## WHERE MAGNETISM IS

This leads us to wonder where these magnetic forces may be found and though we do not know what it is, a great deal is known of the "Fields" through which the force of magnetism acts and along what "Lines" these forces go.

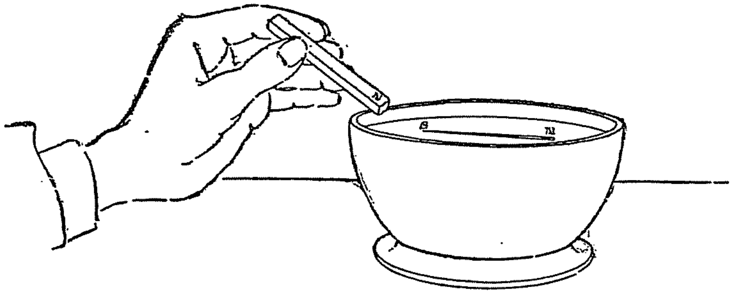



FIG. 11

Floating Needle and Bar Magnet. Small Needles Can Be Laid Gently on the Surface of Water and Will Float.

Try this experiment to prove it. Take a bar magnet. Lay it on the table on top of a piece of writing paper. Move a compass, starting at one pole of the magnet, gradually toward the other pole, stopping at distances equal to a little more than the length of the compass needle. Let the compass needle come to rest in each place and when we have noticed the position it takes, draw a picture of this position on the piece of paper as in Figure 12. Notice how the picture seems to make long, circular lines reaching from one pole to the other, crowded together at the poles and spreading apart at a position halfway between the poles.

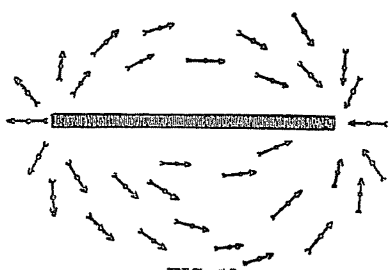


FIG. 12



These lines gave the earlier discoverers of magnetic power the idea of calling them Lines of Force and, after drawing this picture, can we not easily imagine these magnetic lines of force spreading out in all directions from the pole tips? Yes, they spread IN ALL directions.

You will find this is true if you take your magnetized sewing needle suspended by a little thread at its middle and hold it over the magnet from the north to the south pole, you will see the dip of the needle changes. If you set a paper up back of the needle and draw these changes, you would see a line coming up in the air just the same as those made by the compass on the flat piece of paper. See Figure 13.

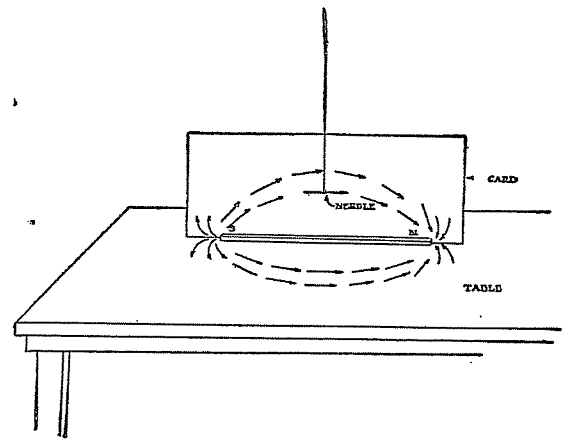



FIG. 13

Let us take the iron filings again. Sprinkle them on a piece of cardboard or glass and place the bar magnet under it. By tapping the glass gently, the iron filings will arrange themselves in lines starting from one pole and circling around towards the other pole.

Try a horseshoe magnet and you will find lines crowding between the north and south poles, some starting up in the air and some swerving in large circles from the north and south poles. This should tell us that most of the magnetic lines seek the shortest distance between the poles, crowding just as many lines as possible in the space. The remaining lines swing out and occupy the next available space on their journey toward the opposite pole. See Figures 14 and 15.

