Easy Electrical Experiments

And How to Make Them

AN ELEMENTARY HAND-BOOK OF LESSONS, EXPERIMENTS AND INVENTIONS FOR BEGINNERS AS WELL AS ADVANCED STUDENTS, WRITTEN IN A SIMPLE AND EASILY UNDERSTOOD LANGUAGE

BY

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PREFACE.

The series of electrical experiments which follow were originally published in serial form in Popular Mechanics. Their appearance in book form is warranted by the very flattering reception which has been accorded them and the numerous requests to have the articles in a more permanent shape. They have been presented in very nearly the same order as that in which they originally appeared.

The experiments are designed for those boys who are not so fortunate as to possess a large assortment of tools, and who have had little training in the use of tools. Were the experiments designed for trained machinists, with a liberal supply of tools and appliances at hand, the designs might in some cases be worked out in a more complete and serviceable manner. But for the average boy, with few tools, and a desire to learn the principles underlying the construction of the more common electrical appliances, it is thought that the designs presented are far better than more elaborate ones which might be beyond his reach.

The author can only express the wish that the experiments in their present form may be of interest to his many young friends, whose kind words of approval have been a constant source of encouragement.

L. P. D.

CHAPTER I.

SIMPLE EXPERIMENTAL BATTERY.

Electricity exists in two forms—as a stationary charge, and as a moving current. The former is not of much practical value to us, while the latter is of immense value. It is the electric current that runs our street cars and lights our houses, and enables us to do the many other wonderful things with which every one is more or less familiar. There are at least three methods by which this electric current may be produced, two of which are in every day use. One of these methods is to use a Voltaic cell, or battery, and the other method is to generate the current by means of a dynamo driven by a steam engine or other source of power. When we wish to use current on a large scale, the dynamo method is much the cheapest to use. But for all purposes where only a small amount of current is needed, it is much cheaper to generate it by means of a battery.

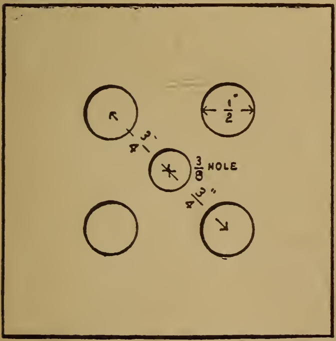


FIG 1

A powerful and efficient battery for experimental purposes can be made by any amateur at an insignificant cost. For this purpose there will be needed four tumblers (the kind with vertical sides) about 2½ inches in internal diameter; four pieces of pine ½ inch thick and three inches square; four zinc rods ⅜ inches in diameter, such as may be bought at any electrical supply store at a cost of a few cents each, and 16 carbon rods, ½ inch in diameter and 5 inches long, such as may be picked up under any electric street light.

Cut a piece of board three inches square and ½ inch thick. In the center bore a ⅜-inch hole; ¾ from the center of this hole bore four other holes ⅜ in diameter and equally spaced around the central hole. (See Fig. 1.) File every trace of copper from the surface of the carbon rods (if they are copper plated) and having filed them to a length of 5 inches, push four of them through the ½ holes so that they project 3½ inches from the lower side of the board. They should fit snugly, and be wedged in if necessary.

In a tin dish large enough to admit the board which forms the top of the cell just made, melt some paraffine wax until it just begins to smoke, taking care not to heat it hot enough so that it will take fire. Immerse the board and the short projecting ends of the carbons in this hot wax, leaving it there for five minutes. Do not immerse the long projecting ends of the carbon in the wax, nor get the wax on these ends, for this will impair the efficiency of the cell. The object of the wax is to make the board and the upper ends of the carbon rods impervious to acids and moisture.

Remove the board and carbons from the wax, shake off the superfluous wax and let them drain bottom side up, until cool. We have now four carbon rods, mounted upon a paraffined board, the whole forming one pole of our cell. A zinc rod forms the other pole, and one of them should now be pushed through the hole in the middle of the board, until it projects the same distance from the lower side of the board as the carbon rods do. The zinc must not touch the carbon rods, as this would spoil the action of the cell.

All that is left to do now is to connect the carbon rods with each other. An easy way to do this is to take a piece of bare copper wire (not insulated), about six feet long, and wrap it tightly around one carbon about ten times, then carry it on to the next, wrapping it around the second, then on to the rest of the carbons. All wax should be scraped off before this is done until a clean carbon surface is obtained. After wrapping the wire around the fourth carbon, twist it about itself two or three times, and carry the loose end to a binding post screwed to one corner of the board. Insert the apparatus just constructed into one of the tumblers, and one of the cells is complete, with the exception, of course, of the liquid which is to be used. Its appearance is shown in Fig. 2. Proceed in this manner with each of the other cells Four is a sufficient number of cells for most purposes, although the amateur may wish to make more for special purpose.

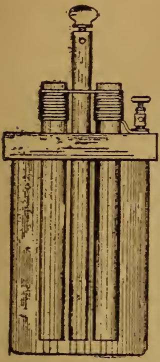


FIG 2

A liquid for use in these cells can be made as follows: Dissolve 8 oz. of bichromate of potash in two quarts of hot water. When cold add 8 oz. commercial sulphuric acid. A caution must be given regarding the use of this acid. First, never let it touch the fingers or clothing or any similar article. It will destroy them like fire. Next, never pour water or any solution into the acid. Always pour the acid very slowly into the water, stirring constantly. On account of the destructive qualities of this acid, it is almost imperative that the tumblers containing it should stand on some sort of a tray. This may be made of a shallow wooden box about one inch deep, thoroughly soaked in paraffine. Whenever the battery is not in use, the carbons and zinc rods must be removed from the acid and set aside to drain. The tray should be large enough for this purpose. In using the cells, connect the carbon terminal of the first cell to the zinc of the second, the carbon of the second to the zinc of the third and the carbon of the third to the zinc of the fourth. This will leave free the zinc pole of the first cell and the carbon pole of the fourth cell, which will form the terminals of our battery.

In a later paper, we shall see how we may, by a little extra work, improve the working of these cells, and how we may perform many interesting experiments with them.

CHAPTER II.

SIMPLE GALVANOMETER.

In setting up the battery described in the preceding chapter, fill the tumbler about two-thirds full of the solution, place the zinc and carbon rods in the solution, and join the cells in the manner described—that is, join the zinc pole of the first cell to the carbon pole of the next, and so on. Cells joined in this way are said to be in series. In order to show the effects of the electric current, two or three simple experiments will be described.

In an ordinary tumbler prepare a very weak solution of salt in water. Run a piece of bare copper wire from the zinc pole of the first cell to the tumbler of water, fastening it so that it will dip into the water a little way. Run another wire from the carbon pole of the fourth cell, and dipping into the tumbler of water but not touching the first wire. If the battery has been set up as directed, there will be seen in the water bubbles of gas, which rise from around the wires. This may be most plainly seen by placing the tumbler between the eye and the light. Break the circuit by disconnecting the end of the wire connected to the zinc pole of the battery. It will be noticed that the bubbles cease instantly. Upon touching the wire again to the zinc, the bubbles again appear. Clearly then, there is some process going on in the tumbler of water, which is caused by the passage of some invisible agent from the battery through the wires to the tumbler. That which is flowing in the wire is the electric current. The bubbles of gas seen rising through the water are hydrogen and oxygen, of which the water is composed.

The electric current passing through the water decomposes it—that is, separates the hydrogen and oxygen. We shall learn at some future time how the effect just described is turned to good use in the storage battery.

Another experiment showing the magnetic effect of the current is very interesting. Procure a small pocket compass such as may be bought for about twenty-five cents, consisting of a magnetic needle about one inch long, swinging freely on a pivot at the center of a circular scale. Such a needle if left to itself will point nearly north and south. Having placed it upon a piece of board resting on a table, drive two wooden pins into the board about six inches apart.

Adjust the board and the compass so that a wire stretched between the two pins will be parallel to the needle, and about one-half inch above it. Connect the north end of the wire just mentioned to the carbon pole of the battery, and the south end to the zinc pole.

Note carefully the position of the compass needle before and after making the final connection. It will be found that when the wire is connected so that a current flows through it, the needle is deflected so that its north end points to the east of north. Try the same experiment when the wire connecting the pins is lowered so as run beneath the needle. Also try the effect of reversing the connection of the wires running to the battery. Finally wrap a piece of fine insulated wire several times around the outside of the compass case, turn the latter until the needle is parallel to the wires, and try the effect of connecting the terminals of this coil to the battery.

In all these cases there is an effect produced upon the needle by the current, this effect increasing with the number of turns of the insulated wire around the compass case. The experiments just described will help the student to understand the action of the following simple instrument, for the detection of weak currents.

Procure a block of whitewood, two and one-half inches square, and one-half inch in thickness. In its center bore a hole just big enough to receive the case containing the compass already mentioned, and deep enough to allow the compass to sink in until its top is even with the upper surface of the block. On one edge of the block cut two slots, each one-half inch in width and threeeighths inch deep. The centers of these slots should be five-eighths of an inch from the corners of the block. Do the same with the edge of the block directly opposite to this one. In these slots wind ten layers of No. 24 double cotton covered magnet wire, as shown in Fig. 1. These are the coils which are to carry

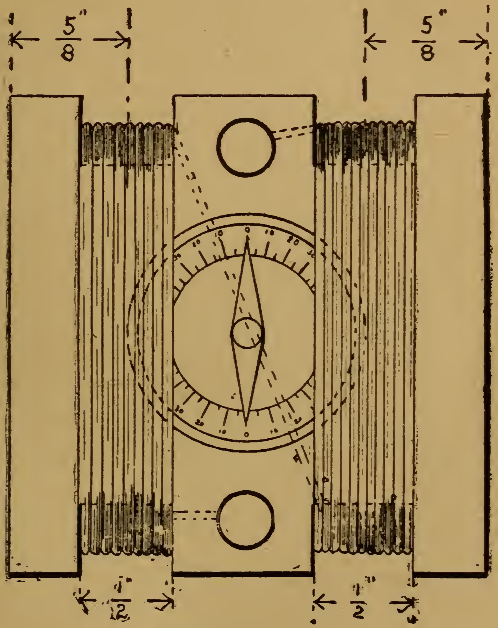


FIG. 1

the current and which are to act upon the needle, causing it to deflect when a current passes through them. Beginning with the left hand coil, wind it over and around the block until the required ten layers is obtained, then cross the wire on the under side of the block over to the right hand slot, and without breaking it, continue winding in the second slot *in the same direction* as the first coil was wound. Some difficulty may be found in keeping the layers evenly wound, especially at the middle of the coil. It may be necessary to bind the turns of each layer together by wrapping a thread around them at this point, before winding the next layer. The even winding of each layer is essential to the good appearance of the completed instrument.

When the second coil has its ten layers neatly wound, fasten the beginning of the first coil and the end of the second to two small binding posts. To enable the instrument to stand firmly upon a table, glue four cleats one-half inch thick to the under side of the board, one at each corner. Give the whole board and the coils two coats of brown shellac, and our instrument is complete. Such an instrument is called a galvanometer, and is a very useful piece of apparatus. There are many other forms of galvanometer, but their consideration must be left for another

CHAPTER III.

