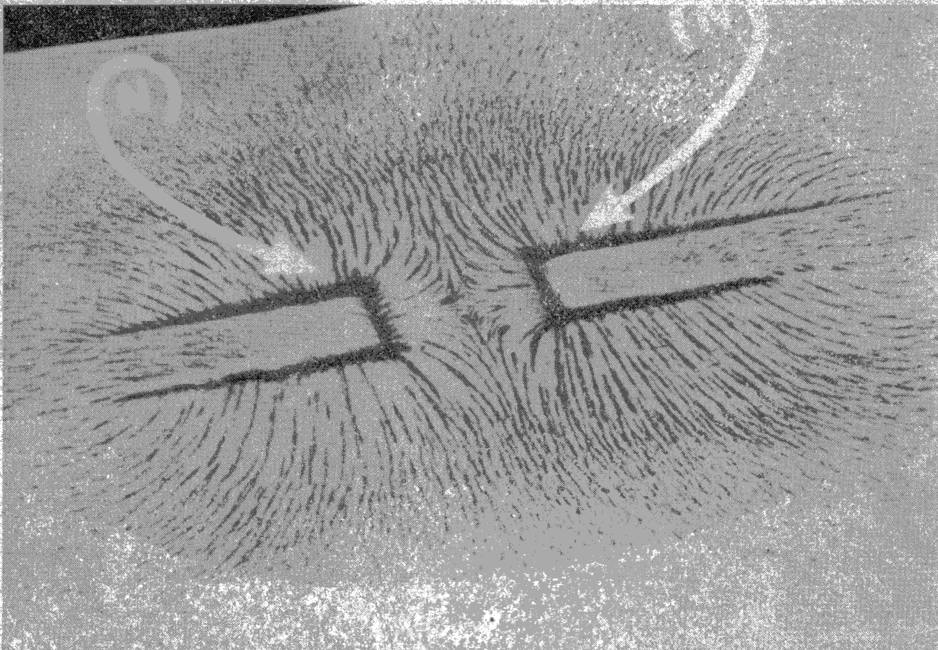
HOW LINES OF FORCE ARE APPLIED IN RADIO AND TELEVISION

Lesson No. ND-3

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO



Courtesy Jam Handy

Lines of force of two magnets are made visible by placing the magnets under paper and sprinkling iron filings on top. Like poles repel, crowd lines apart.

How Lines of Force Are Applied in Radio and Television

LESSON ND 3

You are now entering a phase of your study which is most interesting and fascinating—in fact, when you thoroughly comprehend the full significance of the actions set forth in this lesson, you will have a good understanding of one of the chief basic principles which makes radio and television possible. Once these basic laws are thoroughly understood, it will be comparatively easy for you to follow the expansion and development of these same principles as applied to more advanced radio and television circuits. Thus, you can see how vitally important it is that you consider and study this lesson in careful detail.

Right at the start, let us give you some good advice. Don't expect to understand the broad application of these principles at once. Only basic fundamental principles will be taken up in this lesson. Various practical applications will be taken up in full detail in other lessons.

MAGNETISM

Radio makes use of two types of forces. These are called **electromagnetic and electrostatic.** In this lesson both subjects will be considered, taking up **magnetism** first.

The word **electromagnetic** may also be referred to as **electromagnetism** and very often the word **magnetic** is used to denote the same thing. You will become accustomed to these various terms as you make progress with your studies.

The laws which govern or control electromagnetism are easy to understand if you will try to visualize the various actions in terms of physical objects. Like the electron theory, magnetic principles are more or less abstract. You cannot see magnetism, nor can you feel it—yet you can easily observe its effects. That is how scientists have learned so much about magnetism—they have studied its effects for years, and while there is still much they do not know about it, they have learned enough about its actions to make it perform many of our modern electrical wonders.

Electricity and magnetism are very closely related—each representing a different form of electron energy. It is possible to transform electric energy into magnetic energy and then change this again into electric energy, as you will soon see—it is interesting indeed to study just how this transformation may be accomplished.

Before going into this study we want you to understand that you must **use your imagination** in visualizing magnetic principles. There is a perfectly good reason why this is necessary. First of all, you cannot see magnetism. To a certain extent, this places you in somewhat the same position as a blind man. Someone may hold an apple before a blind man—of course, he cannot see the apple—yet he can feel it and can also taste it, and from these effects he can get a very good idea of the apple itself. The situation is somewhat similar in regard to magnetism. Of course you cannot see or taste magnetism. However, the point we want to make clear is that magnetism is just as much beyond the comprehension of a normal man (as to how it looks) as an apple is to a blind man. With this broad qualification in mind, consider carefully the following principles of magnetism.

First, you will study a simple and natural magnet—nature has provided materials and evidences which prove that magnetism is a part of our universe, just as air is a part of it. Why this is so no one knows, but it is known that such a force exists which, after all, is the most important point.

MAGNETS PROVIDED BY NATURE

Long ago in Asia Minor (in the province of Magnesia) a certain iron or rock ore having very peculiar properties was found. It was found that this particular iron ore would act on certain other metals at a distance. It is not known who first discovered this particular action, but it has been observed since the earliest times.

From the name of the Magnesia province the word **magnet** is obtained. Thus, when certain metals exhibit the characteristic of affecting other objects at a distance, they are called magnets, and, of course, from magnet the words magnetism and magnetic are derived.

It has been found that if an oblong length of magnetic iron is suspended in the center by a thread so that the iron is free to rotate, it will always exhibit a very defi-

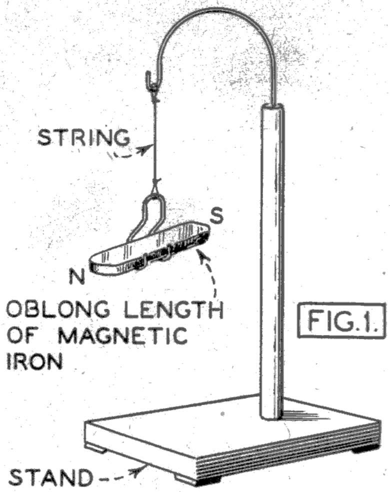


FIG. 1.

nite characteristic—that is, one certain end of the iron will (when it comes to rest) point to the approximate geographical North Pole of the earth—the other end will point towards the approximate geographical South Pole of the earth. (See Fig. 1.) This proves that the poles of the earth have a very definite power over the magnetic iron—scientists think of this power as **lines of force.** That is, it seems that these lines of force exist between the North and South Poles of the earth—spreading out so as to cover the whole surface of the earth, as in Fig. 2. **The area over which the lines of force act** is called a **magnetic field,** or more commonly, this is shortened to **field.**

It has been proved that the magnetic lines of force of the earth acting on (or going through) the Magnesian iron ore deposit magnetizes the iron ore, and by this action causes the mineral to also exhibit magnetic lines of force. That is the explanation of how this particular mineral, or any other, obtains its apparent natural magnetic effects. It is important to note at this point that the natural magnetic lines of force from the earth, in passing through great masses of iron, imparts to the iron a permanent magnetic affect. All this has been accomplished by invisible magnetic lines of force passing through the iron. As a result the iron itself becomes a magnet and in turn radiates its own magnetic lines of force. There is another way of imparting magnetism from one magnetic substance to another. If a small metal tool such as a screwdriver is stroked briskly several times across a permanent bar magnet, the screwdriver will take on magnetism from the bar magnet. (Fig. 3.) Thus it should be clear that magnetism may be imparted to suitable metals through the medium of magnetic lines of force or by mechanical action as illustrated in Fig. 3, where the screwdriver is rubbed across the length of the bar

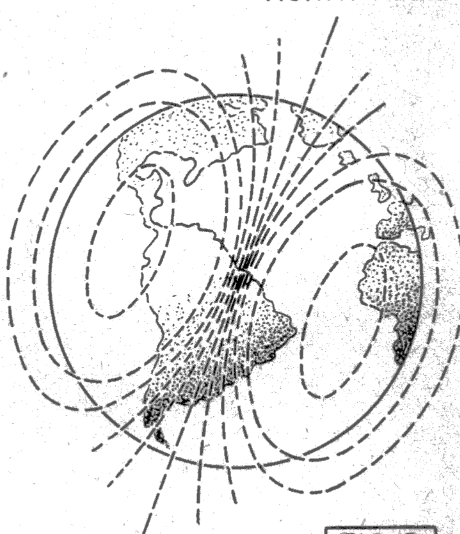


FIG. 2.

MAGNETIC FIELD ABOUT THE EARTH

FIG. 3.

magnet. Further on it will be shown how metal may be magnetized electrically, and so cause it to show the effects of magnetism.

The question naturally comes up as to why the Magnesian iron ore shows magnetic effects (due to the earth's lines of force) while other iron ore deposits may not show the same effect.

The answer to this is, that the magnetic field of the earth is relatively weak and will not show measurable effects on small, **impure iron ore deposits.** The effect is best noticed where there is a large concentration of iron ore or where the iron is in a very pure state. This magnetic effect is not confined to the province of Magnesia—the effect was merely observed first in this particular district. It so happens that the ore in this district has a high iron content and for that reason shows strong magnetic characteristics, which may not show up in other less concentrated ores. Thus it is seen that the relatively weak field of the earth will not affect certain low content iron ore deposits,—that is, the effect is not enough to be noticed. In large, tall buildings, however, where the framework is iron, the earth's field will permanently magnetize the framework of the building.

You now see how nature has provided natural magnets, and having this basis to work on, you may begin the study of magnetism with a more or less tangible picture in your mind of why magnetism occurs.

Once again, we want to make it plain that magnetism is a force which you cannot see, and that no one knows exactly what it is. It is known, however, that this invisible force reaches out into space and that it will act in a certain definite way on certain substances. With these qualifications in mind, you are now ready to learn more about magnetic lines of force.

THE POLES OF A MAGNET

You will remember it was stated that if an oblong piece of the Magnesian iron ore were suspended at the center by a thread, when it became stationary one end of the ore would point to the North Pole of the earth and the other end would point to the South Pole. **This is a fundamental action of a magnet.** From this observed effect, scientists have called that end of the magnet pointing toward the North Pole, the North seeking pole of the magnet—the other end, of course, they named the South seeking pole. These expressions are often shortened to simply North (N) and South (S). Thus, every magnet has a N and S pole.

