net is used for unloading cars of heavy iron. In the picture, you will see several hundred pounds of pig iron clinging to the bars of the magnet.

The magnet is usually suspended on a crane or derrick so that it can be swung from one place to another and raised or lowered to do the lifting. First, it is lowered to the place where the iron is resting. The electricity is turned on and the big chunks of iron jump up and cling securely to the bottom of the magnet. Then the derrick is swung up in the air and around to the unloading point, the current turned off and the iron falls at once. The magnet is swung back over the iron and continues back and forth until the entire load has been moved. How much faster and better this is than the old fashioned way of having six or seven men load the pieces one by one on a box swung by an ordinary derrick and then having to unload them again.

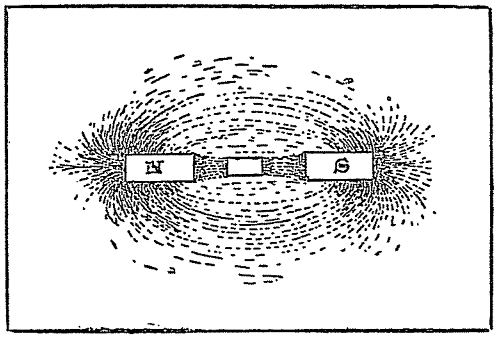

FIG. 35

You can make one of these magnetic loaders easily with your little electro-magnet and have lots of fun transferring iron wire, etc., from one spot to another.

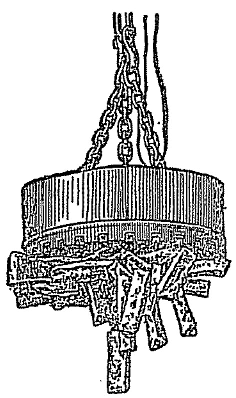

FIG. 36

MAGNET MOTOR

Now that we have found that a coil of wire is similar to a bar or horseshoe magnet when

a current is flowing in it, we are ready to believe that a permanent magnet will act on an electro-magnet.

We can try this by suspending the electro-magnet in front of one pole of a bar magnet which has been laid on top of one of the corks. When the current is turned on, the coil will move according to the attraction or repulsion of the bar magnet. Now, if the current

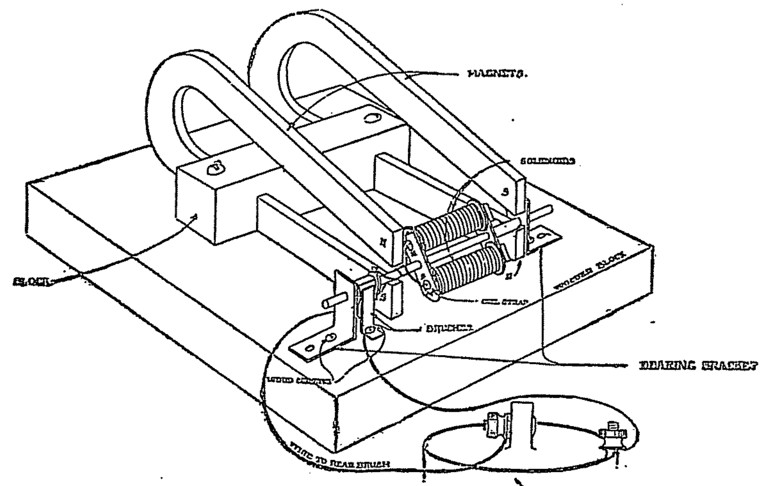

FIG. 37

is reversed, the coil will move in the opposite direction. If we are able to change the direction of the current fast enough, the coil will swing backward and forward like a pendulum. We can, by attaching a little rod to the core, turn a crank, producing a motor having the same action as the steam engine known as the reciprocating engine. A much better motor is shown in Figure 37.