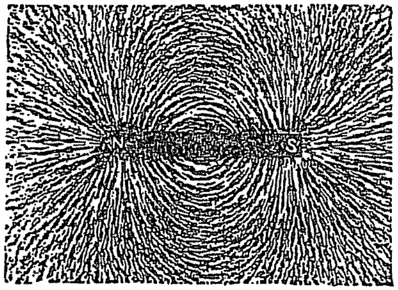


FIG. 14

Now that this experiment has been performed, some of us will think that if we sprinkle the filings on the glass over two north or south poles, which are near together, we should see the lines repel each other. Put your two bar magnets under the glass and sprinkle filings on top and you will surely see this wonderful result. See Figure 16.

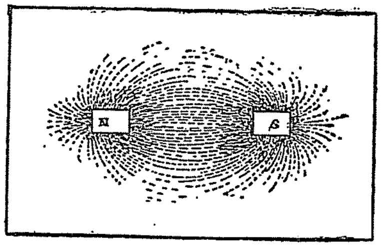


FIG. 15

Another curious thing about a magnet is that if you break one in the middle you will still have north and south poles. Take one of the magnetized needles and break it in half. Hold one of the broken pieces toward the compass. What happens? In agreement with the rules noted above, the north pole of the compass needle is attracted by the south pole of the broken needle. Should you break it again, you would find that the broken piece has north and south





poles which attract or repel the compass needle according to whether you hold unlike or like poles toward each other.

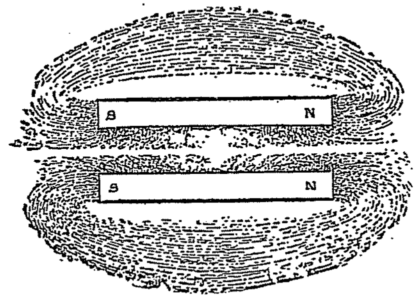



FIG. 16

Figure 17 shows a magnet broken twice and if we could break it into the smallest pieces, each little piece would still have its north and south poles. In fact, one theory in regard to magnetism is that the little pieces or molecules of metal in any piece of iron or steel, in becoming magnetized, try to push with one end toward the north and the other end toward the south.

## KINDS OF MAGNETS

There are two kinds of permanent magnets, the bar and the horseshoe magnet, Figure 18. These are the two most common artificial magnets and they are also known as permanent magnets because they hold magnetism for a long time. The horseshoe magnet will lift three or four times as much as a bar magnet and is the strongest permanent magnet in use. When it is necessary to get a stronger pull than these will give, an electro magnet is used which we will study later.

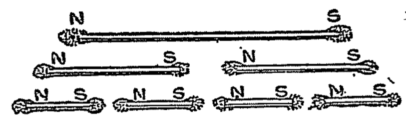



FIG. 17

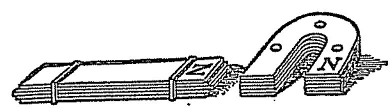


FIG. 18
Bar Magnet and Horseshoe Magnet Made Up of Thin Strips Fastened Together.

## MAGNETIC MATERIALS

So far we have been talking about iron and steel and lodestones, but have not considered any other materials. As good scientists, we ought to discover whether any other things can be attracted or repelled, so let us try a few experiments.

Take a piece of copper. Does it stick to the magnet? Try brass, wood, paper, fibre, cloth. If you make a list, you will find iron and steel are the only common materials which magnetism will move. Cobalt and nickel are also attracted by magnets.

There are a few substances such as bismuth, antimony phosphorus which are called DIA-MAGNETIC because they apparently are repelled from both of the magnet poles, but it is not possible for us to experiment with these so we will content ourselves with more common materials and substances.

Hold an end of one of your bar magnets near a steel ball. You will find there is attraction for both the north and south poles. This seems to dispute the statement that "Like poles repel and unlike poles attract". It is caused by the ball being round; therefore having no points or poles. MAGNETIC SUBSTANCES WITHOUT POLES ALWAYS ATTRACT EITHER POLE OF A MAGNET.

