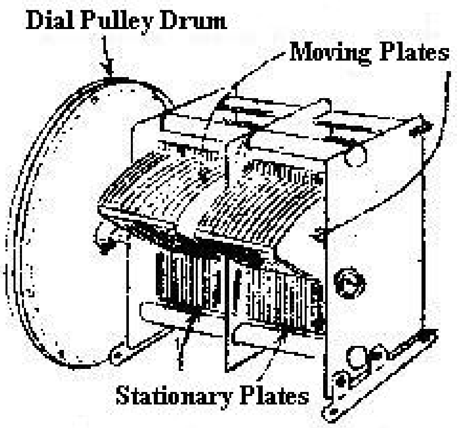
LESSON NO. 15

Undoubtedly you have looked inside a radio set to see what happens as you turn the tuning knob. Only one thing moves or rather only one set of parts has any motion. The moving parts are one of the sets of plates of each section of the "tuning condenser".

In Figure 1 you will sea one of these tuning condensers attached to a pulley drum which is part of the tuning dial mechanism. The tuning knob is attached to the drum, usually by cord or flexible cable, and as you turn this knob it rotates the drum and moves the condenser plates. If the receiver is in operation, movement of the condenser plates causes first one broadcast station to "come in" and fade out, only to be followed by another station. So it goes, all up and down the dial. You are "tuning" the receiver

Most tuning dials have the station call signs directly marked on them. The carefully designed tuning condensers and coils are so accurately made that turning the knob and moving the dial pointer to a particular call sign will automatically move the tuning condenser plates to just the right position to tune in that station, if it is broadcasting.



Two Gang Tuning Condenser

Figure 1.

A tuning condenser with its movable plates in three different positions is shown in Figure 2. Looking carefully at the condenser, you will see that its two principal parts are two sets of plates. The plates of one set are stationary and remain fixed in their original positions. The other plates are attached to a shaft and as the shaft turns, these plates move in between the fixed ones, depending which way you turn the dial.

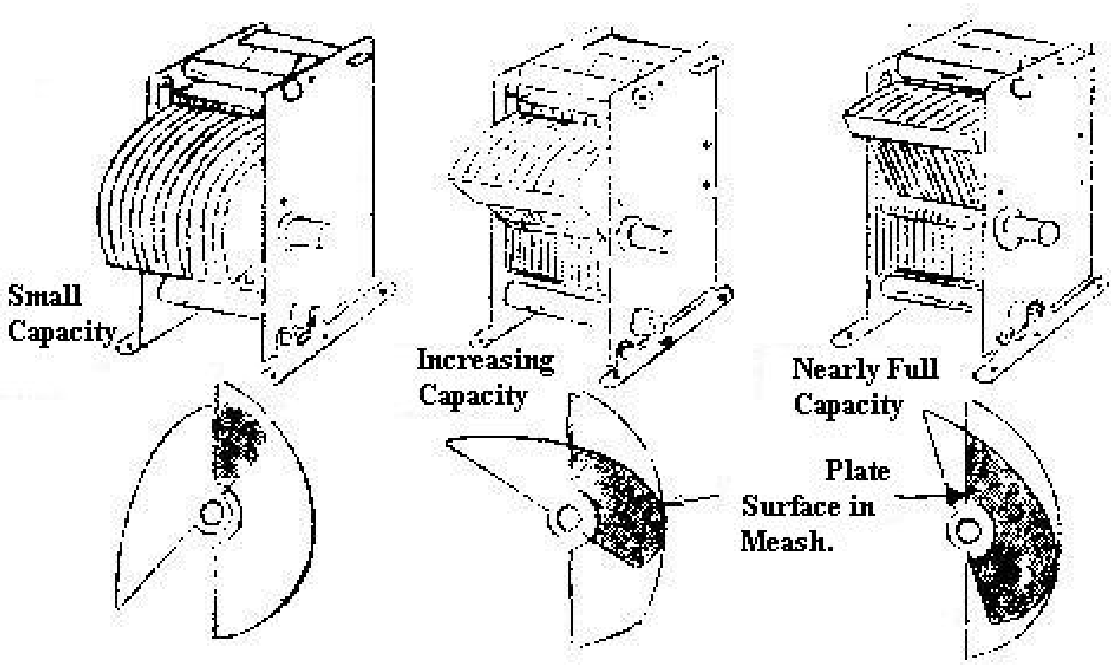


Figure 2.

The three pictures in the lower part of Figure 2 show what is happening, You recall that a condenser consists of plates separated from one another by a dielectric. Air is the dielectric of the tuning condenser. The only part of the plate surface which is effective in producing capacity is the part opposite another plate. The only part of the air dielectric which can be placed under an electrical strain is the part between the plates.

In the condenser at the left of Figure 2, only a small portion of the plate surface is In mesh or is opposite the surface of the stationary plates. Therefore, in this position the condenser has small capacity. Moving the plates farther into mesh as in the centre picture of Figure 2 increases the capacity because more plate surface is in use. Moving the plates nearly all the way in as at the right causes the condenser to have nearly its full capacity. When the plates are all the way in, you have the maximum possible capacity far that particular condenser.

Then the operation of tuning consists of changing the capacity of a condenser, or changing the capacity of several similar condensers a11 connected together. By this simple operation you are able to select from several hundreds of stations on the air at one time just one particular station to which you wish to listen. All the other stations are there, all of them are sending out radio waves, and all those waves are striking your aerial at the same time. Yet you hear but the one station. As far as your receiver is concerned there is only one difference between one transmitting station and another. The difference is indicated in Figure 3.

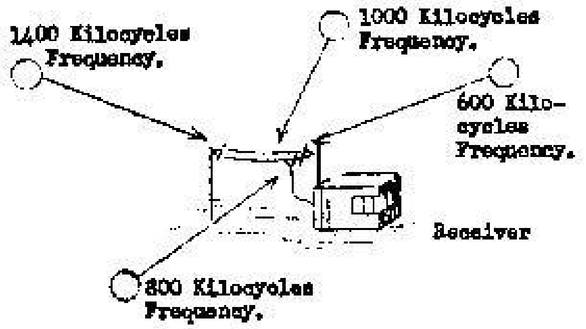


Figure 3.

The different stations send out "carrier waves" of different frequencies. Broadcasting stations use the frequencies between about 500 kilocycles and 1600 kilocycles.

A kilocycle, as you remember, in 1,000 cycles per sec.

Now we may conclude that changing the capacity of the receiver tuning condenser changes he frequency to which the set responds. The set accepts one frequency and at the same time rejects all the others.

Of course the same effect may be achieved by changing the inductance of the coil in a tuned circuit and this method is actually used in television receivers when changing from one channel to another. Variable inductance tuning is also used in some motor vehicle radio receivers. Further details about each of these specialised applications will be provided towards the and of this lesson.

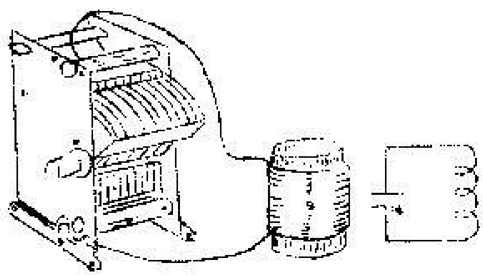


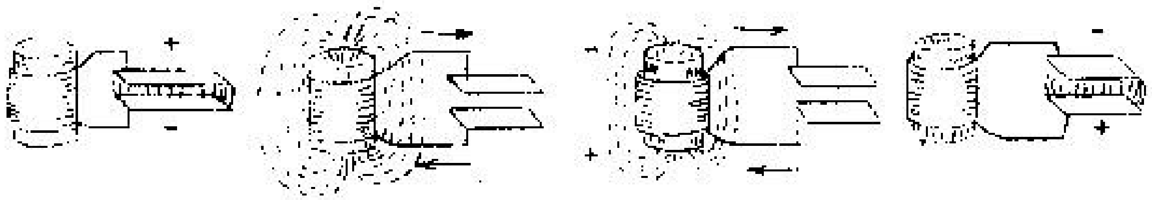
Figure 4.

Were you to trace out the connections made to each of the tuning condensers in the receiver, you would find that each one connects to a coil as in Figure 4. The symbol for such a circuit is shown at the right hand side of this illustration. Such an arrangement of coil and condenser makes what we call an "oscillating circuit" or an "oscillatory circuit". The action that takes place In one of these circuits is as follows:-

At the left hand side of Figure 5 we start off with a charge on the plates of the condenser. This means that one plate is at a higher potential than the other. The difference in potential causes a flow of current from one plate, through the coil winding and back to the other plate.

Flow of current through the winding produces a field of lines of force around the coil as shown at the right hand side of Figure 5. The condenser is discharging. This means that the voltage difference between the condenser plates is diminishing. Once the condenser is fully discharged, it has no voltage left to maintain the flow of current, so the current tends to stop. As it decreases, the magnetic field around the coil collapses back through the winding as at the left hand side of

Figure 6. Movement of the lines of force <u>back through the winding</u> generates a counter E.M.F. in the coil which tends to prevent the current from stopping, that is, positive at the bottom of the coil and negative at the top as shown. This counter E.M.F. actually forces the electrons to keep on moving in the same direction, that is, on into the top condenser plate and away from the bottom plate so that the condenser becomes charged again. But now the bottom plate is positive and the top negative. The circuit has completed one half cycle of its oscillation.



Condenser Charged Potential difference between plates.

Current through Coil Produces Field of Force around Coil.

Collapse of Field produces voltage in coil.

Current from coil produces charge on Condenser Plates.

Figure 5.

Figure 6.

The energy of the falling lines of force now having been expended in charging the condenser, the charge of the condenser again exerts itself in causing electrons to flow back again from the top plate to the bottom. The lines of force are again set up and again keep the current going when the condenser's charge has been expended. This charges the condenser again, positive at the top and negative at the bottom, just as it was at the start.

The oscillating circuit has now completed one whole cycle; the entire process is repeated over again many times, the energy being stored at one instant in the condenser's charge and then in the coil's field. The preceding explanation has been based upon the modern conception of electron movement from the negative end of the circuit to the positive end. Although this conception of current flow was introduced in an earlier lesson we remain conscious of the fact that many students will have had some initial training in electrical theory and practice before commencing this Radio Course, and that such training may have assumed the older conventional idea of current flowing from positive to negative. As initial impressions are sometimes hard to change, many people brought up on the conventional idea prefer to retain it and think always in terms of current flowing from positive to negative. There is nothing fundamentally wrong with this provided one remembers always that a flow of current is actually a movement of electrons and that movement of electrons from negative to positive and flow of current from positive to negative simply represents two ways of referring to the same thing. For this reason we have made a practice of using both methods of expression so that students may think either in terms of electron movement or conventional current flow, whichever they prefer.

The preceding reference to the alternate charge and discharge of a condenser when connected in a tuned circuit may be changed to conventional current flow terminology by simply reversing the direction of the arrows shown on the illustrations and transposing the terms “top” and “bottom” when referring to the condenser plates. However, do not overlook the fact that the respective polarity of the plates remain the same. At the left of Figure 5, the top plate of the condenser will still be positive while the bottom plate is negative and at the right hand side of Figure 6 the top plate will still be negative while the bottom plate will be positive.

Flow of current back and forth in this circuit means that the current must overcome the resistance of the circuit. Current flowing through a resistance means that power is being used up or converted into heat and lost. This loss of power gradually reduces the voltage and the amount of current flowing until finally the oscillations are reduced to nothing.

The number of oscillations and their strength thus depends on the voltage applied in the first place and on the resistance of the circuit. The greater the applied voltage the more powerful will be the oscillations and the longer will they continue. The greater the circuit resistance the weaker will be the oscillations and the quicker they will cease.

BALANCED REACTANCES .

In one of the early lessons, you were shown a picture of a spring and a weight on opposite ends of a pivoted beam. You can see the same thing in Figure 7. The spring is of such strength that it just balances or supports the weight, and, of course, the weight is just heavy enough to counteract the spring's tension.

If you compress the spring, then release it, the spring will stretch out and the weight will drop. Then the spring will contract and raise the weight. The weight will drop and stretch the spring. The spring will again contract and so the action will go on.

The spring in Figure: 7 corresponds to the condenser in the oscillatory circuit and the weight corresponds to the coil, Energy will oscillate back and forth between spring and weight, first appearing in the tension of the spring, then in the elevated position of the weight. The oscillations of the spring and weight Will continue until the energy is used up in overcoming friction of the beam's pivot.

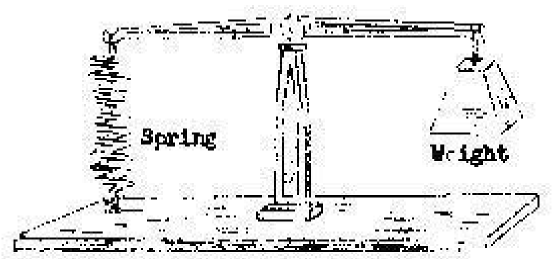


Figure 7.

This friction corresponds to the resistance of the oscillatory circuit.

If, in Figure 7, you were to use a very light spring or a very stiff one with the same weight, there would be a different balance between the energy contained in the spring and in the weight. The oscillations would be at a different rate than before. Likewise, were you to use a very light weight or a very heavy one with the same spring you again would have a different balance and oscillations at a different rate, faster or slower.

We will find that a similar balance is required in the electric circuit if the oscillations are to be of the greatest possible strength at a certain rate or frequency.

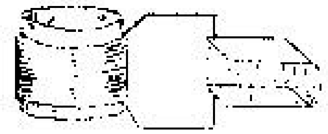


Figure 8.

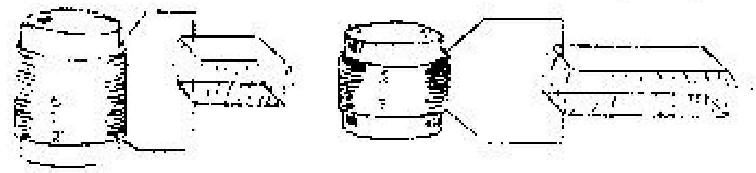


Figure 9.

In figure 8 we have a coil and a condenser which we will assume are correctly balanced for one particular frequency. They are balanced because the number of ohms inductive reactance of the coil is the same as the number of ohms capacitive reactance of the condenser.

Were you to use a much larger coil with the same condenser, as at the left hand side of Figure 9, the balance would be destroyed for that frequency but they would balance for some new frequency. And were you to use a much larger condenser with the same coil, as at the right hand side of Figure 9, you would again have an imperfect match for that particular frequency but again, they would balance for some other frequency.

In the last lesson you spent a great deal of time studying reactance. You discovered that reactance changes with frequency. Because reactance actually does change with change of frequency we must secure our balance between inductive and capacitive reactances for curtain frequencies - the frequencies of the stations to which we wish to listen.

POSITIVE AND NEGATIVE REACTANCES.

You learned that the reactance of a coil increases with increase of frequency. As

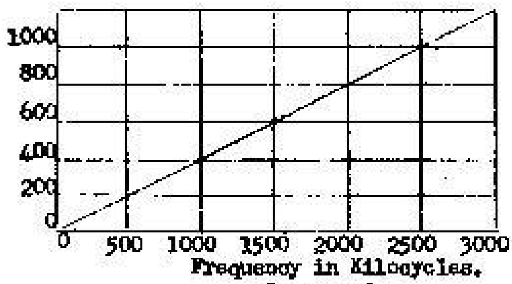


Figure 10.

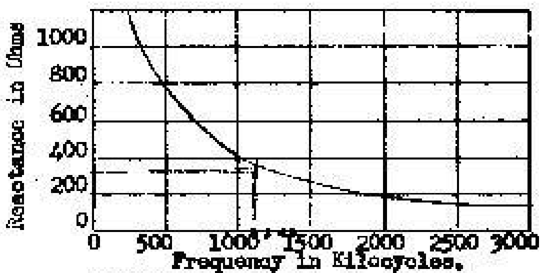


Figure 11.

L 15 - 6.

the frequency goes up the coil's reactance goes up with it. We call the coil's reactance “Positive reactance”.

You also learned that the reactance of a condenser gets less and less as the frequency of the applied voltage is increased. As the frequency goes up the condenser's reactance goes down. We call the condenser's reactance “negative reactance”. The reactance of a coil at various frequencies is shown by the graph in Figure 10. This coil has an inductance of approximately 64 microhenries. At zero frequency, which is direct current, the reactance is zero because there is no such thing as reactance unless we have a changing current. At a frequency of 500 kilocycles the coil's reactance is 200 ohms as shown by the graph. At 1000 kilocycles the reactance is 400 ohms, and so the reactance increases with frequency all the way up the line on the graph in Figure 14. This is positive reactance - it increases with increase of frequency.

The reactance of a condenser at various frequencies is shown in Figure 11. This condenser has a capacity of approximately 0.0004 microfarad. This is four ten thousands of a microfarad or 400 micro-microfarads. The reactance to direct current, zero frequency, is not shown because it would be so extremely high that the curve could not take it in. You remember that direct current cannot got through a condenser.

At a frequency of 500 kilocycles in Figure 11, the condenser's reactance is 800 ohms. At a frequency of 1400 kilocycles the reactance has dropped to 400 ohms. The reactance continues to drop as the frequency increases - here we have negative reactance.

<u>COMBINING THE REACTANCES.</u>

In Figure l2 graphs of Figures 10 and 11 have been combined. The top half of

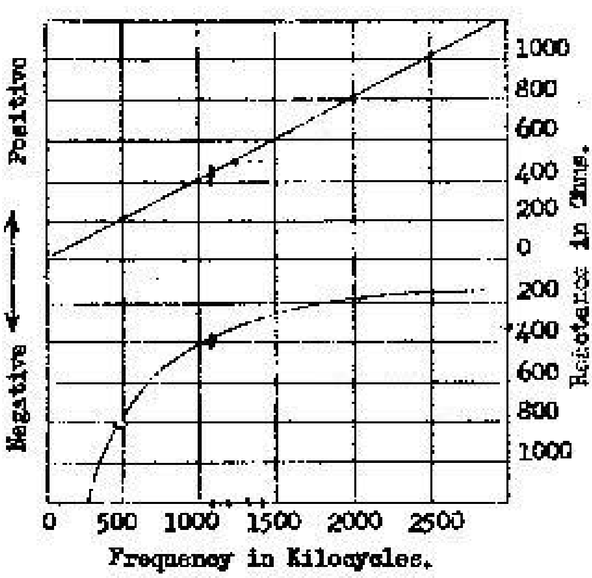


Figure 12.

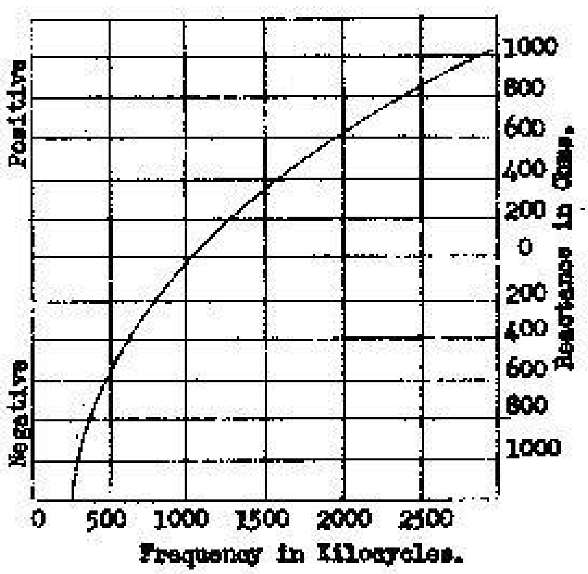


Figure 11.

this graph in Figure 12 is exactly like the graph of Figure 10, it shows the positive reactance of the coil. You will notice that the line for zero reactance is across the centre of Figure 12. The positive reactance is shown above this zero line and the negative reactance is shown below the zero line. Positive reactance increases as it gets farther above the zero line and negative reactance increases as it gets farther below the zero line.

The lower part of figure 12 is like Figure 11, but the curve has to be turned upside down because the number of ohms reactance increases as it goes downward. You will see that the lower part of Figure 12 shows the same number of ohms for each frequency as shown in Figure 11.

Now look at Figure 13. Here we have combined the reactances of Figure 12 into a single curve. Take the 500-kilocycle frequency far an example. In Figure 12 we have 800 ohms negative reactance in the condenser and 200 ohms positive reactance in the coil. So, the 200 ohms positive reactance is taken away from the 800 ohms negative reactance, leaving the difference, 600 ohms negative reactance at 500 kilocycles. Consequently the curve of Figure 13 shows that at 500 kilocycles frequency we have a negative reactance of 600 ohms. Now we'll take the 1000 kilocycle frequency. Looking at Figure 12, we have a positive reactance of 400 ohms in the coil. Down below we have a negative reactance of 400 ohms in the condenser. We combine the two reactances, 400 ohms positive and 400 ohms negative. They balance each other and we have no reactance. This happens at a frequency of 1000 kilocycles. Nothing opposes the flow of alternating current except the ohmic resistance in the coil and condenser - the reactance is gone. The curve of Figure 13 crosses the zero reactance line at 1000 kilocycles.

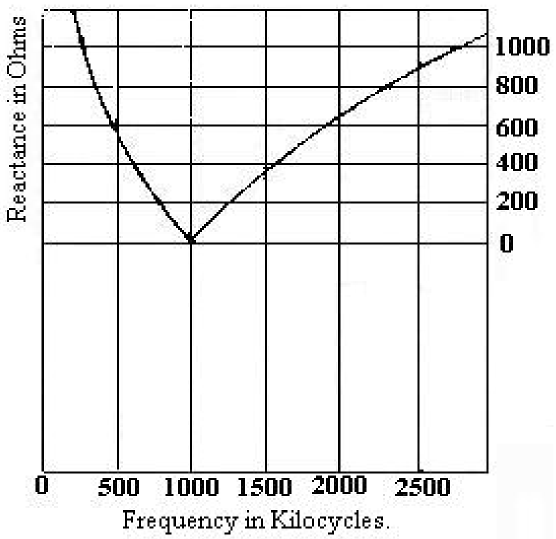


Figure 14.

Zero reactance is called “resonance”. The circuit composed of a 64 micro henry coil and a 0.0004 microfarad condenser is resonant at a frequency of 1000 kilocycles. Continuing with the curve of Figure 13 at 1500 kilocycles we have 600 ohms positive reactance and 266 ohms negative reactance so the result is a positive reactance of the difference, or 334 ohms as shown by the curve. At 2000 kilocycles we have, From Figure 12 a positive reactance of 800 ohms and a negative reactance of 200 ohms. This makes a net reactance of 300 minus 200, or 600 ohms positive reactance. The rest of the curve of Figure 13 shows the net reactances at the other frequencies. In Figure 14 we have made one more change.   We have put al the net reactances from Figure 13 back above the zero line. The alternating current is opposed at low frequencies mostly by the negative capacity reactance of the condenser. At the frequencies above resonance the alternating current is opposed mostly by the positive inductive reactance of the coil. Except at resonance the alternating current is opposed by one reactance or the other really by the combination of the two. So to show the reactance to alternating current of various frequencies we can indicate it as in Figure 14.

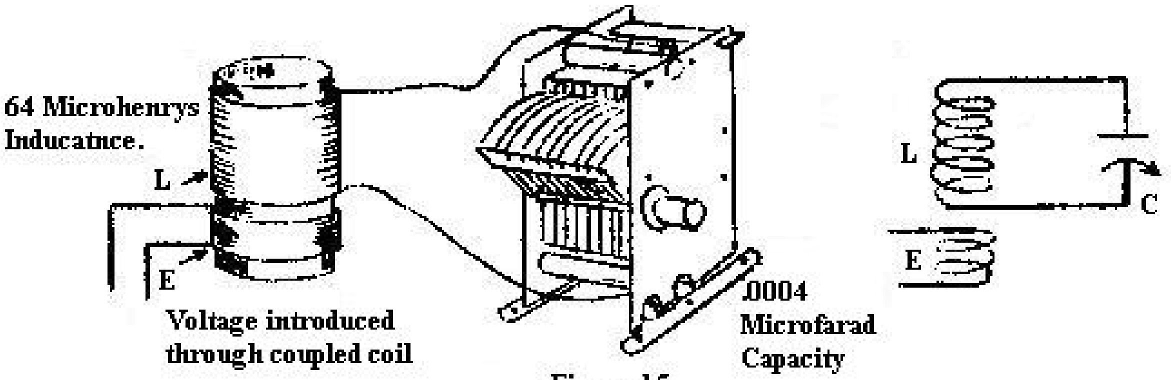
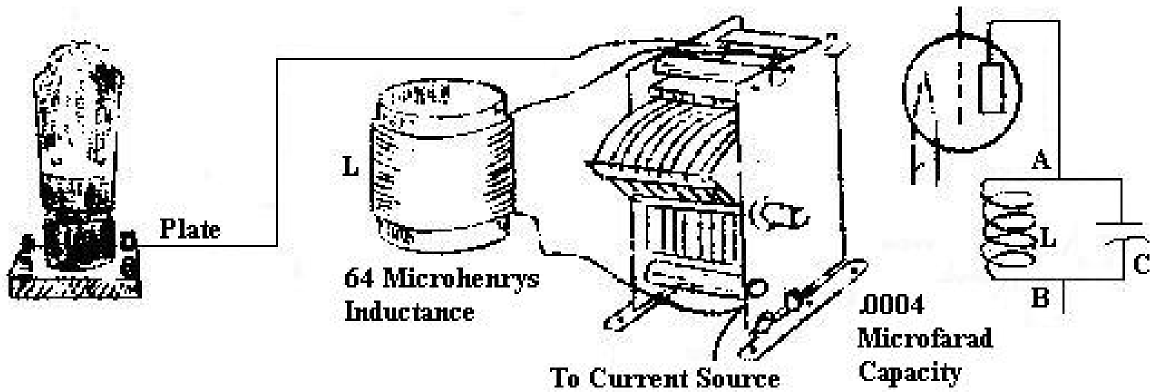


Figure 15.

AMOUNT OF CURRENT IN THE RESONANT CIRCUIT.

Voltage can be applied to a resonant circuit in any one of several ways. Two of the most common methods are shown in Figures 15 and 16. In Figure 15, voltage Is introduced into the coil "L" through its coupling with Coil "E". A changing current in "E" produces a field which encloses "L" and generates a voltage in "L". Coil "E" may be included in the plate circuit of a radio tube.

The method shown in Figure 16 places the resonant circuit, coil "L" and condenser "C" in series with the plate circuit of the tube. This method is seldom used in modern practice. The impedance of the coil and condenser combination forms impedance in the plate circuit. We need a high impedance or high reactance in the plate circuit in order to secure good amplification from the tube. In the circuit of Figure 16 there is a drop of voltage between "A" and "B".