From the foregoing you can easily see that there is an attraction between the poles of the earth and the poles of a magnet. By studying this action, scientists have learned much about the laws that govern magnetism. One important thing that has been proved is the attraction and repulsion of the poles of magnets. It has been found that the North pole of one magnet will attract the South pole of another magnet and that two North poles (of different magnets) will repel one another. From this we get our first important magnetic law which may be stated as follows:

(1) **Like magnetic poles repel one another.**

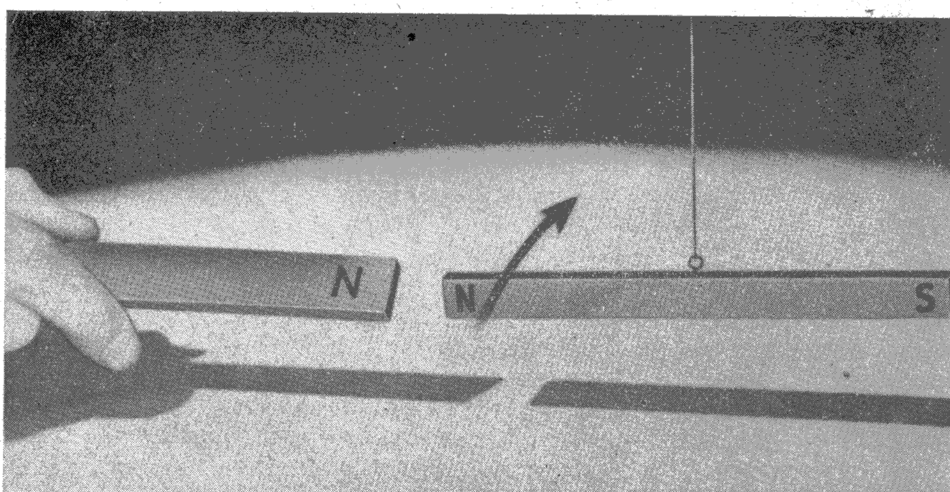
(2) **Unlike magnetic poles attract one another.**

This is a very important law and you should remember it.

The Magnesian iron, as found in the natural state, is called a natural magnet. Such a magnet has little practical value. However, from the study of the simple natural magnet, man has learned to create large, strong, useful magnets. This is usually accomplished electrically, as you will learn as you progress with your studies. But before going into this, it will be necessary for you to study more about the laws which govern magnetic lines of force.

By careful research and study it has been found that the lines of force about a magnet have a very definite path and extend in certain directions. **Inside** a straight bar magnet the lines of force extend from the South to the North pole. This means that they leave the magnet at the North pole and reenter it at the South pole. Thus, there is a continuous mass of magnetic lines in and about a permanent magnet all the time. (By permanent magnet we mean one like the Magnesia iron ore—one that permanently shows magnetic effects. There are other temporary magnets which are called **electromagnets**—you will study these in detail later.)

When magnetic lines of force about a magnet are referred to, reference is made to just a few lines. (See the lines of force in Fig. 4.) Likewise, when these are represented on paper, only a few lines



Courtesy Jam Handy

Proof that like poles, when placed near each other cause the magnets to be pushed apart. The magnet suspended by the string will spin away from the one held by hand.

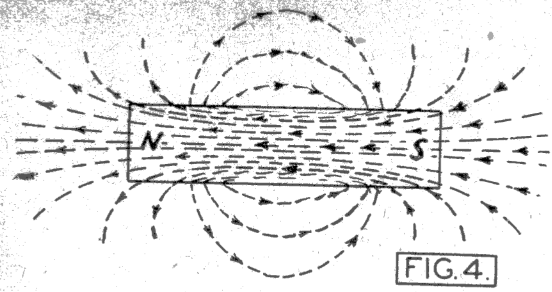


FIG. 4.

MAGNETIC FIELD ABOUT A BAR MAGNET

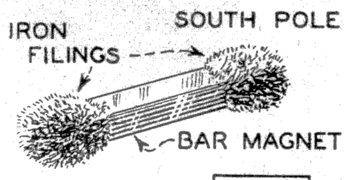


FIG. 5.

The magnetic field of a bar magnet is in force at both extremities, or poles, and in a globular band around the middle. If dipped in iron filings it will look as above.

are shown. **But this does not represent actual conditions.** Even if a large number of lines could be shown on paper, this would serve only to indicate direction and intensity. The important point you should understand is the fact that **magnetism is intangible.** The nearest approach to making it tangible we have is to show lines on paper which represents this force. All electrical literature bears out this statement. Magnetism is not a thing that you can divide into unit lines. We use the expression **lines of force** simply for convenience—all other electrical literature is written from the same viewpoint—thus, the expression is not new. Magnetism is a continuous uninterrupted force in its normal state extending out in all directions, but, of course, limited in its intensity at a distance.

DEMONSTRATING THE LINES OF FORCE

There are several classical experiments which may be performed that will demonstrate the proof of magnetic lines of force. Such demonstrations have been made over and over again, so it is not necessary for you to make the setups to prove these things unless you wish to do so for your own personal satisfaction.

Natural magnets as found in nature are often referred to as lodestone, meaning leading stone, used by the ancients as a crude form of compass to lead them in the right direction. A natural lodestone or an ordinary bar magnet and a few iron filings may be used to demonstrate the attracting qualities of magnetism. Iron filings are tiny bits of iron or steel obtainable from any machine shop where drill presses, lathes, etc., are used. An ordinary cardboard box half full of iron filings is entirely sufficient for this experiment. If you place a lodestone or small bar magnet among the group of iron filings in the box, you will find that the filings are immediately attracted to the magnet. Further you will find the greatest attraction at the two ends of the magnet. In fact, there will be a great mass of filings sticking to the magnet ends which you can clearly see if you lift the magnet from among the group of filings. Fig. 5 shows this effect in detail.

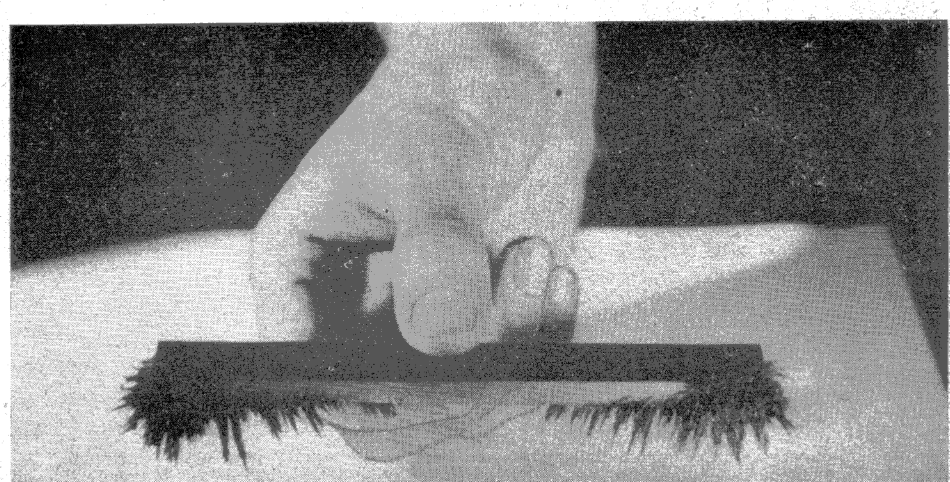
There is a good reason why the filings cling to the ends of the magnet and not so well to its center. **The metal of which the bar magnet is made is a good conductor of magnetism, whereas air is not.** Thus within the length of the bar magnet the lines of force have a good path over which they can travel with little opposition. At the ends of the magnet the lines of force spread out over a wide area because there is no good conducting medium to confine them to a given path. It should be clear, then, that at the ends of the bar magnet the lines of force converge as they enter or leave the magnet, and at these ends there is the greatest concentration of lines of force anywhere outside of the magnet itself. Thus, attraction at these points is greatest and that is the reason there is the greatest mass of filings at the magnet ends. Inside the bar magnet the lines of force are concentrated along the iron path and there is little or no external magnetic effect along the length of the magnet.

Figure 4 shows an imaginary grouping of magnetic lines of force in and about a bar magnet. **An important point to remember about this is that the magnetic lines of force external to the magnet are exactly equal to those within the magnet.** Those outside of the magnet spread out in ever-widening circles in much the same manner as water waves after a small stone is dropped into it.

ELECTROMAGNETISM

In order to get a fundamental understanding of magnetism, it is necessary to study the magnetism associated with electrons and atoms. From this study you can build up a concrete conception of magnetism which will go a long way in helping you to understand other radio principles. You will no doubt realize the significance of this as progress is made from one lesson to another.

All electrons in dynamic motion have about them a magnetic field which may be pictured somewhat as in Fig. 6. This field is strongest at or near the electron. The strength of the field further away from the electron is less than it is immediately about the electron. The distance between the magnetic lines in Fig. 6 are drawn to show this effect.



Courtesy Jam Handy

Photo above shows how filings not only gather thickly at the poles of the magnet, but stand straight out like vegetation, following the force-line pattern.

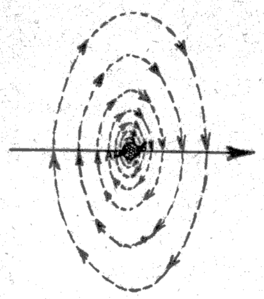


FIG. 6.

Left: Electrons, like magnets, have definite lines of force around them.

Right: Left hand rule for determining direction of magnetic field.