This motor was made with two 6-inch horseshoe magnets and the description below covers a motor of this size. Should you have horseshoe magnets of a different size, you can readily make a similar motor by changing the proportions of the different parts. First, place two horseshoe magnets side by side as shown in the picture. Clamp them in place on a wooden block by means of a smaller wooden block, approximately 2½ inches long and 1 inch square on the ends. This block should be cut out so that it fits tightly over one side of each of the magnets. Be sure that when these magnets are in place one of them has its north pole upmost and the other with the north pole at the bottom. Next wind two little electro magnets or solenoids about 1 inch long. Those in the picture were made by first bending up a thin sheet of metal around a screw, slipping two round discs about ¾ inch diameter made of red fibre or heavy pasteboard over the ends of it. Between these discs lay over the tin about three wrappings of thin paper (writing paper will do), pasting in place. In order to make the fibre discs tight on the ends of the metal you can hammer the metal over, after the paper is in place, so that the ends are spread larger than the hole in the washers. Pierce two little holes in each washer with a small nail, one hole being as near the center and one as near outside as it is possible to make them. These are for the ends of the wire which is next to be wound on. Poke one wire through the center hole in one of the fibres and then wind as tightly as possible five or six layers of a wire about No. 24 or No. 26 Brown & Sharpe gauge. This may be either enamel covered or cotton covered. Two of these solenoid coils are required. Next make two strips of brass ⅜ inch wide and 1⅜ inches long, brass .040 inch thick is very good for this purpose. These pieces must have a hole through the center for the shaft and two holes at the end for the screws which will hold the coils in place. When these pieces are complete, put two screws, which you will use to bind the coils together, through the outside holes of one strip. Then set the coils on, so that when the current is sent through them, the end of one coil, under the head of the screw will be north, the opposite end of the other coil will be north. The text above will explain how to do this. On the other

end of the coils place the second brass strip over the screws, then tighten both in place by two nuts. The screws used in the model made for Figure 37 were two steel round head machine screws, 6-32 thread, 1⅛ inches long. The shaft is made of brass rod approximately 3¾ inches long and ⅛ inch diameter. The bearing brackets for holding the shaft are made of brass .040 inch thick bent in an "L" shape, with holes for screwing them to the board and holes for the shaft to stick through at such a height that they will hold the shaft half way between the two poles of the magnet. Two brushes must be made also of an "L" shape. This can be made of .010 or .015 brass 3/16 inch wide, and when screwed to the board they must stand up at least ⅞ inch. The commutator or device for carrying the current through the brushes to the coils is the next thing and is the hardest to make. It is shown most clearly in Figure 38 and consists of two round fibre discs with holes through their center, so that they fit tightly on the shaft. Their outside diameter is about ½ inch. Then two pieces of brass .040 inch thick are formed in a rounded shape, with small ends make to stick through the fibre so that they fasten the two fibres and themselves together, leaving a space between each brass segment just dividing these so that they divide the circle which they form into two equal parts. A very convenient way to make these pieces would be to buy a piece of brass tubing and saw it in half. Also, instead of using fibre end pieces a small round block of wood could be made with a hole drilled through it, and the brass pieces could be fastened to the block by small pins. Great care must be used, however, if this method is followed, that the pins do not touch both brass pieces or rest against the shaft. The free ends of the magnet coils must be connected to the ends of the brass pieces on the commutator, as shown in Figure 38. Note that the break between the two brass pieces on the commutator is exactly on a horizontal line when the coils are directly one above the other.

If you have placed your horseshoe magnets so that the north pole of one is at the bottom and the north pole of the other at the top and have made connections for your terminals as explained for the electro-magnet, your little motor will keep on turning until you shut off the current. How can we explain this action?

When the current is turned on, the ends of the steel screws become poles. Let us suppose that you have assembled your horseshoe magnet so its north pole stands in front of the electro-magnet's north pole. The other end of the magnet must be the south pole, and this stands in front of the horseshoe magnet's south pole. At the bottom polarities are reversed, but the same condition is found; that is, two like poles together. In our previous experiments, we found that like poles repel each other and that is true here. The north poles push against each other and the coil moves around, trying to get in front of the south pole, but when halfway around, the slot in the commutator causes the current to change its direction and the north pole changes to a south pole and tries to get away from the south pole of the permanent magnet, only to have the current reversed again; and so it keeps on jumping around and around the shaft, like poles being driven away from like poles and drawn toward unlike poles as long as the current flows.