VARIOUS TYPES OF CELLS.

If the student has experimented with the form of battery described in Chapter I., he has probably noticed a violent action going on in the neighborhood of the zinc rods. Bubbles of gas are constantly coming from the solution, whose odor is extremely irritating. This gas is hydrogen, and it is set free from the acid of which it forms a part, when the latter dissolves the zinc. If the zinc rod were perfectly pure, there would be no such action as has been described, if the solution used were of proper strength. We could remedy the trouble by using zinc rods which are pure, but they are very expensive, and we can secure the same result in another way.

Remove the zinc rods from the solution after they have been immersed for three or four minutes, rinse them in clear water, and touch the end of one of them to a drop of mercury. Some of the latter will adhere to the zinc. Take a piece of cloth, and rub the mercury over the lower half of the rod. It will spread easily and rapidly, if the zinc be perfectly clean, until the lower part of the rod is covered with a bright, shiny layer of mercury. This process is called amalgamating the zinc. If there are black spots where the mercury does not flow easily, immerse again in the acid, and repeat the process.

After all the zincs have been thus amalgamated, replace them in the cells. There should be hardly any escape of gas now.

When no current is being taken from a battery, we say that is on open circuit. In this condition with zinc rods well amalgamated, there should be hardly any action between the acid and the zinc. It is usually the case, however, that the zinc will slowly dissolve, even with the precaution just described. So the zinc and carbon rods should be removed from the solution when the battery is not in use.

The neatest way of accomplishing this result is to use the arrangement shown in Fig. 1. The tumblers containing the solution are held in a trough made of pine boards thoroughly boiled in hot paraffine. At the ends of this trough are two upright pieces about one foot high, which support a horizontal shaft provided with a crank, by means of which the rods may be raised

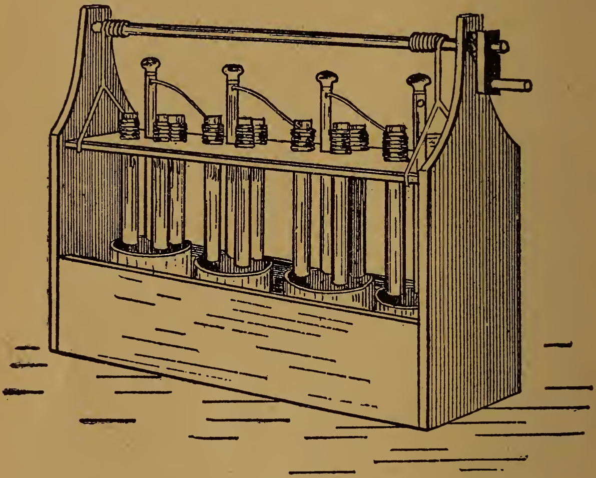


FIG. 1.

from the solution. Fasten a light strip of pine along each side of the square pieces of board which hold the rods, so that the latter are rigidly fastened together at the proper distance apart to easily fit into the tumblers when they are in the trough.

Attach the frame work carrying the rods to the horizontal shaft above mentioned by cords, so that when the crank is turned the rods will be raised from the solution. A ratchet on the crank shaft, with a retaining pawl on the upright will enable us to leave the rods at any desired height.

The student must not think that the form of battery which has been described is the only kind that could be made. As a matter of fact almost any two metals placed in a liquid capable of dissolving one of the metals more than the other, would give us an electric current. To prove this statement and to investigate the relative values of the different metals for use in galvanic batteries, the following experiments are interesting:

Procure small strip or rods of copper, zinc, iron, carbon, lead and tin. Prepare also solutions of salt, sulphuric acid (see directions in Chapter I), and sal-ammoniac.

Take any two of the above metals, and immerse them in the salt solution. Run wires from the strips to the galvanometer just constructed, and notice if the needle moves when you make the final connection. Repeat this with the same strips when immersed in the other solutions. Try also as many different combinations of metals as you have at your disposal. It will be noticed that the effect produced upon the needle is stronger in some cases than in others. The combination of zinc, carbon, and

Name of Cell.	Materials Used.	Solutions Used.	E. M. F.
Daniell	Zinc Copper	Zinc Sul. Copper Sul.	1.08
Gravity	Zinc Copper	Zinc Sul. Copper Sul.	1.08
Leclanche	Zinc Carbon	Sal-Ammoniac	1.40
Grove	Zinc Platinum	Sul. Acid Nitric Acid	1.80
Bunsen	Zinc Carbon	Sul. Acid Nitric Acid	1.80
Poggendorf	Zinc Carbon	Chromic Acid	2.00
Fuller	Zinc Carbon	Salt Pot. Bi-Chromate	2.00
Edison-Lalande	Zinc Copper	Caustic potash	0.80

sulphuric acid will probably be found to produce the most marked effect. But for some purposes other combinations are used. For instance, if we wished to make a battery to ring an electric bell, we would use zinc and carbon rods, and a solution of sal-ammoniac.

Each different combination has received a special name, generally that of the man who invented it. A few of these are given in the following table. It will be noticed that many of the cells use two liquids. This is for the purpose of keeping the current constant, as it is found that the strength of the current falls off after a little, when only a single liquid is used. The abbreviation E. M. F. stands for electro motive force.

CHAPTER IV.

HOW TO MAKE A TANGENT GALVANOMETER.

In chapter two, directions were given for making a galvanometer for the detection of electric currents. While an instrument such as was there described is very useful for general testing purposes, it is not at all suitable for the measurement of currents. The tangent galvanometer, on the other hand, is an instrument in which the parts are so related that we can readily calculate the strength of the current flowing through it.

To make such an instrument, take a piece of whitewood ½ inch thick, and saw out of it a ring whose outer diameter is 10½ inches, and whose inner diameter is 9 inches.

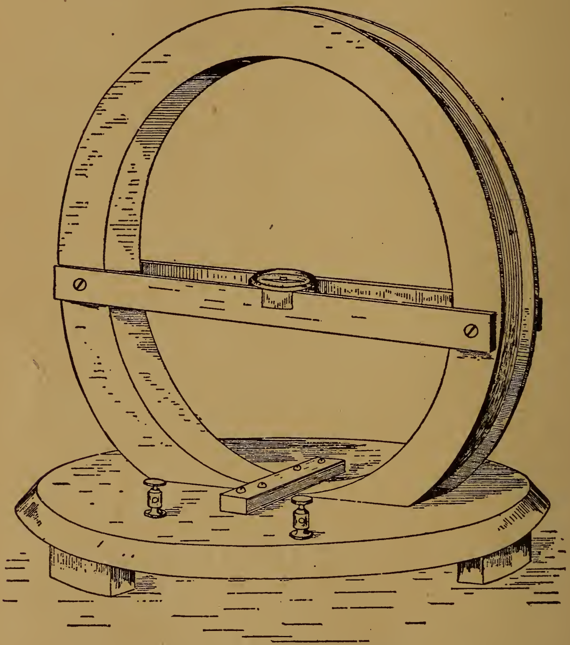
Cut two similar rings from a piece of whitewood ¼ inch thick, the rings in this case being 11 inches in outer diameter, and 9 inches in inner diameter. Glue these pieces together so that the thicker ring is between the two thinner ones, forming a ring with a channel on its outer surface which is ¼ inch deep and ½ inch wide.

From another piece of whitewood ¾ inch thick cut a circular piece 11 inches in diameter. In the center of this cut a hole 6 5-16 inches in length, and 1 inch wide. This last piece is to serve as a base upon which the ring is to be supported vertically. Three cleats ½ inch square should be glued to the bottom of the board to serve as supports for the instrument.

The arrangement is clearly shown in the accompanying figure. The ring should fit into the slot in the base so that its inner surface is just even with the upper surface of the base board, and is secured by a small strip screwed to the base board as shown.

The cutting of these circular pieces is not at all difficult if a band saw driven by power be used, such as almost every fair sized carpenter shop should possess. It can be done, however, by means of an ordinary key-hole saw.

Before mounting the ring upon its base, wind in the groove upon its circumference eight turns of No. 16 double cotton covered magnet wire. Fasten the loose ends together with a string temporarily. Across the two flat sides of the ring fasten two strips of whitewood ⅝ inches wide, ¼ inch thick, and 11 inches



TANGENT GALVANOMETER

long. These should be fastened so that their upper edges pass exactly through the center of the ring.

Procure an ordinary pocket compass about 1¼ inches in diameter and cut grooves in the middle of the last mentioned strips, with the center of the needle exactly at the center of the coil. Its zero mark should lie half way between the two strips.

Now place the ring supporting the compass at its center, into the slot in the base board, connect the two ends of the wire to two binding posts, give the whole a coat of brown shellac, and the instrument is ready for service. All dimensions given are very important. Any deviation from them will introduce errors in the results obtained by its use.

To use the instrument, first remove from its neighborhood all pieces of iron or steel, especially any magnets that may be in the vicinity. At this point it may be mentioned that all screws used in the instrument should be made of brass. Set the galvanometer upon a level table, and turn it until the needle, pointing north and south, and swinging freely, lies exactly in the plane of the coil. If the directions regarding the mounting of the needle have been followed, it will then point to zero. Send the current from one cell of battery through the coils. The needle will be deflected to the one side or the other, and will finally come to rest at a certain angle,—let us say 45 degrees. The dimensions of the instrument have been so chosen that when the deflection is 45 degrees, the current flowing through the coils upon the ring is one-half an ampere. The ampere is the unit chosen to designate the strength of an electric current. For other angles, the value of the current may be found from the following table:

Angles.	Current.
10 degrees	.088 amp.
20 "	.182 "
30 "	.289 "
40 "	.420 "
45 "	.500 "
50 "	.600 "
55 "	.715 "
60 "	.865 "
70 "	1.375 "

Since the force with which the earth acts upon a magnetic needle varies for different places, the values just given for the current will not be true for all parts of the country. The table gives correct values for the immediate vicinity of Chicago, and for that section of the United States lying east of Chicago, and north of the Ohio River. For places south of the Ohio and east of the Mississippi, the results given in the table for the values of current should be multiplied by 1.3.

CHAPTER V.

MAGNETISM.

Nearly every one is familiar with the effects produced by the small steel "horse-shoe" magnets, so common in the amateur experimenter's laboratory. They have the property of attracting to themselves pieces of iron and steel when small bits of these metals are placed near them. Indeed, a magnet has the power of communicating its magnetism permanently to other bodies, such as needles and tools made of steel. Many a boy has magnetized his knife by rubbing it over a magnet, so that it will pick up needles and pins and other small articles. The strangest part of it is that from one magnet we can make a thousand other magnets by rubbing bits of steel over it, without in the least weakening the original magnet. What is this force which we call magnetism? Clearly it is not a fluid, as was formerly supposed; for a magnetized bar weighs no more than an unmagnetized one. And how could a magnet communicate some of its magnetism to another body, without losing some of its own properties, if the magnetic effects were dependent upon some fluid residing within the metal? Clearly the only difference between a magnetized and an unmagnetized body must be a difference in their internal conditions.