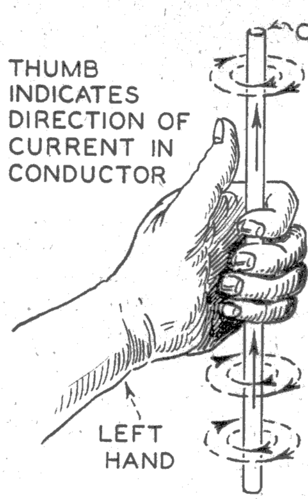
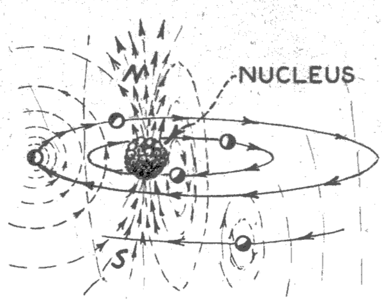


FIG. 7.

If the speed of the electron is increased, (which it is under certain circumstances), the intensity of its field as well as the distance it travels also increases. When an electron is revolving around its nucleus several million times per second it will produce a magnetic force in the direction of travel of the electron, as in Fig. 6—the long arrow in this figure indicates the direction—in this case it is assumed to be traveling from left to right. Remember that as an electron current flow has a definite direction in which it travels so does the magnetic field which accompanies it have direction. By experiment it has been proved that the magnetic field of a dynamically moving electron is at direct right angles to the direction in which the electron moves. This is clearly shown by the position of the circles in Fig. 6. The smaller arrowheads in the circles point in the direction of the movement of the magnetic field. A well-known rule will always establish the direction of the magnetic lines of force about a single wire conductor—if you will remember to apply it. It is called the left hand rule and applies in every case, **if you consider electron current flow to be from negative to positive.** To apply this rule, use your left hand as shown in Fig. 7. Imagine your thumb to point in the direction of electron current flow and grasp an imaginary wire as shown. Your fingers then point in the direction which the magnetic lines of force take in circling about the wire.

Due to the direction of travel of the electron around the nucleus of an atom, lines of force will be caused to extend upward through the nucleus. Thus, a complete atom can be magnetic. (See Fig. 8.) There is the same relation with regard to the sun, the earth and the other planets. The sun has a strong magnetic field, which is at right angles to the direction in which the earth travels. Likewise, the earth has a magnetic field which is at right angles to the orbit of the moon revolving around the earth. Later on you will study more about the right angle direction in regard to the electric field, which is a different type of field with respect to magnetism.

The electron, in moving along a straight wire will carry with it its



CUMULATIVE EFFECT OF ELECTRONS TO BUILD A MAGNETIC FIELD THROUGH THE NUCLEUS

FIG. 8.

own magnetic field, as explained for Fig. 6. To carry the idea further, consider two electrons close to one another and both dynamically moving. **Both will have magnetic fields which will merge or combine somewhat as pictured in Fig. 9A. Three electrons will have an even greater combining effort, the total field will appear somewhat as shown in Fig. 9B.** Finally, when there is many millions of electrons dynamically moving at high velocity (as, for instance, current flow along a wire), the magnetic field would appear somewhat as in Fig. 9C, were it visible.

If you consider an entire wire, remembering that many millions of electrons are flowing and that the **speed** or velocity of the electron determines the distance which the field reaches, then you may easily imagine that the magnetism extends out to a considerable distance away from the wire. This field is in circular form extending outside of the wire, as well as through it, as pictured in Fig. 9D. Here, again, the lines simply indicate the direction of the pressure, stress or influence which is called magnetism.

Now, if the electrons are forced to dynamically stop flowing along a wire (they can be made to do this by opening a switch) **their external magnetic field will disappear.** If the electrons are made to reverse their direction of travel, **the magnetism will reverse as indicated by the lines of force in Fig. 9E.** It is important to remember that these

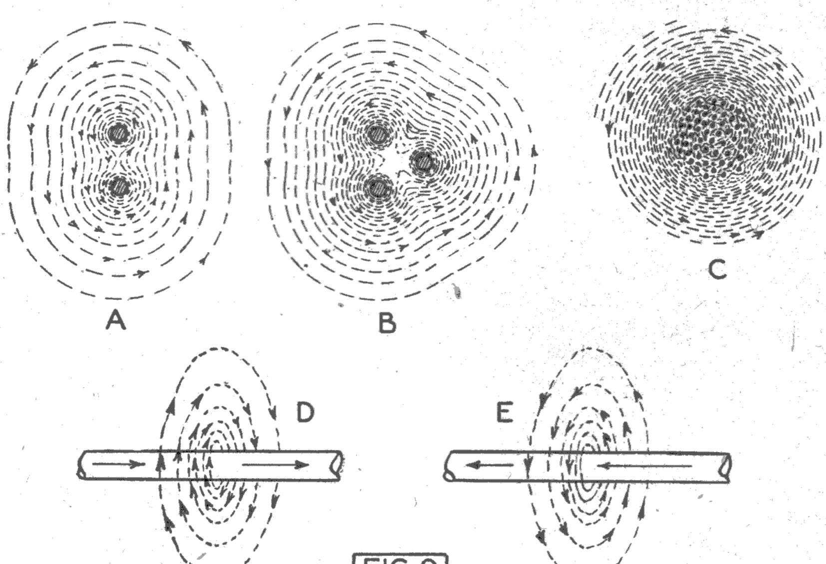


FIG. 9.

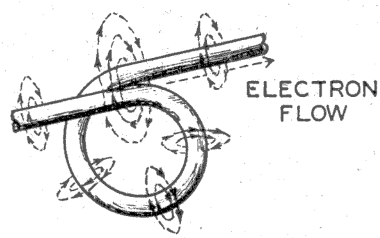
lines of force extend out and away from the wire to considerable distances. You will soon see in the progress of your studies how these lines of force will affect wires, first at several inches away through air or space, then many feet away indication will be noticed and then from a few miles to many thousands of miles. This same magnetism carries radio signals around the earth.

The gradual reduction of the intensity or strength of a magnetic field may be compared to the shell of atmosphere surrounding the earth. The air becomes thinner (less dense) up from the earth, but there is no sharp dividing line between the atmosphere and outer space. Thus the magnetic field about a wire carrying current extends out until its intensity is so small that it cannot be measured. To get a basis from which to determine the relation between the current intensity and the magnetic field produced by it, a point may be chosen at a definite distance from the wire, say one inch. By using this system it has been found that the **magnetic field is exactly proportional to the current flow in the wire,** providing no magnetic materials are present. If the current is doubled, the force of the field is also doubled, or if the current is reduced ten times, the field is in like manner reduced ten times in intensity. Thus there is a true proportion between current flow and magnetism.

It is **impossible** for an electron to be in dynamic motion without its magnetic field accompanying it. If moving electrons (comprising current flow) are stopped, the magnetic field at the source must also stop. If you create a magnetic field caused by electrons in dynamic motion, it will tend to make all electrons in the area of influence **move.** Just as surely as the **electron in motion** will produce a **magnetic field, a magnetic field in motion will tend to produce moving electrons,** or in other words cause an electric current to flow.

CREATING ELECTRO-MAGNETIC FIELDS BY MEANS OF COILS

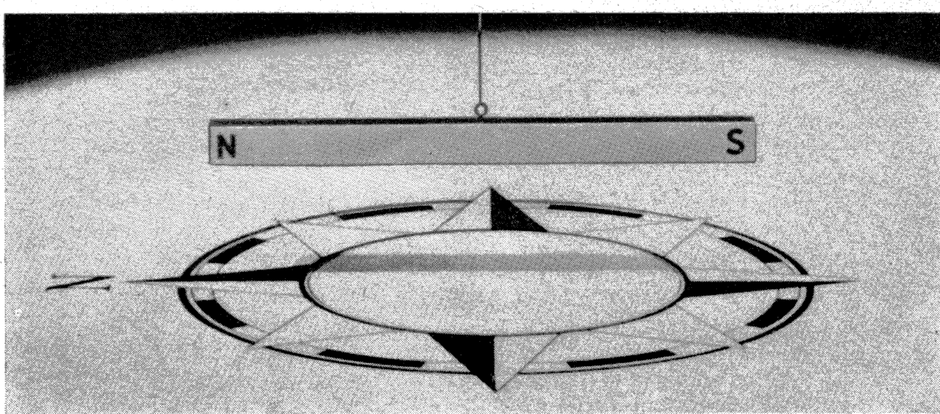
Here is an important fact—be sure to remember it. In a magnetic field **of fixed intensity, there is no magnetic motion.** Thus a magnetic



SHOWING HOW MAGNETISM MULTIPLIES WHEN A LOOP OF WIRE IS USED

FIG.10.

field produced by the flow of **direct current** is fixed and steady—its pressure or area of influence is merely being exerted in a definite direction. With AC, on the other hand, the magnetic lines of force change their direction and of course in this case there is motion or a changing magnetic field—but more about this later. **Do not** confuse the arrows used in Figs. 6 through 9 (which indicate the direction of the magnetic force), with the idea of continuous motion. This idea of a fixed magnetic field is analogous to a compressed coil spring. A coil spring may be compressed and may



Courtesy Jam Handy

If a straight bar magnet is hung by a thread, the pole of the magnet which points toward the north is called the "North-Seeking Pole," or just North Pole." Other pole is called "South Pole."

remain quite stationary, and yet the direction in which its force is exerted may be represented with an arrow.

In many ways a magnetic field in and around a straight length of wire, such as described in the foregoing, will be useful, but for other uses there must be magnetic **fields** of **different kinds** and of different intensities.

In further consideration of this, suppose a length of wire is looped as shown in Fig. 10. If this is done there will be two lengths of wire passing close to one another, both having magnetic fields, and it will be noticed that for a short distance the two loops of wire are parallel. Current is flowing in the two adjacent lengths of the wire in the same direction.

Now in exactly the same manner that the two individual fields of a pair of electrons combine to form a single field, as shown in Fig. 9A, the two fields about the two lengths of wire will also combine as shown in Fig. 10.