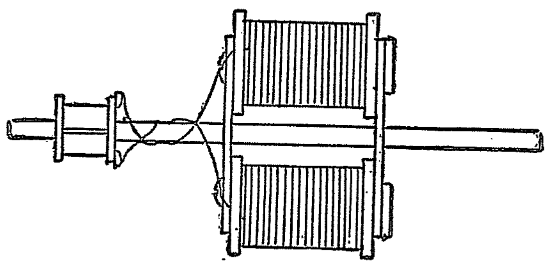
FIG. 38

By using two or more dry batteries, or a current transformer, this little motor can be made to drive mechanical toys.

Chapter III

ELECTRO-MAGNETIC INDUCTION

Now you may think we have reached the limit of electro-magnet investigation, for we can see how to build a motor, and our imagination readily pictures it running streets cars, elevators, machinery, etc., but there is one step further which was discovered by Faraday.

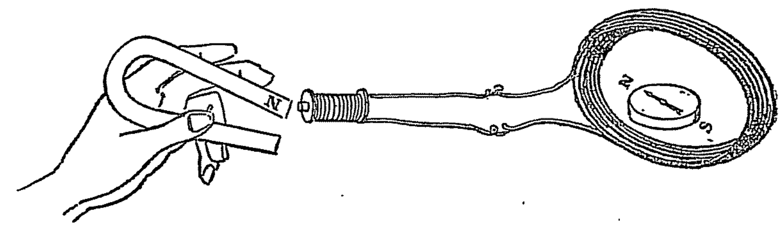

FIG. 39

Make a solenoid coil and connect it to a coil of wire. The greater the number of turns of wire on the coil the better, unless the wire is very fine. Place the coil around the needle of a compass, as shown in Figure 39.

Now place the north pole of a permanent magnet in front of the solenoid and remove it quickly. Place it back again. If you watch carefully, you see a slight movement of the needle. Faraday discovered this and formed the belief that, by moving the wire through the field of a permanent magnet or by moving the field so as to cut across the wire or other conductor, a flow of electric current is started by induction through the wire. He

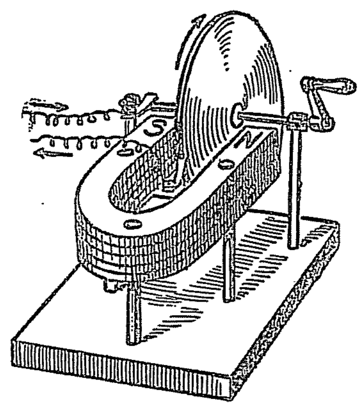

FIG. 40

finally made a machine, as shown in Figure 40, which you can easily copy with horseshoe magnets.

He placed a copper disc on a metal shaft between the poles of the horseshoe magnet. On an edge of the disc he placed a brush and another brush on the shaft, and connected wire to these. He revolved the handle so that the disc turned around in the direction of the arrow. He found that the current flowed out of one wire into the other after they were joined.

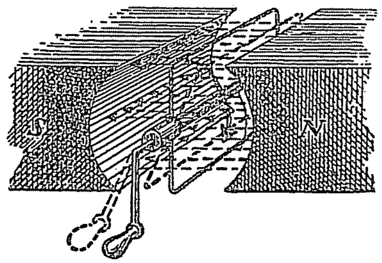

FIG. 41

Figure 41 shows the next step with a copper wire bent around the shaft in place of the copper disc. This gives the same result