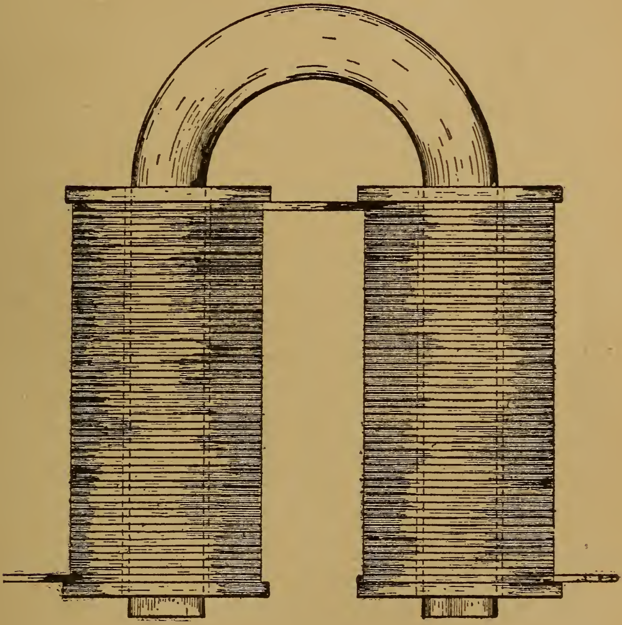
Every magnet has two poles, usually at its ends. Around these poles there is a region where the magnetism is especially noticeable. Pieces of steel placed there will be attracted or repelled. A straight bar of magnetized steel, if hung up by a thread at its center so as to hang horizontally, will turn so as to point north and south. The same end always points to the north, and is called the north pole of the magnet, the opposite end being called the south pole. If two magnets be brought close together, so that their north poles are near each other, they will repel. But if the south pole of one be presented to the north pole of the other, they will attract. The student may easily verify these statements by using magnetized sewing needles, suspended by fine silk threads.

A very pretty experiment is as follows:—

Procure a small horseshoe magnet, about six inches long. Place it horizontally upon a sunny window sill, and having lowered the window shade, cover the magnet with a piece of blue print paper such as amateur photographers commonly use. Sprinkle upon this some very fine iron filings, holding the hand some distance above the magnet, and sifting the filings slowly through the fingers. Tap the paper gently to make the filings arrange themselves in regular lines. Now raise the shade, and allow the sun to shine upon the blueprint paper for about five minutes. Then shake off the filings, and place the paper in a dish of water. A beautiful picture of the magnetic field around the magnet will be obtained. The experiment may be varied by using a photographic plate, exposing it to lamplight instead of daylight, thus obtaining a negative from which a fine print may be made.

Electric currents may be made to produce magnets. Many persons for this reason confuse magnetism and electricity, supposing them to be one and the same thing, but they are not. A powerful magnet operated by an electric current may be made as follows:

Have a blacksmith cut for you a rod of soft iron or steel, 12 inches long and $\frac{5}{8}$ inch in diameter. After being cut it should be bent into the form of the letter U, with the parallel arms of the bar about $1\frac{7}{8}$ inches apart. Make two wooden spools, each $3\frac{1}{2}$ inches long and $1\frac{3}{4}$ inches in external diameter. There should be a hole through the center of each spool, $\frac{5}{8}$ inch in diameter, so that they will slip on the arms of the iron bar just described. These spools are, of course, best made in a lathe, but the writer has made them with no tools but a $\frac{5}{8}$ inch bit, and brace, and a sharp jack knife. In the latter case it is better to cut out the shank of the spool separate from the ends of the spool, and to glue the parts together with the aid of a few small brads. The shank of the spool should be as thin as is consistent with mechanical strength.



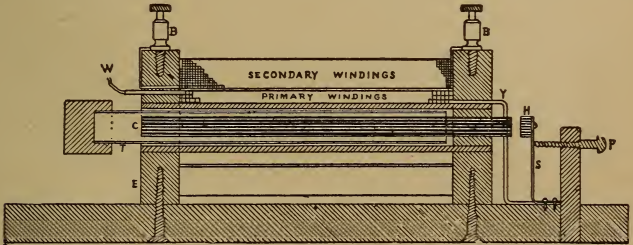
On each spool wind nine layers of No. 18 double cotton covered magnet wire. Be sure and wind each layer evenly and tightly, as this adds much to the appearance of the finished coil. When wound, slip the two spools of wire upon the iron core, and wedge them tightly in place. Connect one end of the first coil to one end of the second coil. Be sure, however, that they are connected in the following manner. Holding the magnet with its ends toward you, imagine a current to be flowing into one terminal of the left hand coil and out at the other, so as to go around the magnet core in the same direction as the hands of a clock move. Connect the terminal of the first coil by which the current leaves the coil to one terminal of the second coil, in such a manner that the current will go around the seond coil in a direction opposite to that in which the hands of a clock move. Looking at the end of the magnet, the current will seem to trace a figure 8 in going around the coils. Connect the two loose terminals to a powerful battery, and it will be found that the iron core becomes strongly magnetized whenever a current flows through the coils, but that it loses nearly all its magnetism as soon as the current ceases.

CHAPTER VI.

HOW TO MAKE AN INDUCTION COIL.

A most interesting piece of apparatus and one that is quite easily made, is an induction coil. The present chapter deals with the construction of such a coil which may be used for medical purposes, or for general experiments.

An induction coil consists of four esential parts. These are, (1) a core of soft iron; (2) a primary coil of a few turns, wound close to the core; (3) a secondary coil of many turns wound outside the primary coil, but separated from it, and (4) a device for rapidly making and breaking the current which flows through the primary coil. An inspection of the accompanying figure



will show the relation of these four parts. The core "C" is made up of a bundle of soft iron wires, very straight, and accurately cut to a length of 4¾ inches. The wires should be bound together very tightly, forming a core, when completed, whose diameter is ¼ inch, measured just outside the iron. The wrapping should be done with stout linen thread, wound very tightly and close together, leaving, however, a bare space at one end of core for a distance of ¾ inch from the end.

For the shank of the spool which is to support the coil, make a wooden cylinder ⅝ inch outside diameter, and 4½ inch long, with a ½ inch hole through its entire length. This leaves a thickness of only 1-16 inch for the material forming the spool, and is in consequence a little difficult to make. The best way is to bore a ½ inch hole lengthwise through a block of wood of considerable size, and then turn or whittle the block down until it is of the required outside diameter. For the heads of the spool take two pieces of whitewood, ½ inch thick and 2 inches square, and bore in the center of each a ⅝ inch hole. The shank just constructed should fit tightly in these holes and be glued in place, forming a spool with square heads and a round shank, with a ½ inch hole running throughout its entire length.

The iron core first made is supported from one end only, in the figure the right hand end. Make a plug, slightly tapering, which will just fit the ½ inch hole in the end of the spool. Bore through its center a hole which will fit tightly around the iron core. Drive the core into the plug, and drive the latter into the hole in the end of the spool, making a tight fit in each case. The core will then be supported by the plug, and should project ¼ inch from the end of the spool.

We are now all ready for making a device for varying the strength of the "shock" obtained from the coil. This consists of a tube, shown at "T," which is made of metal and slips over the iron core, and into the inside of the hole in the wooden spool. This is why we supported the iron core from only one end, so that we could leave the other end free for the insertion of this tube. Procure some very thin sheet copper or brass, or even tin, and bend some of it into the form of a tube 4½ inches long and 7-16 inch in external diameter, and solder it smoothly. It should slip easily into the space between the iron core and the spool. The soldering is very important for the proper working of the coil. Perhaps some of those who read this may be so fortunate as to secure a thin piece of brass tubing at a hardware store, of the proper dimensions. If so, this is much the best plan. Fit to one end of the tube a wooden handle, and adjust the tube until it slides in and out freely in the space provided.

Upon the spool wind three layers of No. 18 double cotton covered magnet wire. The ends should project through small holes in the head of the spool. This forms the primary coil. Wind two layers of stiff writing paper outside this, gluing it in place, and paying special attention to the ends of the spool where the paper should fit tightly against the heads. Outside this wind 5 oz. of No. 36 double silk covered magnet wire. This ought to make a secondary coil of a depth of about ⅜ inch. Connect its terminals to two binding posts "B," as shown. Be very careful in handling this wire, as it breaks very easily. Do not try to wind it from a loose coil, as it is sure to snarl and break. Support it upon a reel or spool from which it may be directly wound to the coil. The inside terminal of this secondary coil should pass through a small hole in the end of the spool. This is necessary to prevent short circuiting the coil.

The circuit breaker shown at "H" is made of a piece of soft iron attached to the very thin spring "S," which is screwed to the baseboard. Pressing against this is the screw "P," made of brass, and supported as shown. Connect one terminal "Y" of the primary coil to this spring. Connect one pole of a strong battery to "P" and the other to "W" and the hammer "H" will begin to fly back and forth very rapidly, making and breaking the circuit between "S" and "P" at every movement. It may be necessary to turn "S" so as to secure the proper relation between the different parts. The hammer "H" should be about ⅛ inch from the end of the core.

On connecting two wires to the binding posts marked "B," a current will be obtained capable of giving shocks to the persons holding the wires. The strength of these shocks may be varied by sliding the tube "T" in and out, the shocks being the weakest when it is pushed in as far as it will go.

CHAPTER VII

A SIMPLE ELECTRIC MOTOR.

An electric motor has three esential parts. These are (1) a magnet capable of furnishing a powerful magnetic field; (2) an armature, turning in this field, carrying the current which drives the motor; and (3) a commutator for leading the current into the revolving armature. In the simple motor about to be described, the first of these, the field magnet, is made of two 6-inch horse-shoe magnets, such as may be bought for about twenty-five cents each. The armature consists of two simple coils, and the commutator is simply a cylinder of brass, split lengthwise into two sections.