If you should wind more turns of wire alongside one another, all of the separate fields of the individual wires will combine or merge together forming one big single magnetic field. Several turns of wire are shown in cross section form in Fig. 11, as though all of them were cut in the center. By forming a coil (wrapping several turns together), various lengths of wire will all contribute to the forming of a single field (which is very strong in the center of the coil) and all of the lines of force will cooperate in the same direction, just

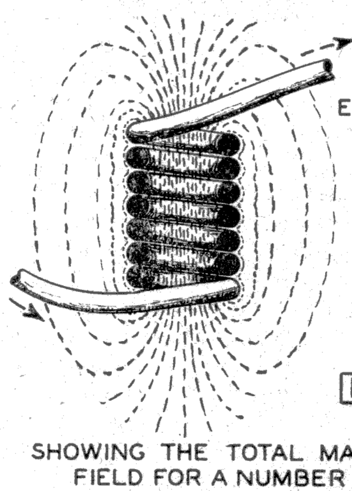


FIG.11

SHOWING THE TOTAL MAGNETIC FIELD FOR A NUMBER OF LOOPS FORMING A COIL as explained for the electrons in Fig. 9.

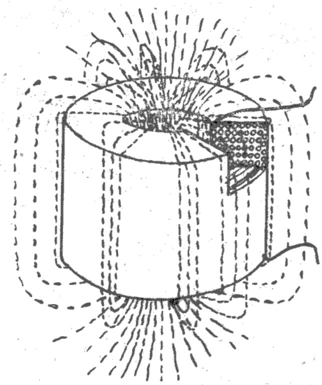
While magnetism also exists outside of the coil and away from it, it spreads over so much space that it is **not** very strong or intense at any **one** place. The total outside field extending indefinitely from the coil, however, is equal to the total inside field in intensity. Each turn of wire that is added to this coil carrying a current will also add to the total magnetism.

Consider another type of coil with a great many turns of wire wound layer after layer as shown in Fig. 12. If it has 50 times the number of turns of wire that the one in Fig. 11 has, it will have a magnetic field 50 times the strength of the coil in Fig. 11, provided, of course, that the same value of current of electrons is flowing in both coils.

You are now prepared to consider the effect that a magnetic field will have on various other substances. Although it is necessary to get down to considerable detail in the following study, it will all naturally follow the principles already covered in this lesson. If you understand the foregoing, the following will not be at all difficult.

THE MAGNETIC NATURE OF METALS

It has been carefully pointed out that the direction of movement of any magnetic field depends on the direction of movement of electrons which produce the field. Now, every known substance is made up of electrons which are in various states of motion—these move either in orbits of atoms (static motion) or they are in the act of forced motion (dynamic) as, for instance, along a wire conductor. Ordinarily, the orbits of the electrons of various substances are in various directions relative to one another. There are, of course, quite a number of electrons in each atom except that of hydrogen which has only one electron. Furthermore, they may be revolving around the nucleus in opposite directions, with the magnetic forces of one exactly balancing out those of another. The atom

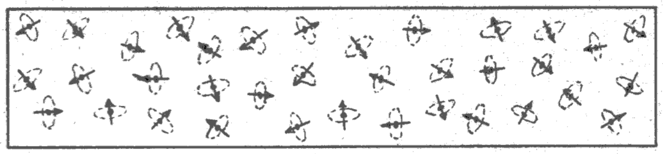


SHOWING HOW MAGNETISM WILL FORM ALL AROUND A COIL CARRYING CURRENT

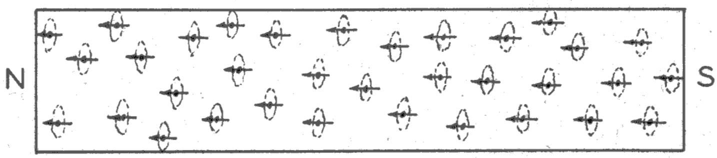
FIG.12.

as a unit may thus contribute no external magnetic influence whatever to the substance of which it is a part.

Hence, the individual or unit magnetism of the atom contributed by the revolving electron may be in any direction whatever or may be balanced out completely. For a substance not under magnetic stress every electron moving in the North direction will have a corresponding electron moving in the South direction. For every one or more moving in the up direction, there will be one or an equal number moving in the down direction.

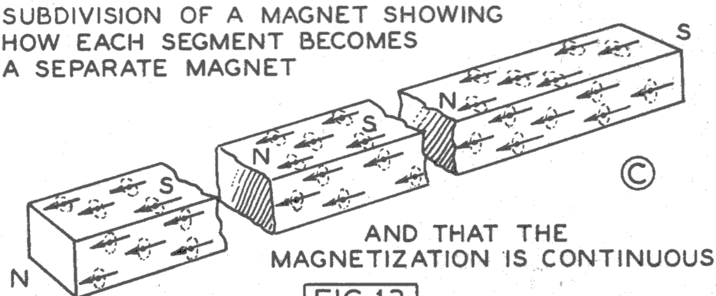


ORDINARY SUBSTANCE OR MAGNETIC SUBSTANCE BEFORE MAGNETIZING. (A)



MAGNETIC SUBSTANCE AFTER MAGNETIZING SHOWING HOW THE ELECTRON ORBITS ARE LINED UP – NOTE THAT THE ELECTRONS ARE ALL REVOLVING IN THE SAME DIRECTION. (B)

SUBDIVISION OF A MAGNET SHOWING HOW EACH SEGMENT BECOMES A SEPARATE MAGNET



AND THAT THE MAGNETIZATION IS CONTINUOUS (C)

FIG.13.

There are so many billions of electrons in each substance that for each one having its force in one direction, there will be another one exerting its force in the other direction which is to say that in a normal substance the magnetic forces are balanced.

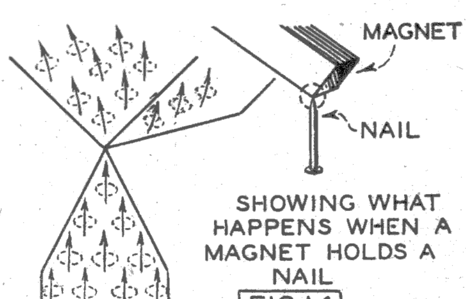
The effect for any non-magnetic material in a normal state is such that no total magnetism will be developed. Thus, if a piece of wood, glass or lead is placed in the coil of Fig. 12 it will not change the field in any way. This is because the position of the atoms (with their electron orbits) will not be disturbed. **In these non-magnetic substances the magnetism is completely balanced out, due to the fact that the energy of the electrons in one direction is equal to that in all other directions so that no external magnetism exists.** Therefore, when magnetic lines of force are impressed through them no change is made in the material. The magnetic field, due to a current flow through the coil, will pass right through the empty space **(ether)** between the atoms of the non-magnetic substance without increasing, decreasing or changing the atoms of the substance in any way. Remember this point, as it will be useful to you in the future.

MAGNETIC COILS AND CORES

Practical use is made of these principles throughout radio. For instance the coil of Fig. 12 is very similar to a dynamic speaker field winding. **An iron core inserted in it will concentrate a powerful magnetic field in a small area.** Many other types of radio coils make use of iron cores in solid and powdered form. For the opposite effect coils are wound on wood and other types of non-magnetic materials. These merely serve as forms to support the coil winding. From this you can see that it is important for you to have a general knowledge of these principles.

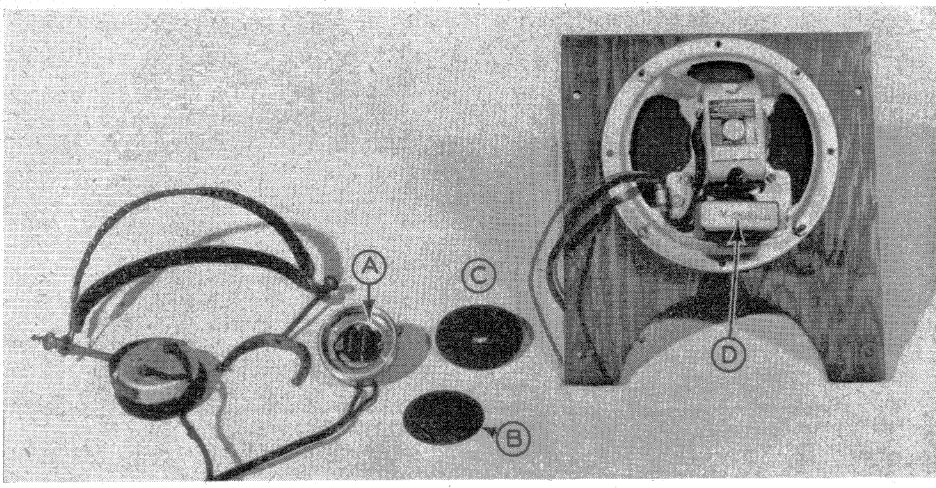
An imaginary view of a **magnetic substance** before magnetizing is shown in Fig. 13A. This represents the condition of its atoms before any external magnetism acts on it. The short arrows represent the magnetic field of each atom. While it is true that every atom arrow pointing vertically or even approximately so, adds (its intensity) to the total external magnetism, yet every one pointing down or approximately so, subtracts (its own intensity) from the total field. **Thus, before any external magnetism is applied the substance has no external magnetic effects. Non-magnetic** substances are not like this, because the atoms of which they are composed are non-magnetic to begin with, a wood coil form for instance. Materials in this condition neither hinder nor help the magnetic field applied through them.

If you should place a piece of soft iron, steel, cobalt, or nickel through the coil of Fig. 12 while it is carrying current, something quite **different** will happen. The magnetism produced by the coil carrying a current will **rotate the orbits** of many of the electrons of the magnetic metal substances so that their effects will be impressed in one direction—namely, the direction of the external field acting on them. See Fig. 13B. For balanced atoms in a magnetic substance, some of the electrons may be reversed in their orbits so that the atom will be sensitive to magnetic influence. The external or applied magnetism will then tend to turn these orbits so that the separate magnetic influence of each atom will be aligned or impressed in the direction of the applied lines of force. The force which builds magnetism by aligning the influences of moving electrons is **called magnetomotive force.** Using a piece of soft iron the field originally caused by the coil alone will be strengthened or intensified many thousands of times. This is because the soft iron is a better conductor of magnetic lines of force than air. The iron core concentrates the lines of force in a minimum area. All of this is due to the **change in position** of many of the orbits of the electrons in the iron. Moreover, if the iron is removed from the coil some of the atoms of the iron will temporarily remain in their new positions and the iron will display the



SHOWING WHAT HAPPENS WHEN A MAGNET HOLDS A NAIL

FIG.14.