We now want to find out how much current flows in these resonant circuits at the different frequencies. The amount of current will depend on the voltage applied to the circuit and on the impedance of the circuit. The impedance is a combination of the reactance and the resistance. The reactance is shown in Figure 14. We will assume that the resistance of the circuit is 10 ohms, When we speak here of “resistance” we mean a11 the effects that act like resistance and which cause a loss of power in the circuit. We will study this resistance to high frequency currents later on. The resistance really changes somewhat with change of frequency, but to make this explanation simpler we will just say that we have 10 ohms resistance at all frequencies in the coil and condenser combination of Figures 15 and 16.

You could figure out the Impedance at various frequencies from the formula given in your last lesson, but to save you that trouble, following is a list of the reactances taken from Figure 14 and the impedance resulting from the 10 ohms resistance to high frequency alternating currents.

Frequency in Kilocycles.	Reactance in Ohms.	Impedance in Ohms.
250	1,100	1100.45
500	600	600.08
750	260	260.2
1,000	0	10
1,250	190	190.3
1,500	330	330.1
2,000	600	600.08

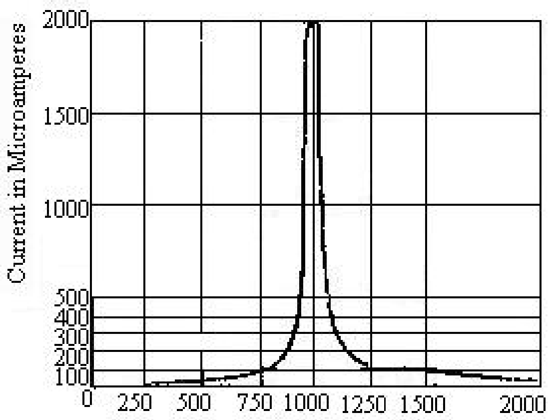


Figure 17.

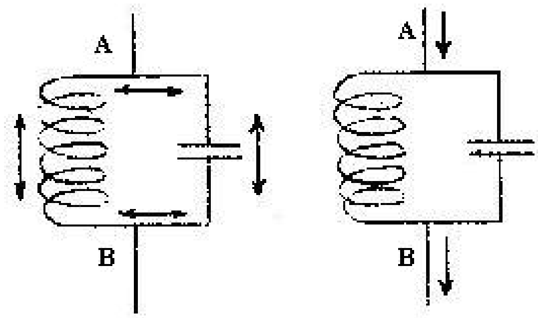


Figure 18

In this table you should notice something of importance. At frequencies quite far removed from the resonant frequency the impedance in almost exactly the same as the reactance. Closer to the resonant frequency, the impedance begins to rise more above the reactance. At resonance there is no reactance, but there is still impedances, the impedance at the resonant frequency being equal to the re-sistance of 10 ohms.

Now that we know the impedance

at the different frequencies, we will assume an applied potential of 20 millivolts 20 thousandths of a volt and figure out the amount of current which will flow in our oscillatory circuit. The current in microamperes is equal to the number of millivolts multiplied by 1000 and divided by the number of ohms impedance. Here is of current values.

Frequency in Kilocycles.	Impedance in Ohms.	Current in Microamperes.
250	1100.045	18.181
500	600.08	33.329
750	260.2	76.864
1,000	10	2000
1,250	190.3	105.097
1,500	330.1	60.588
2,000	600.08	33.329

In this list just look where the current goes at resonance, or at 1.000 kilocycles. At resonance we have 2,000 microamperes – many times the current that flows at any other frequency. The only way to really see electrical actions is to put them on a graph, so that's what we'll do with the values of the current in this list. They are plotted in Figure 17. The current at resonance goes up to a sharp peak, if the resistance is low.

OSCILLATING CURRENT.

The current which rises to 2,000 microamperes (2 milliamperes) in Figure 17 is the "oscillating current". It circulates back and forth between coil and condenser, following the path shown by the arrows in the diagram at the left hand side of Figure 18. This oscillating current does not flaw through from "A" to "B" in Figure 18. There is another current, called the "line current" which does flow from "A" to "B" in the right hand diagram of Figure 18 as shown by the arrows. You remember that our oscillatory circuit (at its resonant frequency of 1,000 kilocycles) had a coil reactance of 400 ohms. Then we are actually sending a current of 2 milliamperes (2,000 microamperes) through a reactance of 440 ohms. How much voltage does it take to do this?

The number of millivolts is equal to the number of milliamperes times the number of ohms. So, multiplying 2 (milliamperes) by 400 (ohms) we find that a pressure of 800 millivolts is acting round the circuit shown by the arrows in Figure 18.Here we have resonance producing an oscillatory potential of 800 millivolts, yet we applied only 20 millivolts across the ends of the circuit. We have 40 times the original voltage.

To any current of 1,000 kilocycles attempting to pass through this resonant circuit, as from "A" to "B" in Figure 18 at the right, there is a very great opposition. We had, in the case we are studying., 40 times the original voltage and we have 40 times the original reactance of 400 ohms. In other words we find that there is an impedance of 40 times 400, or 16,000 ohms to flow of current from "A" to "B" through the resonant circuit. This is called the circuit's "dynamic impedance". Now look back at Figure 16. The oscillatory circuit in the plate circuit of the tube has an impedance of 16,000 ohms to current at the resonant frequency of 1,000 kilocycles which flows through it from the tube to the current source.

We can learn the opposition, in ohms or dynamic impedance, of any resonant circuit at its resonant frequency to current through it from a simple formula. Here it is:

$$\text{Ohms} = \frac{\text{Inductance in Microhenries}}{\text{Capacity in Microfarads} \times \text{Ohms of high frequency resistance}}$$

As an example we will calculate the dynamic impedance of the circuit of Figure 16. We have 64 microhenries inductance, 0.0004 microfarad capacity and 10 ohms of high frequency resistance. Filling these values into the formula, we have :

$$\text{Ohms} = \frac{64}{0.0004 \times 10} = \frac{64}{0.004} = 16{,}000$$

Unless you got into the design of radio circuits you won't be using a formula such as this one very much. But it is likely that you may want to do some experimental figuring on your own account, so you are given this formula and lots of others similar to it. Even though you don't make use of this kind of information while you are studying your radio course this first time through, you will probably use it in your future work:

RESONANT FREQUENCY.

In order to make our circuit resonant at 1,000 kilocycles we used an inductance of 64 microhenries and a capacity of 0.0004 microfarads. We found that these two parts form a circuit which is resonant at the frequency which makes their reactance equal, because then the reactances balance out and leave only the resistance to oppose current flow. In Figure 19 the coil reactance curve of Figure 10 and the capacity, or condenser reactance curve of Figure 11 are drawn on the one graph.

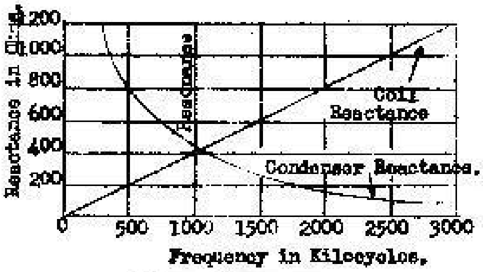


Figure 19.

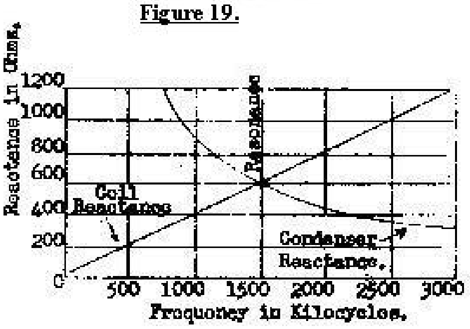
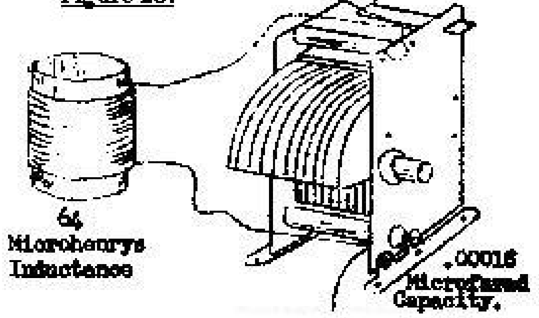


Figure 21.

Figure 20.



Notice that the two curves cross each other at the resonant frequency, 1,000 kilocycles.

Now look back at figure 16 and notice the position of the condenser plates. They are nearly all the way in mesh. In Figure 20 the plates of the same condenser have been moved farther out of mesh. This has reduced the capacity of the condenser from 0.0004 microfarad to approximately 0.00018 microfarad capacity. it is more difficult for the alternating current to flow in this smaller capacity, consequently the reactance must be greater.

In Figure 21 the two reactance curves are again shown. The coil curve is the same as the one in Figure 19; for the 61, microhenry coil. But here the condenser curve is for the smaller capacity; the one of 0.00018 microfarad, which gives us greater reactance for each frequency. The two curves of Figure 21 cross each other at a frequency of 1500 kilocycles. So the coil and condenser of Figure 20 are resonant at 1500 kilocycles, whereas the circuit of Figure 16 (with the same parts) is resonant at 1,000 kilocycles.

Moving the condenser plates, changing the condenser capacity and changing its reactance has changed the point of resonance. With the condenser set as in Figure 16 we will have the greatest amplification at 1000 kilocycles while with it set as in Figure 20 the greatest amplification occurs at 1500 kilocycles.

Now you see how movement of the condenser plates in the receiver allows the reception first of one station transmitting, on one frequency, then allows reception of a different station because that station transmits on a different frequency.

Our next step is to take the condenser of Figure 16, leaving its plates in the position for 0.0004 microfarads capacity, and connect it to a larger coil. This new combination is shown in Figure 22. We will say that the coil in Figure 22 has an inductance of 256 microhenries, four times the inductance of the first coil.

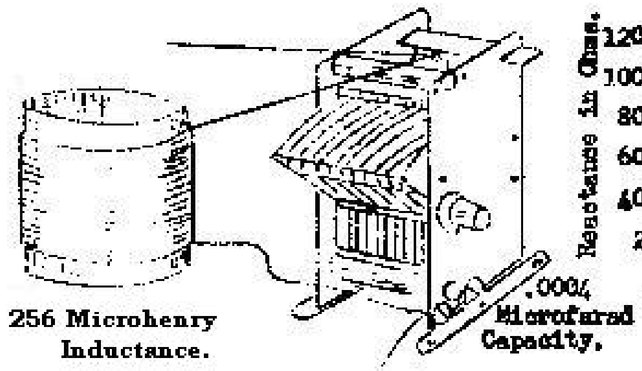


Figure 22.

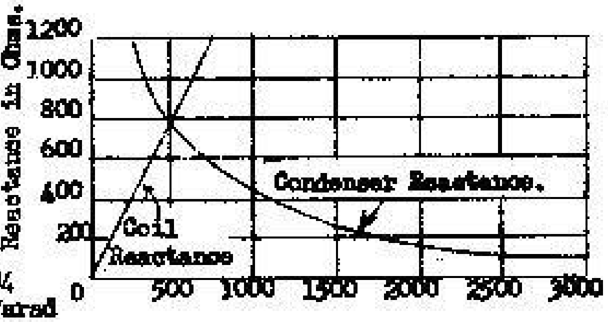


Figure 23.

We will make a new set of reactance curves for the parts in Figure 22. These curves are shown in Figure 23. The larger coil with its greater inductance makes the coil reactance go up very rapidly with increase of frequency. The two reactance curves cross on the 500 kilocycle line, so this combination of 256 microhenries inductance with 0.0004 microfarad capacity is resonant at a frequency of 500 kilocycles.

Now it is quite apparent that changing the capacity, with the inductance remaining the same, will change the resonant frequency. Also that changing the inductance, the capacity remaining the same, likewise makes a change in the resonant frequency. It is also true that no matter what the inductance and no matter what the capacity of an oscillatory circuit, the combination will be resonant at some frequency.

The frequency at which a combination of capacity and inductance is resonant does not depend alone on the capacity. Neither does it depend alone on the inductance, It depends on the combination of capacity and inductance. We can truthfully say that the frequency of resonance depends on the product of the capacity and the inductance or on the capacity and the inductance multiplied together.

This can be made plainer with a simple example. Let the frequency be represented by the number "64". You might take a capacity represented by "8" and an inductance represented by "8". Multiplying 8 by 8 gives you 64. You might also take a capacity represented by "4" and an inductance represented by "16" because multiplying by l6 gives 64, the same result. Again you might take the numbers "2" and "32" and multiply them together to got "64".

It is the same with capacity and inductance. You may take a large capacity and a small inductance, a small capacity and a large inductance, or a moderate capacity and a moderate inductance. The combination of any of those pairs will give the same frequency.

To get resonance at some certain frequency you can use a big condenser and a small coil, a small condenser and a big coil, or a medium size in both condenser and coil- all resulting in resonance at the same frequency. Like all other actions in radio, there is a very definite rule for resonant frequency. It is stated by the following formula:-

$$\text{Resonant frequency in cycles} = \frac{1}{2\pi\sqrt{2\,L \times C}}$$

In this formula "L" is the inductance in henries and "C" is the capacity in farads, It is generally more convenient to work in terms of microhenries and microfarads instead of henries and farads. To suit these units, formula (2) becomes:-

$$\text{Resonant frequency in cycles} = \frac{1{,}000{,}000}{2\pi\sqrt{\text{microhenries} \times \text{microfarads}}}$$

If we wish our answer to be in kilocycles Instead of cycles, formula (3) becomes:-

$$\text{Resonant frequency in kilocycles} = \frac{1{,}000}{2\pi\sqrt{\text{microhenries} \times \text{microfarads}}}$$

We can simplify formula (4) still further by dividing the "2" in the bottom line into the “1,000” and obtaining the figure “159”. Formula (4) can therefore be rewritten:-

$$\text{Resonant frequency in kilocycles} = \frac{159}{\sqrt{\text{inductance in microhenries} \times \text{capacity in mfds.}}}$$

This formula says that you are to multiply together the number of microhenries inductance and the number of microfarads capacity, then find the square root of the result. The number “159” is then divided by the square root you found. The final answer gives you the number of kilocycles at which that combination of capacity and inductance will be resonant.

It is generally rather hard to work out square roots, so these formulae would be difficult to use. Luckily there is a very easy way of finding what capacity is needed for any inductance or of finding what inductance is needed for any capacity when the combination is to be resonant at a certain frequency. You see, any coil can be made resonant at any frequency by choosing a proper condenser capacity to go with the coil. Also, any condenser or any capacity can be made resonant at any frequency by choosing the right coil to go with it.

In talking about condenser capacities we have been figuring in microfarads. That is a unit commonly used. One of the common tuning condensers has a capacity of 0.00042 microfarad. Decimals aren't as easy to work with as whole numbers and we can just as well speak of our condenser capacities in micro-microfarads, and get whole numbers. A capacity of 0.00042 microfarad is the same as a capacity of 420 micro--microfarads. A further abbreviation of terms is available in the picofarad. The picofarad has the same numerical value as the micro-microfarad, thus 420 picofarads represents the same value of capacity as 420 micro-microfarads. The abbreviation for picofarad is p.f.

All you have to do in changing microfarads to micro-microfarads is to add enough noughts (0) to the decimal figure so that you have six figures following the decimal point, then leave off all the noughts between the decimal point and the first number. To change 0.00042 microfarads, you add the noughts to make six figures and have “0.000420”. Then you leave off everything to the left of the “4” and this gives you 420 - the number of micro-microfarads. Here is a list of all common condenser sizes with their capacities in both microfarads and in micro- microfarads or pf.

Microfarads.	Micro-microfarads Or Picofarads.
0.00042	420
0.0004	400
0.000385	385
0.00035	350
0.0003	300
0.00025	250
0.00015	150
0.0001	100

According to this way of naming capacities, the condenser of Figure 16 and Figure 22 has a capacity of 400 micro-microfarads and the condenser of Figure 20 has a capacity of 180 micro-microfarads. We had these odd amounts of capacity because the plates of these condensers are shown part of the way out of mesh. The capacities given in the list are the "maximum capacities" of standard tuning condensers. The maximum capacity is the capacity when the condenser plates are all the way in mesh.

OSCILLATON CONSTANTS.

To calculate the correct capacity or inductance to tune a circuit to resonance use is made of "oscillation constants" An oscillation constant Is a number which can be divided by the capacity to find the inductance, or which can be divided by the inductance to find the capacity required to tune to resonance, at the frequency which corresponds to the particular oscillation constant used.

The oscillation constant for any frequency can be found by using either of the following formulae:

$$\text{Oscillation constant} = \frac{10^{12}}{(2\pi \times \text{frequency in kilocycles})^2}$$

or

$$\text{Oscillation constant} = \left(\frac{159{,}155}{\text{frequency in kilocycles}}\right)^2$$

The highest frequency used in broadcasting is 1605 kilocycles. The lowest frequency is 525 kilocycles. In tuning a broadcasting receiver you have to make it resonant at 1605 kilocycles at one end of the dial and resonant to 525 kilocycles at the other and. All carrier wave frequencies are included between these limits. Consequently we are usually only concerned with the oscillation constants for those two extreme frequencies, because if the circuit can be tuned to the highest and to the lowest frequencies used by broadcasting stations it must also tune to all the frequencies in between those two.

The two important oscillation constants have been worked out by means of the above formula and that for 525 kilocycles is 91,809 and for 1,605 kilocycles 9,801. To find the number of microhenries inductance of a coil which will make a resonant circuit at either of these frequencies divide the oscillation constant by the condenser capacity in micro-microfarads. Any other frequency requires the use of the proper oscillation constant for it.

As an example, say you want to know the Inductance of a coil which will tune to 525 kilocycles with a condenser of 400 micro-microfarads capacity. You divide the oscillation constant, 91,809, by 400 and the result is 229.5 microhenries for the coil. Now find the coil inductance with which the same condenser will tune to 1,605 kilocycles. You divide the other oscillation constant, 9,801 by 400 and get as a result 24.5 microhenries inductance for the coil. But in ordinary radio receivers we don't change the coil - the coil remains the same for all frequencies, and we change the condenser capacity. So now we'll work with the fixed inductances.

The oscillation constants are the same - “91,809” for 525 kilocycles and “9,801”for 1,605 kilocycles. To find the required condenser capacity in micro-microfarads you divide the oscillation constant by the coil's inductance in microhenries. Supposing we have a coil of 210 microhenries inductance, what capacity is needed for 525 kilocycles. You divide the oscillation constant, “91,809”, by 210 and get as a result 437.1 micro-microfarads for the condenser capacity. Then to find the capacity for 1,605 kilocycles you divide the other constant, “9,801”, by 210 and find that you need a capacity of 46.6 micro-microfarads.

Now you will have to be able to change the condenser capacity from 437.1 micro microfarads at 525 kilocycles dawn to 46.6 micro-microfarads at 1,605 kilocycles. What size condenser will you use ? One of the standard sizes has a maximum capacity of about 420 micro-microfarads and since this is even greater than 437 when we add the parallel capacity of the usual trimming condenser amounting to about 30 micro-microfarads, we can use that size. Turning the plates out of mesh will gradually reduce the capacity. Good tuning condensers have a “minimum capacity”, with their plates all the way out of mesh, which is one-tenth, or less, of their maximum capacity. If the parallel capacity introduced by the trimming condenser is included, the minimum capacity of the condenser is close to 1/10th of the maximum. So this 400 micro-microfarad condenser will reduce its capacity to about 45 micro-microfarads (one-tenth of 420 plus 30), This is below the smallest capacity we need for tuning so we can cover the whole broadcast range of frequencies with the condenser of 420 micro-microfarads capacity and the coil of 210 microhenries inductance.

Because the minimum capacity of 45 micro-microfarads is very close to the 46.6 micro-microfarads required to tune to 1,605 kilocycles with a coil of 210 micro-henries inductance, we would find it necessary to make some adjustment to the parallel trimming condenser to ensure a more even margin or overlap at each extreme of the tuning range. The nature of the trimming condensers and the manner in which they are used will be explained in the next lesson.

The things to figure with are the maximum capacity of the tuning condenser and the oscillation constant for the lowest frequency, 525 kilocycles. Dividing that constant, “91,809” by the condenser-capacity will give you the number of micro henries inductance required in the coil. The other end of the dial, at 1,605 kilocycles, will be taken care of by the change in capacity as you turn the condenser plates out of mesh.

Here is a list of coil inductances needed with each of the standard tuning condensers to let you tune to resonance over the whole broadcast range of frequencies.

Tuning Condenser Capacities. Microfarads.	Micro-Microfarads.	Inductance of Coil In Microhenries.
0.00042	420	199.36 or 200
0.0004	400	209.3 or 210
0.000385	385	217.4 or 220
0.00035	350	239.22 or 240
0.0003	300	279.1 or 280
0.00025	250	334.92 or 340
0.00015	150	558.2 or 560
0.0001	100	837.3 or 840

We allow slightly more inductance than actually required so that the set will. surely tune to the lowest frequency with a little left over. The two smallest sizes of condensers are not used in broadcast receivers because with coils of such large inductance we run into other troubles which you will be told about in a later lesson.

APERIODIC CIRCUIT.

The circuits which we have studied so far in this work sheet have been oscillatory circuits in which energy oscillates back and forth between a coil and e condenser. It is possible to have a circuit containing inductance and capacity And so much resistance that a11 the energy is used up during the first half cycle and the current does not reverse its direction at all, but just dies away without making an oscillation. Such a circuit is said to be "aperiodic", it has no period and when alternating current is applied to it no frequency can be found at which oscillations occur.

NATURAL FREQUENCY.

If a circuit has a certain amount of inductance and a certain amount of capacity it will be resonant at some particular frequency. At this frequency there will be the greatest possible flow of current in the circuit. We have used the new "resonant frequency" for this particular number of cycles per second at which the greatest flow of current takes place.

We might say that it is natural for the circuit to oscillate at the one frequency and we sometimes use the name "natural frequency". The natural frequency and the resonant frequency are the same.

FUNDAMENTAL FREQUENCY.

You have learned that any circuit oscillates at a frequency determined by the amount of inductance and the amount of capacity in the circuit. Later on in your studies you will find that, in addition to carrying a very large current at one resonant frequency, some circuits will carry currents almost as large at one or more other frequencies.

You might have a condition somewhat like that indicated in Figure 24 where the current increases at a number of different frequencies. The lowest frequency at which the current reaches a high value is called the "fundamental frequency" and is the resonant frequency of the circuit, the other frequencies of high current are called "harmonic frequencies". We use these terms mostly when we are speaking of aerials which radiate signals. These harmonic frequencies are always multiples of the fundamental frequency.

VARIABLE INDUCTANCE TUNING.

Earlier in this lesson it was stated that the frequency at which a tuned circuit resonates may be changed by altering the inductance of the coil. To turn to a lower frequency the inductance of the coil is increased while to tune to a higher frequency the inductance of the coil is reduced.

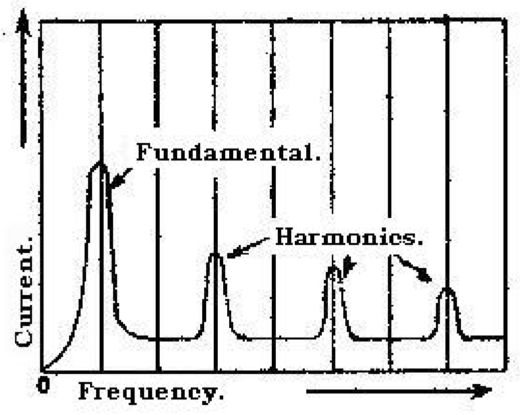


Figure 24

In the great majority of radio receivers, tuning is carried out by varying the capacity in the oscillatory circuits while the inductance remains at a fixed value. This method of tuning was also employed in radio receivers designed for use in motor vehicles until manufacturers realised that distraction of a driver's attention while tuning a radio receiver with the car in motion could create a traffic hazard. Some form of automatic or semi-automatic tuning was clearly desirable.

A direct result was the introduction of push-button tuning. This allowed the required station to be brought in by simply pressing the appropriate button on the instrument panel of the vehicle.

The first receivers of this type were merely adapted to use the standard variable capacitance method of tuning, in that the push-buttons were mechanically linked to the receiver's variable condensers, by a system of levers, so that depression of a particular button would automatically turn the condenser to a pre-sat position and so bring in a particular programme. Usually at least five pre-set positions were available so that the user could have the choice of any one of five programmes. In an effort to do away with the somewhat bulky system of levers and gears required to actuate the variable condensers some manufacturers resorted to variation of inductance instead of variation of capacity when tuning from one station to another. One method of achieving this result employed a separate set of coils for each frequency required. If a choice of five different programmes was desired, five sets of tuning coils were installed. Depression of the appropriate push-button connected one set of coils into the tuning circuits and allowed that particular programme to be received. If, while listening to a station tuned by No. 1 set of coils, No. 2 button was depressed, No. 1 set of coils would be disconnected and No. 2 set connected into the circuit in place of them. As a consequence, one programme would be tuned out and another tuned in automatically. With this system variation of inductance for each set of coils was achieved by using a different number of turns for each set. A greater number of turns would increase the inductance of the coils while a lesser number of turns would reduce the inductance.

Another factor which influences the inductance of a coil is the permeability of the material on which the coil is wound. Permeability, a property of magnetic materials which is discussed in later lessons, indicates whether such material will provide a path for a large or small number of magnetic lines of force. If a materiel has high permeability it will provide a path for a comparatively large number of lines of force while if it has low permeability it will only provide a path for a comparatively few number of lines of force. If, with a core material having a certain permeability, a coil has an inductance of so many microhenries, substitution of a metal having higher permeability will bring about an increase in the coil inductance. Conversely, the use of a core material having lower permeability will reduce the inductance.

A similar effect can be produced by changing the amount of permeable material used as core material. A greater quantity of material used in the core will raise the inductance while a reduction of the core material quantity will reduce the inductance.

This latter effect has been used in some push-button tuning units. In this type of unit only one set of coils is used. Tuning is carried out by moving a “slug” of high permeability metallic dust embedded in a plastic material in or out of the centre of the coils. Moving the “slug” further into the coils reduces the frequency at which the tuned circuits will resonate, while moving the “s1ug” in the reverse direction will reduce the inductance and so increase the frequency at which the tuned circuits will resonate. Movement of the “slug” is, of course, carried out by depressing one of a number of push-buttons. Each one is mechanically adjusted to move the “slug” to a pre-determined position, and thus provide a choice of programmes.