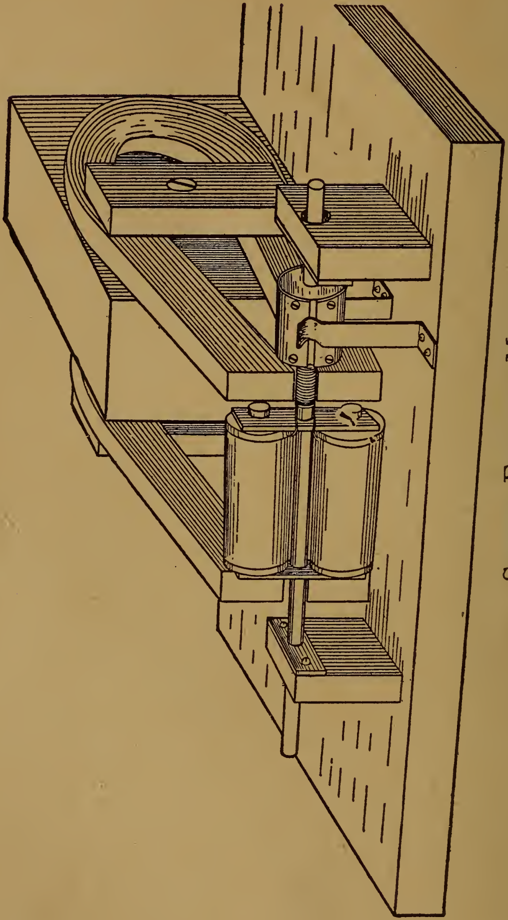
To make the armature, proceed as follows: From a rod of soft iron ¼ inch in diameter cut two pieces 1¾ inches long. Wrap each one with a layer of stout paper, gluing it smoothly in place. Upon each wind a coil of No. 24 double cotton covered magnet wire, each coil being 1½ inches long and ¾ inch in external diameter. These coils may best be made by making wooden heads, ¾ inch in diameter, for the end of the coils, with a hole in their centers of such size that they will fit tightly upon the iron core. Drive them on to the iron core so that they leave a clear space at each end of ⅛ inch. Then wind the space between them with wire as just explained. Great pains must be taken to have both spools evenly wound and of the same size and weight. Take a piece of brass rod 3-16 inch in diameter, 6 inches long, and perfectly straight. This is for the shaft. Cut from a piece of brass 1-16 inch thick two pieces, each 1½ inches long and ½ wide. Bore three holes in each. The first of these holes is at the center and is 3-16 inch in diameter. The other two holes are ½ inch each side of the center and are ¼ inch in diameter.

Having made the coils as directed, mount them upon the shaft, as shown in the figure. The two brass strips are slipped upon the shaft, and with the latter passing through the center holes and the iron cores slipping into the outer holes in each. Press the strips tightly against the coils, and solder the strips firmly to the brass shaft, thus fastening the coils firmly to the shaft and in the middle of the latter. Connect one terminal of one coil to one terminal of the other in such a way that the current will go around one coil in a direction opposite to that in which it goes around the other. Leave the remaining two ends hanging free for the present.

The commutator should next be made. To do this mount tightly upon the shaft a block of hard wood ¾ inch long and ⅝ inch in diameter. This wooden cylinder revolves with the shaft. It should fit the latter tightly and its outer end is ½ inch from the end of the shaft. Take a thin piece of sheet copper and bend it into the form of a hollow cylinder ¾ inch long, of such size as to just fit upon the wooden cylinder upon the shaft. Fasten it there with eight of the smallest brass screws obtainable. These screws should be equally spaced, four on each end, and on no account should they be long enough to strike through and touch the shaft, as this will spoil the commutator. After this cylinder is in place, cut it with a file into two equal sections, with the spaces dividing these sections running the same way as the shaft. The two sections must be entirely separated so that there is no electrical connection between them.

Wrap the shaft between the commutator and the coils with a layer of thin paper, and run each of the two free ends of the coils to a section of the commutator. Between the commutator and the coils these wires should lie close against the shaft, but separated from it by the layer of paper just mentioned, and separated from each other. They should be tightly bound to the shaft by close wrappings of fine silk thread. The appearance of the finished armature is shown in the figure.

The field magnets are two 6-inch horseshoe magnets, such as may be easily secured. Be sure and select two which have at



SIMPLE ELECTRIC MOTOR.

least ¼ inch clearance between their poles. The shaft just described has to revolve in the space between the poles, and this will be a difficult matter to arrange if the magnet poles are closer together than ¼ inch. Indeed, it may be necessary to file the shaft a little at the points where it passes between the poles, in order to allow the shaft to turn freely when the conducting wires are in place upon it.

To support the magnets, fasten a block of wood to a suitable base board, the dimensions of the block being 3 inches by 1⅞ inches by 4 inches. The block should be placed with its narrow face even with the edge of the board, and with the long axis of this face in a vertical position. Fasten the magnets to the sides of this block by cleats, held on by screws, thus enabling us to vary the position of the magnets until they are exactly right, when by tightening the screws they will immediately be clamped in place.

Support the armature as shown in the picture between the poles of the magnets. Two precautions are necessary. First, be sure that the north pole of one magnet and the south pole of the other are uppermost. This can be determined by trial, although the north pole of a magnet is usually stamped "N." Next, be sure when the coils are so placed that one is directly above the other that the commutator is so fixed upon the shaft that the two slots are horizontal.

The supports for the shaft may be made of two blocks of wood. A piece of brass screwed to each, with a hole just large enough to allow the shaft to turn freely, will make a fairly good bearing.

Fasten two springs of very thin brass to the base board, and adjust each until it bears firmly upon the commutator. Upon connecting the two brushes to a battery of four or five bi-chromate cells, the motor will revolve very rapidly and with considerable power.

CHAPTER VIII.

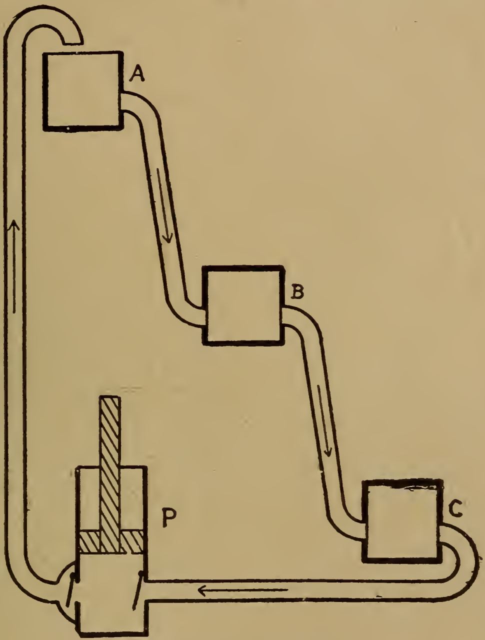
ELECTRIC UNITS.

One of the most important points in the study of electricity is to get accustomed to the use of electrical units, and to learn how to use them intelligently. The chief trouble arises from the peculiar nature of the agent with which we are dealing, and the peculiar names given to the units.

It is clear to every one who has experimented at all with electricity, that there is something in every electrical circuit which forces the current to flow through that circuit. That which causes the current to flow has received the name electro-motive force (E. M. F.). Now to express the value of any electro-motive force, we must have a unit of electro-motive force. This unit has received the name volt, in honor of Volta, one of the early experimenters in electricity.

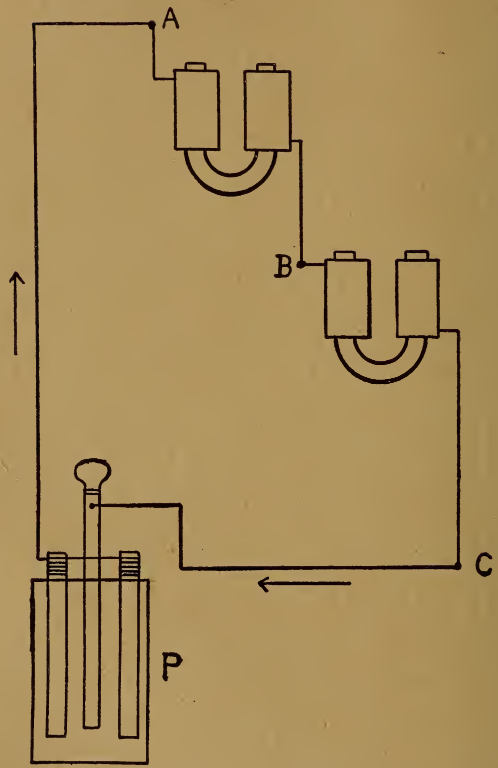
Now the very existence of this electro-motive force proves that there must be something about an electric conductor by reason of which it tends to oppose the passage of the current. If there were no opposition to the passage of the current, there would be no need of an E. M. F. to cause the current to flow. This property which all bodies possess to a greater or less degree, of resisting the passage of a current, is called resistance. The unit of resistance is called the ohm, in honor of Dr. Ohm, a celebrated German scientist.

An electro-motive force acting upon a given resistance causes a current to flow through the latter. Now this current may be strong and it may be weak, depending for its value upon two things. If the E. M. F. be high and the resistance low, the value of the current will be large. But if the resistance be very high, the current may be very small even though the E. M. F. be large. So we see that a circuit with a high E. M. F. in it will not necessarily produce a strong current, unless the resistance be low. The number of volts in a circuit gives us no idea of the strength of the current, until we know the resistance of the circuit. The strength of the current is expressed in amperes. There is a simple law connecting the values of current, E. M. F.



CIRCUIT OF WATER.

in volts, divided by the resistance in ohms. This is a very important law and every student of electricity should become familiar with it. Thus, suppose that we know the resistance of an incandescent lamp to be 200 ohms. What current will flow through it when it is attached to a 110 volt circuit? According to the rule just given the current is 110 divided by 220, or ½ ampere.



Electrical Circuit.

Very much the same conditions are met with in the circulation of water in the system illustrated in the accompanying figure, "Circuit of Water."

Suppose the tank A to be partly filled with water, and that a pipe connects it with B and C. Because of the difference in level between A and B or B and C water will flow downward through the system. There will be friction between the moving water and the pipes and the rate of flow of water will depend not only upon the difference in level between the tanks, but also upon the frictional resistance met with in the piping. At P is a pump to raise the water from C back to A as fast as it flows down into C. What pressure must this pump exert? Clearly it must exert a pressure equal to that between A and B, plus that between B and C, plus whatever back pressure results from friction.

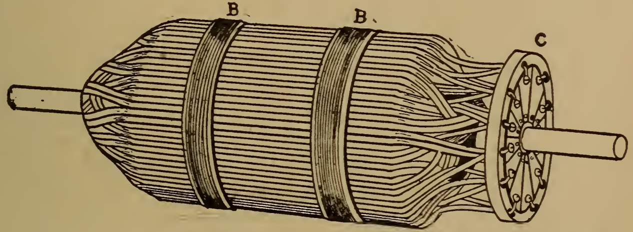
Now consider the diagram "Electrical Circuit." It has been lettered to correspond with the hydrodynamic diagram just described. Current will flow from A to B through the connecting wire if there is a difference of potential (electrical level) between the two points. Similarly, there will be a flow of current from B to C, if B be at a higher potential (electrical level) than C. This flow of current will, however, be opposed by the electrical resistance of the conducting wires. To make the flow continuous, there must be something at P capable of forcing the current back to A again. The apparatus to accomplish this is an electric battery, which we have already studied. The power which it possesses of sending the current through the electrical circuit is called electro-motive force, and in the case just illustrated, is equal to the sum of the difference of potential between A and B plus that between B and C, plus whatever difference of potential is necessary to send the current through the remaining portions of the circuit including the battery itself.

Thus we see that difference of level in the case of a water circuit is very smilar to the term difference of potential that we measure, as the electro-motive force in a circuit often has to be obtained by calculation. In the same way, frictional resistance to moving water is in some respects similar to electrical resistance, though the comparison must not be carried too far. And finally, the rate of flow of water through the system described, expressed in cu. ft. per second, is very similar in its significance to the term "strength of current" in an electrical circuit.