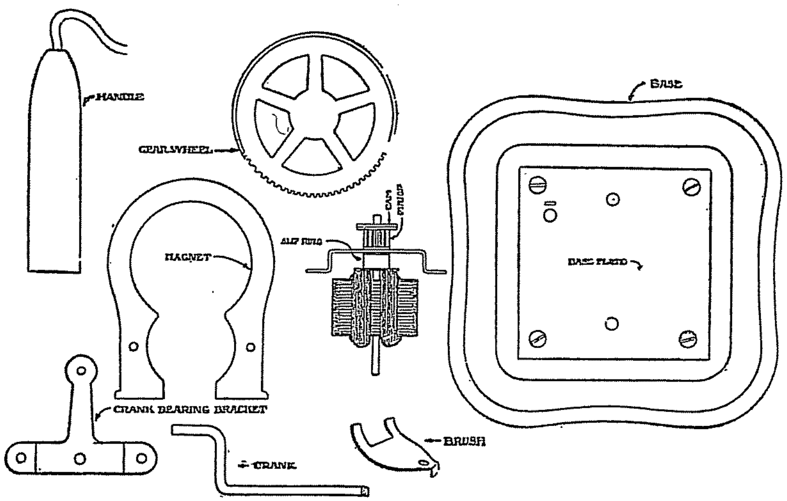

FIG. 42A

as before, with the exception that in one position no current flows. In the position 90° from this, the most current flows. Between these, the current rises from zero to the highest value, then falls again to zero. This is due to the fact that the wire conductor will cut none of the lines of magnetic force in one position, while in the other, it is cutting the greatest number. It is extremely hard to measure a current in one turn of wire such as shown in the picture, but we can increase the action by putting several turns of wire around the shaft.

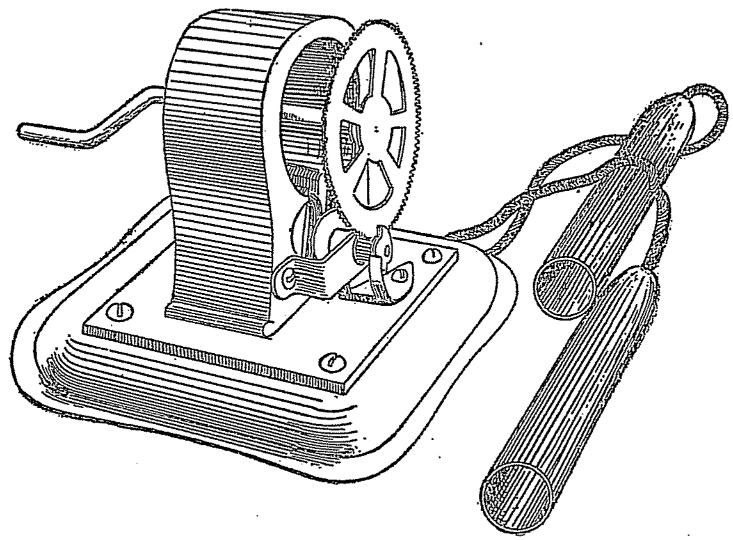

FIG. 42B

A device commonly known as a magneto or shocker illustrates this principle very well. You do not have to measure the electricity with a compass in this machine, for you can feel it by taking hold of the handles on the ends of the flexible copper cords when someone turns the crank which drives the armature around. Figure 42A shows the various parts of the magneto with their names.

Figure 42B shows the method of assembling this magneto. The strength of electricity increases in accordance with the speed in which the handle is turning the armature.

You can also make a little dynamo by changing the winding on one of these machines which can operate other motors and electric lights.

The motors described have used permanent magnets to produce a magnetic field. The earliest motors and generators were all made in this way. Later it was discovered even soft iron wire or soft iron plates retained a little magnetism, which is called residual magnetism. As stated in regard to the electro-magnet, the yoke or core made the magnetic lines produced by the coil of wire crowd themselves through it rather than pass through the air.

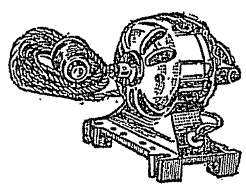

FIG. 43

Relying upon these peculiarities, motors and generators were then built which had coils of wire connected, so that, when current is flowing, they set up north and south poles which act on the revolving part, commonly called armature, just as the force from the permanent magnets acted on the armature between them. These are the types of motors and generators now commonly used.