Some of the parts in a radio using magnets. (A) Small electromagnet with thousands of turns of small wire, used in headphone with metal diaphragm (B), and rubber earpiece (C). (D) points towards large electromagnet for speaker field.

same magnetic properties as the coil.

If hard steel is used for this experiment most of the atoms will remain in their new positions and the steel will be permanently magnetized. Thus you see how electricity may be used to magnetize a bar magnet. This is true also for some few other substances, such as cobalt, nickel and liquid oxygen, but to a lesser degree.

Fig. 13B is a graphic representation of the positions of the atoms of the iron or steel after they have been subjected to magnetism.

You can further demonstrate that this condition exists throughout the entire length of the iron or steel by cutting a bar magnet into several pieces. Each piece will become a separate magnet as shown in Fig. 13C. This is further proof of the inherent magnetic nature of the electron and atom, because no matter how many times you divide the bar magnet in Fig. 13C and no matter how small the individual pieces become each piece will still show the effects of a North and South pole. It follows then that if you could divide the bar magnet into its finite atoms and electrons they too would show the same magnetic effects.

This individual nature of a limited number of substances seems to have a definite relation to mechanical motion. If you hold a magnetic substance in a magnetic field, either that of the earth or one produced by a coil of wire, and tap it sharply with a hammer (create motion) the tapping seems to aid the electrons in assuming their correct positions. On the other hand, if you magnetize a piece of steel, take it away from the field used for the process and then tap it, it will lose some of its magnetism.

If you bring a bar magnet near a piece of iron such as a nail, its field will immediately extend into the nail, and will turn the orbits of many of the electrons in the nail. The North pole of one magnet will attract the South pole of another —similar to the law for electrons and protons—like charges repel, unlike charges attract. **Thus like magnetic poles repel and unlike magnetic poles attract.** The nail or a piece of iron or steel will, therefore, be drawn to the magnet pole, as pictured in Fig. 14. The other end of the magnet will attract iron for the same reason, but in this case, all of the S poles of the atoms

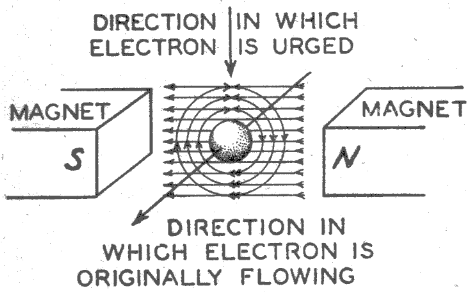


FIG. 15.

of the magnet will be attracting the N poles of the smaller piece of metal. The piece of iron or steel will become a magnet itself, at first strong while under the direct influence of the magnet and then weaker as it is removed—but as was explained, **many of the atoms will now maintain their newly acquired positions.**

An ordinary piece of steel will become magnetic if placed in line with the N-S poles of the earth, and if a steel needle is floated on a cork or piece of wood in water it will turn its poles toward the poles of the earth. In other words it will act as a compass. Its magnetism will be increased if it is struck sharply while in this position, and will be reversed if its position is reversed.

Both permanent and electromagnets are used widely in radio, and it is all based on the foregoing explanation of how iron or steel is affected by magnetism.

CHANGING FORMS OF ENERGY

Consider now some of the more common applications of magnetism as exemplified in radio practice. You will see how the force of magnetism called magnetomotive force can be converted to electrical force called electromotiveforce, or voltage. This study is most important because the principles are employed over and over again in radio and television circuits. So make sure you understand these principles as you advance with your studies.

Where a conductive path such as a copper wire circuit is provided for a voltage, electrons will move in the wire, forming a current of electrons, or simply a flow of current. It has been explained that, due to the nature of an electron, **when it dynamically moves it creates a magnetic field.** Remember also that an electron is always in motion. When it is not traveling along a conductor by jumping from one atom to another, it is revolving around the nucleus of an atom at an extremely high speed estimated at several million revolutions per second. Thus, in the usual or normal state the electron always has its magnetic field. However, when there is no voltage to shift electrons away from their atoms, all of these fields are in various directions (as explained formerly) giving no total external magnetic field. If an external magnetic field, such as that which exists between two permanent magnetic poles, is caused to sweep through a conductor having free electrons, it will move the electrons as indicated in Fig. 15. The straight arrows in this figure show magnetic lines of force between the two bar magnets—leaving the N pole of one magnet and entering the S pole of the other magnet. The circular arrows represent the magnetic field about the electrons.

All electrons in this permanent magnetic field will be similarly affected and their combined movement will form an electron current flow in the conductor. When an electron or group of electrons is displaced—that is, moved from one place to another, they take their charges with them and add a negative charge to the material in which they are found. This is one way in which electricity can be caused to exist in a conductor by means of magnetic lines of force. This is an elementary principle, and later on it will be shown how practical use is made of this principle.

When electrons are removed from one place, that same place becomes positively charged, and is placed in such a condition as to cause it to attract electrons. For example, if you utilize the principle of Fig. 15 and cause a number of electrons to move to the right in a conductor (in which they were originally equally distributed as in Fig. 16A), a voltage will be established between the ends of the conductor. Since more of the electrons accumulate at the right end, (see Fig. 16B) it is negative as each electron has a negative charge. The other end is positive because many of the atoms have lost their electrons and hence become positive. This is the condition in a conductor when magnetic lines of force are used to cause current flow in a circuit in which no current originally existed.

Referring again to Fig. 16B, if the electrons are prevented from drifting back to the left by the

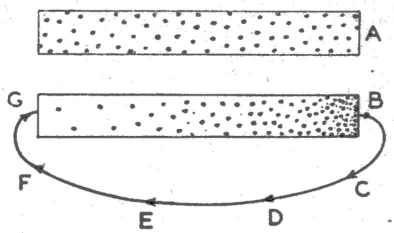


FIG.16.

voltage created in the conductor, and an external circuit is connected such as the wire C,D,E,F and G, the electrons will press themselves out into the external circuit and force their way into it, as there are fewer of them in the wire at the left end. It is assumed here that before connecting the external circuit of C-G of Fig. 16B that the electrons in the connecting circuit were originally distributed as for Fig. 16A. As soon as some of the electrons move from B to C, in Fig. 16B those at C will become crowded and since they cannot move against the pressure of electrons at B, they will move to a less crowded section of the wire at D. Those at D will in turn move along to E, etc. until they are all equally distributed in the external circuit and the conductor G-B. No more voltage will then exist anywhere along the circuit. This is the action which takes place in a conductor when magnetic lines of force are caused to induce a voltage in the conductor.

VOLTAGE INDUCTION FROM A MAGNETIC FIELD

Next will be described an important point which must be studied closely. **In order to displace electrons or to form voltage, the magnetic field must be in motion, or the conductor must move.** If the magnetic field is stationary, no matter how powerful, it can only

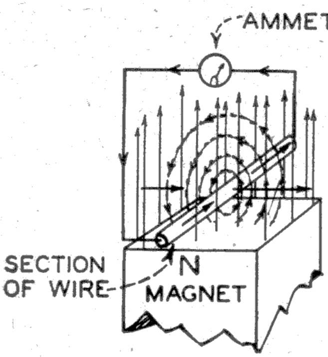


FIG.17

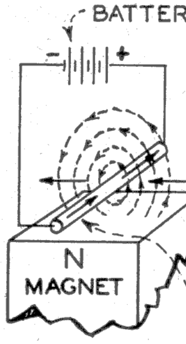


FIG.18

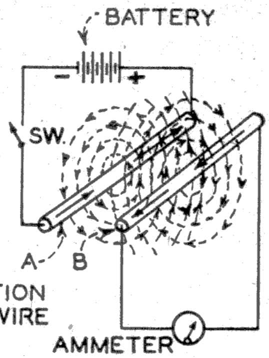


FIG.19

change the directions of the orbits of some electrons in some few substances such as iron, nickel, and cobalt—it cannot under ordinary conditions permanently displace the free electrons of the conductor. If the field does not move or change in strength, the wire or conductor must move for creation or maintenance of a voltage. You will learn later on that a magnetic field due to AC can induce a voltage from one conductor to another whereas this is not possible with DC. **It will only produce a steady or an unvarying magnetic field.**

If a magnet field is being impressed through a conductor it moves each individual free electron and a current will result. The number of free electrons in dynamic motion as well as their speed or movement will now depend on the strength of the field impressed and other things to be explained a little later.

For a better understanding of this principle assume there is a section of wire as in Fig. 17, and that it is moved swiftly across a magnet pole with unvarying magnetic lines of force. Each free electron of the wire will now be under magnetic stress and many will be moved in the direction indicated by the short arrowheads along the wire circuit; as a result of this electron movement an electron current will be indicated by the ammeter, **(Fig. 17)** thereby proving that a current flow actually does take place in the wire. When the wire is no longer moved across the pole of the magnet the current will cease to flow as proved by the action of the meter. On the other hand the faster the wire is moved, the more will be the current. All conventional electrical generators are designed to operate on this principle.

If you replace the ammeter in Fig. 17 with a **battery**, as in Fig. 18, the magnetic field, due to the battery current in the wire, **will react against the field** of the permanent magnet and cause the **wire to move.** On this simple principle all electric motors operate.

Instead of having a **permanent magnet** to form the magnetic field a wire or coil through which current is flowing may be used. Thus in Fig. 19 note there is wire A carrying current from a battery and wire B placed close to it. On closing the switch SW in the battery circuit, the current, in rising from zero to a maximum value will momentarily build up a changing magnetic field around A and it will expand in every direction. This will induce a voltage in wire B and will cause an electron current flow to take place in it. With a current flow in the B circuit, there must be an accompanying magnetic field, which is shown by the circular arrows pointing to the right. By following the action in detail, it will be noticed that this other field, called a secondary field, is in the **reverse direction** with respect to the first or primary field. This important point will be enlarged upon later, and should be remembered.