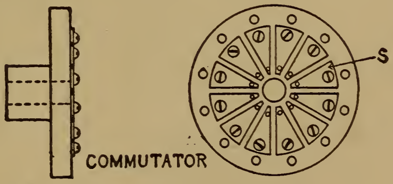
CHAP. IX —HOW TO MAKE A 1-20 H. P. MOTOR.

THE ARMATURE AND COMMUTATOR.

If the directions given in the last paper for winding the armature have been followed, the entire surface of the latter will have been covered with four layers of wire, distributed in twelve coils, each coil terminating in two wires whose tagged



ARMATURE AND COMMUTATOR



SIDE VIEW END VIEW

ends project from one end of the armature. The first thing to do after seeing that the winding is smoothly in place is to apply what are called "binding wires." These are shown at B in the figure, and are for the purpose of holding the wires firmly in place when the armature rotates rapidly. The wires tend to fly outward, and they must be held tightly to the core by wires wound around the finished armature. Wind a strip of heavy wrapping paper ½ inch wide completely around the armature near one end, and upon this strip wind six complete turns of No. 20 brass wire. This wire should be drawn very tight, and should be evenly wound. Solder it smoothly at two or three different points around the armature, and cut off the ends very close and smoothly, so that there will be no sharp points projecting. All superfluous solder should be smoothed off with a file, so that the armature may rotate very close to an iron pole piece without striking the latter. Wind a similar coil of brass wire at the other end of the armature protecting the wires by a heavy strip of paper as before.

Now we come to the making of an important part of our motor, called the commutator. Turn out a piece of hard wood of the shape shown in the side view of the commutator. The hub, or smaller part, is ⅝ inch in diameter and ⅜ inch long. The flange, or larger part, is 2 inches in diameter and ¼ inch thick. Through the center is a hole just large enough so that the wooden spool will slip tightly upon the shaft. It must fit so tightly that it turns upon the shaft with difficulty.

Now cut out of a piece of sheet copper a circle 1¼ inches in diameter. Bore a hole through its center ¼ inch in diameter. Then divide the circular copper disc into twelve equal parts by lines running through the center. This can easily be done by drawing two lines through the center at right angles, which will divide the circular disc into four equal parts. Then divide each of the four sections into three parts, and this will make twelve sections into which the circle is divided. With a sharp-pointed knife cut this disc into twelve parts by drawing the point continually back and forth over these lines, using considerable pressure. It may dull the point of the knife somewhat, but if an old knife be used it will do no harm. There will then be twelve copper sectors of the shape shown at S.

Now draw on the outer face of the wooden spool just made a circle 1½ inches in diameter. Divide it into twelve equal parts by lines running through the center. Place each of the copper sectors just made so that its broad end just coincides with this circle, and so that it lies exactly in the center of one of the sections just marked upon the wooden disc. Fasten it there by a ⅜ inch round-headed brass screw at its large end, and by a very small brad, driven through the copper strip as close as is possible, to the inner end of the latter. Fasten the remainder of the twelve strips in a similar manner to the wooden disc. As the copper sectors were cut from a 1¼ inch circle, and the circle upon the disc is 1½ inches in diameter, there will be a space between each copper sector and its neighbor about 1-16 inch wide. Be very sure that there is no metallic connection between any two of the strips. They must not touch each other nor the shaft, nor must the brad which holds one strip touch the brad which holds the next strip, nor should it touch the shaft.

Number these sectors from 1 to 12. Slip the commutator upon the shaft, so that sector No. 1 is opposite to coil No. 1, with the copper sectors facing outward. Then connect the end of coil No. 1 (E-1) and the beginning of coil No. 2 (B-2) to sector No. 1. Connect the end of coil No. 2 (E-2) and the beginning of coil No. 3 (B-3) to sector No. 2. Proceed in this manner, connecting the end of each coil and the beginning of the next coil to a sector in the commutator. When you have gone clear around the armature, connect the end of coil No. 12 and the beginning of coil No. 1 to sector No. 12 of the commutator. These connections should be made by twisting the two wires together and passing one of them through a hole in the wooden spool just above each sector, and clamping it firmly under the brass screw. Draw all wires as tight as possible, and be sure that the commutator is tight against the armature coils.

CHAP. X —HOW TO MAKE A 1-20 H. P. MOTOR.

THE FIELD MAGNET.

In the preceding chapters directions have been given for constructing the armature, or the rotating part of the motor. Besides this, there must be constructed the field magnet, which surrounds the armature, and furnishes the magnetic field which causes the armature to rotate.

The field magnet frame must be of iron, and this is where the main difficulty comes in. The best form of frame could be made by having it cast to the proper shape. But not every boy is situated so as to have access to a foundry, and besides, the difficulty of constructing patterns properly would make it inadvisable to attempt this method of construction. The form described in this chapter has been designed with the idea that everybody has access to a blacksmith shop, and can readily induce the man at the anvil to do the necessary work, which is very simple.

The form of the field magnets is clearly shown in Fig. 1, where A represents pieces of iron, bent into the shape shown, and bolted together at the top, with a piece of iron, B, clamped between them. The strips A are made of a piece of iron bar ¼ inch thick, 1¼ inches wide and about 8 inches long. As shown in Fig. 2 there are four of these strips bolted to a piece of iron at the top.

It may be well to state that the reader may exercise considerable ingenuity in the choice of arrangement of his material. That is, if it should happen that no iron stock is available whose dimensions are the same as those given, then the amateur can modify the dimensions given to conform to his particular case. Be very sure, however, that the diameter of the circular chamber at the bottom of the magnet is exactly 2½ inches. Too much care cannot be exercised in making the iron conform to the right shape and dimensions at this point. For this reason it is well to cut a circular disc from a piece of thin sheet iron, of a diameter of 2½ inches. By holding this against the curved portion, on the inside face of the iron, any irregularity in the shape of the iron can be quickly detected.

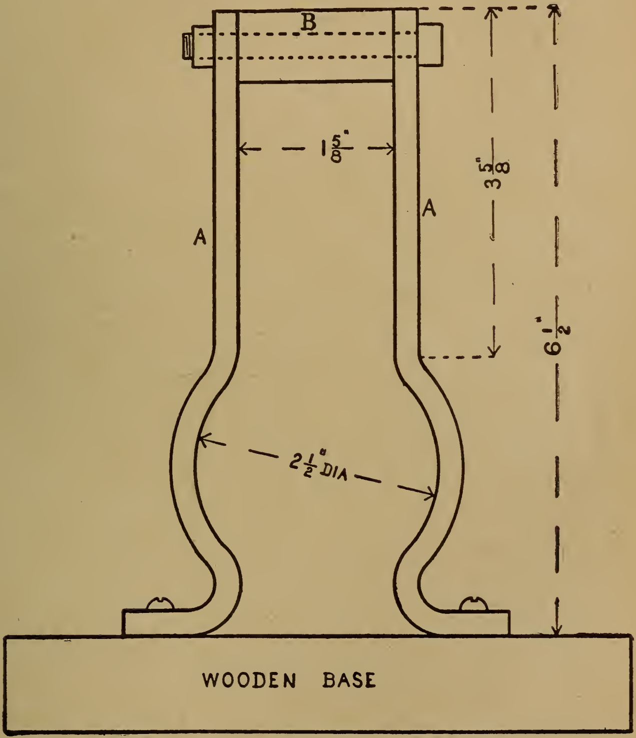


Fig. 1

The iron block shown at B is 1⅝ inches wide, 1 inch thick and 2½ inches long. Here again the amateur may, if necessary, use two blocks of iron instead of one, if a piece of iron of the right shape be not available, but the dimensions and construction given are thought to be the simplest and best.

Having caused four pieces of iron of the shape and dimensions shown at A to be constructed, have a machinist bore a ⅜-inch

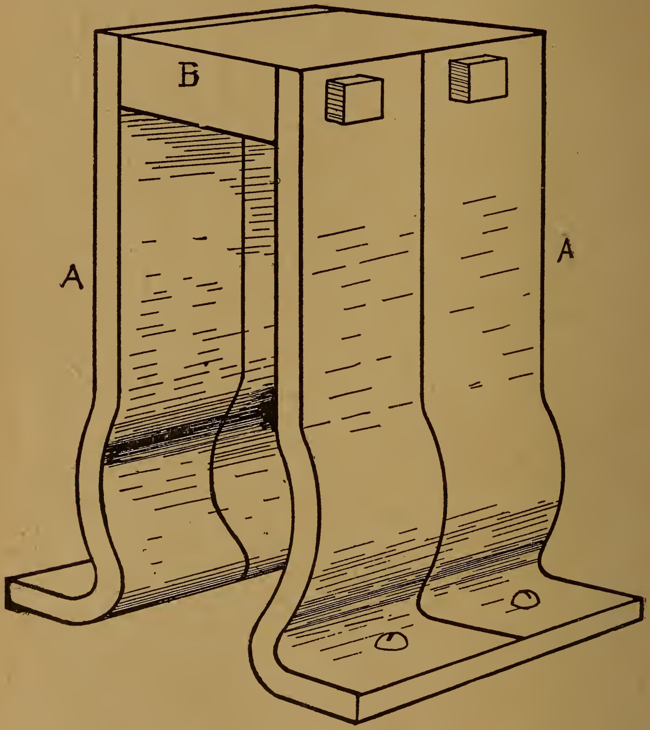


FIG 2.

hole through each at the top, the hole being in the center and at a distance of ½ inch from the end of the bar. Having procured a block of iron such as is shown at B, and of the size, just given, have two ⅜-inch holes bored through it from one of the 1-inch faces to the other. These holes should be so placed that the strips when bolted to the iron block will lie closely together, with their outer edges even with the ends of the block. Procure two bolts (preferably with square heads) ⅜ inch in diameter and 2½ inches long. These are for the purpose of clamping the pieces to the block. Before this is done, however, have a ¼-inch hole drilled through the projecting foot at the bottom of each iron strip so as to be able to screw the pieces firmly to a board.

With a file smooth off the faces of the block B, and the inside faces of the strips A, so that they will fit smoothly together. Then bolt them together tightly. Then test the circular chamber at the bottom to see if it is of the right diameter and form. If there are any irregularities in it smooth them off with a coarse file. If the faces of the iron block at the top are not square, it may be found that the iron strips are not in line. File the block until it is of the right shape to make the strips lie parallel and in line.

Procure a piece of board for a base, 1 inch thick, 12 inches long and 6 inches wide. Mount the field magnet frame upon this board in its center, by means of heavy screws passing through the holes in the projecting feet at the bottom. Be sure that the magnet frame is parallel with the edges of the board and in its center.

CHAP. XI —HOW TO MAKE A 1-20 H. P. MOTOR.

WINDING THE FIELD MAGNET.