TELEVISION TUNING UNITS.

We see another application for variable inductance tuning in television receivers. The problems associated with tuning a television receiver from one station to another are vastly different to those related to the tuning of an ordinary radio receiver designed to operate on either the medium wave broadcast band or one or other of the short wave bands. Considering the short wave band of a normal dual wave receiver we find that the frequency coverage is usually between 7 megacycles per second and 23 megacycles per second, a bandwidth of 16 megacycles. The frequencies on which television stations in Australia operate either now or in the future range from the lower limit of Channel 1 (49 megacycles) to the upper limit of Channel 10 (216 megacycles). This represents a total bandwidth of 165 megacycles per second, approximately 10 times that required to tune over the short wave band in ordinary sound broadcasting. There can be no question of using variable capacity tuning to cover such an enormous frequency range because it would be impossible to provide a condenser with a sufficiently large ratio between maximum and minimum capacity which would, at the same time, have a sufficiently small minimum capacity to allow the tuned circuit to reach the extreme high frequency end of the television band.

The problem is overcome quite simply by using coils having fixed inductance, small inductance for the higher frequency channels and larger inductance for the lower frequency channels, and switching each set of coils in or out as we tune to a different channel.

As with any tuned circuit, resonance will only occur when inductance and capacity are both present and when the reactance of the inductive and capacitive components are equal. The tuning capacity in an ordinary radio receiver is quite obvious as it consists of a comparatively large variable condenser or condensers where there is more than one tuned circuit. The capacity which resonates with the inductance in television receiver tuned circuits is, however, not at all obvious, being distributed throughout the circuit. There is capacity between adjacent turns of a tuning coil, between wiring and grounded metal surfaces, and also across input and output circuits of radio valves. The sum of all these capacities, together with vary small values of inductance, is sufficient to provide a resonant circuit when we are working at the very high frequencies associated with television. Additional capacity in the form of a very small trimming condenser is provided to allow fine control of tuning after one has switched to the required channel.

In one form of television tuner, known as a "turret" tuner, each set of coils is wired directly to switch contacts set in a moulded plastic block. There are usually two such blocks for each channel. One strip containing the aerial and R.F. coil while the other contains the oscillator coil. The moulded blocks are clipped into a drum like structure which may be rotated by a shaft protruding through the front of the receiver cabinet. As the drum is rotated the contacts on the outside of the moulded strips connect with a set of spring "fingers" which connect the appropriate set of coils to the various grid and plate circuits of the valves associated with the tuner. To allow for slight variations of distributed capacity, the inductance of each set of coils may be increased or decreased slightly by altering the permeability of the core within small limits. A turret tuner of the type mentioned above is illustrated by Figure 25.

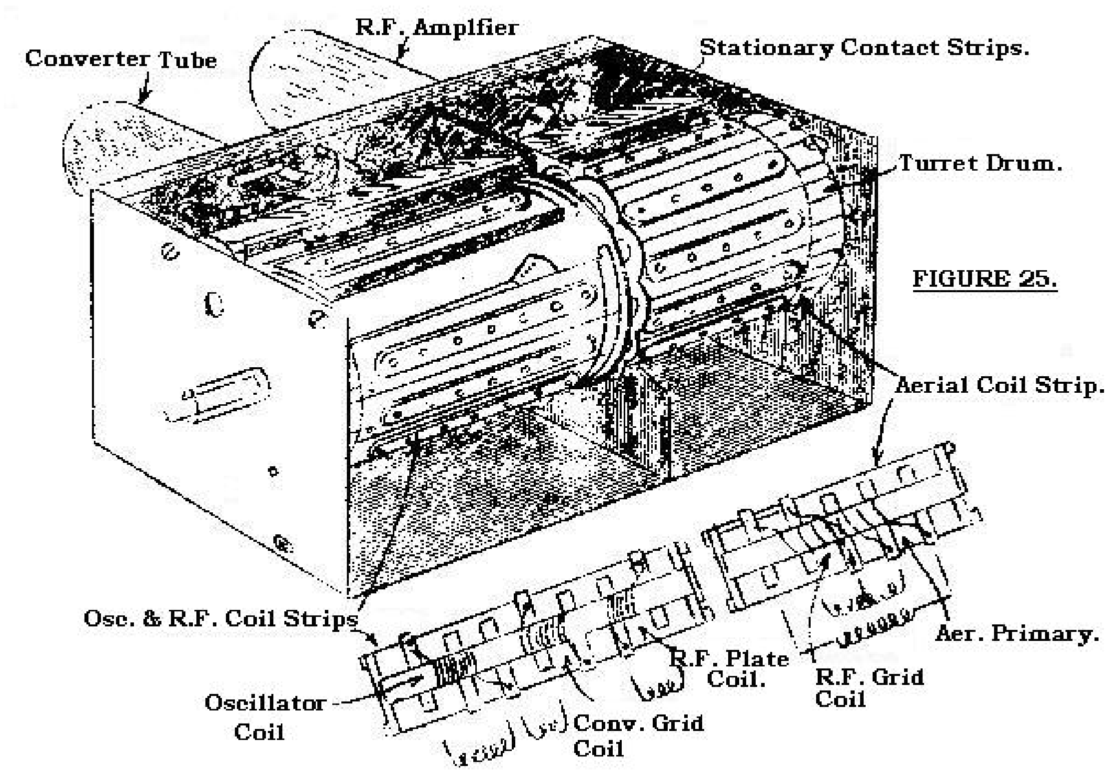


FIGURE 25.

SUMMARY OF THIS LESSON.

In this lesson you have studied the most important circuit in radio. The symbol for an oscillatory circuit composed of a coil and a condenser is almost a symbol of radio itself. When the reactance of the coil and the condenser are exactly equal they balance each other and allow current to oscillate in the circuit as easily as if there were no reactance there at all. Under these conditions current flows back and forth round the circuit, the energy being stored up in the circuit first in the condenser's charge and then in the coil's magnetic field.

This state of resonance only holds for one particular frequency, because if another frequency is applied to the circuit one of the reactances goes up while the other goes down, and so they are no longer equal and the current is opposed by the reactance that is left. If the capacity of the condenser is altered its reactance is also altered, and so the two reactances will now be equal at some different frequency, and a transmitting station of that frequency will now be received.

You have also learned that a circuit can be tuned by varying the inductance while the capacity remains unaltered and that the capacity used to resonate with a coil may not be actually visible but may be scattered throughout a circuit in distributed form. Distributed capacity is discussed with greater detail in later lessons dealing with its effect in audio-frequency amplifiers.

When a circuit is resonant the oscillating current rises to a very high value and builds up very high voltages across the combination of coil and condenser. This high voltage opposes any alternating current which is trying to pass through the parallel circuit from one side to the other and so makes a path of high impedance to it.

The more resistance there is in the oscillatory circuit the less will be the amount of oscillating current, the less the voltage developed across the circuit, and the less the circuit's impedance to current through it. We want as much impedance as possible to this current, so we always take care to keep the resistance as low as possible. Also the less the resistance in the circuit, the greater is the oscillating current at resonance in comparison with the current at any other frequency and the more selective the tuned circuit becomes.

The more reactance we have in the coil and condenser, that is the larger the coil and smaller the condenser, the more voltage we have built up across the circuit and the more amplification we get. However, if we make the coil too large and the condenser too small, our variable condenser will not be able to cover the whole of the range of frequencies we want to receive. So for receiving the broadcast stations on frequencies between 525 and 1605 kilocycles we generally use a variable condenser having a minimum capacity of 385 to 420 mmf. with a coil having an inductance of about 220 to 200 microhenries.

The size of coil for any condenser to give resonance at any other frequency can be found by using a table of oscillation constants, or by the formula given in this lesson.

OSCILLATION CONSTANT FOR ANY FREQUENCY EQUALS INDUCTANCE IN MICROHENRIES X CAPACITY IN MICRO-MICROFARADS.

Frequency K.C.	Wavelength Meters.	Oscillation Constant.	Frequency K.C.	Wavelength Meters	Oscillation Constant.
100,000	3	2.5	650	461	60,000
75,000	4	4.5	600	500	70,400
60,000	5	7	550	545	83,730
50,000	6	10.1	500	600	101,300
30,000	10	28.2	490	612	105,500
15,000	20	113	480	625	110,000
10,000	30	253	470	638	114,700
7,500	40	450	460	652	199,800
6,000	50	704	455	659	122,600
5,000	60	1,014	450	667	125,300
3,000	100	2,820	440	682	131,000
2,000	150	6,330	420	714	143,900
1,600	188	9,890	400	750	158,300
1,500	200	11,270	375	800	180,100
1,400	214	12,930	350	857	207,000
1,300	231	15,000	325	923	239,000
1,200	250	17,600	300	1,000	282,000
1,100	273	20,900	275	1,091	335,000
1,000	300	25,300	250	1,200	406,000
950	316	28,100	225	1,333	502,000
900	333	31,300	200	1,500	633,000
850	353	35,200	175	1,714	828,000
800	375	39,600	150	2,000	1,127,000
750	400	45,100	125	2,400	1,622,000
700	428	51,700	100	3,000	2,530,000

EXAMINATION QUESTIONS – No. 15.

1. What difference is there between carrier waves of different transmitting stations that allows a receiver to select one station and reject the others ?

2. At resonance there is no net reactance in an oscillatory circuit. Then what is there in the circuit to prevent the oscillations from continuing indefinitely?

3. Is the reactance of a coil called positive reactance or negative reactance? Why ?

4. As the frequency increases does the reactance of a condenser become greater or les?

5. If, at 1100 kilocycles, a coil has a reactance of 500 ohms, what must be the reactances of a condenser to make the coil and condenser resonant at this frequency ?

6. What happens to the amount of current in an oscillatory circuit at resonance? Why ?

7. In order to tune a radio circuit to a lower frequency, do you increase or decrease the capacity of the tuning condenser ? Explain the reason.

8. If a circuit is resonant at a certain frequency and you want to use a coil of more inductance with the resonant frequency remaining unchanged will you have to use a condenser of greater or less capacity? Why ?

9. The oscillation constant for 550 kilocycles is 83,730. What must be the inductance microhenries of a coil to tune with a condenser of 410 micro-microfarads capacity at 550 kilocycles ?

10. If you find that a circuit is resonant at several different frequencies, is the fundamental frequency the highest or the lowest of those frequencies?What are the other frequencies called ?

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LESSON NO. 16

VARIABLE CONDENSERS – THEIR PURPOSE, CONSTRUCTION AND USE.

Before getting into the subject of tuning condenser operation and construction we shall review briefly the work done by these condensers in radio circuits. The purpose of a tuning condenser is to make its circuit resonant at the carrier frequency which you wish to receive. At resonance, currents of this frequency areexceedingly large and currents at all other frequencies are very small in comparison.

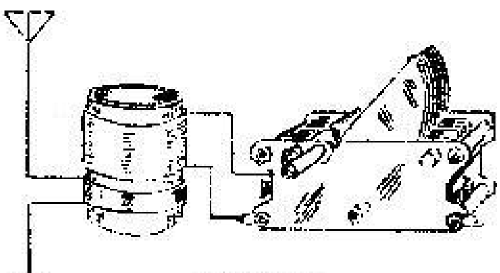

Figure 1.

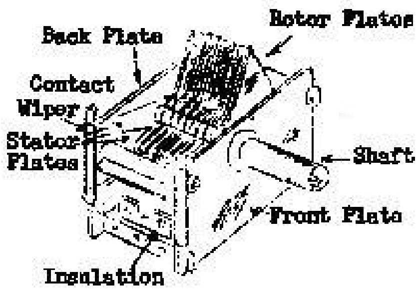

Figure 2.

A condenser tunes its circuit to resonance by changing its own reactance. As the plates are turned out of mesh, the condenser's capacity gets less and less, its reactance becomes higher and higher. The condenser's reactance is negative, while the reactance of the tuning coil is positive. Whenever the condenser's negative reactance is made to just equal the coil's positive reactance at a certain frequency, all reactance to currents of that frequency will disappear from the tuned circuit. With no reactance remaining, any signal at this resonant frequency will produce very great currents in the condenser-coil circuit and high voltages will be generated.

Consider the coil and condenser of Figure l, The coil has an inductance of 318 microhenrys and the condenser has a maximum capacity of 300 micro-microfarads or 0.0003 microfarads when the plates are all the way in mesh. Let us write down the reactance of the coil at several different frequencies used for broadcasting. Here they are;

550 kilocycles frequency .... 1100 ohms reactance.
750 kilocycles frequency........... 1500 ohms reactance.
1,000 kilocycles frequency .... 2000 ohms reactance.
1250 kilocycles frequency .... 2500 ohms reactance.
1500 kilocycles frequency .... 3000 ohms reactance.
1600 kilocycles frequency ....3200 ohms reactance.

If you want to receive a signal from a station transmitting on any one of these frequencies, all you have to do is turn the condenser shaft until the condenser's reactance equals the coil's reactance for the frequency you want to get. From this list you see that the higher the frequency to be received, the greater must be the reactance of the condenser. To increase the reactance you have to turn the plates out of mesh, so the higher the frequency the further out of mesh you turn the condenser plates. That is all there is to tuning.

Were you to calculate the capacity needed in the condenser to match the coil's reactance at the frequencies in the foregoing list you would find that it would take about 265 micro-microfarads at 550 kilocycles and about 35 micro-microfarads at 1500 kilocycles. The capacity at the low frequency is about seven and one-half times the capacity for the high frequency. Therefore, the movement of the condenser plates must change the capacity by this proportion at least. As a matter of fact, most tuning condensers are made to change their capacity about ten or more times. That is, a condenser having a maximum capacity of 300 micro-microfarads will have a minimum capacity with its plates all the way out of at least 30 micro-microfarads, but generally much less. Most condensers currently manufactured have a minimum capacity between 11 and 15 micro-microfarads.

PARTS OF A CONDENSER.

A typical tuning condenser is shown in Figure 2. The plates which remain fixed in place are called the “stator”, while those which are moved as the condenser’s capacity is changed are called the “rotor”. These are the two chief parts of the condenser. The rotor plates are carried by the condenser shaft, which, in turn, is mounted in two bearings one in each end plate. One bearing is in the front plate and the other is in the back plate. The two end plates, front and back, are held in their correct relative positions by spacer rods or a metal frame. This condenser is mounted on the receiver chassis by bolts passing through the mounting brackets.

The rotor plates, their shaft, the bearings, the end plates and the spacer rods all are made of metal and all fastened tightly together. Therefore, all these parts taken together form one electrical part of the condenser -- the rotor plate assembly. From the electrical standpoint these parts make up one part of the condenser and this part is provided with a rotor terminal or lug to which the outside wiring may be connected.

The other part of the condenser, considered electrically, is the stator. The stator plates are supported in the condenser of Figure 2 by small pieces of insulation, one on the top and one on the bottom of the condenser. The stator is provided with a soldering lug to which wires may be connected.

ROTOR CONNECTIONS.

It is essential that a good electrical contact be maintained between the rotor plates and the rotor terminal no matter what the position of the plates and even while they are being moved from one position to another. It is not safe to depend on the shaft bearings to make this connection because these bearings finally collect dirt and become loose and in addition are usually greased. This results in noisy reception.

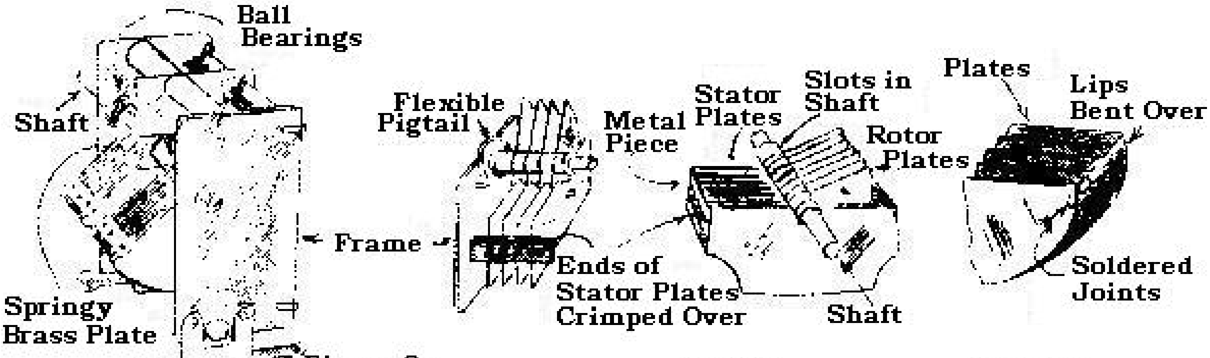

Figure 3. Figure 4. Figure 5.

To provide a dependable contact, the condenser of Figure 2 has a contact spring or wiper to which the connection is soldered and bearing with considerable pressure against the shaft.

A similar method of insuring good electrical connection is shown applied to a "two gang" condenser at the left of Figure 3. Here a spring brass plate clips on to the centre section of the condenser frame and fits into two grooves cut in the rotor shaft. It is important that the rotor plates be "earthed" by means of a wire soldered to this spring brass plate. At the right of Figure 3 a short length of flexible wire or springy metal strip is attached between the shaft and frame. As the rotor plates move this "pigtail" connection coils up around the shaft or straightens out. Either of these methods provides a very satisfactory connection, but the spring wiper method has been the one most commonly employed during the last several years. It has the advantage that one end of the wiper may be extended to provide an effective ground connection to the rotor plates and condenser frame. The flexible pigtail type has a tendency to break under conditions of hard usage, leaving that particular rotor section with an inefficient connection to frame.

PLATE FASTENINGS.

Good electrical connection is of first importance throughout a condenser at all times. There must be the least possible resistance to flow of current between parts which are supposed to be connected together. One method of fastening rotor plates to their shaft is shown in Figure 3. Slots are cut on the shaft and the rotor plates are pressed firmly into the slots.

One method of fastening the stator plates is also shown in Figure 4. Here the edges of the plates are pressed into grooves in a metal piece at each end which connects all the stator plates together electrically. A very tight press fit insures a fairly secure joint.

When plates are made of brass or some metal which can be readily soldered it is better practice to run solder over the joints between plates and supports. Solder might easily be applied to the construction of Figure 4 by flowing it on to the plates and bushings where their edges come together. Some condensers have all the rotor plates fastened to each other and all the stators similarly fastened to each other with lips like those in Figure 5. The lip on one plate is bent over until it rests on the lip of the next plate and the joint thus made is thoroughly soldered, making all plates thus joined act as one electrical conductor. Most condensers are made with aluminium plates and as it is almost impossible to solder to aluminium, a good press fit has to be relied upon for good conductivity in these condensers.

The entire rotor plate assembly is sometimes cast as one piece of metal. The stator plates may also be cast as one piece. This construction is ideal from the electrical stand point but is quite costly.

Brass and aluminium are the two metals generally used in the construction of tuning condensers. Brass is an excellent conductor, it is not magnetic and has plenty of mechanical strength. Soldering to parts made of brass is very easily done. About the only objection to brass is that it corrodes but this is prevented by covering the surface with a thin layer of lacquer which protects the metal from the air and moisture.

Aluminium does not corrode as badly as brass. In order that there may be good electrical conduction between two surfaces of aluminium, both of them must be very clean and must be held together tightly to keep them clean.

Condenser plates must be strong and rigid to keep them from warping or from being bent out of shape (which would change the capacity). Aluminium is a very rigid metal and makes good durable plates. Brass is more flexible and is often ridged to give it stiffness. Whether the plates are thick or thin makes little difference. Thin plates reduce certain kinds of electrical losses while thick ones reduce resistance by providing a larger path for the currents flowing in the condenser and also prevent the possibility of the plates vibrating by the action of the loudspeaker and producing a howl in the speaker.

Some years ago, it was not unusual to find the outer plate at one end of each rotor section slotted so that individual portions of that particular plate could be bent nearer to or farther from its adjacent stator plate. This was done to facilitate "tracking" between the tuned circuits of superheterodyne receivers, a subject which will be treated at some length in later lessons.

<u>CONDENSER INSULATION.</u>

The stator plates are held rigidly in place and are kept properly spaced from the rotor plates by the insulation. You can see the insulation in Figure 2 for one type of construction and In Figure 6 for another type. This insulation is often made of some kind of phenol compound such as “bakelite”. The material used must have very great resistance to passage of electric current through it or over its surface. It must be of such nature that there is very little loss of electrical energy in it.

Bakelite and similar products, also certain kinds of glass and of quartz meet all requirements for condenser insulation. Hard rubber would be perfectly satisfactory as far as the requirements already mentioned are concerned, but hard rubber has not enough mechanical strength to fill the bill. This rubber will get out of shape and then the plates would change their positions or would even touch and cause a short circuit.

Whatever insulation is used should be kept as far as possible from the stator and rotor plates. The greater the distance, the less likely it is that some of the lines of force forming the condenser's field will stray from their proper place between the plates and pass through the insulation rather than through the air. The air between the plates forms the condenser's dielectric. The insulation should not form part of the dielectric and will not do so if it is kept away from the plates. It is also desirable to use the least possible bulk of insulation because reducing the amount of insulation further reduces the tendency of the electrostatic lines of force to stray away from their proper place in the condenser. The design of Figure 6 is good in this respect because there is only the one piece of insulation running across the bottom of the condenser.

Another method of placing the insulation out of the way of the plates is shown in Figure 7. Here the stator plates are joined together and supported by a metal bar. The ends of this bar are passed through the pieces of insulation which are attached to the end plates, running vertically as shown.

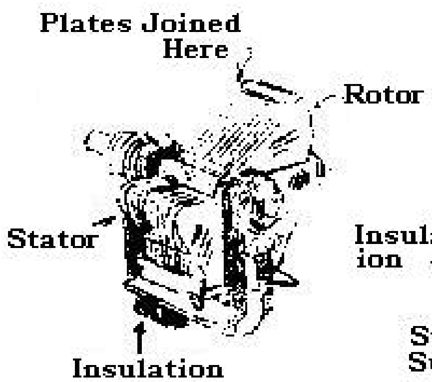

Figure 6.

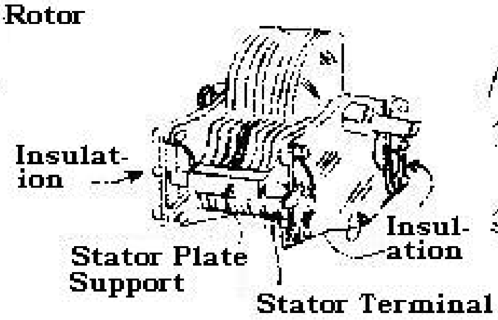

Figure 7.

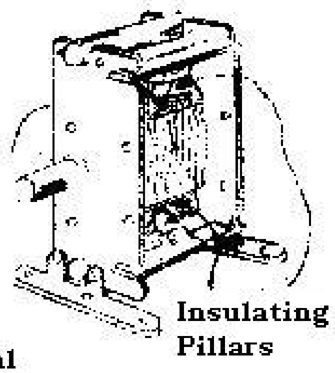

Figure 8.

The distance, measured along the insulation, between the stator terminal and the nearest metal which is connected to the end plates and rotor assembly should be as long as it can be made. This practice makes it harder for electricity to leak across between stator and rotor of the condenser because any leakage current will have to travel further over the insulation with well spaced terminals. Notice how this precaution is observed in the condenser of Figure 7. In some makes of condensers the insulation is reduced to a very_small amount by using small balls or pillars about 5/32" in diameter made of isolantite or bakelite to insulate the stator plates. Figure 8 shows a condenser with a small isolantite pillar at the top and bottom of the stator plates.

NUMBER OF STATOR AND ROTOR PLATES.

At one time, in the earlier days of radio, tuning condensers were commonly rated in the number of plates. This rating is no longer in use; nowadays all condensers are specified according to their capacity in microfarads or in micro-microfarads, because after all it is the only specification which rapidly and definitely identifies a condenser. Specifying the number of plates can give no indication of capacity unless all manufacturers standardise on plate area and spacing between adjacent plates.

According to the old rating, a "43-plate" condenser had a capacity of 1000 micro microfarads or 0.001 microfarad; a "23-plate" condenser had a capacity of 500 mmfds, or 0.0005 mfd; a "17-plate" size had a capacity of 350 mmfds, or 0.00035 mfd.; and the "13-plate" condensers had a capacity of 250 mmfds, or 0,00025 mfd. These figures assume a measure of standardisation among manufacturers of the period. Some condensers have one more stator plate than they have rotors while others have one extra rotor plate. There is no definite rule either way. Still other condensers have an equal number of both kinds of plates.

The condenser at the left hand side of Figure 9 has five rotor plates and four stator plates. This brings a rotor plate at each end of the collection of plates. The rotor plates are electrically connected to the end plates, consequently are at the same potential. When two pieces of metal are at the same potential, there is no capacity affect between them. Therefore there is no capacity effect between the end plates and the outside rotor plates.

The condenser at the right hand side of Figure 9 has one extra stator plate,

therefore is a stator on each end of the collection of plates. The stators are insulated from the end plates, consequently there can be a potential difference and there is a capacity effect between the end plates and the stator plates. Because of this extra capacity to the end plates, the right hand condenser has slightly more total capacity

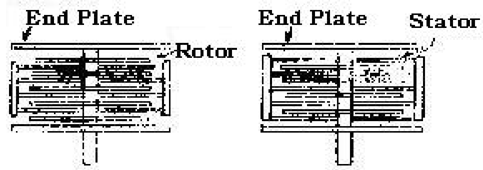

Figure 9.

than the left hand and, even though it has the same number and same size of plates.

STRAIGHT LINE CAPACITY CONDENSER.
The condenser of Figure 10 has rotor plates shaped like half circles or semi-circles. It is what we call a "straight line capacity" condenser because the capacity changes exactly according to Law far you turn the rotor.

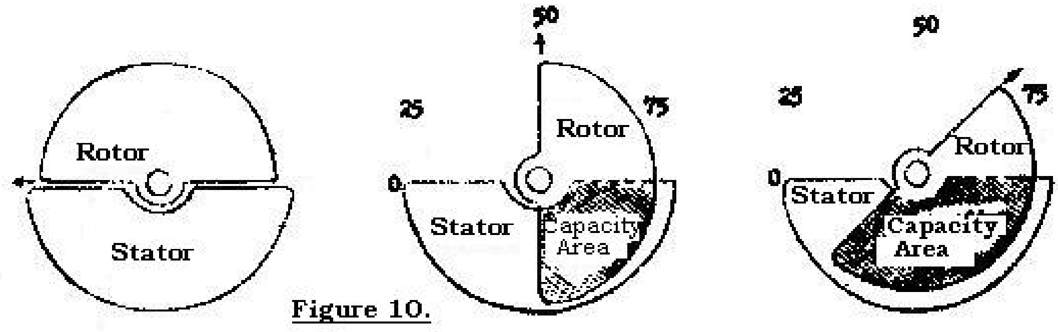

Figure 10.