## MAGNETIC INDUCTION

Let us take a small piece of glass and sprinkle iron filings on top of it. Hold the glass up and place a bar magnet underneath it. What happens? The little iron filings jump into curious forms piling up on top of each other, others forming together in lines running from one pole of the magnet to the other. Repeat this experiment using a horseshoe magnet, and again you will see the little fellows piling up in long strings. Hold the horseshoe magnet against a bottle full of iron wire or iron filings and you can lift it from the table without touching it with your hands. Put iron filings on a piece of cardboard or paper and your magnet underneath. What happens? The magnetism has its effect through the glass or paper each time. Repeat this experiment with other materials.



We find that magnetism is forced through all the non-magnetic materials, but if we take a tin cup or iron dish and pour some of the iron filings on it, holding the magnet underneath, there is no effect. We can then say that magnetic material acts as a shield against the passage of magnetism, but non-magnetic material offers little resistance to magnetic force.

This is good to remember when you carry a watch near any electric machinery or on the street cars. The best way to keep your watch from having its spring magnetized is to enclose it in a soft iron case. Some people use a hard rubber case but we have already found, by experiment, that this is non-magnetic, and, therefore, does not stop the force of magnetism.

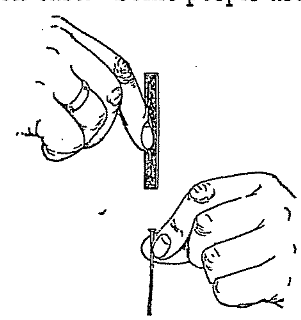


FIG. 19

One more experiment is to take a bar magnet and with the other hand hold a piece of iron wire near one of the poles of the magnet, being careful not to touch it, as shown in Figure 19. Touch the end of the iron wire to one of the other little pieces of iron wire and see what happens. We have discovered that the first iron wire has the power to attract the second wire to it, but if the magnet is removed, the second wire will soon fall off. We have learned two new things. First, that a magnet may make unmagnetic things strongly magnetized. This is done through non-magnetic material, and is called INDUCTION. We have also found that some magnetic material loses its magnetism very easily. By experiment, we find that soft iron will not hold magnetism, but hard iron, and especially hard steel, will remain magnetic for years. If you try scratching a magnet, you will notice that it is very hard in comparison with iron wires, screws, etc.

The magnetism of the greatest magnet of all, the earth, will convert, by induction, any piece of iron or steel into a magnet. Almost all the iron and steel framework of buildings and bridges around you are magnetized. Steel ships are so strongly magnetic that they influence the magnetic needles of their compasses so much that every little while the compasses have to be adjusted, and, in adjusting, they are protected from the ship's magnetism by means of balls of soft iron placed in such a position around the compass that it neutralizes these outside magnetic forces.

## TERRESTRIAL INDUCTION

An interesting experiment to further illustrate the preceding paragraph can be made with a piece of iron; for example, an ordinary stove poker. If you hold it in a horizontal position, pointing east and west, generally both ends will attract either end of the compass needle, showing that the poker has not yet become polarized; but if you hold it in a north-south direction and bring the needle near one end you will notice from the direction of the needle that the poker has become magnetized with distinct north and south poles, for it will repel the north pole of the compass at one end and attract it at the other. If you turn the poker in the east-west position again both ends will attract the same end of the compass needle, showing that it is again non-magnetic. To increase the effects of the induced action of the earth hold the poker north-south