Having made the frame of the field magnet, the next thing is to wind the coils of wire upon the frame, which are to excite the magnet. For this purpose there will be required four pounds of No. 16 double cotton covered magnet wire. Make also four pieces of wood, ⅛ inch thick, 3¾ inches long, and 1½ inches wide. In the middle of each of these cut a slot ¼ inch wide and 2½ inches long. These are to form the ends of the coils

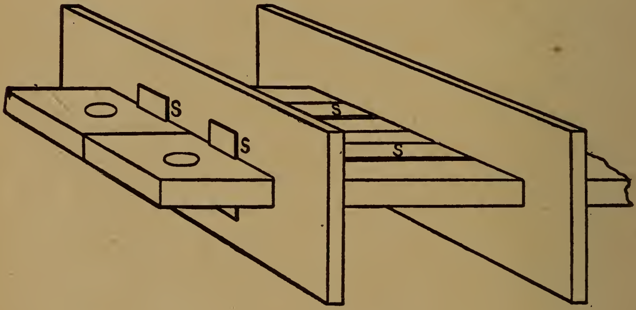


FIG I

of wire and are for the purpose of holding the wire in place. Smooth them off nicely with sand paper, and round the corners a little. Unclamp the magnet frame from the iron block and clamp the two pieces forming one side firmly in a vise. In this way they are firmly held in position until the wooden strips just mentioned are in place, and the wire is wound.

The manner of fastening the strips in place upon the core is shown in Fig. 1. Make four strips out of fairly thick sheet iron, ½ inch wide and 3 inches long. These are shown at S in Fig. 1. With a knife, cut away a little from the inside of the slots in the wooden heads of the coil so that they will slip on to the iron cores and at the same time allow the strips of sheet iron to be

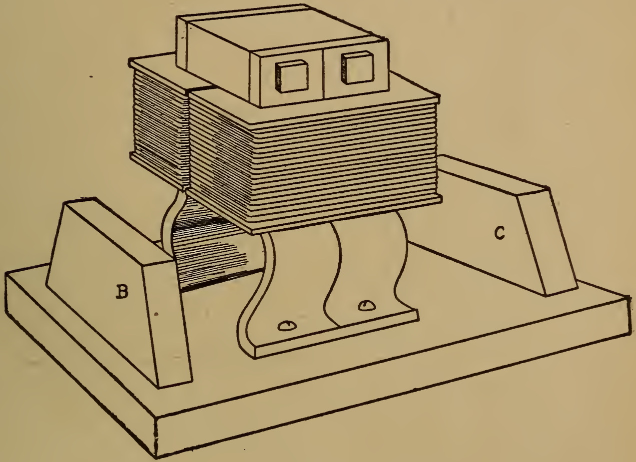


Fig 2

inserted between the iron and the wood. Then bend the ends of the iron strips up at right angles, so that there will be a free space between the wooden strips 2 inches long. There should be two of the iron strips on each side of each iron core. Now slip the strips and the pieces of wood mounted as in Fig. 1 along the iron core so that the upper one is 1 inch from the upper end of the iron core. To fasten it there, apply a coating of glue (not mucilage) to the surface of the iron between the wooden strips, and wrap firmly around it two layers of heavy paper, two inches wide. This paper is for two purposes. First, it holds the iron strips and the wooden heads firmly in place.

Second, it protects the iron core so that the wire to be wound upon it shall not touch the iron.

In the space thus formed on each pair of iron cores is to be wound 10 layers of the magnet wire already mentioned. In starting the winding bore a small hole through the lower of the wooden strips close to the core, on the outside of the frame. Through this hole pass the beginning of the wire which is to form the coil. Then wind ten layers very smoothly and evenly. It will be necessary to hold the iron core firmly in this and the other operations by clamping one end of it in a vise. After the coil is complete, fasten the outer end so that it cannot uncoil, and then put the frame together by means of the bolts at the top. Connect one terminal of one coil to one terminal of the other in such a way that the current going around one coil in a certain direction will go around the second coil in the opposite direction. That is, the current would trace an imaginary letter S in going around the two coils. The appearance of the finished magnet is shown in Fig. 2.

The supports for the shaft next claim our attention. Directions were given in the preceding paper for mounting the field magnet upon the base board. At one end of the board, and at a distance of 2⅝ inches from that end of the field magnet, mount a piece of wood, cut from a board ⅝ inches thick. This piece of wood is tapering in shape, being three inches wide at the bottom, tapering to two inches in width at the top. Its height is 2¼ inches. It is to be placed so that its center is on a line drawn lengthwise through the center of the board, and is at right angles to this line. It is fastened to the board by screws passing upward through the base board. The distance of 2⅝ inches mentioned is measured between the end of the magnet frame and the inside edge of the upright strip.

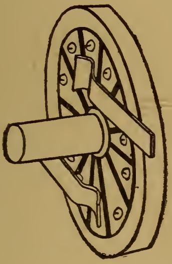
At the other end of the board is another exactly similar piece, only it is at a distance of 1⅜ inches from the magnet frame. These uprights are shown at B and C in Fig. 2.

CHAP. XII —HOW TO MAKE A 1-20 H. P. MOTOR.

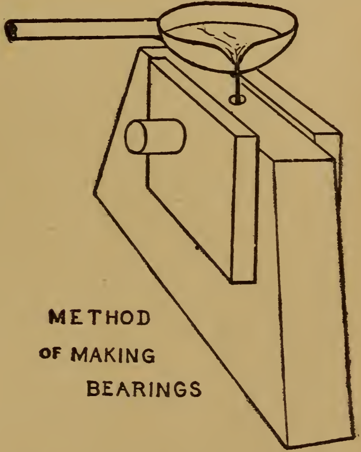
ASSEMBLY OF MOTOR.

The different parts of the motor are now complete, and it remains only to assemble these parts in their proper order. The diameter of the armature is such as to leave a little less than ⅛ inch clearance all around, when it is placed in the circular chamber at the bottom of the field magnet. It must be mounted in its bearings so as to revolve freely in the center of this space.

To do this remove the wooden uprights at each end of the



BRUSHES AND COMMUTATOR.



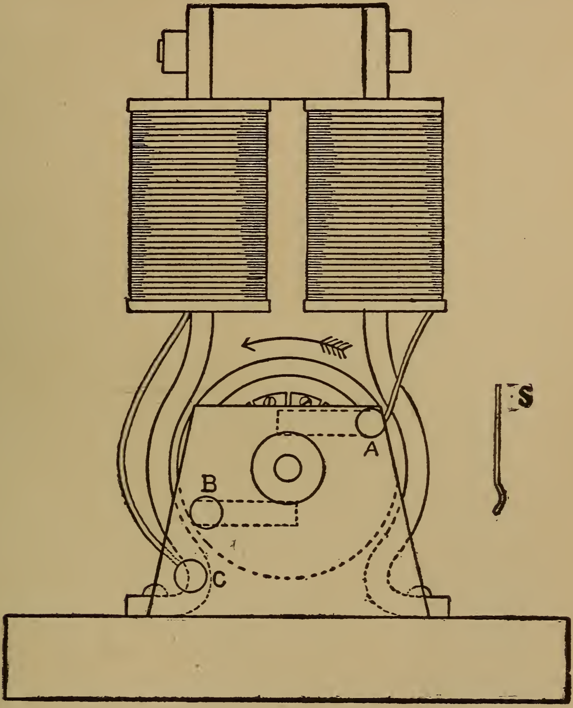
METHOD OF MAKING BEARINGS

board. Wrap around the armature enough paper, evenly wound on, so that the armature with the paper wrapped upon it shall just slip into the circular space designed for it. The paper is only a temporary arrangement for locating the armature in the center. Place it so that the ends of the armature project equally from each side of the magnet. Also be sure that the commutator is on that side of the magnet which has the widest clearance between the magnet frame and upright piece. If all directions have been followed, there will be at least 1 inch of clear shaft projecting from the commutator end of the armature, and 1⅛ inches projecting from the other end.

Measure the height of the shaft above the base board. In the middle of the two uprights, bore two holes, whose centers are the same height above the base as the center of the shaft. These holes should be ⅝ inch in diameter. When these uprights are replaced, the end of the shaft should just come even with the outer surface of the upright on the commutator end, and on the opposite end should project at least ½ inch beyond the upright, to allow room for a pulley.

Make four pieces of wood, 1½ inches square, ¼ inch thick and with a smooth hole through the center just large enough to fit tightly upon the shaft. Slip one of these upon each end of the shaft. Replace the wooden uprights, allowing the shaft to project through the centers of the ⅝ inch holes in the uprights. Then slip the remaining two pieces just constructed upon the ends of the shaft, and push the four pieces of wood tightly against the uprights. Screw or clamp them there with a carpenter's screw clamp. Bore a ⅛ inch hole from the top of each upright down into the circular chamber thus formed in the wooden upright. Then melt some babbitt metal, or if this cannot be secured, lead will do very well, and pour it through the ⅛ inch hole so as to fill the space between the shaft and wooden uprights. The object of the square pieces of wood which were just slipped upon the shaft is to make a little chamber in the upright into which the melted metal is poured as just described. Accordingly they must fit the shaft tightly and must fit smoothly against the faces of the upright.

Now remove the uprights, remove the pieces of wood from the shaft, and unwrap the paper from around the armature. These have served their purpose, and may be thrown away. The bearings just made will probably fit the shaft too tightly, and should be carefully reamed out until the shaft turns very freely, when oiled, but not loose enough to rattle. In replacing the upright strips, care must be taken to put them on at the same end and in the same position as when the bearings were



End View of Motor.

cast, as otherwise the shaft will bind. The bottom of the uprights should be very smooth and square for the same reason.

There will be a little room for the shaft to slip sidewise, if all dimensions are correct. At the commutator end, the latter should be kept at least ½ inch from the bearing by means of a brass ring of that width slipped upon the shaft. Be very sure, however, that this ring does not touch the commutator segments. Failure to observe this precaution will render the motor useless. At the other end of the shaft a narrow ring should also be slipped on, so as to keep the armature from moving sidewise. This last ring is also very important, as it keeps the armature wires from striking against the bearing, and must not be omitted.

The brushes which are to press upon the commutator and carry the current to the armature must next be made. These should be cut out of very thin sheet copper, very springy and flexible. They are about 1½ inches long, ¼ inch wide and of the shape shown at S. One is attached to the upright as shown at A. It bears firmly against the commutator on a vertical line passing through the center of the shaft. The other spring of the same size and shape is shown at B, and presses against the commutator directly below the shaft, as shown by the dotted line.

These springs are connected to binding posts as shown at C, which connects with one terminal of the field coil. The other terminal of the field connects to A.

The battery to run the motor is connected to posts B and C. The motor should then run in the direction indicated by the arrow. If it does not interchange the wires which run to C and A from the field coils.

The motor is designed for a maximum capacity of 5 amperes and eight volts. A suitable battery for running the motor will be described in a later paper.