In the centre drawing of Figure 10 the rotor has been turned half way through its total movement from "0" to "50" on the dial readings. Then half of the surface or area of the rotor plate is in mesh with the stator plates. The capacity of a condenser is in proportion to the plate area in mesh, so with the rotor turned half way in we have one-half the total capacity.

In the right hand drawing of Figure 10 the rotor has been turned to "75" on its dial, or three-quarters of the whole way into mesh with the stator. Then we have a capacity area of three-quarters of the whole rotor area and have three-quarters of the condensers total or maximum capacity.

We will assume a condenser of the straight line capacity type having a maximum capacity of 500 micro-microfarads. How many micro-microfarads, or what proportion of this maximum capacity, must we have to tune to various broadcasting frequencies?

First we must calculate the capacity needed for various frequencies. If the condenser is used with a coil having an inductance of 175 microhenrys the following list gives the amount of capacity needed for tuning to several places in the broadcast band.

550	kilocycles	.... 482 mmfds.	1100	kilocycles	.... 120 mmfds.
600	"	.... 402 mmfds.	1150	"	.... 109 mmfds.
650	"	.... 343 mmfds.	1200	"	.... 101 mmfds.
700	"	.... 297 mmfds.	1250	"	.... 93 mmfds.
750	"	.... 257 mmfds.	1300	"	.... 86 mmfds.
800	"	.... 226 mmfds.	1350	"	.... 79 mmfds.
850	"	.... 201 mmfds.	1400	"	.... 74 mmfds
900	"	.... 179 mmfds.	1450	"	.... 69 mmfds.
950	"	.... 160 mmfds	1500	"	.... 65 mmfds
1000	"	.... 145 mmfds	1550	"	.... 60 mmfds.
1050	"	.... 131 mmfds	1600	"	.... 56 nnfds.

Now notice some things that this list brings out very clearly. Remember, with the straight line capacity condenser, the capacity is in exact proportion to the dial readings or to the amount you turn the condenser shaft. Also remember that there is a broadcasting channel every 10 kilocycles; that is, there are channels at 550, 560, 570, 580, 590, 600 kilocycles, and so throughout the entire range. In the list given above, the capacity for every fifth channel or every fifth frequency is shown. In Australia not all the possible channels are actually used.

From 550 to 700 kilocycles we change from 482 mmfds, to 297 mmfds; a change of 185 mmfds for 150 kilocycles.

From 700 to 850 kilocycles we change from 297 mmfds, to 201 mmfds; or 96 mmfds. for 150 kilocycles.

From 850 to 1,000 kilocycles we change from 201 to 145 mmfds, or 56 mmfds. for 150 kilocycles.

From 1000 to 1150 kcs. we go from 145 to 109 mmfds.; 36 mmfds, for 150 kilocycles.

From 1150 to 1300 kcs. we go from 109 to 86 mmfds.; 23 mmfds. for 150 kilocycles.

From 1300 to 1500 kcs. we go from 86 to 69 mmfds.; 17 mmfds. for 150 kilocycles.

Between 550 and 700 kilocycles there are fifteen broadcast channels and we alter the condenser capacity 185 mmfds., more than one-third of the total capacity and more than one-third of our total dial movement for fifteen stations.

Between 1300 and 1450 kilocycles we again have fifteen channels, fifteen places to find stations, but we change the capacity only 17 mmfds. We would have a station for approximately each one micro-microfarad change. All across the dial gives us 500 micro-microfarads, so to separate these stations around 1450 kilocycles we would have to move the dial only one five-hundredth part of its total movement to get from one station to the next.

At one end of the dial you find stations separated by a movement of more than twelve mmfds., or a movement of 1/40 of the whole dial. At the other end you find stations separated by only one mmfd. a movement of 1/500 of the dial. At one end you will move the dial a long way to change from one station to the next one, while at the other one it would be almost impossible to make a movement small enough to go from one station to the next. Therefore, this type of condenser is not satisfactory for tuning purposes.

In the early days of radio we did actually use such condensers, but then there where only two broadcast channels whereas now there are more than 100 available channels. Straight line capacity condensers are now used only for laboratory and experimental work.

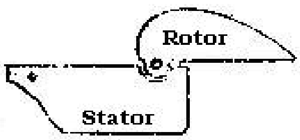

Figure 11.

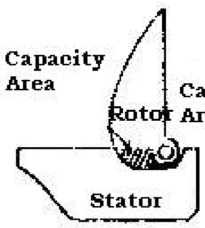

Figure 12.

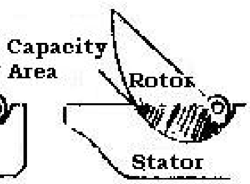

FIGURE 13.

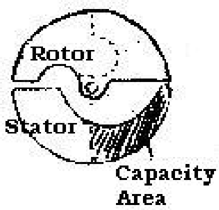

Figure 14.

STRAIGHT LINE FREQUENCY CONDENSERS.

Since the broadcast stations arc separated according to frequency, and since the separation between channels Is 10 kilocycles from one end to the other of the whole range, it is but natural to build tuning condensers which have equal movements of their dials for change from one channel to the next. Such a condenser goes by the name of “straight line frequency”.

The plates of a straight line frequency condenser, which are designed so that the rotor shape provides the straight line effect, would look somewhat like those in Figure 11. The rotor is long and has a sharp taper toward the outer and. The sane condenser, in the position given by one-half of the total dial movement is shown in Figure 12. Notice that, although there has been a large dial movement or large movement of the rotor shaft, only a small portion of the plates is in mush. Again look back at the list of capacities required for various frequencies. That list applies to a 500 micro-microfarad condenser which may be assumed to have a minimum capacity with the plates all the way out, of about 50 micro-microfarads. At 1600 kilocycles the list shows 56 mmfds., which is 6 mmfds. More than the minimum capacity of 50 mmfds. At that frequency of 1600 kilocycles we are using about 6 mmfds. of the variable capacity. At 1000 kilocycles we need a total of 145 mmfds. according to the list and this will be the 50 mmfds. minimum plus 95 mmfds. of the variable part of the capacity. So at 1000 kilocycles we are using about 95 mmfds, of the total variable capacity of 450 mmfds. We say the variable capacity is 450 mmfds. because we have to subtract from the condenser's maximum capacity, its minimum of 50 mmfds. Which is always there and which is not variable.

A frequency of 1000 kilocycles is about half way between 550 kilocycles and 1500 kilocycles, consequently is about half way around the dial movement for a straight line frequency condenser. In Figure 12 we have moved the dial half and have about one-fifth of the whole capacity area in use. Since from the foregoing paragraph, we need about 95 mmfds. of our variable capacity and have a total 450 mmfds. to work with, the capacity area of Figure 12 must be about right because 95 is about one-fifth of 450.

In Figure 13 the straight line frequency condenser has been turned further into mesh, to the position corresponding to about 800 kilocycles frequency. Here we have approximately 40 per cent of our whole variable capacity in use. You see, the capacity of this condenser increases very slowly at first, then more and more rapidly. This gives an even separation of stations on the dial because from our list of capacities and frequencies, you can sec that the change of capacity must be more and more rapid for equal changes of frequency as we go up the dial.

It is possible to get the straight line frequency effect by proper shaping of the stator plates just as wall as by shaping of the rotors. A stator shaped for straight line frequency work is shown in Figure 14. The capacity area with the dial turned through half its movement is shaded on the stator.

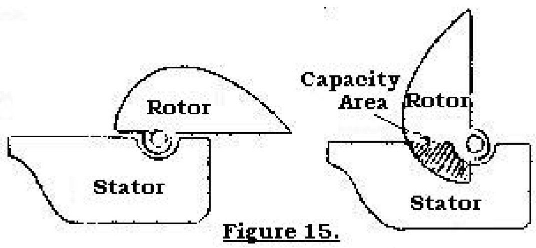

Figure 15.

STRAIGHT LINE WAVELENGTH CONDENSERS.

Before all broadcast stations were definitely assigned to certain frequencies, those stations as well as most other transmitters operated on “wavelengths” rather than on frequencies. You have already learned the relation between wavelength and frequency and how long wavelengths correspond to low frequencies.

In between the time of the straight line capacity condenser and. the arrival of the straight line frequency typo we used a good many “straight line wavelength” condensers. As you might suppose, those condensers provide separation according to wavelengths just as the newer type provides separation according to frequency. With the straight line wavelength unit you will find that a spacing of ten wavelengths at one part of the dial is the same as a spacing for any other ten wavelengths at some other part of the dial.

The shape of the plates of a straight line wavelength condenser are shown in Figure 15. You can see that turning the rotor plates half way on the dial divisions gives considerably more capacity area than a similar position for the straight line frequency type in Figure 12.

With a straight line wavelength condenser you got better separation of the high frequency stations than with the old straight capacity type, but you do not have as good separation as with the straight line frequency type. It is possible to use straight line wavelength condensers in modern receivers and have satisfactory separation on all except the stations operating at very high frequencies.

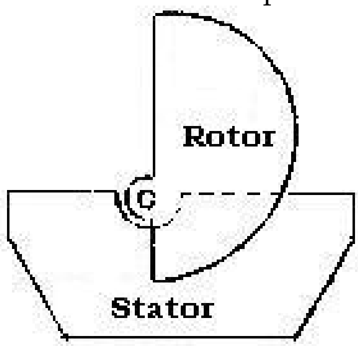

Figure 16.

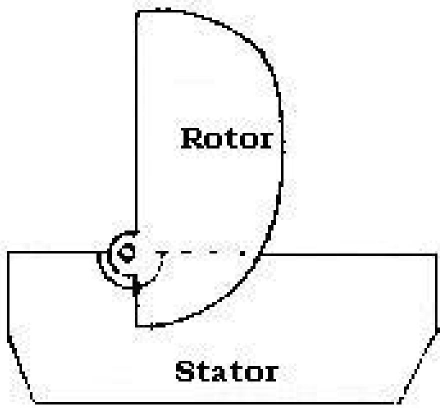

Figure 17.

A straight line wavelength condenser changes its capacity according to the “square” of the amount you turn it, and is sometimes called a “square-law” condenser. For example, the difference in capacity between “20” and “40” on a dial would be in proportion to the difference between 400 (square of 20) and 1600 (square of 40). Doub1ing the dial reading will give four times the capacity.

MODIFIED CONDENSERS.

A true straight line frequency condenser must use plates either of considerable overall size as in Figure 14 or else must use a large number of smaller plates to provide the required capacity. With the condenser of Figure 14 we find a very great width from one side to the other when the plates are all the way out of mesh. This width, of course , requires a lot of space within the receiver.

These objections to the straight line frequency condenser have led to the use of modified straight line frequency condensers. These are in between the true straight line frequency type and the straight line wavelength type in their shape and characteristics. They tend to bunch the high frequency stations closer together than true straight lire frequency condensers, but they are better in this respect than the straight line wavelength or straight line capacity types. Nearly all modern sets use modified condensers to conserve space and give a better mechanical construction.

The problem of maintaining a satisfactory frequency-capacity relationship has been aggravated by the modern trend towards miniaturisation. As components, including variable condensers, have become smaller and smaller, manufacturers have been forced to adopt various modifications in physical shape to preserve an adequate ratio between maximum and minimum capacity. Two types of miniature variable condenser in current use are illustrated by Figures 16 and 17. Notice that even though both follow a modified straight line frequency characteristic., the shape of the rotor plates differs slightly.

CHANGING CONDENSER CAPACITIES.

Sometimes you find a tuning condenser which will not quite reach the stations on the highest frequencies or else will not quite reach those at very low frequencies. You can correct either of those conditions by using a small fixed condenser along with the regular tuning condenser.

To reach a higher frequency you need loss capacity. To reach a lower frequency you need more capacity.

You can make the capacity less, so as to reach higher frequencies, by connecting a fixed condenser in series with the tuning condenser as in Figure l8. You can make the capacity greater by connecting a fixed condenser in parallel with the tuning condenser as shown in Figure 19. To make a series connection you take off the wire

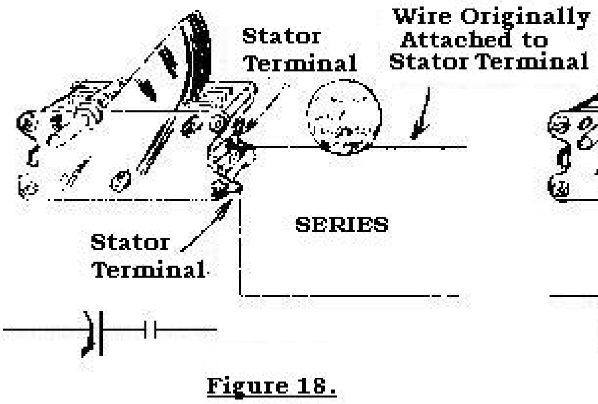

Figure 18.

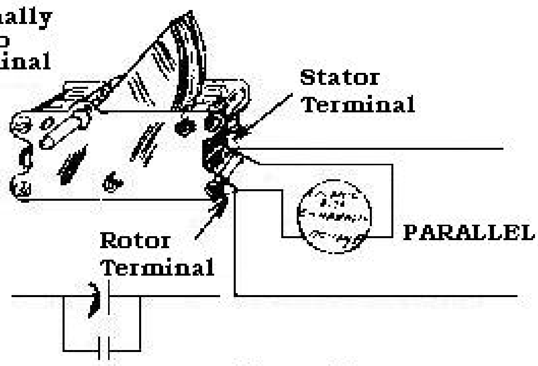

Figure 19.

or wires connected to the stator terminal of the tuning condenser, connect one side of the small condenser to this stator terminal and attach the wire or wires removed to the other side of the small condenser. To make the parallel connection you do not take off any wires but just connect the extra condenser between the stator terminal and the rotor terminal as shown.

Although there is seldom any need to make such modifications as are outlined above, to modern receivers using factory built coils and tuning condensers conforming to present day standards, it is necessary far the student to be completely aware of the effects of series and parallel capacity because modern superheterodyne receivers make use of series and parallel condensers to achieve accurate tracking between dial pointer and station call-sign throughout the receiver's tuning range.

As you will learn in later lessons, a superheterodyne receiver takes a radio signal and mixes it with another signal developed by the receiver's own oscillator, the result being a third signal which is amplified, detected, or rectified, and converted to sound in the usual way.

Because the internally developed oscillation is always at a higher frequency than that of the incoming radio carrier wave, the section of the tuning condenser controlling the oscillator frequency must have a smaller capacity range than the other sections of the tuning gang. Reduction of the ratio between maximum and minimum capacity is achieved by connecting another small condenser in series with the oscillator tuning condenser. This condenser is called a “padder” or “padding condenser”. As we have mentioned earlier, the theory related to the superheterodyne principle is discussed fully in later lessons.

When you use a series condenser you charge the tuning for all stations, making them all come in with the tuning condenser turned further into mesh than before. If, before you used the series condenser, you received a given station at one point on the tuning dial, you will now have to turn the dial further in the direction that turns the plates into mesh in order to receive that same station. This will let you get stations which are at higher frequencies, but it will cut off some of the other end of the tuning range. As a general rule, when you cannot get far enough in one direction you have room to spare on the other and of the dial, so cutting off some of the other end does not make any difference.

When you use a parallel condenser you also change the tuning of all stations, but now you move them the other way on the dial. To get stations which you received before at certain dial settings, you will have to turn the dial further in the direction which moves the condenser plates out of mesh. Here again you will gain at one end of the dial and will lose at the other end.

If the set with which you are working uses a dial numbered from “0” to “100” you generally find the high frequency stations at the low numbers and the low frequency stations at the high numbers on the dial. Then, using a series condenser will move all stations up on the dial and will leave more room at the lower end for the high frequency stations. Using the parallel condenser will move all stations down on the dial, will leave more room at the upper end to receive more of the low frequency stations.

Now, about the size or capacity of the fixed condenser. You do not want much change of tuning capacity because much change will throw the tuning away off. With the series connection, the greater the capacity of the extra condenser, the less change you will make in the total tuning capacity. For tuning condensers of 500 mmfds. capacity you can try fixed condensers of 0.004, 0.005, 0.0075 and 0.01 mfd. capacity. These will change the total capacity from 10 per cent to about 5 per cent.

If the tuning condenser has less capacity than 500 mmfds., the same extra fixed condensers will work., but will give you a smaller percentage change in the total capacity, the easiest way is to make the connection., then try out the receiver to see how it tunes.

With the parallel connection, the smaller the extra fixed condenser's capacity the less change you will make in the total tuning capacity. You will not want to use any fixed condenser of more than 0.0001 mfd. capacity. Smaller sizes, such as 0.00008, 0.00006 and 0.00004 will make plenty of change in most cases.

CONDENSERS IN SERIES AND IN PARRALEL.

You must have noticed that with the series connection we want to use a large extra capacity, while with the parallel connection we want to use a very small extra capacity - yet both make about the same percentage change in the total capacity for tuning.

Condensers in parallel add their capacities together. The three condensers in Figure 20 are connected in parallel because current can divide between them part going through each one. Their combined capacity is the sum of the separate capacities, like this:

1000 mmfds. or .001 mfd.
250 mmfds. or .00025mfd.
500 mmfds. or .0005 mfd.
1750 mmfds. or .00175mfd.

It does not make any difference whether the condensers are of the fixed type as shown or are variable tuning condensers, or are part of one kind and the rest of another -- the rule holds good just the same. Condensers in parallel add their capacities. That is why, in Figure 19 for the parallel condenser, you add only a small one because then you make only a small change in the total capacity of the two condensers.

Another thing which must be considered is the following. All coils. in addition to having inductance and resistance, have a small amount of capacity. This capacity, generally called distributed capacity, exists between the various turns of the coil and between the coil and nearby metal parts. In addition, all valves have a certain amount of capacity between their grid and the other elements and also all wires in the receiver have a certain amount of capacity to other wires, metal objects and the metal chassis. While each of these condenser effects is very small in itself, we find that the combined capacity made up of the coil capacity, valve capacity and that of the wires joining these units generally mounts up to about 20 mmfds, in ordinary sets. You know that the coil and tube are wired in parallel with the variable condenser in ordinary tuning circuits, so you will realise that the 20 mmfds. or so of distributed capacity is in parallel with the tuning condenser and therefore must be added to the tuning condenser capacity. The addition of this extra capacity has the effect of decreasing the range of frequencies to which the circuit can be tuned.

Supposing our condenser has a maximum capacity of 385 mmfds, and a minimum capacity of 25 mmfds. The distributed capacity in the circuit amounts to 20 mmfds. Now the total maximum Capacity is 405 mmfds and the total minimum capacity is 45 mmfds, or a variation of nine times (the maximum capacity is nine times the minimum capacity).

The range of frequencies which the circuit will tune to is approximately equal to the square root of the change in capacity, so the variation in frequency in this case will be the square root of 9, or 3 times. This means that if the lowest frequency the

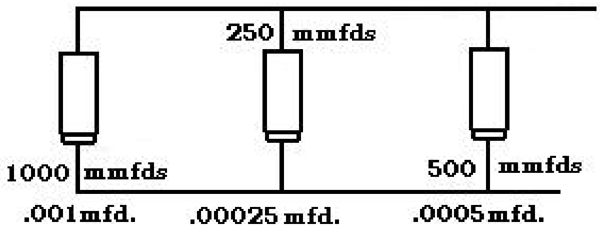

Figure 20.

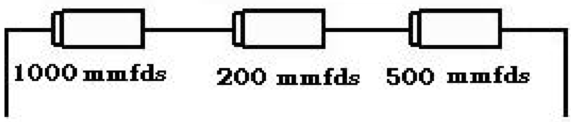

Figure 21.

circuit will tune to is, say, 525 K.C. to allow a small margin at the low frequency end of the broadcast band, the highest frequency will be 3 times 525 K.C. or 1575 K.C..

The important point to remember is that the distributed capacity must be taken into consideration when considering the tuning range of a particular condenser and coil.

When condensers are connected in series, as in Figure 21, the reciprocal of their combined capacity is equal to the sum of the reciprocals of the separate capacities. This is not so simple. You know that the reciprocal of any number is “1” divided by that number. For the three condensers shown in Figure 21 we would go about figuring their combined capacity by writing down the reciprocals like this:

$$\frac{1}{1000} + \frac{1}{200} + \frac{1}{500} = \frac{1}{\text{Combined Capacities}}$$

You have to change all the fractions so that they can be added; you change them all so they have the same “denominator” or the same number under the line. Then our figures look this way:

$$\frac{1}{1000} + \frac{5}{200} + \frac{2}{500} = \frac{8}{1000}$$

So we have 8/l000 amounting to the same as “1” over the “combined capacity”. Then, turning this fraction upside down, we have 1000/8 as equal to the “combined capacity” divided by “1”. Any number divided by one is the number itself, so 1000/8 is the combined capacity. This fraction is equal to 125, so the combined capacity of the three condensers is 125 micro-microfarads.

The combined capacity of any number of condensers in series with each other is less than the smallest separate capacity, is less than the capacity of any one of the separate condensers. If you remember this fact you will not often have to figure out the actual capacity of condensers in series -- just remember it will be smaller than the smallest of the separate capacities.

Now you have learned how to calculate the combined values of both series and parallel connections of condensers or capacities, and also of resistors or resistances and of

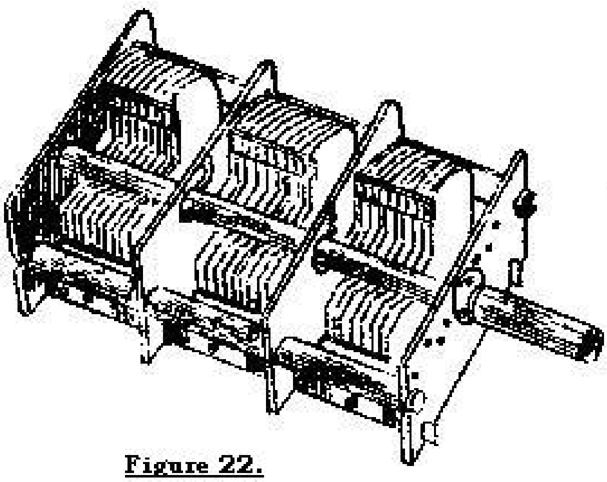

Figure 22.

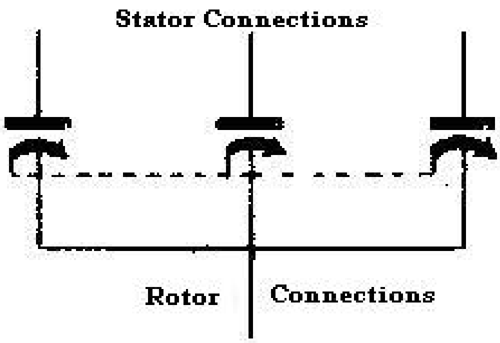

Figure 23.

coils or inductances. We have just dealt with capacities. The resistances and inductances were in earlier lessons. Here is a little table to remind you of what happens when we make series or parallel connections of these things.

Kind of Unit Being Handled	Combined Value.	
	When Connected in Series.	When connected in Parallel.
Resistances	Add Separate Resistances.	Add Reciprocals.
Inductances	Add Separate Inductances.	Add Reciprocals.
Capacities	Add Reciprocals	Add Separate Capacities.

Of course, when you add the reciprocals, the sum of the reciprocals is equal to the reciprocal of the combined value. You can see from this table that resistances and capacities act just the opposite way.

GANG CONDENSERS.

In modern types of radio receivers we seldom, if ever, use single tuning condensers all by themselves. We "gang" them -- use several similar units all connected together so that their rotor plates move together.

Some receivers for broadcast work use one or more stages of radio frequency amplification. Each stage is tuned by means of a tuning condenser. In the earlier set, you would find three or more tuning dials and you would have to work first one then the others until you got them all in tune. With that kind of set it was a real job to find a distant station and only the real "fans" had patience enough to do it.

Every part of each tuned radio frequency stage is just like the corresponding part in each other stage. Therefore, when such a set is properly designed and built we can have all the condensers alike and can work them all together so that they all have the same capacity at any one time.

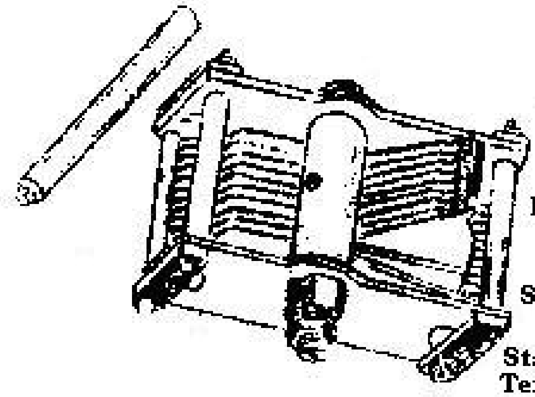

Fig. 24

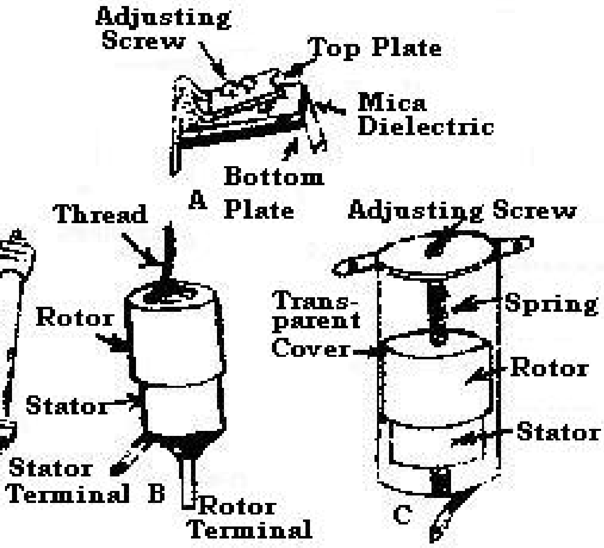

Fig. 25

A typical gang condenser containing three tuning sections is shown in Figure 22. All of the rotor assemblies are attached to the one long shaft. Turning this shaft moves all the sections together. Using a common shaft connects all the rotors together electrically. This works out all right because the rotor side of all condensers is connected to the “B-minus” or the grounded side of the circuit in practically all receivers. Each stator plate assembly is thoroughly insulated and separated from all the other stators. The symbol for such a condenser, showing the electrical connections, is shown in Figure 23. The broken line shows that all the rotors are connected together.