Instead of two wires as in Fig. 19, these principles may be expanded one step further by use of two coils, as in Fig. 20. The reason for this will be clear if you remember that the amount of magnetism which can be produced by a coil is very much greater than that produced by a straight wire, due to the accumulation of magnetism. In Fig. 20 the two coils are shown in the same relative position so that the field of one (A) will extend into the other (B). From your study of Fig. 19 you will recognize how this circuit will operate. When the switch is closed, the field about (A) will momentarily build up as the electrons force their way through the winding, and this field will extend over into coil (B). Voltage will be **induced** or created from magnetism in coil (B) and the meter will indicate the resulting current flow. Think this over a bit. Note particularly that this has caused a voltage to be transferred from one circuit to a second circuit in which there is **no battery** or other source of electrical power. This is the main point we want you to

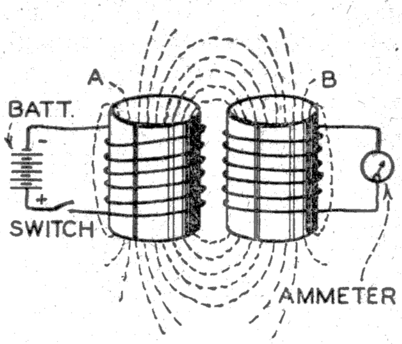


FIG. 20.

understand from your studies of Figs. 15 to 20. You should remember **why** this action is possible because this principle of **voltage induction** will be referred to often in lessons which are to follow.

In all of the preceding examples, the amount of current flow will be quite small. An extremely sensitive instrument would be necessary to get a meter indication in Figs. 17, 19 and 20. All of these experiments have actually been conducted in much the same manner as they are shown here—they represent **facts** which you should remember.

You will recall the explanation of the manner in which iron or magnetic metals acted when subjected to a magnetic field. The effect of magnetism on ordinary iron is so great that with ordinary instruments and small currents, very definite indications are obtained. One way to place iron in the field of Fig. 20 is to bend several large nails U shaped to fit in both coils,

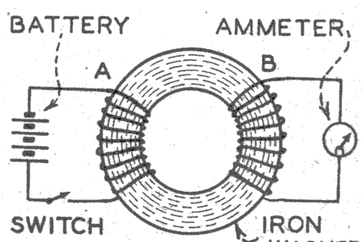
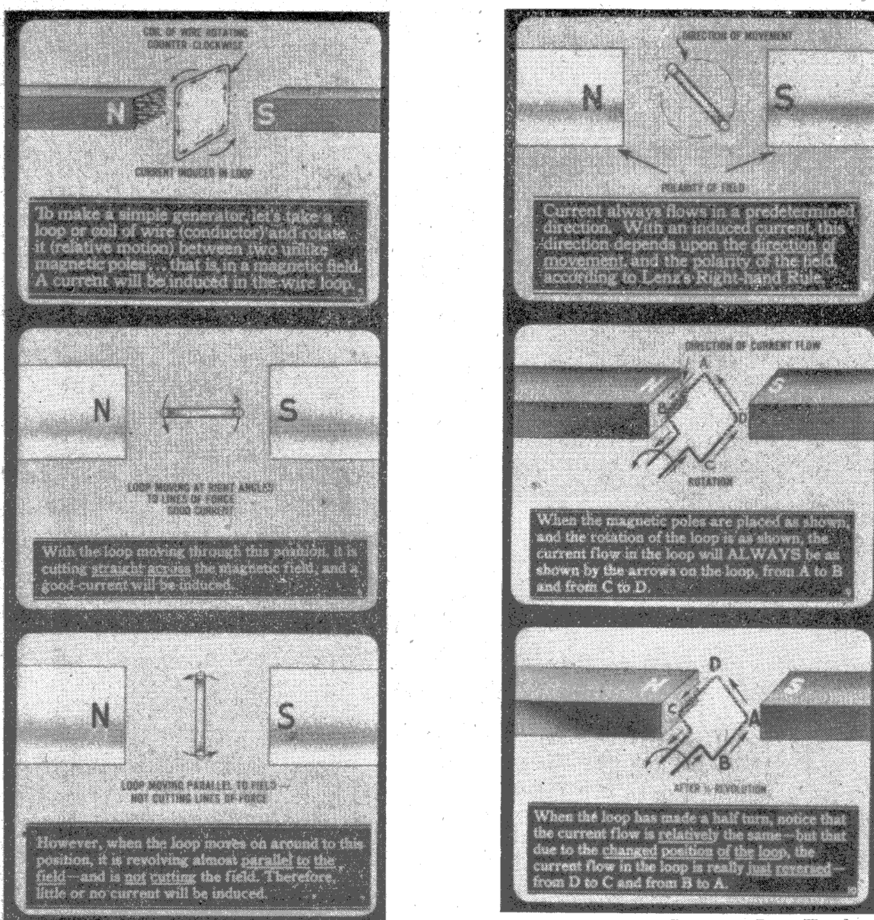


FIG. 21.



Courtesy Jam Handy

These photos show the basic principles of the generator, and how a simple one can be made using two ordinary bar magnets and a loop of copper wire.

or select a ring of iron, such as a large washer or binder ring, winding the wire on it as shown in Fig. 21. The ring set-up is by far the best, as there is iron in the entire magnetic path. By closing the switch of Fig. 21 an enormous momentary field is produced as compared to the same arrangement with air, wood or lead or any other non-magnetic substance. This demonstrates the principle on which all electrical transformers operate. When you come to the practical application of transformers in radio, this basic principle should be remembered.

If you were watching the meter needle in an actual circuit, similar to Figs. 20 and 21, you would see that it would indicate current immediately on closing the switch. The needle would then drop to zero rapidly. This of course checks with your understanding of magnetism, as you already know that the magnetic field, due to the battery, is expanding and sweeping through the wires of circuit (B). As the switch is opened, the meter needle will kick back, indicating a current in the opposite direction. When electrons stop flowing (due to voltage application) it simply means that there is no longer a flow of electricity, and as you know, **under such a condition there is a** tendency among the atoms to restore balance. Thus the free electrons start revolving about the atom with which they happen to be associated. The field that is built up in the iron of Fig. 21 vanishes as quickly as the electrons stop flowing in the circuit, and in so doing sweeps across all of the wires, inducing large voltages in them. **Remember, a moving field is the only one that will induce voltages from one circuit to another.** That is the reason in Figs. 20 and 21 that voltage is induced in the second circuit (B) only when current is first turned on and when it is cut off. These are the only times there is a changing magnetic field, since the battery current is of the DC type. While the meter indicates the presence of current in circuit (B), there will probably be a spark across the contacts of the switch in circuit (A) as it is opened. This results from a large voltage production at this time, due to the collapsing lines of force (fast rate of change). With just the battery and switch in the circuit there will be little or no spark, showing that the spark or arc is not due to the voltage of the battery. Another lesson on **inductance** will treat this subject in detail.

There is another important principle you should know about magnetically induced voltages; that is the direction in which the field or conductor is moving. In Fig. 22 is shown a uniform magnetic field represented by the vertical lines and spaces. The entire space is considered to be filled with magnetism and the vertical lines show that it is impressed vertically and that it is uniformly distributed. The lines are used to simply indicate the space the field occupies, not as a measure of magnetism.

In this figure the end view of a wire conductor is considered to be at (O). Next consider what happens when it is moved in various directions such as (O-A), (O-B), (O-C), etc. When the conductor moves from (O) to (A) it is directly in line or parallel with the direction of the field. No matter how fast it moves in this direction **no voltage will be induced in it,** because it has not cut or swept across any lines of force.

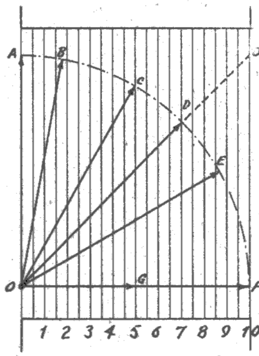


FIG. 22.

Now, if this same conductor is moved from (O) to (F), at right angles to the field force, it has cut through a section of the entire field. Assume that it has moved fast enough to have ten volts induced into it. Suppose now the conductor (O) is moved from (O) to (E), the same distance as (O-F) and in the same time. It has cut through only a little more than 8½ of the 10 units from (O) to (F). The value of the induced voltage depends on the rate at which the conductor cuts across the magnetic field. It should be clear therefore, that the voltage induced in this case will be only about 8.5/10 or 85% of the voltage induced by the motion from (O) to (F). Thus only about 8.5 volts would be induced.

In moving from (O) to (D) the conductor cuts through even fewer lines of force (about 70%), inducing only 7 volts. Similarly a movement (O-C) would induce about 5 volts and a movement (O-B) would induce less than 2 volts.

To induce 10 volts by moving in the direction (O-D), for example, the conductor would have to continue to (D′) and it would have to move the entire distance (O-D′) **in the same time** it formerly required to move from (O) to (F). This is about 30% farther, and hence the conductor would have to move 30% faster.