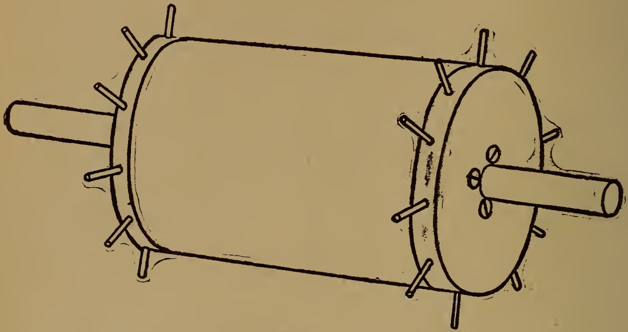
CHAPTER XII A

HOW TO MAKE 1-20 HORSE POWER MOTOR. THE ARMATURE CORE

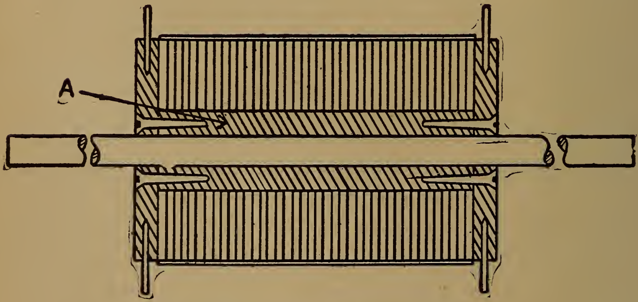
This and the following chapters will deal with the construction of a small motor designed for practical service, and yet capable of being constructed with tools which boys ordinarily possess, except in one or two instances where a little lathe work is absolutely essential. In the construction of such a motor the armature, or rotating part naturally occupies our attention first. It is to be of the so-called drum type, consisting of a large number of coils of wire wound lengthwise over a cylindrical core of soft iron which is held upon a shaft.

The first thing to provide for is the shaft. It should be made of a piece of steel rod ¼ inch in diameter, cut to a length of 8½ inches. Rods of this diameter and material may be bought at an ordinary hardware store, and may be cut to the desired length by means of a file.

Upon this shaft is to be mounted a cylinder of hard wood. Its outside diameter is ⅝ inch and its length is 2½ inches. It must fit the shaft very tightly so that it will not turn upon the shaft when the full force of the finished motor is applied to it. To avoid splitting the cylinder in thus forcing it tightly upon the shaft, it is better to make the cylinder by boring a hole lengthwise through a rather large block of wood, forcing the block upon the shaft, and then turning down the block until it is of the right diameter. This cylinder is shown at A in the figure below. It should be so placed that one end of the cylinder is 3¼ inches from the corresponding end of the shaft. Make two circular pieces of hard wood 3-16 inch thick, 1¾ inch in diameter, with a ¼-inch hole in the center of each. These pieces are to be slipped upon the shaft until they lie against the ends of the wooden cylinder already constructed, and are screwed to the latter by four flat headed brass screws ¾ inch



ARMATURE CORE, FINISHED



SECTION THROUGH CENTER

long and as slim as can be secured. The heads of these screws should be counter sunk below the surface of the wood. There has now been formed a wooden spool, mounted upon a shaft, the heads of the spool being removable. Its appearance will be clear from an inspection of the figure. The space between the heads of the spool is to be filled with iron. For this purpose iron washers are the best to use. Procure at a hardware store about 40 iron washers 1¾ inches in external diameter with a hole through the center ⅝ inch in diameter. This is a size which is quite common, and the above dimensions are given for that reason. If, however, the size of the hole should vary considerably from the above, it will do no harm provided the diameter of the shank of the wooden spool upon the shaft be altered to correspond. The outside diameter is, however, very important. For this reason it may be best to purchase the washers first. They are to be strung on to the shank of the spool so as to completely fill the space between the heads of the spool. When the space is filled, the wooden heads can be screwed into place so as to clamp the washers together with moderate pressure. As the washers average about 1-16 inch in thickness, and the space to be filled is 2½ inches, the number above mentioned will probably be needed.

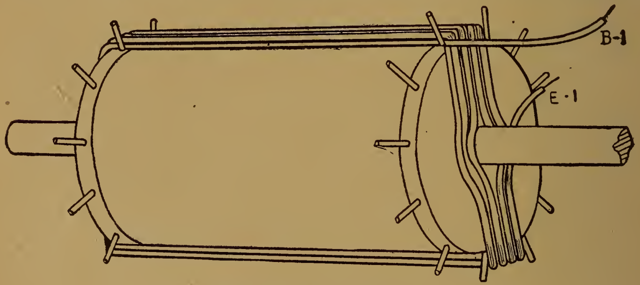
Now divide the circumference of the heads of the wooden spool into 12 parts, marking each division point with a pencil. Procure some small brads ⅝ inches long. With a pair of pliers cut off the heads of these brads. Now drive them into the circumference of the wooden discs, twelve in each head, equally spaced, projecting ¼ inch from the spool and pointing directly toward the center of the shaft. The projecting brads on one end must lie directly in line with those upon the other end. They are for the purpose of holding the coils of wire which are to be wound upon the core. Before this is done, however, the core must be covered with a layer of heavy paper glued smoothly in place in order that the coils of wire may not by any chance touch the iron core. The shaft also should be wrapped around with a layer of stout paper for a distance of one inch from each end of the core.

CHAPTER XIV

HOW TO MAKE A 1-20 HORSE POWER MOTOR. WINDING THE ARMATURE

In the last chapter directions were given for constructing the armature core. Now we will proceed to wind this core with the necessary coils of wire. The brads projecting radially from the ends of the spool are for the purpose of retaining the various coils in place upon the spool. Since we put twelve of these brads upon each end of the spool, there will be spaces between them for twelve coils of wire.

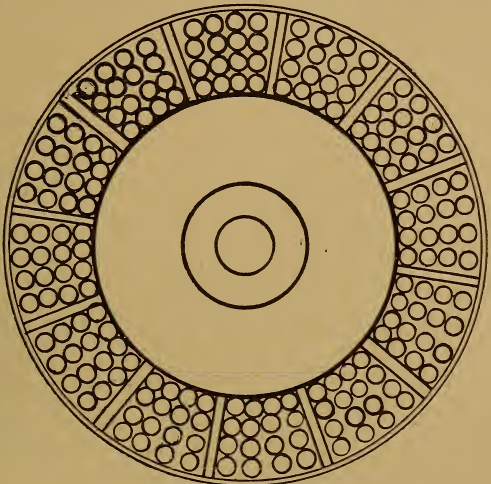
Before beginning the winding of the coils be sure that the



METHOD OF WINDING.

iron washers in the core are completely covered with a layer of paper. Also be very sure that the shaft is wrapped with heavy paper, glued on as directed. The brass screws which hold the heads of the wooden spool in place should be sunk below the surface of the wood, so that it will be impossible for a wire to touch them.

There will be needed for the armature ¾ pound of No. 18 double cotton covered magnet wire. Place it upon a reel or spool upon the work bench so that the wire may easily be unwound from it, taking care in handling the wire to keep it smooth and straight. Support the armature core, with its shaft, in front of this reel of wire, by resting the ends of the shaft upon two blocks with the core hanging between them, so



SECTION OF ARMATURE.

as to allow free access to the latter. Two or three nails driven into the blocks will prevent the shaft from slipping off.

Having made these preparations, we are ready for the winding. Begin at any one of the twelve spaces and wind the first coil in this space. The wire is wound lengthwise along one face of the core, across the other end, back along the opposite face of the core, across the other end and back to the starting point, thus passing entirely around the core lengthwise. The method of winding is clear from an inspection of the figure shown. Each of the coils when complete consists of slight turns of this kind. There will be just room enough between the projecting brads for four turns to lie side by side, so there will be two layers of four turns each. These must be wound very tightly and evenly, all kinks in the wire being smoothed out. Provide a quantity of little leather tags cut from an old shoe. Number one of these B-1, and fasten it firmly to the beginning end of coil No. 1. When this coil is finished—that is, is, when the whole eight turns are evenly wound—cut it off, leaving about six inches for connecting, and tag this end E-1, signifying that this is the end of coil No. 1. Then twist the two wires together temporarily. Proceed then to wind coil No. 2, tagging its ends B-2 and E-2. Coil No. 2 may be wound best in the space to the right of that occupied by coil No. 1. Proceed in this manner with the rest of the twelve coils.

Since each coil reaches around to the opposite side of the core, when six coils are wound all the spaces will have wire in them. But this need cause no trouble. Start to wind coil No. 7 on top of coil No. 1, but begin on the opposite side of the core; that is, coil No. 7 is wound in the space where it would naturally fall, without any notice being taken of the fact that it is wound outside of No. 1. Similarly, coil No. 8 is wound over coil No. 2, but starts on the opposite side of the core.

Of course, where all these wires overlap on the end of the spool, there will be formed a large bunch of wires. But this will do no harm provided great care is used to prevent a bare wire from touching its neighbor or the shaft. If the latter is protected with paper, there will be no trouble. Do not, however, allow the ends of the coils to form a bunch which extends more than one inch from the ends of the spool.

Twelve coils should be wound, very smoothly and evenly, and the ends properly tagged, so that when we come to connect up the coils later we can distinguish the projecting ends of one coil from those of its neighbors.

If the core has been mounted upon the shaft as directed, the shaft will project 3 inches from one end and 2 inches from the other. The winding should begin at that end of the core where the shaft is the longest.

CHAP. XIII—HOW TO MAKE A SET OF TELEGRAPH INSTRUMENTS

PART ONE.

The writer well remembers the satisfaction experienced with his first set of telegraph instruments, made at home and operated by a home-made battery. Such a set can be made with the simplest tools and with a fair amount of mechanical ingenuity, and will work admirably.

For material there will be needed for each instrument, a small quantity of pine board ⅝ inch thick, two iron bolts 3 inches long and 5-16 inch in diameter with a nut on each, a small piece of thin sheet iron and eight ounces of No. 24 double cotton covered magnet wire. The bolts mentioned are the kind used by carriage makers and carpenters. The sheet iron can be obtained by putting an old tomato can into a fire until it is melted apart, and the tin upon its surface is all melted off. This leaves the iron of which the can is made free from tin, and its surface may be cleaned with a bit of sand paper.

Take a piece of board 6½ inches long, 4 inches wide and ⅝ inch thick. This is to serve as a base board upon which the instrument is to be built. At a distance of 3⅜ inches from one end, mount an upright board 4 inches long and 2¾ inches wide. Being as long as the base board is wide, it extends completely across the latter. Before screwing it to the base board, bore two holes in it 5-16 inch in diameter, at a height of 1 inch from one edge, and 1½ inches apart. The appearance of this piece is shown in Fig. 1 at A.

Procure two bolts, of the kind previously described, and of the size mentioned. These are shown at B in Fig. 1. The head end of these bolts is usually square. Cut out of a piece of sheet iron about fifteen pieces 2⅝ inches long and 1 inch wide. Near each end cut a slot just wide enough to fit the end of the bolt just close to the head. The distance between the centers of these slots should be 1½ inches. The cutting can be done with an old pair of shears. There should be enough of these strips to form a pile about 3-16 inch high when tightly pressed together. These are shown at C in Fig. 1.