It is not always convenient to have the several condensers all in one place; it may work out better to have the different ones separated by some space. Then a type such as illustrated in Figure 24 can be used. This condenser has a hole right through the centre of the rotor shaft from end to end. The separate condenser units may be mounted anywhere, just so they are in line with one another, and a single long shaft pushed through al of them. There are one or more set screws in the hollow rotor shafts of each condenser section and after the rotor plates are properly adjusted for position this screw is tightened down, fastening the rotor to the long shaft.

To successfully use a gang condenser of any kind requires exceedingly accurate workmanship and uniformity of materials in the radio frequency amplifier. You can realise that the slightest difference between coils, the least difference between the layout of the wiring or the slightest change between one condenser unit and another will throw the tuning all out of gear. Any of these things will make some slight change in either the capacity, the inductance, or both. Then the different stages will not tune together. One or two will be resonant at a frequency while the others are more or less off resonance. Then you will get only part of the amplification that the set should give because, of course, the voltage falls away off when you get a little bit off the resonant point.

In order to allow for slight variations in wiring and in other parts of different tuning stages, most gang condensers have fitted to each section a small extra condenser connected in parallel with the main tuning condenser section. This small condenser is generally called a “trimmer”, a “compensator” or some similar name. One kind of trimmer condenser is illustrated in Figure 25a. It uses mica for the dielectric between the plates and secures a change of capacity by pressing the top plate down closer to the lower one by means of a screw. The plates are normally held apart by the springiness of the top plate. Turning the screw down forces the plates closer together and increases the capacity. Two other kinds of trimmer condenser are shown at “b” and “c”. Both, are air dielectric types. Capacity is changed by screwing two cylindrical sections one into or out of the other. Screwing the sections together increases the capacity.

Adjustment of 25(b) is by rotation of a small nut attached to the movable outer cylinder. Adjustment of 25(c) is by a screw set in the top of the enclosed assembly. Movement of the screw pushes or pulls the outer cylinder in or out.

The one illustrated at 25(c) is totally enclosed against dust and other foreign matter.

The symbol for a gang condenser equipped with small trimming condensers is shown in Figure 26. Around each main tuning section, in parallel with it, is connected one of the small trimming condensers. Those small condensers have maximum capacities of only a few micro-microfarads. After the receiver is ready for test, if it is found that that all tune exactly together, the auxiliary condenser for the stage out of line is altered in capacity just enough to make the needed correction. In many circuits the trimmer condensers are not

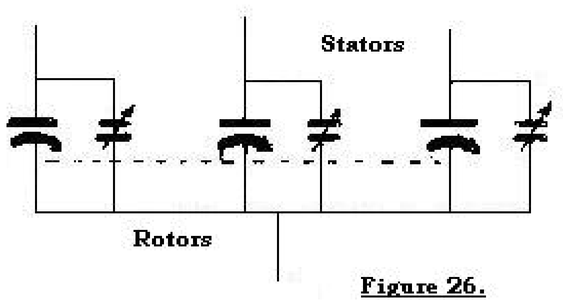

Figure 26.

actually shown connected to the condenser gang, but are completely omitted, it being understood that all modern sets use trimmer condensers either on the gang itself or connected to the coils.

TUNING DIALS.

The subject of tuning dials is really a mechanical one. A tuning dial has no electrical action and by simply looking carefully at these devices, you can always see how they work and what is wrong, if any-thing.

When tuning closely for distant stations the job is much easier if the condenser rotors are moved only a very little distance at a time. To allow this you often find some sort of reduction gear between the knob which is turned by the operator and the main dial and shaft which operate the condenser rotors. Flexible cords running over pulleys are very popular for this work. Other devices include toothed gears or friction wheels, all of which are designed so that it requires several turns of the tuning knob to move the condenser rotors from their fully meshed position to the position where they are completely out of mesh. Those connections which reduce the motion of the condenser shaft are sometimes called “verniers”.

Yet another arrangement not often used nowadays, was to arrange the condenser at right angles to the front panel and to use a large circular, semi-circular or rectangular dial with a friction drive. Most dials are usually illuminated from the side by means of one or more small electric lamps similar to those used in torches. Power for the lamp is usually derived by connecting them to the source which supplies the filament or heater of the amplifying tubes.

Many older types of radio receivers are fitted with dials which have no station call-signs but are merely numbered 0 to 100. One may sometimes be tempted to “modernise” one of these receivers by fitting a new dial inscribed with station call-signs. However, any move in this direction should be carefully considered before actually making the replacement. If the receiver is a very old one, say of mid-1930 vintage, and there are still some receivers of that period in active use the result of such replacement is likely to be very disappointing.

Modern dials have a frequency calibration and, consequently station call-sign spacing which is related to a modified straight line frequency characteristic condenser having a capacity range of about 11 to 410 micro-microfarads. If we fit such a dial to a receiver tuned by condensers having different frequency capacity characteristics, and a noticeably smaller capacity range, considerable difficulty will attend any attempt to make the dial pointer coincide with the call-sign of the station to which we happen to be listening. In most cases it would probably be possible to achieve the desired result at one end of the dial but then ore would find that the pointer would come nowhere near a required station's call-sign at the other end of the dial, or perhaps, even in the middle of the dial.

If it is particularly necessary that the replacement be made, reasonably satisfactory tracking will be achieved if the tuning condenser is also replaced by one suitable for use with the new dial, in which case some mechanical modification would undoubtedly be necessary because modern tuning condenser gangs are much smaller than those employed twenty or more years ago.

The products of present day condenser manufacturers are so similar in characteristics that we need not worry unduly about using a dial expressly designed for a particular condenser, but we most certainly should be careful about fitting a modern dial to an old receiver.

In this lesson we have gone quite deeply into the matter of tuning condensers and their action. The condenser is one-half the oscillatory circuit allows us to pick out the station we wish to hear. The other half is the coil or the inductance. One part of the resonant circuit is just as important as the other, the coil is just as important as the condenser, and the condenser is just as important as the coil.

EXAMINATION QUESTIONS No. 16.

1. Do you increase the capacity of a condenser as you tune to higher frequencies or to lower frequencies? Explain.

2. If the maximum capacity of a tuning condenser is 350 micro-microfarads, about what should be its minimum capacity?

3. Do the stator plates move or stand still.? Are they connected to, or insulated from the condenser frame?

4. Should the insulation of a tuning condenser be close to or far from the plates?

5. Can an old receiver be fitted with a modern dial showing station call signs, without any other modifications? Explain.

6. With a straight line capacity condenser are the stations crowded together at the high frequencies or at the low frequencies?

7. With a straight line frequency condenser does the capacity increase rapidly just as the plates start into mesh or when they are almost all the way in mesh?

8. if there is a separation of 20 dial divisions between stations l00 kilocycles apart when using a straight, line frequency condenser, how many divisions will there be between stations 50 kilocycles apart?

9. In addition to the capacity of the tuning condenser itself, what other capacities affect the range of frequencies to which a resonant circuit will tune?

10. If two condensers, one of 100 mmfds, and one, of 500 mmfds, capacity are connected in series, what will be their combined capacity?

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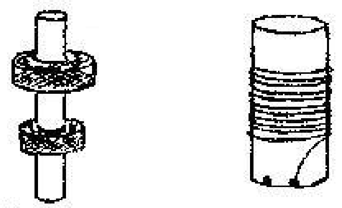
LESSON NO. 17

COILS AND THEIR FUNCTION IN RADIO


Broadcast Coil.

Short Wave Coil.

FIGURE 1.

The coils we use in radio are given the job of forcing the alternating currents to give up part of the energy being carried through the circuit. As those currents flow through the coil we have voltages produced or differences of potential produced across the coil from one end to the other. It is the coil's reactance to alternating current which makes the current work for us.

A coil has reactance because of the coil's inductance. Inductance is the ability of a coil to generate voltage within itself if or to generate voltages in some nearby circuit when there is a charge of the current, flowing in the coil.

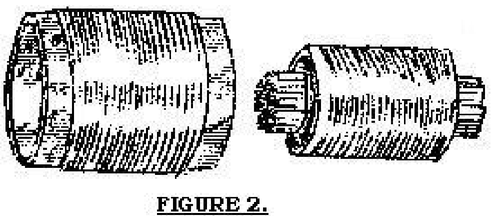


FIGURE 2.

Any coil of wire has inductance in radio transmitters and receiver we make use of many different kinds and shapes of coil. In radio receivers the most noticeable coils are those used in resonant circuits which tune the receiver to various stations. These are the coils you can see in Figure 1 and they are the kind we are going to investigate in this lesson. Frequently these coils are enclosed in a metal screening "can" and so are not readily visible. Even if the "can" is removed from a modern tuning coil it is generally still invisible because of a complete coating of moisture excluding wax.

One kind of coil which may be used in parts of radio sets carrying high frequency or radio frequency currents is shown at the, left hand side of figure 2. This coil consists of a single layer of wire wound evenly and closely on the outside of a piece of tubing which is made from insulating material. We call this a single layer "solenoid coil".

Inside of the winding tube of the left hand coil in Figure 2 there is nothing but air. The inside, or the core of this coil is of air --- therefore, it is called an "air-core coil". At the right hand side of Figure 2 is a coil wound around a bundle of iron wires. This is called an "iron-core coil". Most coils used for carrying currents at radio frequencies are of the air-core type. The coils used in the audio frequency circuits and in the circuits handling power current at house lighting frequencies are of the iron-core type.

<u>THINGS WHICH AFFECT INDUCTANCE.</u>

The inductance of a coil depends on the number of turns of wire, on the length of the windings and on the diameter of the winding. Now, to this list, we will add two more things which have their effect on the coil's inductance.

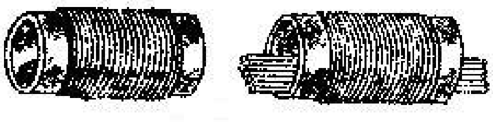


Fig.3

Were you to test the air-core coil shown at the left hand side of Figure 3 you would find that it has very little inductance because it is a small coil and has only a few turns of wire. Then, taking a handful of iron wires or rods, you might slip some of them inside the coil as at the right hand side of Figure 3. The effect of the iron would be to immediately increase the coil's inductance. The more iron you put inside the coil, the greater the inductance will become.

The reason for thin action is very simple. Iron carries magnetic lines of force ever so much easier than air carries them. Therefore, with a given amount of power used in the coil, the iron will allow the production of many times the number of lines of force. The greater the number of lines, the greater the voltage generated and since the voltage is in proportion to the inductance we must have mere inductance, so the kind of material in and around the coil changes the inductance.

Now we come to the last thing affecting a coil's inductance -- this being the "shape factor". The shape factor turns out to be nothing more than a number, a number which depends on the ratio of the coil's diameter to its length. A. "ratio" is the relation of one thing to another written out in the form of a fraction. The ratio of diameter to length means the number which you get by dividing the diameter by the length. Thus, if the winding of a coil has a diameter of 4 inches and this winding is 2 inches long, you divide 4 by 2 and get as a result the number 2, which is the ratio. If the coil happened to be 2 inches in diameter and 4 inches long, you would divide 2 by 4 and get 2/4 which is equal to 1/2 or, in decimals is equal to 0.5 -- the ratio of the 2 inch diameter to the 4-inch length.

At the und of this lesson you will find a table or list of shape factors corresponding to various ratios of diameter to length. To use this table you divide the diameter of the winding in inches by the length of the winding in inches. This gives you the ratio. Then you find thin ratio in the table and opposite it you will find the shape factor number. If the ratio you get is between two of these numbers you can use a shape factor between the two.

All of our calculations here refer to single layer, close wound cylindrical coils like the type shown at the left hand side of figure 2. This is the most generally used kind of coil, and, for a given amount of wire, gives us the most inductance.

In figure 4 you can see all the things which affect the inductance of a coil, at least all which affect the inductance of the kind of coil we are investigating just now.

Notice that the "length of winding" has nothing whatever to do with the length of the piece of tubing on which the wire is wound. The winding length is the distance from one end of the wire part to the other end of this part. The "diameter" is the distance from the centre of a wire on one side of the coil to the centre of a wire directly opposite. You can see what I mean by the dimensions marked "D" in the right hand drawing. The "radius" is the distance from the exact centre of the coil out to the middle of one of the wires in the winding -- the dimension marked "r" in the right hand drawing. The radius is equal to one-half the diameter. In determining these dimensions of the coil we are considering the wire winding only and do not take into account the form or tube carrying the winding.

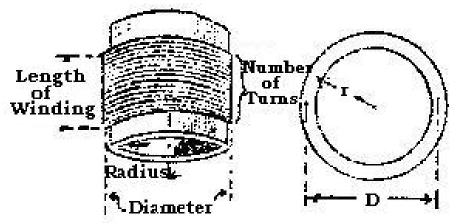


Fig. 4

As with everything in radio we can calculate the result of sizes and shapes by using a formula. Here is the way in which we work out the inductance of a coil:-

$$\text{Inductance in Microhenrys} = \frac{(\text{number of turns})^2 \times (\text{radius})^2 \times (\text{shape factor})}{\text{Length of winding} \times 10}$$

This formula says to square the number of turns, square the radius, multiply those two together and multiply the result by the shape factor. Then you divide that number by ten times the length f the winding. All dimensions are taken in inches.

Take this formula as an example: There are any number of things which it will tell you. Among other things it says that the inductance of the coil depends not on the number of turns directly, but on the square of the number of turns. The left hand coil in Figure 5 has 20 has 20 turns and the right hand one has 40 turns. Other wise they are alike, anyone would say that the right hand coil would have twice the inductance of the left hand one. But the formula says to square the number of turns, to multiply the number by itself. So you square 20 and get (20x20) 400. Then you square 40 and get (40 x 40) 1600.

So with no other difference between the coils except twice the number of turns in one of them, that one will have four times instead of twice the inductance.

Then take the coils of Figure 6. The only difference between them is that the left hand one is 4 inches in diameter and the right hand one is 2 inches in diameter. Then since the radius is half the diameter, they have radii of 2 inches and 1 inch. The formula (1) tells you that the inductance is in proportion to the square of the radius.

Squaring the left hand coil's radius gives (2x) 4, while squaring the radius of the right

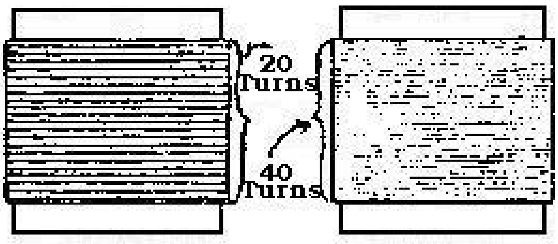


Fig. 5

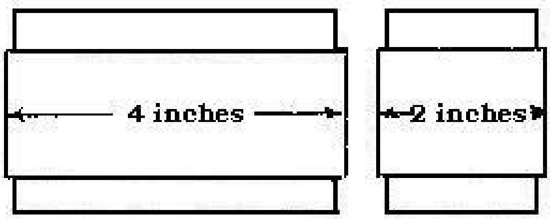


Fig. 6

hand coil gives (lx1) l. The left hand coil will have four times the inductance of the right hand one, yet has only twice the diameter or radius.

Once more look at the formula. You see that the "length of winding" is underneath the line. Any quantity underneath the line has an entirely different affect on the result from the effect of quantities above the line. To illustrate what is meant take the following fractions:

$\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{10}$ $\frac{1}{100}$

You know that one-fourth is smaller than one--half, that one--tenth is smaller than one-fourth, and that one one-hundredth is smaller than one-tenth. Now you see that the <u>larger</u> quantity below the line, the smaller is the real value of the expression. Then look at the following quantities:

$\frac{4}{2}$ $\frac{6}{2}$ $\frac{10}{2}$ $\frac{100}{2}$

We have four halves, then six halves, then ton halves, and. finally one hundred halves. These are equal to the quantities 2, 3, 5 rind 50. So you see that the, larger the quantity above the line, the <u>larger</u> is the final result.

Thon, since the "length of winding" is below the line, we know that the greater the length or the longer the coil, the smaller will be its amount of inductance, all other things remaining the same. We can also tell that increasing the number of turns or increasing the radius will increase the inductance because these things are written above the line in our formula.

This formula for inductance has been taken and some of the things it tells you have been explained. Any other formula is equally instructive. If you examine them carefully and work out what effect a change in one quantity will have on the result you can learn all manner of useful facts.

Now we'll use the formula to work out the inductance of the coil in Fig, 7. We have 68 turns of number 30 double silk covered wire a length of 1 inch and having a radius of 1 inch. Dividing the diameter by the length (2 divided by 1) we get 2 for the ratio. The shape factor table gives, for the ratio 2, a shape factor of 0.526. Then we fill in the formula this way:

$$\frac{68^2 \times 1^2 \times 0.526}{1 \times 10} = \frac{4624 \times 1 \times 0.526}{10} = 243.2 \text{ microhenrys}$$

So we learn that the inductance of this coil is about 24343 microhenrys.

What good does it do to know the inductance? Among other things it tells what size tuning condenser to use. You were told that the "oscillation constant" for 550 kilocycles is the number 83,730. To find the required tuning capacity in micro microfarads you divide the oscillation constant by the inductance in microhenrys.

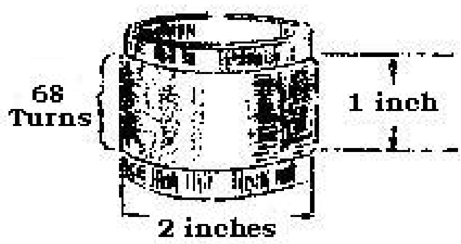


Figure 7.

Dividing 83,730 by 43 (microhenrys) gives approximately 345 micro-microfarads. One of the standard tuning condenser capacities is 350 micro-microfarads or 0.00035 microfarads -- so of course that is the tuning condenser to go with this coil of Figure 7.

EFFECT OF TUNING COIL INDUCTANCE.

The greater the inductance of the coil or the less the capacity of the condenser in a tuned circuit, the greater will be the voltage developed across that circuit. This means that a bigger coil or one of greater inductance will increase the amplification. The amplification depends not only on the tube used but, also on the voltage drop in the circuit connected to the tube's plate.

It is possible, as you know, to use various combinations of inductance in the coil and capacity in the condenser to tune to the same frequency. In broadcast reception we can use any of the standard condenser with suitable coils and tune from 550 kilocycles to 1500 kilocycles. Here is a list of corresponding condenser and coil sizes with the reactances of the coil at 1500 kilocycles.

Condenser Capacity In Micro-Microfarads	Coil Inductance In Microhenrys	Coil Reactance in Ohms At 1500 Kilocycles
250	340	1500
300	285	2688
350	245	2311
400	215	2028
500	175	1651
1000	85	802

A reactance of 1500 ohms is considered to give good results in amplification. More reactance (due to greater inductance) is not objectionable and in fact gives greater amplification provided we do not run into other troubles such as oscillation. These will be explained in a later lesson. A tuning condenser of 500 micro-microfarads capacity is about the largest that will give really good amplification, that is, amplification that compares well with the average good receiver.

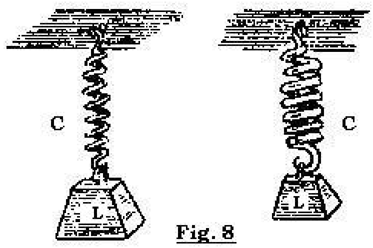


Fig. 8

To make a mechanical comparison with electrical actions in a resonant circuit you can always compare the inductance to a weight and the capacity to a spring. If, as at the left in Figure 8, you have a heavy weight (large inductance) with a comparatively small spring (small capacity) a pull on the weight will set it into oscillation which will be powerful and

which will continue for quite a long time. The lighter weight attached to a stiff spring, or the smaller inductance with a large capacity, as at the right hand side of Figure 8, will have shorter oscillations and these oscillations will die away quite rapidly. The advantage is with the resonant circuit made up of a large inductance and small capacity rather then with the one containing a large capacity and small amount of inductance.

INDUCTANCES IN SERIES AND PARALLEL

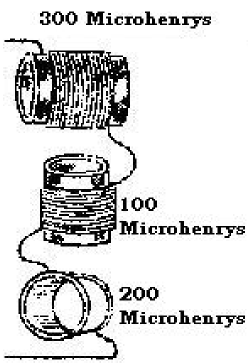


Figure 9.

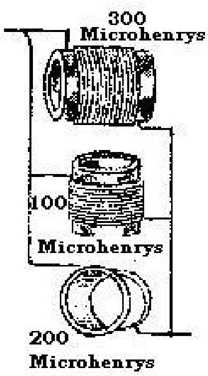


Figure 10.

The three inductance coils of Figure 9 are connected together in series. That is all current flowing through any one of them must also flow through the others. We will assume that the three cols have inductances of 300 microhenrys, 100 microhenrys and 200 microhenrys. The total inductance of the three, connected in series is 300 plus 100 plus 200, or 600 microhenrys. Inductances in series add together just as resistances in series add together.

In Figure 10 we have the same three inductances in parallel so that the total current flowing through each of the coils. The case here is similar to that with

the parallel resistances. The inductance of the three coils combined in a parallel circuit is lass than the inductance of the smallest one of the lot. To figure out the combined inductance we add the reciprocals of the separate inductances and this gives us the reciprocal of the total inductance. A “reciprocal” of any number is “1” divided by that number. Thus the reciprocal of 2 is ½ (which is 1 divided by 2). The reciprocal of 10 is 1/10 (or 1 divided by l0.)

As an example we will calculate the total inductance of the three coils of Fig. 10.
The reciprocals are added as follows:

$$\frac{1}{300} + \frac{1}{100} + \frac{1}{200} = \frac{1}{\text{Inductance}}$$

To add those fractions we have to change them over like this:

$$\frac{2}{600} + \frac{6}{600} + \frac{3}{600} = \frac{11}{600}$$

So we have 11/600 as the reciprocal of the inductance. We turn this fraction upside down, giving 600/11 as the inductance. This cancels out to 54, 6/11 microhenrys inductance for the throe coils in parallel. Therefore inductances in parallel reduce the total inductance to an amount smaller than the smallest of the separate inductances.

<u>OTHER THINGS AFFECTING INDUCTANCE</u>

The items which we have considered are those which have he principal effect on a coil's inductance and they are the ones s ordinarily considered when we work out the inductance in building or remodeling a radio part. There is however, several other things which have a slight effect on inductance.

Frequency changes the apparent inductance of a coil. As the frequency increases, the inductance appears to increase with the frequency. The following list shows how one coil's apparent inductance increases over the broadcast band of frequencies:

Apparent, Inductance at 550 kilocycles . . . . . 300 microhenrys
Apparent Inductance at 700 kilocycles . . . . . . 306 microhenrys
Apparent Inductance at 1000 kilocycles . . . . . 320 microhenrys
Apparent Inductance at 1500 kilocycles . . . . . 355 microhenrys

In order to make up for the greater inductance at the high frequency, the tuning condenser's capacity at this frequency must be still smaller than you would naturally expect. The greater the inductance the smaller must be the capacity to tune to a given frequency. This frequency effect means that the condenser must be able to get down to a smaller minimum capacity than would be the case were the inductance to remain unchanged.

In addition to their inductance all coils have some capacity as well. There is capacity between the different turns of a coil because those turns are metal and they are separated by insulation (a dielectric). This makes a condenser. The resulting capacity is called "distributed capacity" because it is distributed all through the coils winding. We will study distributed capacity a little later on.

This distributed capacity helps to make the coil's inductance appear larger than it really is as the frequency is increased.
Now we will see something that makes the coil's apparent inductance smaller than its real inductance. If the coil, of Fig, 11 has an actual inductance of 300 microhenrys

placing the metal plates in the position shown will make the inductance seem or act as though it were somewhere around 290 microhenrys. Most modern receivers use metal "shielding" around coils and other parts and the effect of this shielding is to reduce the apparent inductance of the coils. Then larger tuning condensers must be used to obtain resonance at a frequency. Providing the shielding is correctly spaced from the coil it does not make a very great change in the apparent inductance.

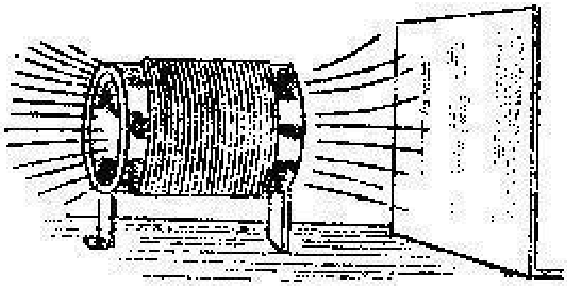


Fig.11

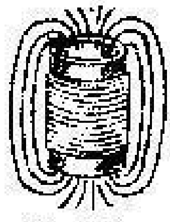


Fig. 12

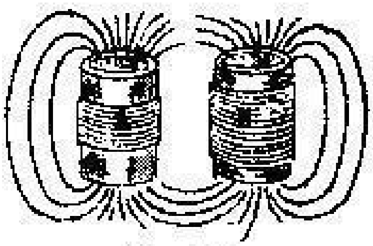


Fig. 13

MUTUAL INDUCTANCE.

The coil of Figure 12 has self inductance, the kind of inductance we have been studying so far. The self-inductance causes voltage to be generated when a change of current makes the lines of force rise and fall. Self-inductance considers the lines of force which cut through the conductors of the coil producing the lines.

The two coils of Figure 13 are placed close together and lines of force generated in either one of them will cut through the wire winding of the other one. Change of current in coil "A" will not only cause a voltage to be generated in coil "A", but the moving lines of force will cause a voltage to be generated also in coil "B". We have self inductance of coil "A", we have the self-inductance of coil "B", and in addition we have the "mutual inductance" which is a property of the two coils together. Mutual inductance is the property or ability of a coil to produce a voltage in another coil.

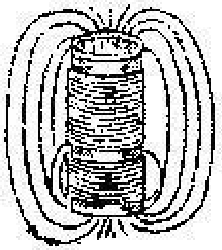


Fig. 14

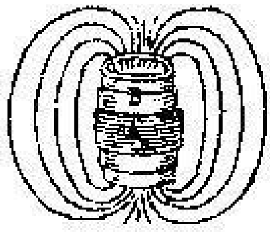


Fig. 15

The coils "A" and "B" may be placed end to end on a single piece of tubing as in Figure 14. Then nearly all the lines of force from one of the coils will pass through the conductors or turns of the other one. The amount of mutual inductance depends on the number of lines which link through both coils, consequently we have much more mutual inductance in Figure 14 than in Figure 13.

Mutual inductance is measured in the same units we use for self-inductance, namely, the henry, the millihenry and the microhenry.