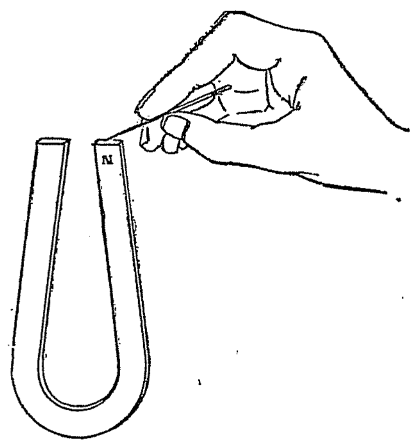



FIG. 20
Single Touch Method

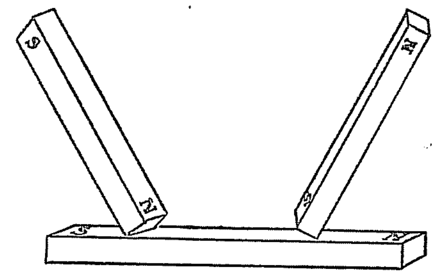


again and give it a few sharp blows with a hammer. This shakes its molecules and enables the induced force of the earth's magnetism to turn them more easily in north-south position. By again exploring with your compass you will find that the poker has become permanently magnetized. To de-magnetize it hold it in an east-west position and hit it a few sharp blows again.

## METHODS OF MAKING MAGNETS

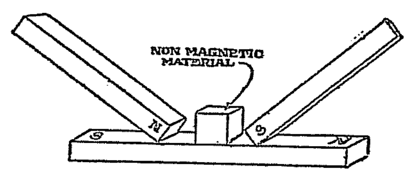
There are three principal methods of making permanent magnets. The first is by single touch, Figure 20. This is what we did in magnetizing our sewing needles when we stroked one pole of our magnet with one end of the needle.

The second method is called the double touch and by it we can magnetize two new magnets at a time holding the ends as shown in Figure 21A, rubbing them along the magnet until they reach the poles. The third method is called the divided touch and is very much like the second except that at the start the two new magnets are not touched together but are carefully separated by a piece of cork, paper, wood, or other non-magnetic material. See Figure 21B.




DOUBLE TOUCH

FIG. 21A




DIVIDED TOUCH

FIG. 21B

We will discuss, a little later, a better method than any of these which will require currents of electricity.

## HEAT AND MAGNETISM

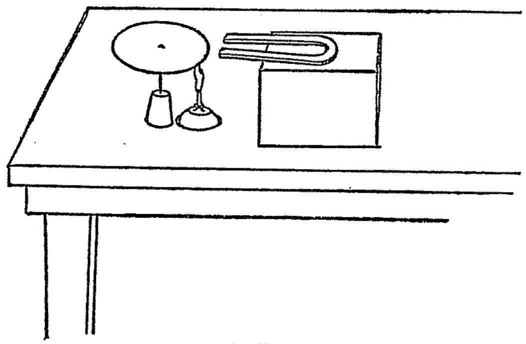


FIG. 22

Magnets lose their magnetism if they are handled roughly or if they are heated too much. A magnetized sewing needle can be de-magnetized by heating it red-hot. An interesting experiment can be made by bending an iron wire in the form of a circle or by using a thin metal disc supported, as shown in Figure 22, in front of a horseshoe magnet. By placing a flame under one side of the iron ring, the ring will begin to turn. This happens because the heated parts are not affected by the magnetic force while the cool parts are attracted. Therefore, the cool section moves forward. If we place the lamp or candle directly in front of the horseshoe magnet, as shown in Figure 22, we can make the ring revolve as long as the flame heats the iron.

# Chapter II

## ELECTRO-MAGNETISM

Now that we have gone through the history of Dr. Gilbert's wonderful discoveries, let us pay a visit to Copenhagen, to the laboratory of Mr. Oersted. We are now in the year 1819 when people are just beginning to hear of steamboats and steam trains and have no electric cars, electric lights, telephones or telegraph. We arrive just in time to find our friend, Mr. Oersted, greatly excited. He asks us to place a sewing needle in a cork with the sharp end sticking straight upwards, putting the compass needle on its point.