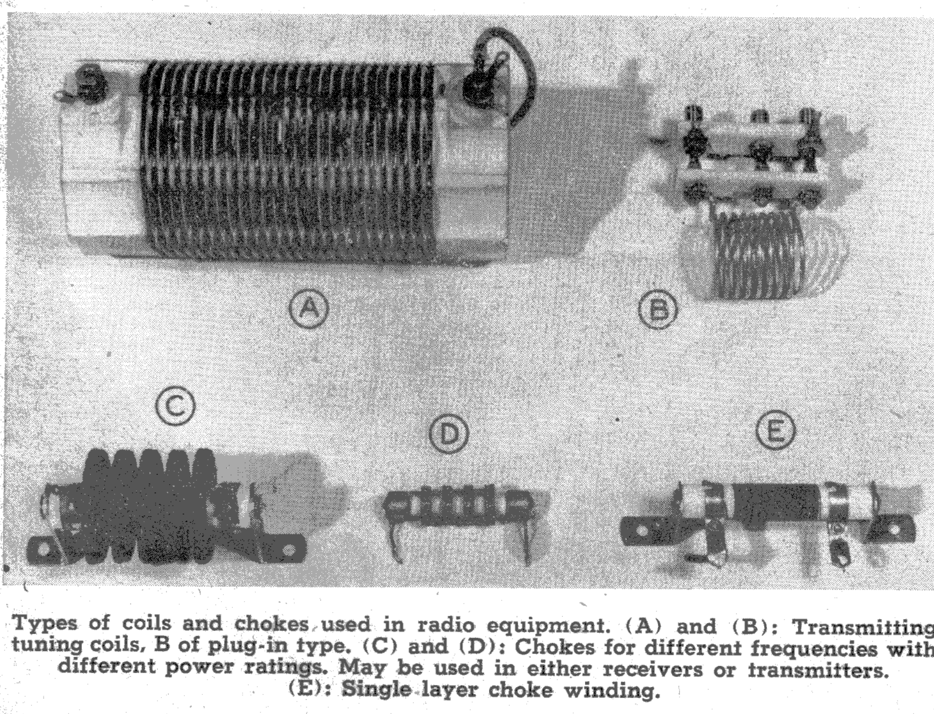
On the other hand, to induce only 5 volts in the conductor, moving in the direction (O-F), it would have to move only half way, or to (G) in the same time that it must reach (C) along the line (O-C). Although the distance (O-C) is twice that of (O-G), the same voltage will be induced in either case, **because the same number of lines of force have been cut in both cases.**

From this and the foregoing it may be seen that the amount of induced voltage in a wire from a magnetic field depends on three things. They are:

(1) The length of wire. A greater length of wire or more turns of wire in a given coil or loop increases the induced voltage.

(2) The rate of speed at which the wire passes through the magnetic field, or the rate of speed at which the magnetic field passes through the wire. This may be compared roughly to the wind bending a slender tree—the stronger the wind, the more the tree will bend.

(3) The direction in which the field passes through the wire. **A wire must pass through a magnetic field at right angles to the lines of force to induce a maximum voltage.** This is an important principle and you should remember it.



Types of coils and chokes used in radio equipment. (A) and (B): Transmitting tuning coils, B of plug-in type. (C) and (D): Chokes for different frequencies with different power ratings. May be used in either receivers or transmitters. (E): Single layer choke winding.

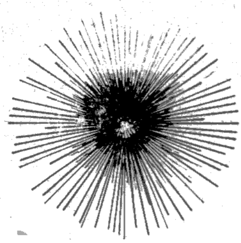


FIG. 23.

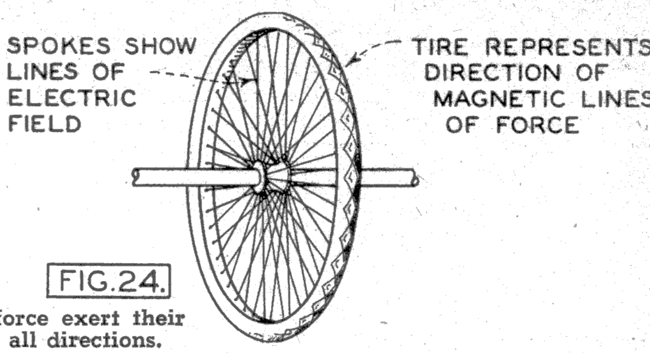


FIG. 24.

How electric lines of force exert their influence outward in all directions. (See text.)

Radio signals are transmitted over great distances by making the magnetic field about a wire change very rapidly. Power is supplied to receivers and transmitters by means of transformers which convert power into magnetism, and from magnetism back to electricity again. Signals are carried from one circuit to another by magnetism, speakers operate by the simple laws and principles just described. Many new things have been learned about magnetism in the past twenty-five years. Today there are literally thousands of things done by magnetism which were unknown twenty-five or fifty years ago.

ELECTROSTATIC LINES OF FORCE

It has been mentioned before that the electron has its own inherent electrical charge which is present all the time, regardless of whether it is in static or dynamic motion. This charge is of negative polarity and is just as fundamental as the electron itself. The mere fact that the electron has an electrical charge (and cannot under any circumstances lose this charge) which will repel another electron at a distance, or by the same token be attracted at a distance through the influence of a positive charge (for instance the unbalanced charge of an atom which has lost free electrons due to chemical or electrical action) is definite proof of an invisible force at work. Too, when you consider the fact that external magnetism is only associated with an electron when it is in dynamic motion, and also that an electron will repel another electron no matter what its state of motion, you have further proof of **another type** of force which definitely is not of a magnetic character. Investigators long ago discovered this **electric charge** of the electron. They compared it with the magnetic effect of the electron, and were able to prove that this electric charge was a totally different type of force than magnetism. Since it was known that this second force was due to the inherent, or natural electrical charge of the electron, it was given the name of **electrostatic** charge to distinguish it from **magnetic effects.** The word **static** comes in here because the electric charge is present **all the time,** whereas the magnetic effect is only present when the electron is in dynamic motion. Experiment proved that this electric charge exerted lines of force which would act at a distance from the electrons, just as experiment proved that there were magnetic lines of force which would act similarly. Thus, lines of force due to the electric charge of the electron are called **electrostatic lines of force** and those due to magnetic action are, of course, called **electromagnetic lines of force,** as you have already learned. To avoid the use of a longer word electrostatic is usually shortened to the word electric. When reference is made to the electrostatic lines of force, the term electric or static field is usually used. This is common practice in the radio profession. Therefore, in the future we will use the terms **electric or static field** and **magnetic field.**

It has been shown previously in this lesson that magnetic lines of force are circular in nature, and that they revolve about an electron as in Fig. 6, or around a conductor in rings as in Figs. 17 through 20. The electric lines of force, on the other hand, exert their influence **in every direction.** Figure 23 shows how the electric lines of force about an electron exert their force outward from the electron. Note, however, that this shows only one side view since a drawing cannot show all sides of a sphere or ball. If you will think of a perfectly round pin cushion with pins stuck into it from every possible angle (representing lines of electric force) you will get a better mental picture of the electric lines of force about an electron. The same principles apply if you consider a group of electrons or a wire conductor either single or in coil form.

From this explanation it should be clear that the greatest difference between the electric and magnetic lines of force is the direction in which they make their forces felt; you should also remember that external magnetism is only associated with the electron while it is in motion, whereas the electric lines of force are ever present.

In your future lessons you will have occasion to study these two fields separately, as well as together. For this reason it is most important that you understand the difference between them and the direction in which they act.

Scientists have proved that every electric field line of force crosses every magnetic line of force at right angles when these two forces are associated with one another. It is important that you get firmly fixed in your own mind just what is meant by a right angle direction; "if one straight line meets another to form equal angles the angles they form are right angles." The magnetic lines are circular in nature. However, in theory you may select an isolated point along the orbit of a magnetic line of force and so consider this one point as a straight line. If you assume that an electric line of force crosses this point, then the angle between the paths of travel of the two types of lines of force will form right angles. Another way to get this right angle direction firmly fixed in your mind is to think of the construction of an ordinary bicycle wheel. Think of the hub of the wheel as the charged electron, let the spokes represent electric lines of force and the tire or rim as magnetic lines of force. Thus there is the rim circling the hub with the spokes radiating outward. The place where the spokes join the rim is where the right angle direction is formed. See Figure 24 for an illustration of this idea.

This figure, however, can only serve to **illustrate the idea of a right angle direction.** The bicycle wheel illustration should not be taken as the true representation of **all** the conditions surrounding a dynamically moving electron. Actually, there are probably thousands of magnetic and electric lines of force associated with a dynamically moving electron, or about a wire through which current is flowing. The electric lines of force move outward away from the electron in every direction, and instead of one circle representing one magnetic line of force as in Fig. 24 (the tire or rim of the wheel) there are probably thousands of them. They are not at a certain distance away from the electron, but occupy all space in and around the electron. These definite qualifications should be kept in mind with reference to Fig. 24.

You will have very little occasion to consider electrostatic and magnetic lines of force **together** except when considering the transmission of radio signals. However, you will have numerous occasions to consider both of them separately. In the study of condensers, you will consider electrostatic lines of force and in the study of inductance, you will be more concerned with magnetic lines of force. A later lesson will be devoted to each of these subjects.

PRINCIPLES OF CONDENSERS

It is practically impossible to show all the effects of electric lines of force around one electron. If you could collect a large number of electrons you would find that they would all repel each other as they all have an equal and like negative charge. When they can**not directly move all other electrons away from them, their repelling force will press out into space in all directions.** Obviously the more electrons gathered together, the greater is their combined pressure, which is called voltage. In a substance having a normal number of electrons there is no accumulated pressure because with each electron there is a corresponding equal positive charge to counteract it.

For the purpose of illustration assume that you could collect a large number of free electrons in a flat metal plate. With a wire connected to such a metal plate (it may be thought of as a storage tank or reservoir of electrons) you can learn much about an electric

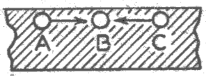


FIG. 25.

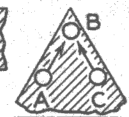


FIG. 26.

field, as will be brought out later. To get an idea of the action of electrons under pressure consider a flat surface, such as that shown in Fig. 25. Electrons (A) and (C) will both repel electron (B). Under this condition, (B) cannot move because of equal pressures. However, if the three are rearranged in the position shown in Fig. 26, so that (B) is crowded near the pointed part of the surface, electron (A) and (C) will repel (B) in approximately the same direction. The net effect is a large repelling force on (B) in **one direction.**

Electron (B) will tend to jump out into the air from this sharp pointed surface. If a sufficient number of electrons do this, sound will be heard and delicate violet sparks will be seen. This is called a **corona** discharge. It will take place until the congestion of the electrons is reduced (such a condition can take place in a manner to be described later) to a degree where the pressure is not great enough to cause the corona discharge. A certain amount of this action is almost always occurring at any sharp pointed surface where a large number of electrons are collected. Many more electrons can be crowded together on a rounded or flat surface for this reason.