In Fig. 15 coil “A” is wound right over the middle of coil “B” and right on top of “B”. This gives the greatest possible mutual inductance for any ordinary construction because nearly all the lines from one coil must link with the other one.

The amount of mutual inductance depends on how close the two coils or two circuits are to each other. They are closer in Figs. 14 and 15 than they are in fig. 13 and we have more mutual inductance the closer we get the circuits to each other.

The amount of mutual inductance depends also on the size of the two circuits or coils. Big coils or coils having large amounts of self-inductance in themselves will have much more mutual inductance when brought together than smaller coils will have.

The shape or design or construction of the two coils or circuits has a great deal to do with the amount of mutual inductance between them. If a coil is built so that its field spreads out a little way, than the, lines composing the field won’t link very well with other circuits and the mutual inductance will be lessened.

Ordinarily, two coils placed end to end as in Fig, 16 would have a considerable amount of mutual inductance because the field of one would pass through the turns of the other. But if a sheet of metal be placed between them as shown, there will

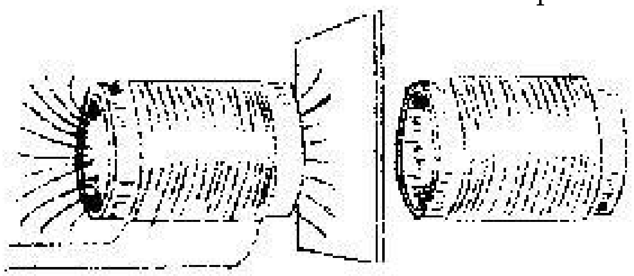


Figure 16.

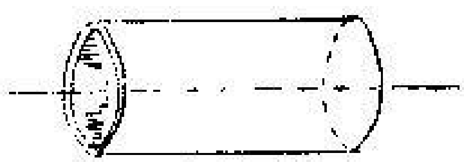


Figure 17.

be little or no mutual inductance. The lines will pass into the metal, will produce voltages in the metal instead of the neighboring coil, and the two coils will have practically no effect an each other.

Now we come to one of the most important things affecting the amount of mutual inductance between two coils -- the angle between their axes. The axis of a coil is a line drawn from end to end through the centre, as the line “A-B” in Fig. 17. The plural of the word “axis” used when speaking of more than one, is the word “axes”.

In Fig, 18, the line “A-B” forms the axis of both coils. The axes of these two coils run together and form a single line. For a given distance apart of those two coils this single axis gives the greatest mutual inductance. If the coils are moved closer there will be more mutual inductance if they are moved farther apart there will be less mutual inductance, but as long as you keep the separation “1” between the coils, the single axis arrangement gives the most mutual inductance.

In Fig. 19 one coil has axis “A-B” and the other has axis “C-D”. These two axes run in the same direction, they are parallel, but they don't form one single line. This arrangement gives less mutual inductance than the arrangement of Fig, 18. If the separation “l” in Fig. 19 is the same as the separation “1” in Fig. 18 separating the axes as in Fig, 19 will reduce the mutual inductance between the two coils

In Fig. 20 one of the coils has axis "A-B" and the other has axis "C-D". The two axes cross each other at "X". They are at an angle to each other. The amount of mutual inductance between these two coils depends on the angle between their axes.

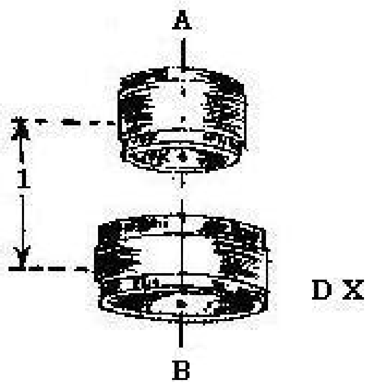


Fig. 18

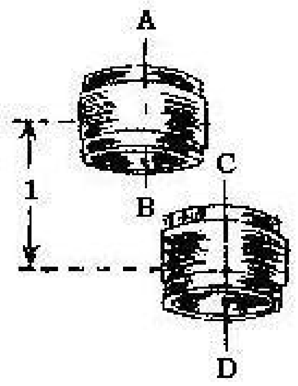


Fig. 19

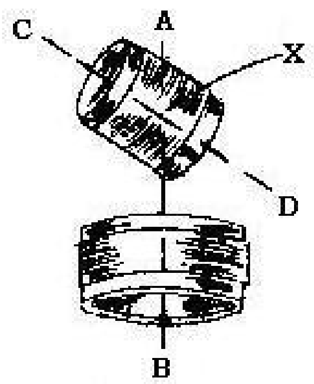


Fig. 20

In Fig. 21 we have the two coils of Fig. 20 with no angle or a zero angle between their axes. This, of course, gives the greatest possible amount of mutual inductance because most of the lines of force from each coil cut the conductors of the other coil.

In Fig. 22 the axes of our coils have been turned at an angle. The axis of one coil, line "A-B", is crossed by the axis of the other, line "C-D", at the point marked "X", Then we have the angle "A-X-C". In Fig. 22 we have about three-quarters as much mutual inductance as in Fig. 21.

In Fig. 23 the axes of the two coils have been turned to a greater angle. Axes "A-B" and "C-D" still cross at "X", but now the angle "A-X-C" is greater than it was in Fig.

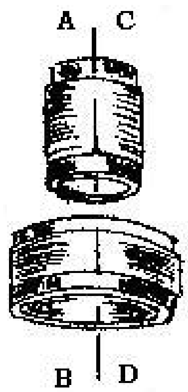


Fig. 21

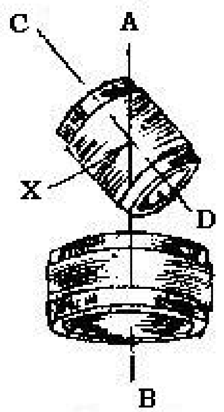


Fig. 22

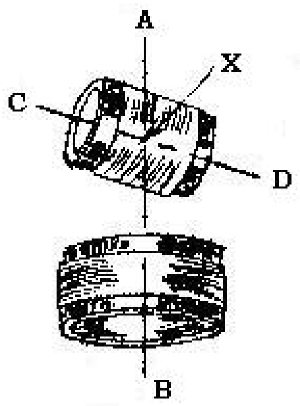


Fig. 23

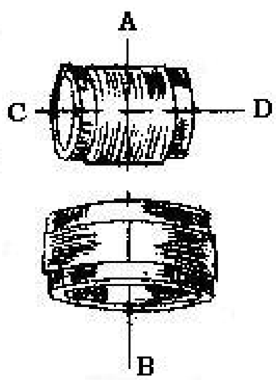


Fig.24

22. This greater angle reduces the amount of mutual inductance which here is about one third as much as it was in fig. 21. The greater the angle between

The coils, the fewer lines of force from one of them can cut the conductors of the other.

In Figure 24 The axes “A-B” and “C-D” cross each other at a right angle, they make a square corner. This is the position of least possible mutual inductance between any two coils. If the axes of one crosses the axis of the other, and If the crossing is a right angle, very few lines from one coil will generate voltage in the other.

COUPLING.

When any two circuits are arranged so that the change of current flowing in one causes voltage in the other, the two circuits are said to be “coupled.” With two coils having mutual inductance, change of current in one of them causes lines of force which cut the conductors of the other coil and generate a voltage in that the other coil. Therefore, two such coils are coupled and have coupling with each other.

All of the pairs of coils in Figure 13 to 24 are coupled by means of the lines of force which are “mutual” to both or which cut through the conductors of both. This coupling effect is due to the inductance of the coils because the inductance produces the lines of force which do the coupling. For this reason we call these couplings by the name “inductive coupling”.

If you take the two coils separates by a great distance from each other, each one alone has self-inductance – it is capable of generating a voltage within itself. If you move these two coils towards each other they will commence to have mutual inductance. The closer they are brought to each other, the more the mutual inductance between them.

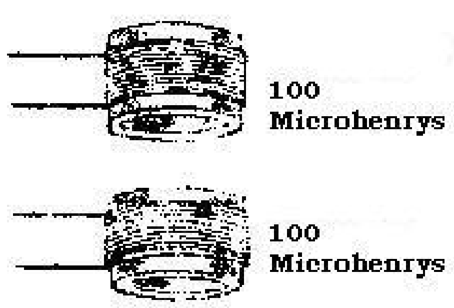


Fig. 25

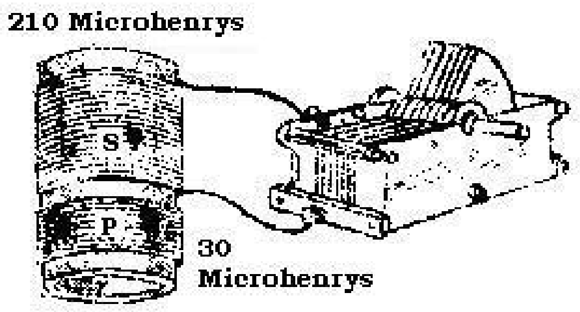


Fig. 26

The two coils then have their self-inductance and also have mutual inductances. The total amount of inductance is then more than the sum of the two self-inductances; it is the sum of these separate inductances plus the mutual inductance. You might take the two coils of Figure 25, each having a self-inductance of 100 microhenrys, and couple them as shown. Upon measuring the inductance of each coil you might find that it had increased to 130 microhenrys and in place of the combined inductances being 200 microhenrys (100 plus 100) it would be 260 microhenrys. The increase is due to mutual inductance which is added to the inductance of each coil.

Suppose you built the tuning coil marked “S” in Figure 26 and connected it to the tuning condenser. Before adding the primary coil "P" though, inductance of the secondary "S" might be 210 microhenrys. But just the minute you added the primary with its own microhenrys, the mutual inductance would get to work and in place of the 210 microhenrys of the secondary you would have something more than 210 microhenrys, you would have added the mutual inductance to the original self-inductance of the secondary and you would change the tuning of the condenser.

Every time you change the coupling and thereby change the mutual inductance between two coils used for tuning a circuit you will change the tuning points of the condenser. If the condenser tunes the circuit to resonance at 600 kilocycles with a dial setting of 80 and you increase the coupling between primary and secondary, you will find that it takes less capacity and you will get the same 600 kilocycles resonance with a lower dial setting.

AMOUNT OF COUPLING.

If two circuits are coupled together so that change of current in one of them makes a considerable voltage in the other one we say that the circuits are "Close coupled" or that the coupling is close or "tight". If change of current in one of them makes only a little voltage change in the other we say that the circuits are "loose-coupled" or that the coupling is loose.

Any device which allows coupling between two circuits is sometimes called a "coupler". This word is more often applied to parts coupling the antenna circuit to the tuned circuits of the receiver than to parts used between two tubes within the set. If the coil "P" in Figure 26 were connected to antenna and ground the whole device, consisting of coils "P" and "S" together with the tubing on which they are wound, could be called an antenna coupler. There is no provision for easily varying or changing the amount of coupling between the two coils in Figure 26, so this particular job could be called a "fixed coupler".

If one coil is mounted, as in Figure 27, so that it may be moved with reference to the other one we can change the amount of mutual inductance and the amount of

Fig. 27

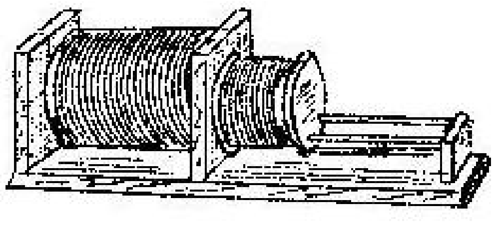


Fig. 28

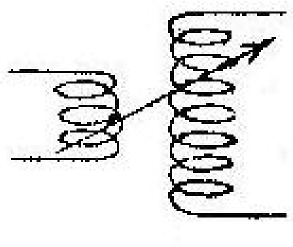


Fig. 29

coupling as was done in Figures 21 to 24. We can vary the amount of coupling and so we call such a device a "variable coupler". The name "vario-coupler" was once used to mean the same thing as variable coupler.

If two coils have the same line for their axes, bringing them closer together along this line will increase the mutual inductance and increase the coupling, while moving the coils further apart will reduce the coupling. A device for thus sliding one coil within another is shown in Figure 28. This is called a "slide coupler".

The slide coupler was used a great deal in some of the early crystal sets, but is now used chiefly for experimental work. The symbol for a variable coupler such as the types shown in Figures 27 and 28 is shown in Figure 29. The symbol shows the two coils with an arrow drawn through them. In radio symbols an arrow always means that the device may be altered while it is being used.

The amount of mutual inductance, and consequently the amount of coupling, depends on the self-inductance of the coil. The more self-inductance, the more mutual inductance and more coupling, with another coil. You also know that the inductance depends on the number of turns, the more turns the greater the inductance. So, by altering the number of turns, we can alter the coupling because we alter the inductance. This is what the device of Figure 30 accomplishes.

In Figure 30 we have a tap switch consisting of a movable arm which may be placed in contact with any one of a number of contact points numbered from “1” to “5”. These taps are connected to the switch contacts. Current through the primary flows from “A” to “B”. The switch arm is set on contact “3” therefore current flows from “A” goes to the top of the primary winding, then through all the turns between “A” and “3”. From tap “3” the current goes over to the switch, through the contact, into the switch arm and to wire “B”. we are then using all the primary turns between points “A” and “3” but are not using the turns between “3” and “5”. If the primary consists of 25 turns, with 5 turns between each two taps, we have 15 turns working between point “A” and point “3”.

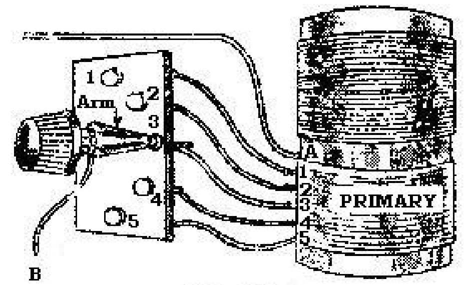


Fig. 30

Now if the switch am is turned up to point “ 1 ”, current through the primary can flow only through the five turns between points “A” and “1” on the coil. If the arm is moved all the way down to point “5” we will use the whole 25 turns Between point “A” and “5”, because current from “A” must go through all these turns to reach wire “B”. Thus moving the switch arm changes the number of turns which carry current and do work. This changes the primary coil's inductance and its coupling with the coil above it. This arrangement, in a considerably refined form, is used in the tuning section of same television receivers.

There are still other ways of using a part of any winding. One method is shown in Figure 3. Here we have a slider contact moved along a part of the winding which is bared of insulation. Current entering through wire “A” will go through the rod, into the slider, and will enter the coil at point “X” where the slider is making contact. This current will then flow through that portion of the coil between point “X” and the right hand end where it flows out through wire “B”. The part of the coil between “X” and the left hand end is not used. The amount of the coil being used, or the number of turns being used, depends on the position of the slider. This changes the inductance of the coil and the amount of its coupling; to any other coil.

In certain types of transmitting sets you will find coils made of copper tubing as in Figure 32. Connections to such a coil may be made with a spring clip as used on Wire "A". Then current will flow only in that portion of the coil between the clip and the terminal. All the turns above the clip being unused, or else used in another part of the circuit. This is still another method of varying the amount of coupling. The symbol for couplings such as shown in Figures 31 and 32 is shown in Figure 33. Variable coupling devices are very seldom used in modern receivers, but are frequently found in old sets which you may be called upon to service at some time.

COEFFICIENT OF COUPLING.

The words "Loose coupling" and "close coupling" are not very definite. We have a definite measure of the amount of coupling, a measure which can be calculated. It is called the "coefficient of coupling" or the "coupling factor"

The closest possible: coupling is indicated by the number "1". This is called unity coupling. No matter how close the coupling, no matter how much the mutual inductance, the coupling can never be greater than "1". We indicate less amounts of coupling by decimal fractions. Thus, half as much coupling as unity coupling is indicated by 0.5

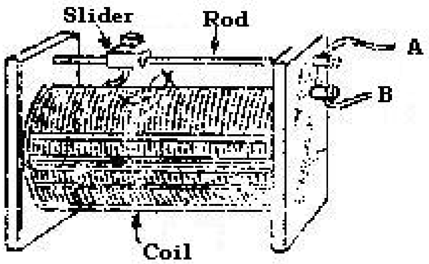


Fig. 31

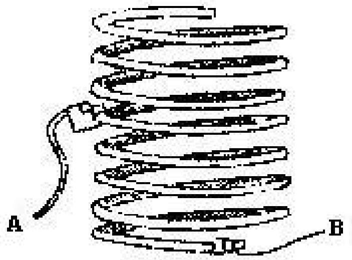


Fig. 32

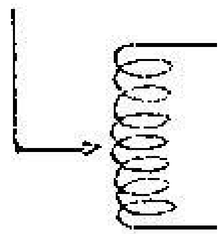


Fig. 33

which is the decimal fraction "five-tenths" or one half. A still smaller coupling would be indicated by the factor or coefficient 0.3, which is three-tenths.

These coupling factors may also be written as percentages. Thus, a coupling of one-half or 0.5 may be written as 50 per cent because fifty per cent of anything is one-half of it. Then a coupling of 0.3 would be 30 per cent and so on.

The official (Institute of Radio Engineers) definition of coefficient of coupling is as follows:-

"The coefficient of coupling is the ratio of the mutual or common impedance component of two circuits to the square root of the product of the total impedance component of the same kind in the two circuits. (Impedance components may consist of inductance, capacity or resistance)".

Following is the formula as arranged for inductive coupling:

$$\text{Coefficient of Coupling} = \frac{\text{Mutual Inductance}}{\sqrt{\text{first inducatnce x second inductance}}} \quad (2)$$

The inductance may be measured in any unit - henrys, millihenrys, or microhenrys. But you must use the same unit all through the formula. If you use microhenrys to measure mutual inductance, you must use microhenrys to measure the inductances of the first circuit and of the second circuit.

Let's calculate the coupling factor for the coils in Figure 34. The left hand winding has an inductance of 32 microhenrys and the right hand one an inductance of 200 microhenrys. Their mutual inductance is 20 microhenrys. Putting these values into the formula, we have:

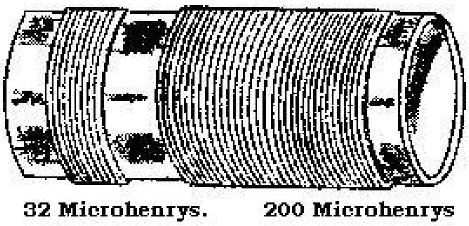


Fig. 34

$$\frac{20}{\sqrt{32 \times 200}} \quad \frac{20}{\sqrt{6400}} \quad \frac{20}{80} =$$

1/4 or 25 per cent.

<u>FINDING THE MUTUAL INDUCTANCE.</u>
In the example just worked out we found the coupling factor to be 25 per cent, But to do this we assumed that the mutual inductance is 20 microhenrys.

There is no simple method of calculating the mutual inductance between two circuits.

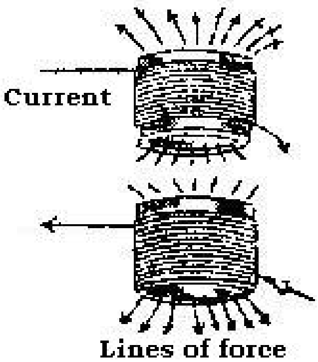


Fig. 35

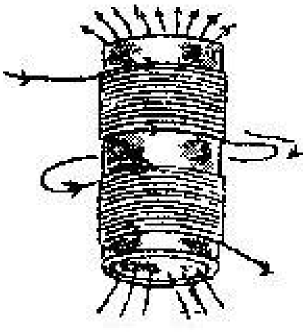


Fig. 36

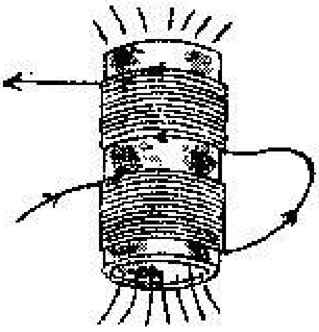


Fig. 37

We generally measure the actual inductances and from them learn the mutual as will be shown.

At the top of Figure 35 current is flowing around the coil winding in the direction shown by the arrow marked “current”. This direction of current flow makes the lines of force come out of the top of the coil and re-enter the bottom. At the bottom of Figure 35 the direction of current has been reversed in its flow around the coil. This reverses the direction of the lines of force and now they come out at the bottom of the coil.

In Figure 36 the two coils are connected so that current flows around both of them in the same direction as shown by the arrows. The lines of force generated in one coil add their affect to the line of the other coil. The two sets of lines or the two fields help each other.

In Figure 37 the same are connected so that current flows one way around the top one and the opposite way around the bottom one. Now the lines of force from one coil oppose those form the, other coil because the lines, are trying to travel in opposite directions. If the coils are alike their fields are alike, and the fields balance each other to some extent. This s is called a "series opposing" connection.

In figure 36 we have the self-inductances working together, or adding and also have the mutual inductance of each coil. This means that the actual inductance is made up of the first inductance plus the second inductance plus twice the mutual inductance. In figure 37 we still have the two self inductances adding but the mutual inductance of each coil is opposing the self inductance so the total inductance now is the first inductance plus the second inductance – twice the mutual inductance.

To find the mutual inductance you first make the connection of figure 36, series aiding and measure the total inductance. Say in one case, you find it to be 2240 microhenrys. Then you change the connections to that of Figure 37, series opposing, and again measure the total inductance. It a1ways will be less; say in this case it proves to be 160 microhenrys. Then you subtract the smaller value of inductance from the larger, 160 taken away from 240 and find that the difference is 80 microhenrys. This in the value of four mutual inductances, so you divide. it by 4.The number 80 divided by 4 gives 20 microhenrys as the mutual inductance between those coils.

The equipment necessary for measuring the total inductances in each case, is somewhat complicated so that it is not an easy matter to determine the mutual inductance.

<u>OTHER KINDS OF COUPLING.</u>

We have spent all this time on studying, inductive coupling because it is by far the most useful and important coupling which we use in radio. There are, however, other kinds of coupling with which we will become quite familiar later on.

In Figure 38 there are two tuned circuits. One of them has s as its capacity the condenser "C1", and as its inductance the two coils "L1" and "M", which, as you can see,

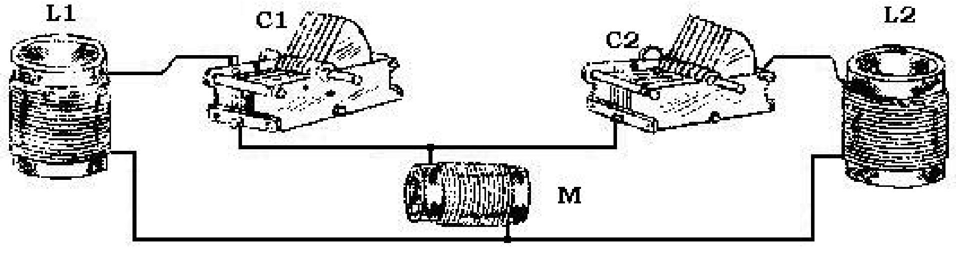


Fig. 38

are connected in series with each and the condenser. The other tuned circuit has as its capacity the condenser “C2” and as its inductance the two coils “L2” and “M” which are connected in series with each other and the condenser. Both tuned circuits contain the coil “M”. The inductance “M” is mutual to both circuits and this mutual inductance provides coupling between the circuit containing “L1” and “C1” and the circuit containing “L2” and “C2”. This arrangement is called “direct inductive coupling”.

A direct inductive coupling is shown in symbols by Figure 39. This is the same circuit us shown in Figure 38, and the parts are similarly marked. The principle of direct inductive coupling is easy to see in Figure 39 and from this diagram you will he able to recognise such coupling when you see similar circuit arrangements in the future.

The circuit of Figure 40 is, with one exception just like that of Figure 39. The exception is that the mutual inductance “M” of Figure 39 is here replaced with a “Mutual Capacity” or a condenser marked “M”. Were you to take out the coil “M” of Figure 38 and replace it with a condenser you would have the circuit of Figure 40. This arrangement is called “capacity coupling or capacitive coupling” because a capacity or condenser provides the reactance which is included in, or is common, to both tuned circuits.

The greater the reactance which is common to both circuits, the closer will be the coupling. You know that the voltage depends on the amount of reactance, the more the reactance the greater the voltage drop across it. More voltage means more energetic action and more coupling. So the more reactance, the more coupling.

In Figure 39 we can secure more reactance by using a coil having greater inductance in other words a larger coil. So a larger coil means a greater direct coupling. In Figure 40 we can secure more reactance by using a smaller condenser or one having less capacity. You remember, the less the capacity the greater its reactance. So with capacity coupling, we secure a closer coupling by using a smaller condenser.

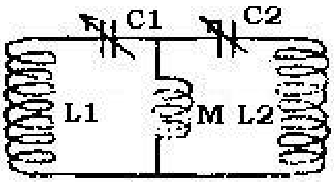


FIGURE 39.

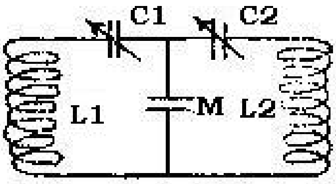


FIGURE 40.

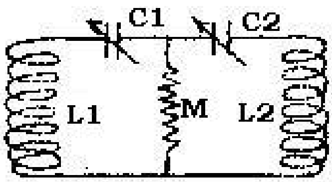


FIGURE 41.

In Figure 41 we have the resistor “M” common or mutual to the two circuits and this makes what we call “resistance coupling”. This particular arrangement would not be used in practise because we do not wish to add resistance to tuned circuits. A least, we don't want to add the amount of resistance which would be required to give us a good degree of coupling.

An actual example of resistance coupling in shown in Figure 42. This is a resistance coupled audio frequency amplifier. The same circuit is shown in symbols by Figure 43.

The plate circuit of the left hand tube consists of the plate, the resistor "R", the current source "B", the connection "X", the filament "F1" and the space between filament and plate. The grid circuit of the right hand tube consists of the grid, the condenser "C", the resistor "R", the battery "B", the connection "X", the filament "F2", and the space between filament and grid. The purpose of condenser "C" is to prevent the high voltage the battery "B" from reaching the grid and making the grid positive. The resistor "R" is common to both the plate circuit of the left hand tube and the grid circuit of the right hand tube; therefore, it provides coupling between these two circuits. When we take up the matter of resistance coupled amplifiers we will make a complete investigation of this kind of coupling.