The difference between a motor and a generator is that a motor is a machine which takes in electricity and gives out mechanical power. A generator is driven by mechanical power and gives out electric current. A generator depends upon the residual magnetism to start the electricity which flows into the winding, after which the field magnet coils are able to build up to the full amount for which the machine is designed. The motor does not require the residual magnetism as the coils receive the current from an outside source as soon as the circuit is closed.

In the experiments given above for electro-magnets, battery current was used. This current is continuous or direct, because it flows continuously in one direction. This gives a steady pull on the magnet.

There are also alternating and pulsating currents which are not steady but flow in surges like waves moving over the sea. Magnets and solenoids for alternating currents are not good for lifting because the magnetism pulsates due to the changing in electricity. They can be used for a number of things where this feature is not objectionable.

All alternating current motors, generators and transformers depend upon magnetism for their operation, but this magnetism is so closely connected with the study of alternating current that it cannot be properly described here in this short space. We can remember, however, that as the electric current changes in direction in a wire, flowing from zero to its highest value, then turning around in the other direction until it is at zero again, that, in strict accordance with the rules and experiments given above for magnetism around a wire, the magnetism revolves backward and forward around the wire and changes in strength following the changes in current.

MAGNETIC SATURATION

We have found that electro-magnets are much stronger than permanent magnets, but there is a limit to the amount of magnetic force a piece of iron or steel can contain, which is called "THE POINT OF SATURATION". The iron and steel seem to soak up magnetism just as a sponge soaks up water until it is thoroughly filled.

We have gone through the field of magnetism from the time of the earliest discoveries to the present. Although we do not know what magnetism is, we do know that other wonderful things seem to be related to it. One theory is that atoms are made up of electromagnetic units called electrons. Light, magnetism and electricity appear to be much the same. Astronomers find that occurrences on the sun affect magnetic needles and that, undoubtedly, sun spots are caused by magnetism. Even gravitation is thought to be caused by some natural magnetic force which attracts all things toward the earth.

It is a mystery to be solved, and in studying it, some of us will discover new wonders for the use of our fellowmen just as Marconi, who astonished the world with his wireless telegraph.

To a real live boy, is not finding out these things far better than dreaming of enchanted castles, magic carpets and similar adventures?

Chapter IV

MAGNETIC TOYS AND TRICKS

MAGNETIC TIGHT ROPE WALKER

Cut some colored paper to represent the front of a stage and hang a horseshoe magnet behind it, so that it will be out of sight of the observers. Hang a stout thread across the stage.

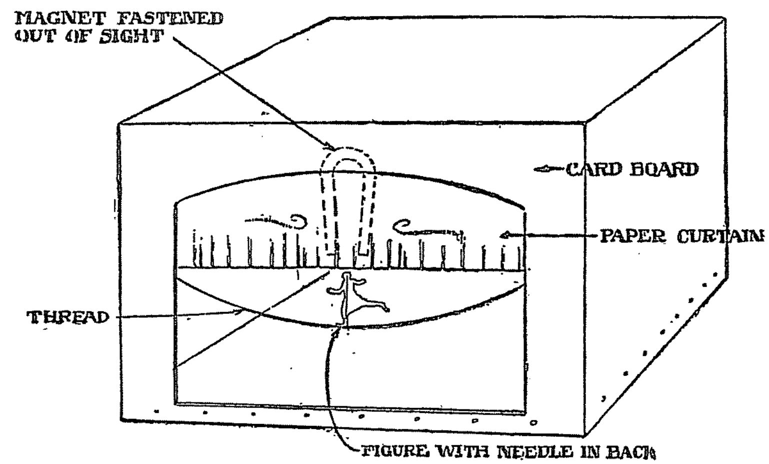

FIG. 44

Cut out little figures of tight-rope walkers from some stiff paper and fasten a steel needle on the back of them, as shown in the picture. Place the tight-rope walkers or acrobats on the thread so that the point of the needle sticks in the thread slightly. See Figure 44. Of course you must arrange this thread so that the head of the figures come directly under the magnet, but not too close, or the pull of the magnet will draw it up.