Now, getting back to the flat metal plate for the collection of electrons; consider it along with another one brought near to its surface. Consider both plates charged—one negative and the other positive. The condition of the electrons in any dielectric material (insulator) which is placed between these two charged plates will be as illustrated in Fig. 27. Under this condition any dielectric substance such as mica, glass, celluloid, etc., will have many of its atoms or molecules distorted from the voltage charge existing in the metal plates. The electrons will come closer to their nucleus on the left and revolve much farther away on the right as illustrated in Fig. 28. The degree or amount of this distortion of the atoms or molecules will depend directly on the distribution of the electrons in the metal plates or on the voltage which is impressed across them, caused by the unbalanced distribution of the electrons in both plates. If the dielectric (material between the plates) is removed, the electron distortion in the dielectric will instantly disappear unless some electrons collect on its negative surface, as shown by the dots distributed over the surface of the dielectric in Fig. 29. Those so collected will tend to keep the atoms or molecules distorted just as the charged plates originally did. If this charged dielectric material is placed between two other uncharged plates, the electrons which have been forced into the dielectric from the original negative metal plate will induce a voltage between them. Many more details on this

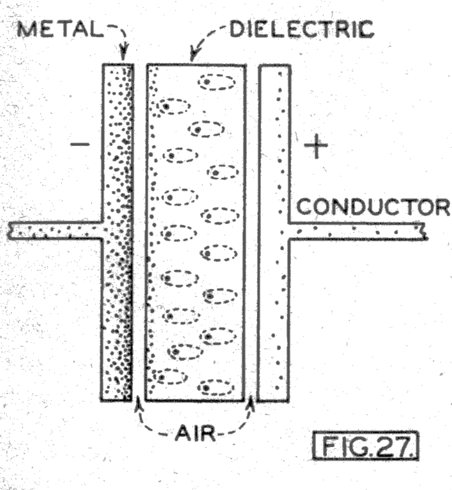
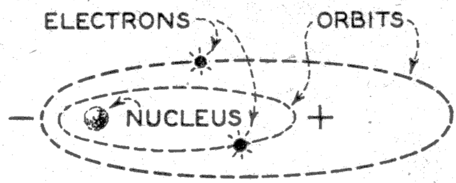


FIG. 27.



SHOWING HOW AN ELECTRIC FIELD DISTORTS AN ATOM

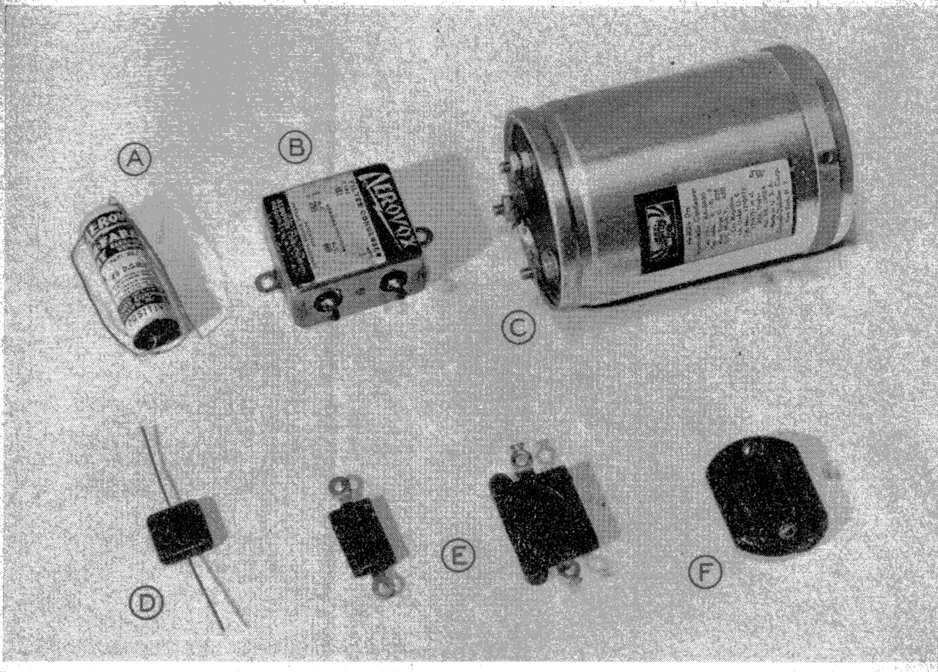
FIG. 28.

principle will be included in your eighth lesson.

It is possible to charge any one metal plate by first rubbing a good dielectric with a substance which has a different electron affinity, then placing it on the plate so as to completely cover it. The electrons accumulated on the dielectric from the rubbing action will tend to charge the plate positively by forcing many electrons out of it. If the plate is discharged by grounding it (touched with the finger), the repelling action of the dielectric will force electrons out of the metal plate in the form of a spark.

When many electrons of a substance, intimately associated with its atoms and molecules are repelled or attracted, the whole body of the substance is repelled or attracted. Thus there is a physical or mechanical force tending to attract plates of unlike charges and repel plates of like charges. Now, coming back to the charged dielectric material which has been placed near a metal plate and then discharged; the attraction at first was eliminated by discharging the metal plate to ground. Although at a neutral or ground potential **with the dielectric in contact with it,** the metal plate becomes charged in opposite polarity by removing the dielectric.

The two metal plates of Figs. 28 and 29 and the dielectric material which have just been described form a very crude electrical **condenser.** Later on a complete lesson



Here are some condensers to be found in the average radio set. A is a compact, large capacity, low voltage dry electrolytic type, used to filter cathode and bias resistors. B is a 1 mfd. high voltage paper dielectric type used for bypassing plate and screen grid circuits. C is a 3-section 8 mfd. high voltage, dry electrolytic type used in AC power supplies to help provide hum-free DC voltage. D, E and F are medium voltage mica dielectric condensers used in circuits of close tolerance with minimum leakage. Courtesy of Aerovox.

(ND-8) will be devoted to condensers, and you will learn much more about them then.

The ability of two metal plates to hold a charge between them is called the **capacity** of a condenser. Mathematically speaking, it is the quantity (Q) of electrons divided by the voltage (E) impressed between the two plates. Thus the **equation** $C=\frac{Q}{E}$ is a good way to think of the capacity value (C). By charging a condenser with a given voltage and removing the charging source, the quantity of electrons on each plate will remain fixed if they do not leak off into the air or elsewhere. Now here is something important. If the quantity is fixed and the capacity is changed, the voltage will change also. If the **capacity is reduced** ten times the **voltage** will **increase** ten times, or if the capacity is **reduced** one hundred times, the voltage will **increase** one hundred times.

Not only is this principle used in the production of very high voltage, but the condenser microphone also makes use of it. The mechanical force tending to pull the plates of unlike charges together is converted into electrical force or voltage as the plates are separateed.

An electrostatic field will displace or move electrons in the direction of its own lines of force, while a magnetic field will displace or move electrons at right angles to itself. Be sure to remember this difference.

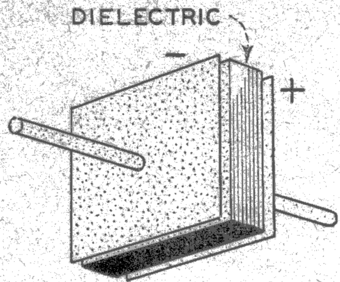


FIG. 29

The tendency of any electron is to reach equilibrium; a condition where all of the forces acting on it are equal or zero. It will continue to move until this condition is established. Its velocity or position at any time depends on these forces. In all of your future studies you will find that electrons will move from a negative part of a conductor to a positive part at a speed depending on the value of the voltage moving the electron.

Use is made of the attraction and repulsion of charged plates in an electrostatic voltmeter and in electrostatic speakers. Use is made of the change in voltage accomplished by a change in capacity of condensers, microphones and electrostatic generators.

The tendency of all electrons to shift so as to reach equilibrium is used in all condensers. A simple example will show this. (See Fig. 30.) The voltage or electron pressure of the battery will force electrons into the condenser at the negative (left) plate and out of the positive plate. The tendency will be for the electrons to reach equilibrium by making them just as numerous on the negative plate of the condenser as on the negative pole of the battery. Also, at the positive plate there will be just as few as on the positive terminal of the battery. Attraction between the electrons on the negative condenser plate and the positive nuclei on the positive plate will allow a large accumulation of electrons to take place on the negative plate. If the plates are moved closer together, more electrons will go into the negative plate and more will move out of the positive plate. In all cases they are in equilibrium on the plates. The force of attraction from the other plate, tending to keep them in the condenser, will be exactly equal to the force tending to send them out, due to their own crowding or back pressure. Accordingly, the voltage of the condenser will be exactly that of the battery as soon as the electrons have time to distribute themselves in this way.

Condensers are used extensively in radio, and they all act according to the principles just described. There are many different kinds of condensers in use, such as variable, adjustable, and fixed, and numerous forms of each. To describe their

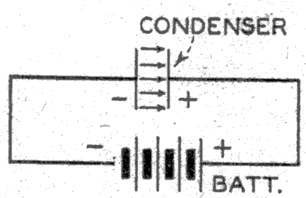


FIG. 30

association with other parts in radio would require considerable space. Therefore, we will reserve a full discussion of electrostatics to a later lesson. What has been said about condensers in this lesson serves only as an introduction.

We cannot stress too strongly that this lesson is one of the most important in your entire Sprayberry Course. Do not by any means regard it lightly, for to do so will **defeat** your understanding of radio principles. Study this lesson over and over again; be patient and go slow. Later we will take up many of the principles of this lesson and show their applications.

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

Questions

No. 1 How does an electron in dynamic motion differ in characteristics from one in a static state?

No. 2 What is the shape of a magnetic field about a wire or conductor carrying a flow of electrons?

No. 3 What relation exists between the velocity of an electron or group of electrons and the amount of magnetism produced in air?

No. 4 What happens in a metal magnetic substance when it is magnetized?

No. 5 When a magnet picks up a piece of iron what new characteristic does the iron take on?

No. 6 What will happen in a wire or conductor through which a magnetic field is made to pass?

No. 7 Instead of an iron washer in Fig. 21, suppose lead, wood or rubber is used. What effect would this have on transferring energy from circuit A to B?

No. 8 With reference to the direction of magnetic lines of force, in what direction must a wire move in a magnetic field to produce maximum voltage?

No. 9 In what direction are the electric lines of force about an electron?

No. 10 What is the difference between a magnetic and a static field?