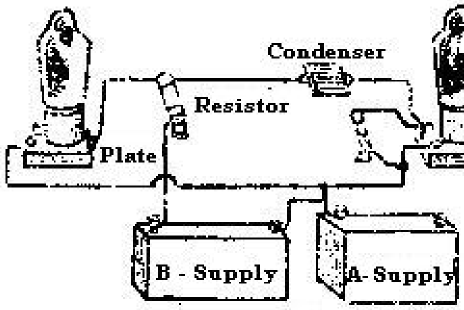


Fig. 42

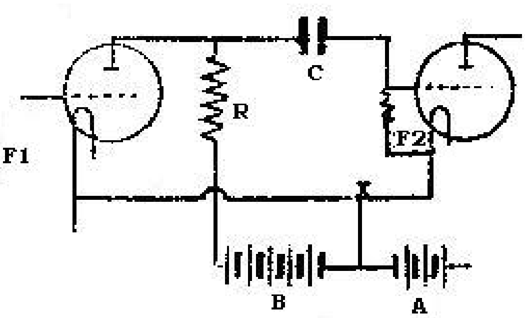


Fig. 43

LITZ WIRE.

From a previous lesson we learnt that the dynamic impedance or gain of a tuned circuit depends on the amount of resistance included in it. The more resistance the less the efficiency becomes. In modern receivers we endeavor to make all parts as efficient as possible, and special material is sometimes used in coils to make the resistance as low as possible.

Generally coils are wound with wire which consists of one strand covered with either enamel or silk insulation, but it has was found that the high radio frequency currents are carried more easily by wire consisting of several strands of very fine wire. Each strand is separately insulated from the others by silk or enamel insulation and all strands are twisted together and wound around with silk to hold then together. This typo of wire is known as "Litzendraht" but in more frequently abbreviated to "Litz" wire. Usually 5,7,9 or 11 thin strands are used, but it is possible to obtain Litz wire with other numbers of strands.

A coil can be wound with litz wire to have exactly coil the same inductance as a similar coil wound with ordinary wire but it will be found that the resistance of the litz wound coil to H.F. currents will be much lower, so that a higher efficiency can be obtained.

IRON CORES FOR R.F. COILS

It is easy to realise that, if a coil can be made to have the desired inductance with only about half the normal length of wire, its resistance will be considerably less than it otherwise would be.

Earlier in this lesson it was pointed out that the inductance of a coil can be increased by placing a certain amount of iron in the centre of the winding. I f we require a certain inductance, to go with a particular tuning condenser to tune to the broadcast range of frequencies, we can obtain the necessary inductance by using fewer turns if we wire them over an iron core instead of using only air in the centre of the coil. The reduction in turns means that less wire will be required and as a result resistance will be decreased.

The type of iron core used in audio frequency or power transformers is not at all suitable for use in R.F. coils there would be tremendous losses which would result in very poor efficiency. To prevent serious losses from taking place, the cores are made of very fine particles of iron mixed together with some binding substance and made either in the form of a small rod or tube in the form of a bobbin.

Figure 44 illustrates the rod or tubular type of core which is usually about 3/8” in diameter and about ½” long. The coil winding could be wound directly on the core, but generally the core is placed inside a piece of insulating tubing and the coil wound on this.

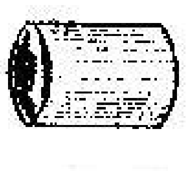


Fig. 44

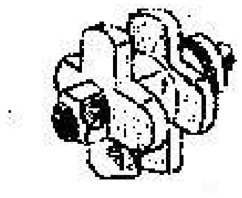


Fig. 45

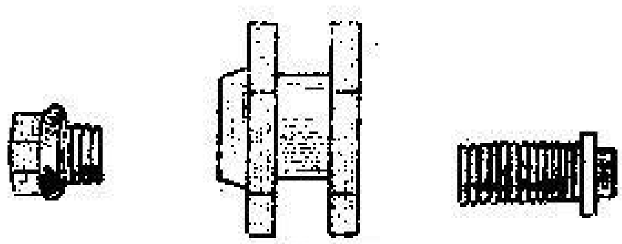


Fig. 46

The bobbin type of core is illustrated in Figure 45 and the parts forming it in Figure 46. The screw at the left of Figure 46 is used for holding the core to the holding strip. In the centre of the bobbin itself and at the right is a screw made of the same material as the bobbin which can be screwed inside the bobbin to vary the amount of iron in the core and consequently adjust the coils inductance.

Losses in the type of iron used in these cores are sufficiently low to permit them to be used in coils carrying any frequency up to the higher end of the broadcast band (1500 K.C.). Coils for higher frequencies than this are wound on ordinary air cored formers.

The formula given in this lesson for finding the inductance of a coil, does not apply to iron cored coils but only to the more usual air cored type. Due to the fact that the inductance depends on the quantity and characteristics of the iron used there is no simple formula for calculating the inductance of iron cored R.F. coils.

DATA SHEET. SHAPE FACTORS.

This is the factor used in formula (1) of Lesson 17 for determining the inductance in Microhenrys of single layer, close wound air core coils.

Diameter Divided by Length.	Shape Factor.	Diameter Divided by Length.	Shape Factor.	Diameter Divided by Length.	Shape Factor.
				6.20	0.280
0.00	1.000	1.9	0.538	6.40	.274
.05	.979	1.95	.532	6.60	.269
.10	.959			6.80	.263
.15	.939	2.00	.526		
.20	.920	2.10	.518	7.00	.258
		2.20	.503	7.20	.254
.25	.902	2.30	.492	7.40	.249
.30	.884	2.40	.482	7.60	.245
.35	.867			7.80	.241
.40	.850	2.50	.472		
.45	.834	2.60	.463	8.00	.237
		2.70	.454	8.50	.227
.50	.818	2.80	.445	9.00	.219
.55	.803	2.90	.437	9.50	.211
.60	.789			10.0	.203
.65	.775	3.00	.429		
.70	.761	3.10	.422	11.0	.190
		3.20	.415	12.0	.179
.75	.748	3.30	.408	13.0	.169
.80	.735	3.40	.401	14.0	.161
.85	.723			15.0	.153
.90	.711	3.50	.394		
.95	.700	3.60	.388	16.0	.146
		3.70	.382	17.0	.139
1.0	.688	3.80	.376	18.0	.134
1.05	.678	3.90	.371	19.0	.128
1.10	.667			20.0	.124
1.15	.657	4.00	.365		
1.20	.648	4.10	.360	22.0	.115
		4.20	.355	24.0	.108
1.25	.638	4.30	.350	26.0	.102
1.30	.629	4.40	.346	28.0	.096
1.35	.620			30.0	.091
1.40	.612	4.50	.341		
1.45	.603	4.60	.336	35.0	.081
		4.70	.332	40.0	.073
1.50	.595	4.80	.328	45.0	.066
1.55	.587	4.90	.324	50.0	.061
1.60	.580				
1.65	.572	5.00	.320	60.0	.053
1.70	.656	5.20	.312	70.0	.047
		5.40	.305	80.0	.042
1.75	.558	5.60	.298	90.0	.038
1.80	.551	5.80	.292	100.0	.035
1.85	.544	6.00	.285		

EXAMINATION QUESTIONS NO. 17

1. Air core coils used in circuits carrying high frequencies, or low frequencies ?

2. If you double the number of turns in a coil, leaving other things unchanged will the inductance be doubled more than doubled or less than doubled?

3. Which will give the greater voltage across the tuned circuit, a large condenser and a small coil or a small condenser and largo coil? Why?

4. If three coils have inductances of 50 microhenrys, 100 microhenrys and 150 microhenrys are connected together in series, but have no inductive coupling, what will be their combined inductance?

5. Does the apparent inductance get larger or smaller as the frequency increases?

6. Which will give the greater coupling, separation of one inch or a separation of two inches between the centre of two coils having both their axes in the same straight line straight line? Why?

7. If you turn two coils so that their axes lie in one straight line will the mutual inductance be more or less than with the two axes turned at right angles?

8. If a coil has an inductance of 200 microhenrys and you couple to it another live coil having an inductance of 50 microhenrys, will the inductance of the first coil remain at 200 microhenrys or will it be more or less than this figure? Explain the reason.

9. Which will give the greater voltage in the secondary of a coupler, a coupling factor of 80% or one of 25%?

10. What is litz wire? What is its advantage over ordinary wire?

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LESSON NO. 18

AMPLIFICATION – ADDING STRENGTH TO THE RADIO SIGNAL

Amplification is an important subject, because in any radio receiver all but two of its valves are amplifiers. In later lessons you will read much more on this subject when we come to radio frequency amplifiers, intermediate frequency amplifiers, and audio frequency voltage and power supplies. This lesson is a comparatively elementary introduction which will prepare you for the more specialised treatment of individual types later on.

AMPLIFICATION FACTOR.

Were you to apply a pressure of 40 volts to the plate of a valve, you might find that a millimeter in the plate circuit would read about 3 mills as in Figure 1. You could increase the amount of plate current by increasing the plate voltage. Using 60 volts on the plate you might find a current of about 5 mills as in Figure 2. It required a change of 20 volts (40 up to 60) in the plate circuit to raise the plate current 2 milliamperes.

In Figures 1 and 2 the grid circuit comes through the coil to the negative filament terminal of the valve, therefore the: grid has a zero grid bias. In Figure 3 we have inserted a small battery in the grid circuit. This battery raises the grid voltage by 2½ volts. Now, with only the origina1 40 volts on the plate there is a plate current of 5 milliamperes, The 2½ volt change in grid voltage has produced just the same change in plate current that was produced by a 20 volt change on the plate itself.

It took eight times as much change of plate voltage as of grid voltage to produce a given change in plate current. The 20 volts plate change divided

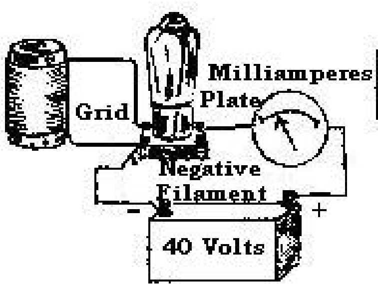


FIGURE 1.

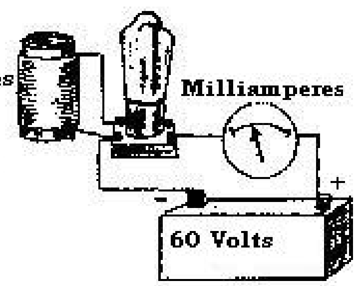


FIGURE 2.

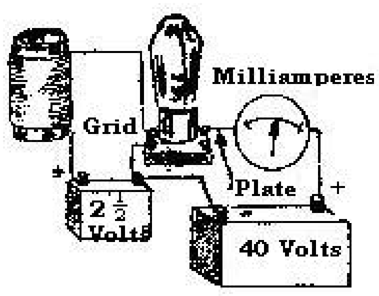


FIGURE 3.

by 2½ volts grid change equals 8, or 8 times 2½ equals 20. So we say that the amplification factor of this tube is 8.

You can see what a great advantage we gain by applying the signal voltage to the grid of a valve. A very small voltage on the grid releases or controls a whole lot of energy in the plate circuit. This energy comes from the B-Battery or from any power unit which supplies plate current to the valve.

A valve may be built to have almost any amplification factor desired. Some of the common types have factors as low as 3 while others have an amplification factor or a "mu" of 1000 and more. The less space there is between the wires of the grid the greater will be the "mu" of the valve because the electrons have to come closer to the grid wires in getting through from filament to plate. The smaller the diameter of the wire used for the grid the greater will be the amplification factor. The greater the distance between grid and plate, the nearer the grid is brought to the filament, the greater will be the grid's control of plate current and the greater the amplification factor.

Why use two valves, each with an amplification of 8, when we could apparently, obtain more amplification with only one valve with a "m" of 1,000? There are many reasons why, in some oases, it is preferable to use two valves to do the work of one, all of which will be explained in the more advanced lessons. Suffice it to say here that, as a general rule, the higher the amplification factor of a valve the smaller will be its permissible grid voltage swing before running into grid current on the one hand and down to the bend of its curve on the: other. As a consequence, the very high "mu" valve may, in certain circumstances, be badly overloaded by its input signal, necessitating the use of another type which, while accepting a larger input signal voltage, will not amplify to the same degree.

VOLTAGE AMPLIFICATION AND POWER AMPLIFICATION.

The amplification we have been talking about so far has been voltage amplification. We have been getting a higher voltage drop in the plate circuit than that which is applied to the grid circuit of the valve. Voltage amplification is very fine in the radio frequency amplifying stages, it is fine in the detector stage and it is what we want in the audio frequency stages immediately following the detector. But high voltage alone will not operate a loudspeaker satisfactorily. To operate the speaker we must have power.

To operate the modern typos of speakers with plenty of volume and with good tone quality under all conditions calls for about 3 watts of power. Having even more than 3 watts available will make for still better results. The "watt" is the unit of electrical power.

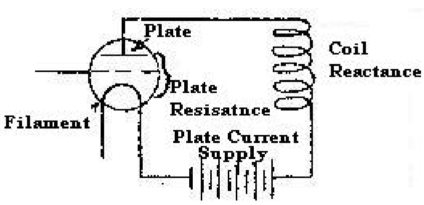


FIGURE 4.

VOLTAGE AMPLIFICATION.

The voltage amplification given by a valve depends on the "mu" or amplification factor. The amplification factor is the greatest multiplication of voltage you could possibly got under ideal conditions. It is the valve's limit of amplifying ability. In actual practice you can never quite reach this limit. Let us find out why.

In Figure 4 You will see a plate circuit including the valve itself, a source of plate current (such as a B-battery) and a coil which, as you know, has reactance. Change in plate current, or alternating current in the plate circuit, is opposed chiefly by the coil's reactance and by the resistance of the space between the valve's plate and

Filament. The opposition met with by alternating current in passing between the plate and the filament is called the “plate resistance” of the valve. In this circuit we have two large amounts of opposition to the plate current variations, the plate resistance and the coil reactance. Both of these are measured in ohms. The resistance of the wiring and of the battery or other source of plate current may be neglected because they are so very small.

In place of Figure 4 we can draw out the equivalent circuit of Figure 5 where the plate resistance is represented by the symbol for a resistance and where the coil's reactance is represented by another symbol far resistance. If current flows around this circuit of Figure 5, it will have to overcome these two resistances just as in Figure 4. Current flowing in the plate circuit would have to overcomes the plate resistance and the coil reactance.

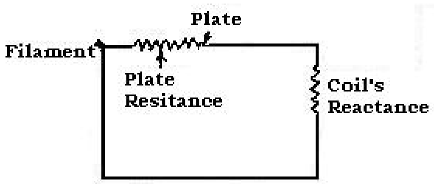


FIGURE 5.

You know that a flow of current through a resistance or through a reactance produces a drop of voltage across the resistance or across the reactance. Then let us take a circuit in which we have a plate resistance of 10,000 ohms, a coil reactance of 10,000 ohms and a current change of 10 milliamperes. According to Ohm's Law, the voltage drop is equal to the ohms times the amperes. A current of 10 milliamperes is equal to 10/1000 ampere or to 1/100 ampere. So we must multiply 10,000 ohms by 1/100 ampere and we get as a result the number 100, which is the voltage drop across the resistance and across the reactance.

If you look back at Figure 4 you will realise that the only part useful to us in getting amplification from the valve or in making use of any voltage step-up in the plate circuit is the coil. The voltage drop across the coil's reactance is useful, because we can get at it to connect it up to something else. But the voltage drop across the valve's plate resistance is wasted because we cannot get in there to apply that voltage to anything else. Then, going back to the above example, the 100-.volt drop across the coil reactance is useful and the other 100-volt drop across the plate resistance is lost.

Another example. Let us have the same plate resistance as before and increase the coil's reactance to 20,000 Ω double it. Assuming the same current change we will get the same voltage drop across the plate resistance, l00 volts, but we will got twice that drop, or 200 volts, across the increased reactance.

Suppose, in place of increasing the coil's reactance, we lowered it. The plate resistance is 10,000 ohms but the outside reactance is only 100 ohms. With the same current change of 10 mills or 1/100 ampere, multiplying the amperes by the ohms we multiply 1/100 by 100 and find that there is only one volt drop across the coil reactance. This one volt is not going to do much for us. Now you can see that the greater the external reactance or resistance is made, the greater will be the voltage drop across it and the greater will be the actual voltage amplification. The amplification depends on two things - on the “mu” of the valve and on the reactance or resistance in the valve's external plate circuit. It also depends on the valve's plate resistance.

In the first example the total voltage drop in the whole circuit divided evenly between the tube and the coil. In the second example we found one third the total voltage in the tube and two-thirds in the coil. In the third example we had one hundred times as much voltage lost in the tube as was made useful across the coil.

Let us use a tube with lower plate resistance, say 2000 ohms resistance between plate and filament, and a coil with 10,000 ohms reactance and have the same: 10 mils or 1/100 ampere current change. This arrangement would give a drop of only 20 volts in the tube and a drop of 100 volts across the coil. We now have five times as much useful voltage as lost voltage because of using a tube with lower plate resistance.

In all those circuits only so much work will be done for a given amount of power applied. We can get the work done inside the tube, where it does us no good, or we can get it done outside the tube whore we can use it to good advantage. The proportion of the work which is useful depends on the relation between the plate resistance and the external reactance or resistance. The greater the external reactance and the less the tube plate resistance, the greater will be the available voltage and the greater the actual voltage amplification.

All of this can be put down in a formula, thus:

$$\text{Voltage amplification} = \frac{\text{Mu x External impedance}}{\text{External Impedance + plate resistance}} \qquad (1)$$

The term “electrical impedance” has been used rather than the reactance or the resistance. The impedance is the combination of the reactance and the resistance, in their opposition to alternating current. For practically all the work in amplification the ohmic résistance of the coils is so small in comparison with their reactance that we can just go ahead and use the number of ohms reactance without waiting to figure out the impedance. Of course, to be very exact, we should use the impedance value.

EFFECT OF FREQUENCY ON AMPLIFICATION.

Do you remember the two things which determine the reactance of a coil? They are the coil's inductance and the frequency of the applied voltage. Now, since the amplification depends on the reactance and the reactance depends on the frequency, then the amplification must depend on the frequency.

$$\text{Reactance in ohms} = \frac{\text{Cycles x henrys inductance x 1000}}{159}$$

Let us consider a circuit of a tube and a transformer. The tube's “mu” is 8½ and its plate resistance is 10,000 ohms. The transformer inductance is 100 henrys. We will calculate some amplification values. Say we are interested in a very low note, one of 100 cycles; also in one near “middle C” (about 250 cycles) and in a violin note of 3000 cycles. Because we are now interested chiefly in the tube, we will assume that the transformer’s inductance remains, the same at all these frequencies in spite of the fact that there is really a slight change in its apparent inductance.

Now for the first frequency, the one of 100 cycles: putting the values in the reactance formula we have:

$$\frac{100\ (\text{cycles}) \times 100\ (\text{henrys}) \times 1000}{159} = 63{,}000 \text{ ohms reactance (approximately)}$$

For the 250 cycle frequency we have:

$$\frac{250\ (\text{cycles}) \times 100\ (\text{henrys}) \times 1000}{159} = 157{,}000 \text{ ohms reactance (approximately)}$$

And for the high frequency of 3000 cycles:

$$\frac{3000\ (\text{cycles}) \times 100\ (\text{henrys}) \times 1000}{159} = 1{,}890{,}000 \text{ ohms reactance (approximately)}$$

Now we have the following reactances:

Reactance at 100 cycles - 63,000 ohms
Reactance at 250 cycles - 157,000 ohms
Reactance at 3000 cycles - 1,890,000 ohms

These reactances can be used in the formula numbered (1) to find the voltage amplifications. At 100 cycles we would have:

$$\text{Voltage amplification} = \frac{8\tfrac{1}{2}\ (\text{tube's mu}) \times 63{,}000\ (\text{external reactance})}{63{,}000 \times (\text{external reactance}) = 10{,}000\ (\text{plate resistance})}$$

Working this example out we find that the amplification is about 7-3/10

Then we can take the same formula and substitute the reactances for the other frequencies. Here are the answers for all three frequencies:

Voltage amplification at 100 cycles, approximately 7-3/10

Voltage amplification at 250 cycles, approximately 8

Voltage amplification at 3000 cycles, approximately 8½

Now you can see that the higher the frequency, the greater the reactance, and the higher the amplifications. You can never get the full "mu" of the tube in voltage amplification because some of the voltage is always lost in the tube's plate resistance. But the higher the external impedance or reactance the closer you can come to this ideal amplification.

GRID RETURN.

The grid return of a tube is the point at which the direct current grid circuit is connected to the tube's filament circuit or to its cathode circuit. Fig. 6 shows the grid return to the negative side of the tube's filament. You can always find the grid return point by starting at the grid itself and following the path which could be followed' by direct current until you reach either the tube's filament or the connection of its cathode. The cathode is the part of an A.C. heater type tube from which electrons are set free.

In following the grid circuit on its way to the grid return point, remember that direct current cannot pass through a condenser. You have to go through wires, coils, resistors and other conductors of direct current. In Fig. 7 the grid return is to the positive side of the filament. In Fig. 8 the grid return is through a C-Battery to the valve's filament.

The grid return to the cathode of an A.C. heater valve is shown in Fig. 9. In Fig. 10 there is a condenser between the grid and the coil in its high frequency circuit. Consequently, direct current could pass only through the resistor and this resistor forms part of the grid return circuit.

The point to which the grid return is made determines the bias voltage placed on the valve's grid. In Fig. 6 it has a zero bias because the grid return is made to the negative end of the filament. The valve in Fig. 7 is using a positive grid bias because the grid return is to the positive side of the filament. The valve in Fig. 8 has a negative grid bias because the grid return is made to the negative side of a C-Battery. In Fig. 9 the grid has a zero bias because its return is made directly to the cathode which corresponds to the negative side of an ordinary filament. The valve in Fig. 10 has a zero bias because the resistor in the grid return circuit connects to the negative side of the filament.

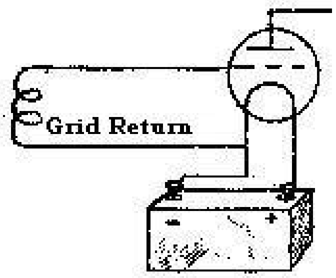


FIGURE 6.

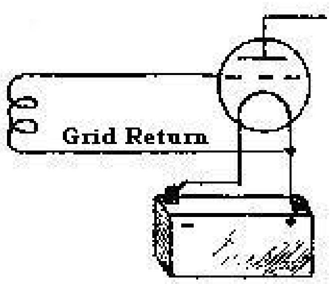


FIGURE 7.

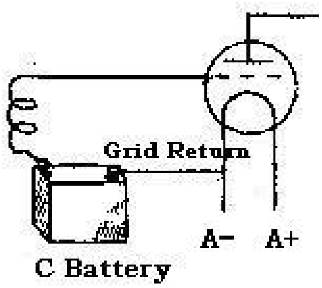


FIGURE 8.

The grid bias voltage is the difference between the potential of the negative side of a filament or the potential of a cathode and the potential of the point to which the grid is connected. If the grid return point is at a voltage higher than that of the negative filament or the cathode, then the grid has a positive bias. If the grid return is to a point at a voltage lower than the negative filament or the cathode, then the grid has a negative bias. If the return is to the negative side of the filament or directly to the cathode, then the grid has no bias or has a zero bias.

SOMETHING ABOUT DISTORTION.

Many times you have heard the word "distortion". What does it mean?
In Fig. 11 the wavy line represents the alternating voltage applied to the grid of a valve and another similar line represents the amplified voltage in the plate circuit. The rises and falls of plate voltage are equal to each other, just as the rises and falls on the grid side are equal. The frequency is the same on both sides. The only change is in the strength of the signal there is no distortion.

In Fig. 12, the changes in the plate circuit side are not true reproductions of those on the grid side. The rises of plate voltage are not as great as the falls in plate voltage. Music or speech amplified in this manner would not sound right and the result would be called distortion. In Fig. 13 the rises of plate voltage are all out of proportion to the falls in plate voltage, and again we have distortion.

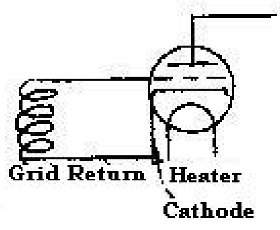


FIGURE 9.

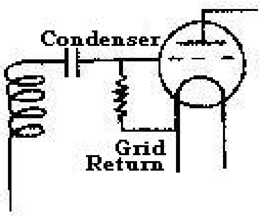


FIGURE 10.

If a true signal voltage is applied to the grid of a valve and if the reproduction of this signal in the plate circuit is not like the input voltage (except for being stronger) then we have distortion. This is true when the valve is being used as an amplifier. Of course the detector is different - it takes in radio frequency and gives out audio frequency

Correct grid bias will prevent most forms of distortion which may arise in an amplifying valve.

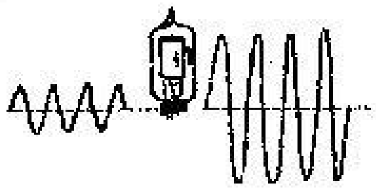


FIGURE 11.

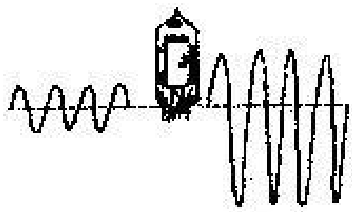


FIGURE 12.

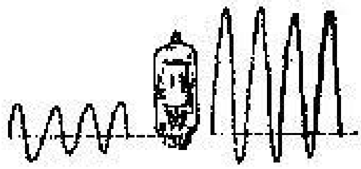


FIGURE 13.

You remember from a previous lesson that so long as the grid has a negative potential with respect to the filament or cathode, no electrons are attracted to the grid and no current flows in the grid circuit. While the grid is positive, however, it attracts electrons and there is a flow of current in the grid circuit.

Suppose you were using zero bias and were applying a 2 volt signal to the grid, that is, a signal which first swings the grid 2 volts positive and then 2 volts negative

This signal is shown at the left in Fig. 14. During the positive signal alternations a small grid current flows, but while it is negative no current flows, this gives a pulsating current in the grid circuit as shown at the centre of Fig.14.

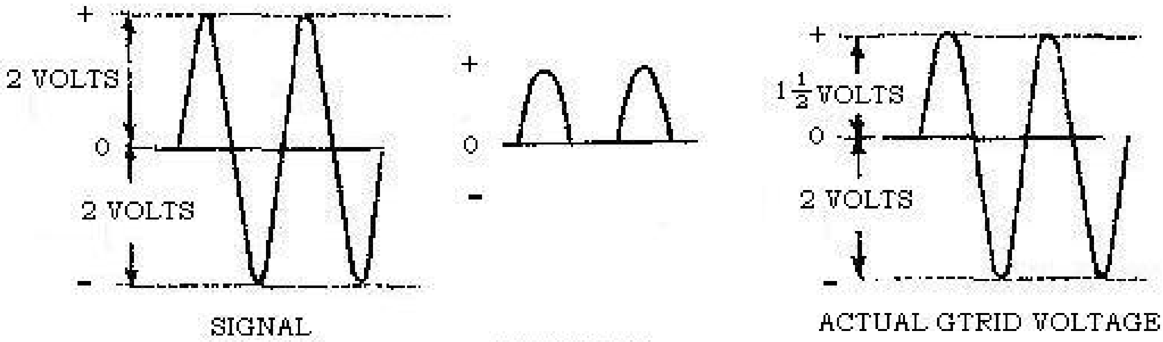


FIGURE 14.