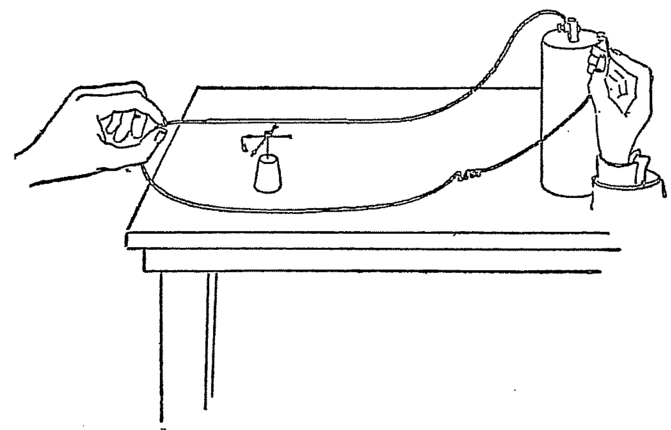


FIG. 23

We are next instructed to attach a copper wire to the middle terminal post of a battery and hold the other end of the wire in our hand, being sure that both ends of this wire are scraped bright and clean. Hold the wire over the needle, as in Figure 23, so that it runs in a straight line in the same direction as the needle is pointing and, with the free end of the wire, touch the outside terminal post of the battery. If the wire is close to the magnetic needle, what do we see? The needle immediately swings around as if some magnetic force is pulling it.

In the study of batteries, we find that the middle binding post is called positive or "+" and the electric current passes out from it toward the outside terminal post which is called negative or "—". If you hold this wire over the compass in such a way that the current flows from south to north, what direction does the north end of the compass needle point? I say "West" and you will find this to be correct.

To remember this, think of the word "SNOW". The letters of this word are explained as follows: S—South, N—North, O—Over, turns W—West.

Now Mr. Oersted asks us to hold the wire in the same position

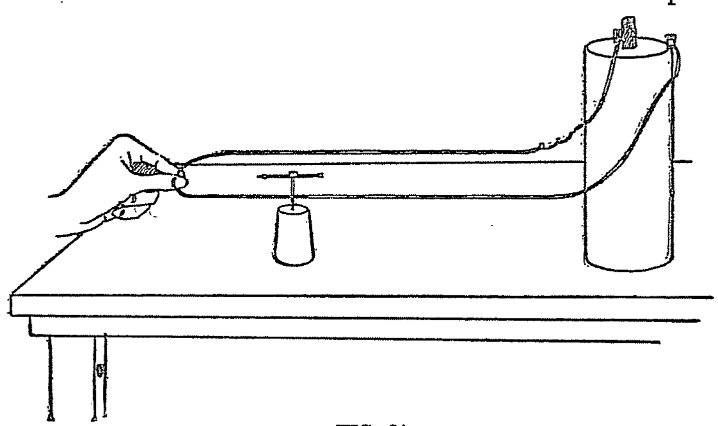


FIG. 24

but under the needle and we find—what? You are ready to say that the needle turns in the opposite direction. This must be due to the current, because when we no longer touch the outside binding post of the battery, the compass swings back to its north and south position.



Later another great scientist, Mr. Ampere, made the following rule by which we can remember which way a flow of current in a wire will affect a magnet needle. "Suppose a man swimming in the wire with the current, always facing the needle, then the N—seeking pole of the needle will be deflected toward his left hand." This discovery of our friend Oersted is one of the greatest steps in the marvelous development in electricity of today. It proves that around electrical current there is a magnetic force acting in accordance with the direction of flow of current.

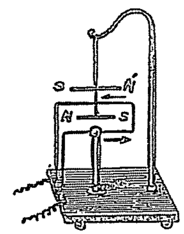



FIG. 25

Place a loop of wire around the needle in such a way that the top of the loop is directly over the bottom part, as shown in Figure 24.

Send a current through the loop from the battery and note the movement of the needle.

A greater turning effect of the needle is obtained by combining the force of the current flowing above the needle with the force flowing below, as shown in Figure 25.