When the figures are arranged in the best position, they will stand up and sway just as tight-rope walkers balance themselves on the slack wire.

MAGIC PENCIL

Take an ordinary lead pencil and split the wood carefully in two pieces. Remove a portion of the lead, as in Figure 45. Magnetize a steel needle, about the same thickness as the lead, and insert in place of the lead. Stick the wood of the pencil together again, using glue

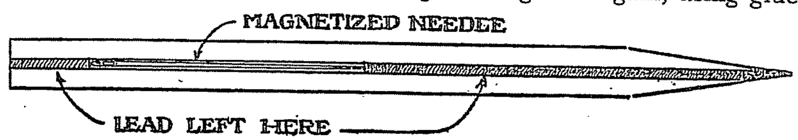

FIG. 45

or shellac, and you have magic wand which will attract small iron and steel pieces to it and cause your compass needle to be attracted or repelled at will.

MAGNETIC NAVY

Make some small wood boats, such as shown in Figure 46, using paper for the sails. Drive a small nail, or, better still, a good-sized needle through the length of the wood.

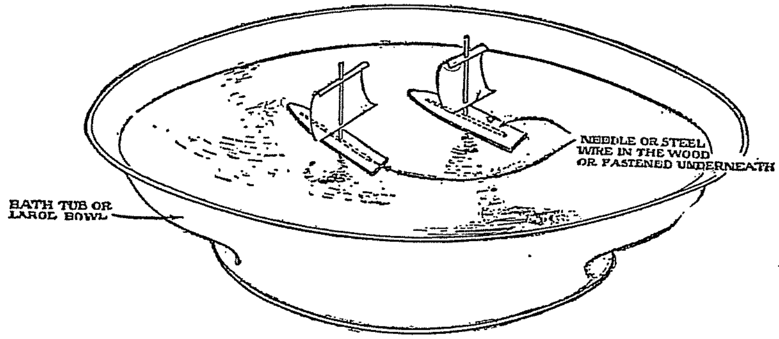

FIG. 46

By holding your magic pencil or your bar magnet toward these boats, they will sail around a dish of water or the bath tub in a most lifelike manner.

MAGNETIC JACK STRAWS

You can have a lot of fun playing Jack Straws in a new way by using pieces of soft iron wire. It will add to the fun to cut pieces

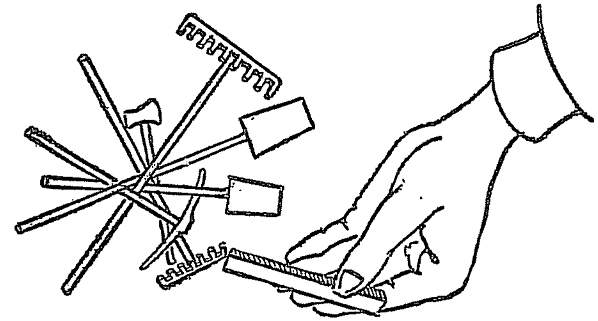

FIG. 47

of wood cork to stick on the ends of the wires, or you can mold forms with sealing wax with the wires and make little hammers, hoes, rakes or other articles, as in Figure 47. The game is played by two people in the same way that the old-fashioned game of Jack Straws is played. First drop the tools in a mixed pile. Each player is given a bar magnet and in turn tries to lift the tools out from the

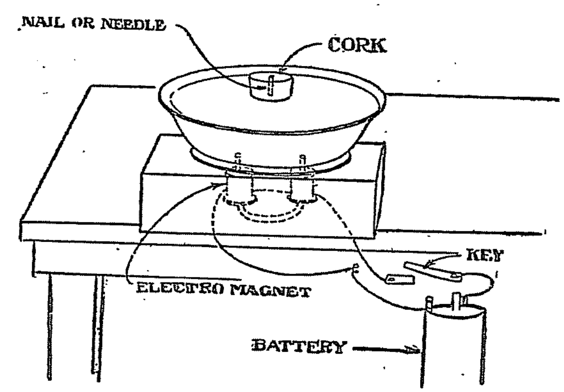

FIG. 48

pile one at a time. The player continues to lift them from the pile until he drops one. He then loses his turn and the other player begins. The game continues until all the articles are removed from the pile and the player having the largest number is declared the winner. This game can be varied by giving numbers to each article. These numbers are added at the end of the game and the player having the highest total is the winner.