It requires an expenditure of energy to force current to flow through the high resistance between grid and filament inside the valve when the grid is positive. When the grid is negative no such energy is required. It is the previous valve's plate circuit which has to supply the lost energy. Unfortunately this valve is not capable of delivering much power, and if you attempt to take energy from its plate circuit to supply the grid of a following valve it fails to do its job. The result is that the voltage in its plate Circuit falls off when energy is taken from it, and of course the voltage supplied to the grid of the next valve also falls off. Now this only occurs when the grid of the second valve is positive, so the decrease in voltage only happens on the positive signal alternations and not on the negative.

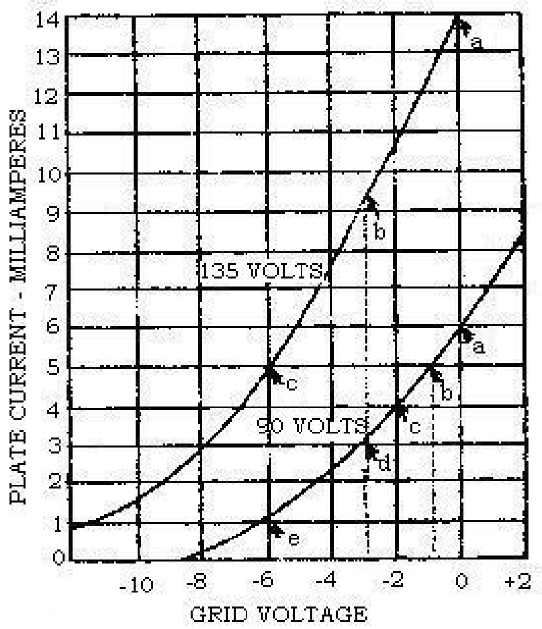


FIGURE 15.

The result is shown at the right in Fig. 14. Instead of the grid going 2 volts positive as it should do, it only goes up to 1½ volts positive. Yet the negative alternations are unaffected, and the grid still goes 2 volts negative. Instead of having an equal rise and fall of grid voltage, it falls more than it rises. The result is that the signal is distorted even before it gets into the valve we are considering.

GRID VOLTAGE.

This kind of distortion, due to grid current, really occurs in the previous valve, but the remedy lies in preventing the grid of the second valve from ever becoming positive. This can be done by applying a negative bias at least as great as the strongest signal voltage to be handled by the grid. Then the signal just makes the grid alternately more negative and less negative. Since the grid is never positive no grid current flows and there is no distortion due to this cause.

In Fig. 15 are two curves for a valve on the same graph. One of them, the one lower down, shows the relation between grid voltage, and plate current when the plate voltage is 90. The other one higher up, shows the relation for 135 volts on the plate.

Look at the 90-volt curve in Fig. 15. At zero grid bias (point “a”) the plate current is 6 mils. At 1 volt negative (point “b”) the current is 5 mils. At 2 volts negative (point “c”) it is 4 mils. At 3 volts negative (point “d”) the plate current is 3 mils. So far we have one mil drop in plate current far each volt drop in grid voltage. But now, continuing on down, the curve commences to change its slope. From negative 3 volts down to negative 6 volts (point “o”) the current drops from 3 mils to 1 mil, a change of 2 mils for 3 volts in place of one mil per volt as before.

Now suppose we put a steady negative grid bias of 3 volts (point “d”) on the tube of Fig. 15 with 90 volts on the plate. If the incoming signal swings 3 volts positive, it will compensate for the grid bias and the actual voltage on the grid will rise to zero (point “a”). The 3-volt positive signal will increase the plate current from 3 mils to 6 mils.

Then, if the signal voltage swings evenly positive and negative, it will change over to 3 volts negative. This will add itself to the steady grid bias and the grid voltage will become 6 volts negative (point “e”). At 6 volts negative the plate current (as shown on the 90-volt curve) will become 1 mil. With even swings of signal voltage, 3 volts each way, the plate current will rise 3 mils (from 3 to 6) but will drop only 2 mils (from 3 to 1). This means distortion. Evidently the 3-volt steady bias is not the right one.

From the foregoing it will be seen that the total swing of signal voltage must be kept on a straight part of the grid-voltage, plate-current curve. Otherwise we will have distortion. The straight part of the 90-volt curve in fig. 15 extends from zero (point “a”) down to 3 volts negative (point “d”). The steady bias voltage must be in the middle of the straight part, or at 1½ volts negative. Then, with a signal that swings no more than 12 volts each way, up and down, the changes of plate current will be equal on both swings.

Now it is quite evident that the greatest signal voltage which may be amplified without distortion when 90 volts is applied to the plate is a signal of 1½ volts. A stronger signal will result in distortion because it either will have to make the grid voltage become positive or else it will force it down to the part of the curve where the slope is changing rapidly.

The way we show an action of this kind is illustrated in Fig, 16. We start off with a regular grid voltage, plate current graph. From the bias voltage which is applied steadily to the grid, we draw a line straight downward, the line “a-e-i” in Fig. 16. On this bias line we draw a line representing the swing of the signal voltage.

In Fig. 16 the signal voltage cycle starts at "a" drops its voltage to 1½ volts negative at "c", then comes back to zero at "e", rises to 1½ volts positive at "g" and. goes back to zero at "i".

If you follow upward on the 12 volt bias line you find it crosses the curve at 4½ mils plate current (point "x"). Consequently, with this 1½-volt negative grid bias, the plate current will be 4½ mils. Now, when the grid signal goes to "c", it makes the grid voltage go down to 3 volts negative. Following upward with the arrow on this 3-volt negative line, it crosses the curve at 3 mils plate current (point "y") so the current drops from 4½, mils to 3 mils.

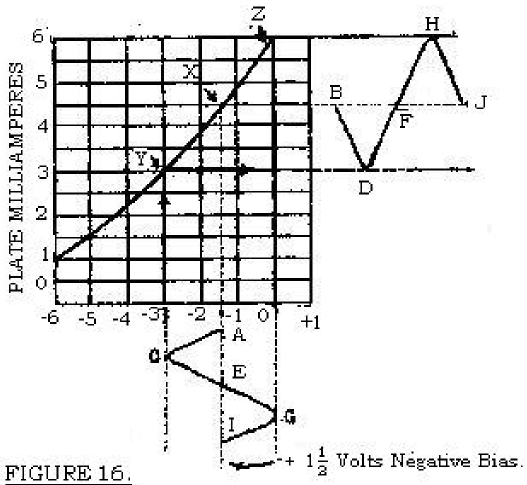


FIGURE 16.

As the signal voltage returns to its own zero at "e", the plate current rises to 4½ mils again because the grid voltage rises to 1½ volts negative. Then the signal voltage swings to 1½ volts positive (its own positive) at "g". This balances the steady grid bias of 1½ volts and the grid voltage becomes zero. Following upward on the zero voltage line we find it crosses the curve at 6 mils (point "z"). Consequently, the plate current increases to 6 mils.

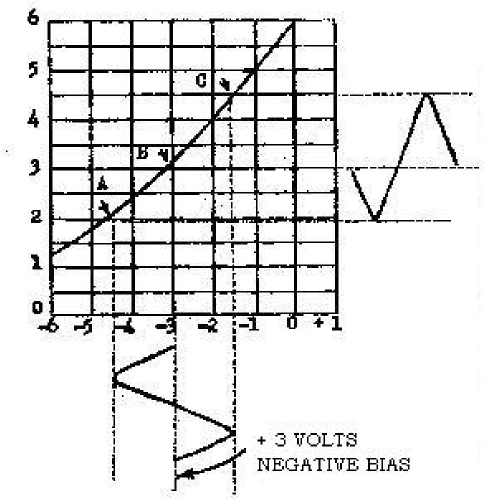


FIGURE 17.

The resulting plate current curve is drawn at the right hand, side of the graph. With the signal voltage at "a", the plate current is at "b" on its curve. This point is on the 4½ mil line extended out from the graph. Then, with the signal voltage at "c" on its curve, the plate current is at "d" on the 3-mil line extended out to the right. The signal voltage at "e" brings the plate current to "f"; The signal voltage at "g" brings the plate current to "h"; and the signal voltage at "i" brings the plate current to "j" on its curve. Now we will see what happens with a 3-volt negative bias. This condition is shown in Figure l7. The 3-volt line is extended downward and the signal with its 12 volt swing each way is drawn on this line. As the signal goes negative the plate current drops to a little less than 2 mils (point "a") from its steady point of 3 mils (point “b”). Then, as the signal voltage swings 12 volts positive the plate current rises to 4½ mils (Point “c”). So you see, with a grid swing of 12 volts each way, the plate current drops only a little over one mil but rises a full mil and one-half. The unequal fall and rise of plate current is shown over at the right hand side of the graph. We have distortion caused by too much negative grid bias.

HANDLING STRONG SIGNALS.

All this time we have been handling a signal of 1½ volts, one which swings 1½ volts positive and 1½ volts negative. But suppose we want to take care of a signal of 3-volt swing or a 3-volt signal, what then?

If you were to use a 3-volt bias, as in Fig. 17, so that the positive swing of the signal would not make the grid voltage go over an the positive side, you would have even worse distortion than shown in Fig. 17, because you would be working still further down on the negative side of the curve, where its slope is changing more and more. If you were to keep the 1½ volt bias of Fig. 16, the 3 volts positive of the signal would use up all the original bias and would throw the grid voltage way over onto the positive side.

This positive voltage on the grid would cause an uneven change of plate current, because a positive voltage allows grid current and produces less plate current change than the same amount of negative voltage, as already explained.

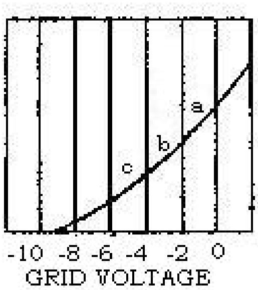


FIGURE 18.

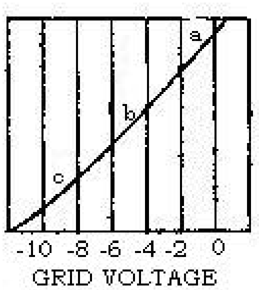


FIGURE 19.

To handle this stronger signal, the one of 3 volts, we must do two things, we must increase the plate voltage on the tube and we must also increase the negative grid bias. If you will look back at Fig. 15 you will see a curve drawn for 135 volts on the plate. In that curve there is an almost straight part from zero grid volts (point “a”) at 14 mills, way down to negative 6 volts. (Point “b”) at 5 mils.

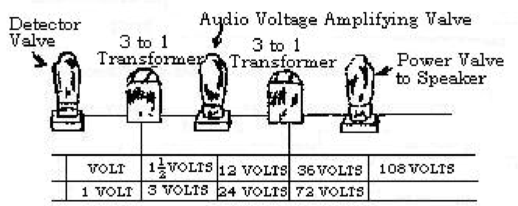


FIGURE 20.

This means that the grid voltage may change from zero down to 6 volts negative and produce equal rises and falls of plate current because all the change will come on the straight part of the curve.

Now, for our 3-volt signal, we can use a 3-volt negative bias. The steady plate current will be about 9½ mils (point “c”). When the signal voltage goes to 3 volts positive the grid voltage will became zero because the bias voltage will be exactly balanced and the plate current will rise to nearly 14 mils. When, with the signal 3 volts negative the grid voltage will be 6 volts negative and the plate current will drop to 5 mils. There is a change each way of about 4 3/8 mils in plate current.

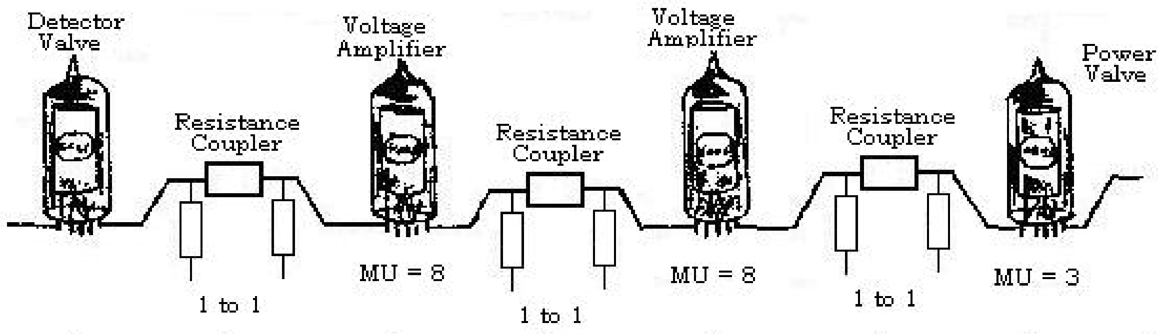
The best we could do with the 1½ volt signal was to get a plate current change of 3 mils (from 3 mils to 6 mils in Fig. 16). With the 3-volt signal and the proper plate voltage and grid bias we are able to get a plate current change of 8¾ mils (from 5 mils to 13¾ mils in Fig. 15). We not only have a great deal more change in current, but we are operating with higher voltages. With more current and more voltage too we are certainly getting a lot more power in watts.

For any valve, there are certain grid biases which correspond to certain plate voltages. When the plate voltage is made high enough to let the signal work on a straight part of the curve, and when the grid bias is equal to the greatest swing of signal voltage, the valve is going to do its best work. Then, and then only, there will be the least possible distortion.

The greatest signal voltage that can be handled is equal to the negative grid bias. Any greater signal will swing the grid voltage over onto a part of the curve that should not be used and distortion will result.

The strength of signal which a valve can handle without distortion depends on the shape of the grid-voltage, plate-current curve. The signal must not extend beyond the straight part of the curve. The length of the straight part depends on the plate voltage - the higher the voltage, the longer the straight part. When we speak of the straight part of the curve, we refer only to the portion which is on the negative side of the zero grid voltage line. The part on the positive side must never be used for the kind of amplifiers generally used in radio receivers.

The grid-voltage, plate-current curve in Fig. 18 is straight from “a” to “c”, from zero down to 4 volts negative. Then the signal voltage may be allowed to swing between these points. The centre of the swing must be at “b”, at the centre of the straight portion of the curve. As shown in Figs. 16 and 17, the signal voltage swings back and forth on the grid bias line. Consequently, in Fig. 18 we must use a 2-volt



$\frac{1}{2}$Volt	$\frac{1}{2}$ Volt	4 volts	4 volts	32 Volts	32 Volts	96 Volts

FIGURE 21.

steady grid bias - then the signal can swing up two volts and down two volts always working on the straight part of the curve. The greatest signal that can be handled is one having a swing of two volts positive and two volts negative in other words, a 2-volt signal.

In Fig. 19 the plate voltage has been raised. The grid-voltage, plate-current curve is higher up and its straight portion is correspondingly longer. The straight portion extends from the zero line at "a" down to the 8 volt negative line at "c". We have 8volts within which to handle a signal. That means the signal voltage can swing 4 volts each way. 4 volts positive and 4 volts negative. To allow this 4 volt swing we will set the steady grid bias on "b", the 4 volt line. Then a 4 volt signal or any signal of less voltage, will stay on the straight pert of the curve. A stronger signal, one of higher voltage, will run off the straight part of the curve and will cause distortion.

Now you can see that the strongest signal that can be handled is the one whose voltage is equal to the grid bias. In Fig. 18 with a 2-volt bias we can handle a 2-volt signal. In Fig. 19 with a 4-volt bias we can handle a 4-volt signal. In Fig. 16 with a 1½ volt bias we can handle a 1½ volt signal. This rule assumes that the bias is placed at the centre of the straight portion of the grid voltage, plate-current curve on the negative side of the zero line

Any signal having a voltage smaller than the grid bias will be handled without distortion because such a signal will stay on the straght part of the curve. The. grid bias fixes the maximum signal strength.

<u>HOW AMPLIFICATION IS LIMITED.</u>

A type of audio frequency amplifying_system which was commonly used at one time, is shown in Fig, 20. Following the detector tube we find a transformer which couples the detector to the audio voltage amplifying tub, then comes another transformer coupling it to the power tube.

Transformers used in audio amplifying systems are capable of stepping up the voltage furnished to them. The amount by which a transformer increases the voltage is called the transformer's ratio. The transformers shown in Fig: 20 are marked "3 to 1" because they multiply the voltage by 3.

We will assume that the detector tube delivers a signal of ½ volt. The transformer steps this voltage up to 3 times ½ making it 1½ volts. The amplification factor of the voltage amplifying tuba is 8½ but we will neglect the fraction and call the "mu" of this tuba 8. Then the 1½ volt signal is multiplied by 8 and comes out as 12 volts. This 12-volt signal is again multiplied by 3 in the transformer and comes to the grid of the power tube with a swing of 36 volts. The "mu" of the power tube is 3, so the 6-volt signal is multiplied by 3 and goes to the loud speaker as 108 volts. We started with ½ volt signal ended with 108 volts, so we multiplied the ½ volt signal by 216. The original signal comas out 216 times as strong so we have in this amplifier an "overall amplification" of 216. This calculation is not vary accurate, because we have been making assumptions which are not strictly true.

To the grid of the voltage amplifying tube we applied a 1½-volt signal which this tube has no trouble in handling without distortion. To the grid of the power tube we applied a signal of 36 volts which is safely within the limit of 40½ volts which this tube can handle. So, providing the detector does not deliver a signal of more than ½ volt, this s amplifier will work without distortion.

Suppose the set were tuned in to a powerful local station, making the detector deliver a signal of 1 volt - what then? Then first transformer makes a 3-volt signal the voltage amplifying tube raises it to 24 volts and the second transformer delivers a 72-volt signal to the poor tube. The power tube will not handle anything more than 40½ volts without distortion and the sounds from the speaker are not pleasant to hear. To avoid distortion we would either have to turn down the volume control or use a larger7.argur power tube in place of the above power tube. This now power tube will have to handle signals up to approximately 80 volts without trouble.

Now we will take the audio amplifying system shown in Figure 21. Here we use resistance coupling instead of transformer coupling. Resistance coupling provides no step up ratio. As a matter of fact, there is a slight loss of voltage, but we will consider that the voltage is transferred from valve to valve without change. We will consider the detector as delivering ½ volt and since the resistance coupler does not increase this voltage, the ½ volt signal is impressed on the grid of the first audio valve. This valve, with its "mu" of 8, multiplies the ½ volt by 8 and delivers 4 volts to the next coupler. There is no step-up in the coupler, so the second audio valve receives the 4 volt signal, multiplies it by 8 and produces 32 volts. This 32-volt signal is applied to the grid of the power valve and is raised to 96 volts by the power valve's "mu" of 3. No valve is overloaded. The first audio valve receives ½ volt and the second one receives 4 volts on the grid, both voltages being well within the valve's ability to amplify without distortion. The power valve receives only 32 volts, whereas its limit is 44 volts. We have no distortion with a detector output of ½ volt.

We will take another resistance coupled amplifier, the one in Figure 22. Here we have one of the high-mu type amplifying valves. This valve has an amplification factor or "mu" of 30, but in actual practice we can seldom realise an amplification of more than 20, so we will use this value of 20 in our calculation.

Starting as before with ½ volt from the detector, this ½ volt reaches the grid of the high-mu valve through the resistance coupler. The high-mu valve increases the signal to 10 volts (½ times 20) and the 10 volt signal reaches the grid of the power valve. Now we have only 10 volts for the power valve grid. Not much use using a power valve the same as above, because we have not enough voltage to get the best work out of such a valve. Also, the "mu" of the above power valve is only 3 and we would got only 10 times 3 or 30 volts into the speaker circuit. We will select a more suitable power valve.

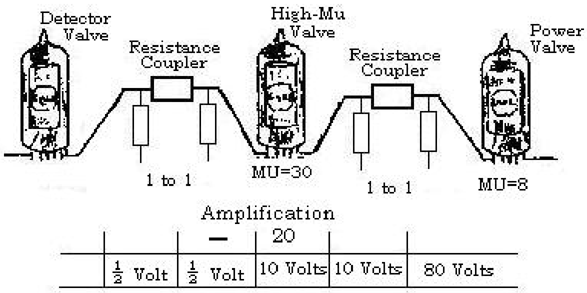


FIGURE 22.

Another power valve has an amplification factor of 8 and will handle signals up to 13½ volts with 180 volts on its plate. This is the valve to use. It handles the 10 volt signal without distortion and delivers 80 volts into the speaker circuit instead of the 30 volts we would have secured with the previous power va1ve.

Every valve has its particular use. Some of them capable of handling strong signals without distortion. Others have large amplification factors. Some are designed to step-up voltages and are primarily "voltage amplifiers". Others are designed to deliver considerable power in watts in their plate circuits and are called "power amplifiers".

POWER AMPLIFICATION.

The power output of a valve, like any other electrical power, is measured in watts. Valve outputs are often measured in milli-watts; one milli-watt being the one-thousandth part of a watt.

The power depends on the voltage change and on the current change, or on the combination of these two things. The output voltage depends on the voltage applied to the valve's grid and on the "mu" or amplification factor of the valve. The "mu" raises the input voltage to the output voltage. The current depends on the plate resistance of the valve and on the impedance of the coils or resistances in the plate circuit. The parts of the plate circuit in which work is done are called the "load". So we call the impedance or reactance of these parts the "load impedance" or the "load reactance".

All of these things can be taken into account by using one formula. Here it is:

$$\text{Watts} = \frac{\text{Load impedance} \times (\text{amplification factor} \times \text{grid voltage})^2}{2 \times (\text{plate resistance} + \text{Load impedance})^2} \quad \text{.......(2)}$$

The top part of this formula says: Multiply the amplification factor by the grid voltage and square the result, then multiply the number you get by the load impedance in ohms. The lower part says to add the plate resistance and the load impedance (in ohms) together and square the result, then multiply that number by 2. Finally, you divide the number you got from the upper part by the number you got from the lower part of the formula and that gives you the number of watts of power in the plate circuit.

The greatest amount of power is obtained when the number of ohms load impedance is exactly equal to the number of ohms plate resistance of the valve. But, strange as it may seem, we do not dare use the greatest possible power because with it we would have a great deal of distortion. Increasing the load impedance reduces the distortion and we find that satisfactory operation is secured when the load impedance in ohms is about twice as great as the valve's plate resistance in ohms. The exact load impedance which is best depends somewhat on various condition of operation, but it is a safe general rule to work on this external impedance as being twice the plate resistance for triode power valves. However, with special types of power valves known as pentodes it is from 1/4 to 1/8 of the plate resistance. Here is a list of the output powers secured from a small and a large power valve according to the formula:

VALVES "A" (Small power valve)

Grid Bias and Signal Voltage	Plate Voltage	Amplification Factor	Plate Resistance	Load Impedance	Power in Watts
16½	90	3	2500 ohms	5000 ohms	109
27	135	3	2200 ohms	4400 ohms	332
33	157	3	2100 ohms	4200 ohms	518
40½	180	2-9/10	2000 ohms	4000 ohms	767

VALVES “B” (Large power valve)

Grid Bias and Signal Voltage	Plate Voltage	Amplification Factor	Plate Resistance	Load Impedance	Power in Watts
9	135	7½	7500 ohms	15000 ohms	67
12	180	7½	7000 ohms	14000 ohms	129
18	250	7½	5600 ohms	11200 ohms	362
27	350	7½	5100 ohms	10200 ohms	894
35	425	7½	5000 ohms	10000 ohms	1530

These two tables will show you some very important things. Notice that the valve “A” will handle a stronger signal without distortion than can be handled by valve “B”, Valve “A” will handle up to 40½ volt signals while valve “B” reaches its limit at a 35-volt signal, Yet, on the 35-volt signal, the valve “B” will deliver about twice the power (1530 milliwatts) that “A” will deliver with the larger input voltage.

You might look into a receiver and find a big power valve similar to “B” and you would expect great performance from it. But suppose that big valve were being supplied with only 180 volts on its plate. It would handle signals only up to 12 volts and would deliver only 129 milliwatts of power. The same plate voltage, 180, applied to valve “A” would allow handling a 40-volt signal and would allow an output power of 767 milli-watts. If you have available only 135 volts or 180 volts for the plate, then the “A” valve is far better than the “B” valve. At 135 plate volts, valve “A” will deliver 332 milliwatts, valve “B” will deliver only 67 milliwatts. At 180 volts the comparison is 767 milliwatts against 129 milliwatts.

But, if you want to handle a 33-volt signal and have the voltage available, then the valve “B” will deliver about 1400 milliwatts as against only 518 milliwatts for the valve “A”. A big power valve is fine if you can “swing the grid” by applying a strong signal. But if you can bring to the power valve only a weak signal the fact that you use a big valve ahead of the speaker is not going to do you a bit of good. Those are the things a radio serviceman has to look out for. Many and many a time you will find grid biases away off from their proper values. Again and again you will find big valves operating with low plate voltages. Almost all good sots will operate to the satisfaction of anyone if you apply the most suitable valves for each part of the work, then operate those valves with the proper plate voltages and grid biases.

EXAMINATION QUESTIONS -- No. 18 & 18A.

1. How many watts of power will be required to light a filament taking 2 amperes of current with a pressure of 5 volts?

2. In the radio frequency amplifying valves are we interested in voltage amplification or in power amplification?

3. Which gives the greater voltage amplification, a load impedance of 12,000 ohms or one of 5,000 ohms? Explain why.

4. Will lowering the plate resistance of a tube increase or decrease the voltage amplification?

5. Does the voltage amplification of a valve with a transformer coupling increase or decrease with higher frequencies? Why?

6. To allow a valve to handle a stronger signal without distortion, would you raise or lower the plate voltage?

7. With a 3-volt signal and a 3-volt negative bias there is no distortion. If a 4-volt signal must be handled. What is it necessary to do in addition to raising the plate voltage? Why?

8. What is the minimum grid bias for handling a signal which swings 4½volts each way?

9. What is the greatest signal voltage that can be handled without distortion by a valve having 250 volts on its plate and a negative grid bias of 30 volts?

10. If you connect a 240 volt, 1000 watt radiator to a 120 volt power line, how much power is used? Why?

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