The compass needle swings at right angles to the wire, as far as you can tell. Larger needles can not swing quite at right angles because the earth's magnetism is pulling them as well as the force caused by the electric current. Is there any way to overcome this?

Suspend a bar magnet on a thread and, about an inch below, another bar magnet with its north pole directly under the top magnet's south pole. See Figure 25. If these two bar magnets are of equal strength, they no longer point north and south and you can turn them in any direction. This is due to the fact that we have the magnets opposing and acting on each other just as two teams of men in a tug-of-war act. If both teams pull at the same time with equal strength

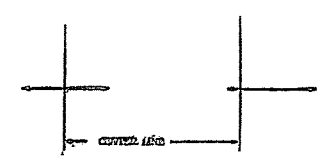


FIG. 26

on a rope, the rope does not move, but when one team pulls harder than the other the rope moves toward the direction in which there is the strongest pull. See Figure 26.

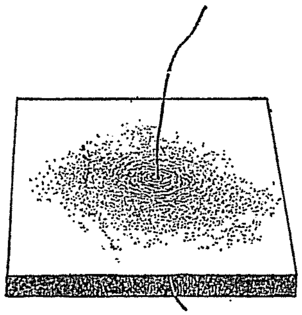


FIG. 27

When we have made the two magnets neutralize the pull of the earth's magnetism, we have then obtained a device which is affected entirely by the current flowing through the wire. We can make an instrument from this for measuring the flow of electricity. When one magnet is placed near the other so that together they neutralize the effect of the earth's magnetism, we say they are "astatic."

## MAGNETIC FORCE ABOUT A WIRE

Push a copper or brass wire through the center of a cardboard. The latter should be about as large as a playing card. Connect the bare ends of the wire to a battery. One dry cell will do, but two or more will give a much better effect. After the current has started to flow, drop a few iron filings on the cardboard as near to the wire as possible. What happens?

Figure 27 shows how the results of this experiment will look. The iron filings arrange themselves in little rings thicker and closer together near the wire and thinner as they go farther away. Remembering what we found about the way which the current flows in the battery, we find by putting the compass around the wire in various places, that these magnetic circles flow one way when the current from the battery goes up the wire, the opposite way when it goes down.

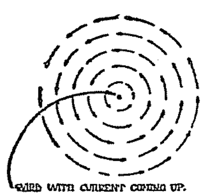



FIG. 28

Figure 28 shows what occurs when the current flows up the wire. The north pole of the



magnetism goes around opposite from the way the hands of clock go. If the current in the wire flows down, the polarity goes around in the same direction as the hands of the clock. Try the compass needle in different positions around the wire and note that the magnetism always whirls around at right angles to the wire.

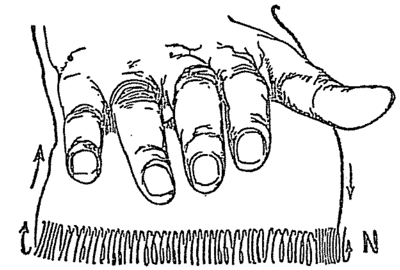



FIG. 29

We have found what happens on a straight wire, now try a crooked wire in form of a spring as shown in Figure 29.

Make the coil large enough to go through a piece of cardboard as in Figure 30, then try again with iron filings or the compass. The result is similar to that produced by a bar magnet. Magnetism around single loops of wire act upon each other to form the magnetic forces shown in Figure 31.