MAGIC CORK

Conceal a large nail or needle in a cork and place in a shallow dish of water under which you have hidden an electro-magnet Figure 48. Connect the wires of the electro-magnet to a battery and make a key, using two pieces of flat brass or copper. Arrange this under a table so that you can press it with your foot. Now tell your friends that you can make the cork sink or swim at your command. If you can fix a head and arms on the cork to resemble a diver, this trick will be much more amusing. When you want him to go down, close the electric circuit and the magnet will pull the needle in the man toward the bottom of the dish, it will bob up again when the circuit is opened.

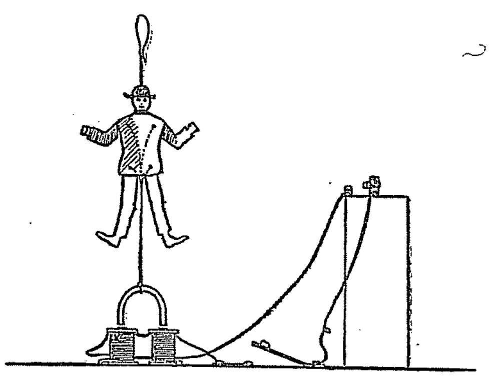

FIG. 49

Another way to make this trick work would be to cut a pasteboard jumping jack, as shown in Figure 49. The string moving the arms and legs should be fastened to the solenoid coil. Closing the circuit makes the little man dance and wave his arms.

MAGNETIC VIBRATION RECORDER

Stick a magnetized needle upright in a cork and beside it place a soft iron wire, with the upper end bent as shown in Figure 50. Magnetize another needle and let it hang by attraction to the iron wire directly over the first needle so that the like poles are together. This device placed on a table or desk will record the slightest vibration in the room and will continue to swing for some time.

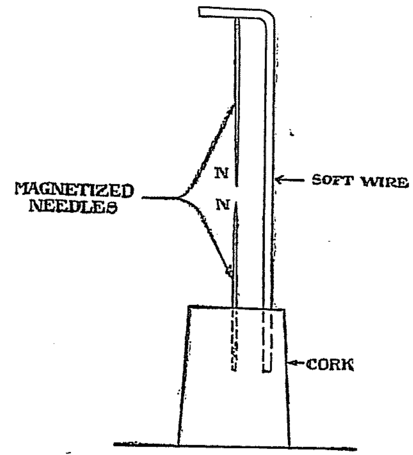

FIG. 50

MAGNETIC TOP

Magnetize a large steel darning needle. Cut a round disc of cardboard and stick the needle through the center, making a top which you can spin with your fingers. See Figure 51. Bend some soft iron pieces in shapes like snakes or s's. Set your top spinning as near one of these as possible and the top will travel along around in front and back of the wire in a most peculiar manner.

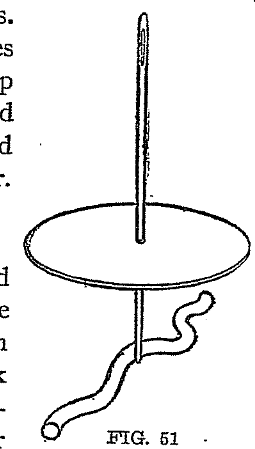

FIG. 51

SLIDING TRICK

Take a long heavy piece of cardboard and fasten over a board at an incline with a space between so that your horseshoe magnet can slide in it. See Figure 52. Tie a stout black thread to the magnet so you can raise or lower it. Place a disc of iron, or some other piece of iron or steel, at the bottom of the cardboard toboggan slide