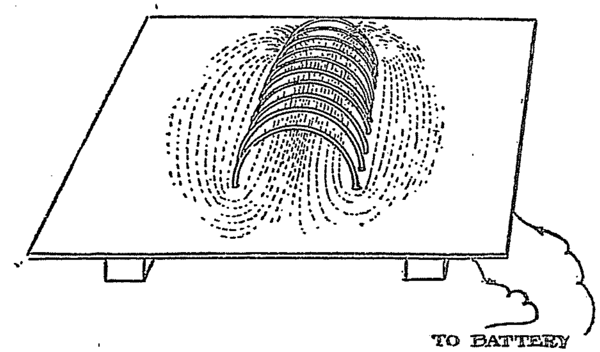



FIG. 30

You will also find that the current flowing in the wire as shown in Figure 32 will set up the north pole on the end marked "N". A good way to remember this is to hold your right hand, as shown in the picture, with the thumb sticking out at right angles from the fingers. If the fingers are closed around the coil pointing in the direction in which the current is flowing, the thumb will point toward the north pole. If you suspend this coil so that it can turn freely and yet be connected to the battery, you will find it points north and south just as your compass did and two coils near each other with the current flowing in them attract and repel each other.

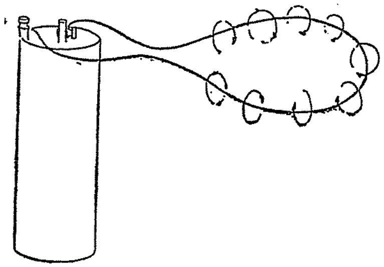


FIG. 31

Attach the ends of two coils of wire to each other and to a battery. These coils can be made by winding some insulated copper wire on ordinary sewing thread spools, or even winding copper wire around tubes of some non-magnetic material. Figure 33 shows two coils wound with No. 26 cotton covered wire on a sleeve of metal with round end pieces of fibre to hold the core together. When you have connected these coils together and to a battery touch the ends in a pile of iron filings and you will get the results shown in Figure 33.

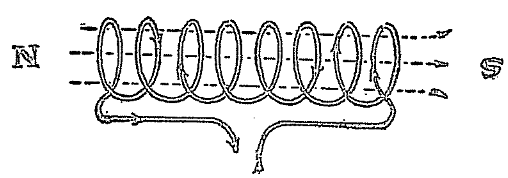



FIG. 32

Figure 34 shows a pair of these coils with a horseshoe shaped yoke placed through them. If you make one of these devices you must be careful and use soft iron for the yoke and also remember to connect the coils with the battery so that the lower end of one will produce a south pole and the other a north pole. This you can do by remembering the right hand rule given above in connection with Figure 32 so that you will have the current flowing in one direction in one coil and in the opposite way in the other. If you wind a coil



of several layers such as is shown in the picture, connect the top wire of one coil to the bottom of the other and you will accomplish the required polarity. After you have made this device try it out in the experiments where you have previously used the horseshoe or bar magnet and you will find that this is much stronger than either of the others and in addition, when the current is not flowing, this magnet loses its power. Such a magnet is called an electro magnet.

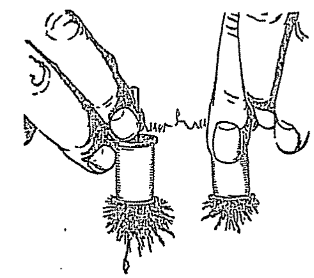


FIG. 33

## FORCE IN THE EASIEST MAGNET PATH

Place iron filings on a glass plate and hold a horseshoe magnet under as shown in Figure 15. The iron filings set themselves in lines showing the field of magnetism running from one pole to the other. Place a small chip of iron or a piece of the soft iron wire between the poles of the magnet as in Figure 35 and you will notice that the iron filings crowd together directly over this, showing that magnetic lines find iron or steel the easiest path through which to travel and they crowd themselves into that path when possible. For this reason the iron core in the coil of the electric magnet makes it much stronger than it would be if we depended upon the coil alone.

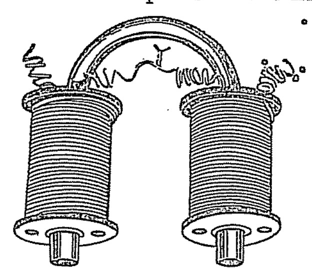


FIG. 34

Boy Scouts should understand how to make an electro-magnet as explained above in order to pass their Boy Scout examination.

Now you have something which is used a great deal in various kinds of work and Figure 36 shows one of them. This electro-mag-