Next cut out four circular pieces of wood, ⅛ inch thick and 1¼ inches in diameter. Through the center of each cut a hole just large enough to fit tightly upon the iron bolts. These

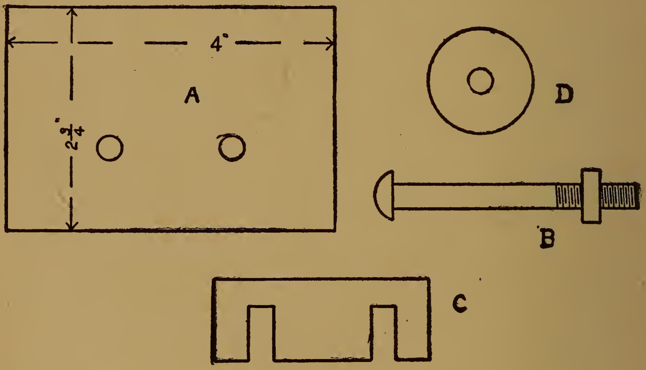


FIG. 1

pieces of wood are to form the heads for the spools of wire to be wound upon the bolts which are to form the cores of an electromagnet. Their appearance is shown at D in the figure.

Slip two of the circular wooden pieces upon one of the bolts. Place one of them at a distance of 3-16 inch from the head of the bolt. Place the other at such a distance that there will be 1½ inches of free space between the two. Cover the iron bolt between these pieces with a layer of heavy paper glued in place. One of the circular pieces should be kept at the proper distance from the head of the bolt by a wedge made of wood inserted between the head and the wooden piece. The position of the other circular piece can be regulated by turning the nut upon the bolt. Wind the space between these two pieces with 12 layers of No. 24 double cotton covered magnet wire. Repeat this operation with the other bolt, thus forming two coils with the bolts as cores.

The strips of iron which were cut out are to connect the bolts together at the end where the heads are. Remove the temporary wooden wedges and insert the strips of iron between the heads of the bolts and the heads of the coils. Put them in first

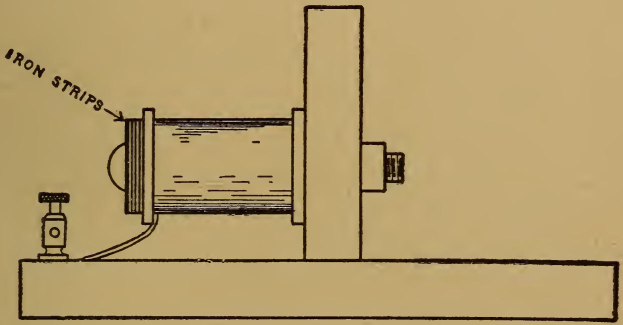


FIG. 2

from one direction and then from the other, so that the slots will run in alternate directions. The finished magnet will then look like the one shown in Fig. 2. Now remove the nuts from the end of the bolts, using great care not to disturb the wooden heads of the spools, and insert the ends of the bolts into the holes in the upright piece first constructed. They should project through the piece about ⅜ of an inch and are clamped firmly in place by screwing the nuts up tight against the board. This will hold the coils firmly against the board, and at the same time clamp the strips of iron at the rear end of the coils very tightly together.

Fasten the piece of board with its attached magnets to the base board by screws passing up through the base board. One end of one coil of wire should be connected to one end of the other coil in such a manner that a current going around the coils will go around one magnet coil in a direction opposite to the direction in which it goes around the other. Connect the free ends to two binding posts. The appearance of the apparatus as thus far constructed is shown in Fig. 2. In the next chapter we shall see how to complete the instrument.

CHAP. XIV—HOW TO MAKE A SET OF TELEGRAPH INSTRUMENTS.

PART TWO.

Having made the coils and mounted them upon the base board as explained in the preceding chapter, the next thing to be done is to make the armature, or moving part, by which we can read the messages.

Cut a piece of wood of the shape shown at R in the accom-

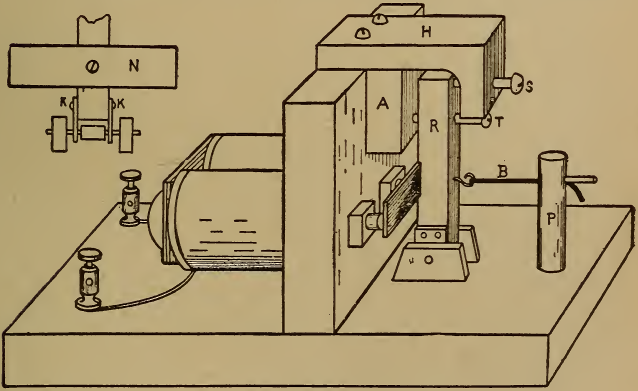


Fig. 3.

panying figure. It is ⅜ inch square, and 2⅛ inches long. At one end fasten two pieces of thin brass or iron ⅜ inch wide and ⅝ inch long. These should project ¼ inch beyond the end of the piece of wood. Before fastening them to the wood, punch two small holes through them near the projecting ends. These pieces of metal are to serve as a sort of hinge, so that when a small nail is pushed through these holes. the piece of wood may swing freely upon the nail. The nail is to be held by two blocks sciewed to the base board as shown at the left of the figure, and the piece is prevented from moving sidewise upon the naii by a small bit of wood in the center of the nail.

A piece of iron, shown at N is next to be screwed to the piece of wood just described. This piece of iron should be 1-16 inch thick if possible, or at least should be made of a sufficient number of thin pieces to make up a total thickness of 1-16 inch. Its length is 2 inches, its width ½ inch, and it is mounted at such a height above the base board that its center is level with the centers of the projecting bolts. It should be at such a distance from the latter that there is about ⅛ inch between the iron strip and the bolt when the wooden piece stands vertical.

At the center of the upright board which sustains the coils, fasten a block of hard wood, shown at A. This block is 1 inch long, ¾ inch wide, and ⅜ inch thick. It should be fastened by means of screws and glue in the position shown.

The piece of wood shown at H is 2 inches long, ¾ inch wide, and ¼ inch thick at its thin end. At the other end it curves around at right angles on its inner side, the arm projecting downward being ⅞ inch long measured outside. When screwed to the upright board as shown, there should be a clear space of ¾ inch between the block A and the inside vertical edge of H. The arm R, when vertical, should be in the center of this space.

Through the armature lever R, bore a hole whose center is ⅛ inch below the end of H. This hole should be large enough so that a brass screw ¾ inch long shall fit tightly in the hole; and be capable of adjustment by turning it one way or the other. Similarly, a brass screw of the same size, shown at S, is screwed through the wooden piece H. If difficulty is experienced in boring these holes without splitting the pieces, bore a very small hole first, and burn it out to the right size with a red hot wire.

These screws are for the following purpose: When there is no current through the magnets, the lever R is held against the screw S by the tension of the rubber band B. When a current goes through the coils, the iron cores acting upon the armature

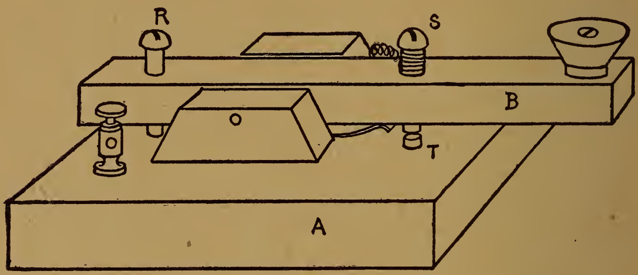
N draw it and the attached lever R toward the magnet, causing the screw T to strike against the block A. Of course, then the screws S and T must be adjusted so that the armature may move back and forth as just described. It moves through about 1/8 inch at its upper end. It is absolutely necessary that the screws be filed flat on the end so as to make a loud sound when they strike the wood.

The rubber band mentioned is fastened to the armature by a hook made from a pin driven through R. The other end passes through a hole in the post P, and is held by a peg driven into the hole in the post.

CHAP XV—HOW TO MAKE A SET OF TELEGRAPH INSTRUMENTS.

PART THREE.

The instrument described in the preceding paper is for the purpose of ticking out the messages which come over the wire. These messages are sent in obedience to the hand of the oper-



ator, who works a "key" so-called, which is simply an instrument for opening and closing, with accuracy, an electric circuit. All that we shall have to do to make our set complete is to make this key.

Cut out a piece of board, 4 inches long, 3 inches wide, and ⅝ inch thick. Draw a line lengthwise through the middle. On this line, and ¾ inch from one end bore a small hole. On the under side of the board enlarge this hole, so that a 1-inch brass screw may be screwed up through this hole, and its head be sunk below the level of the bottom of the board. File this screw off where it projects above the top of the board so that it projects ⅛ inch above the surface, and is flat on its upper end. At the other end of the board insert a similar screw. Also at a point half way between the first screw and the edge of the board, insert another screw in the manner described. This board is shown at A in the accompanying figure.

From a piece of sheet brass or copper cut a piece 2 inches long and ¼ inch wide. Bore a hole through one end, and fasten this end to the board by a screw located ¼ inch from the right hand edge and in the middle of that edge. This strip should be loose enough so that it may be moved sidewise easily.

Make a piece of wood such as is shown at B, 5 inches long and ⅜ inches square. At one end mount a knob made by saw-

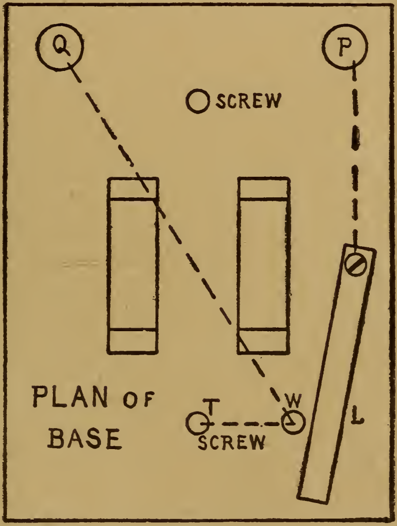


Fig. 2.

ing a small spool in halves. At a distance of 1⅞ inches from this end bore a hole large enough to take a 1 inch brass screw. The hole may be burned out, as described in the last paper, if no drill be available. The lower end of the screw should be filed flat. At a distance of ⅝ inches from the other end insert a similar screw. The distance between these screws should then be 2½ inches, which is the same as the distance between the two central screws on the base board.

The lever B is now to be mounted between two blocks screwed to the base board, as shown in the figure. It should be at such a height that its under edge is ⅝ inch from the base, and is so placed that the two screws, S and R are above the two screws in the base board. A stout round nail held in the upright blocks, passes through the lever B. It should fit the latter tightly, but should be loose enough in the block so that B may move easily up and down. There should be no side movement of the lever, however.

Take a piece of old clock spring, and soften one end by holding it in a flame. Punch two holes through it, and fasten it to the base board, underneath the lever, in such a manner that it presses upward on the front end of the lever, and holds the latter up so that the two screws S and T will not touch unless a pressure is applied to the knob.

Take a piece of fine magnet wire one foot long. Strip the insulation from one end, and wrap it tightly around the screw S. Then coil it up into a spiral and, having stripped the insulation from the wire at a point 3 inches from the screw, twist the bare wire underneath the screw which holds the copper strip L in place. Finally connect the same wire to one binding post P. The screw S, the lever L and the binding post P are then connected together. Finally connect the screws T and W by a wire running in a groove on the under side of the board which runs to the second binding post Q. These connections are shown by dotted lines in Fig. 2. Adjust the screws S and R so that the lever B may move up and down about ⅛ inch.

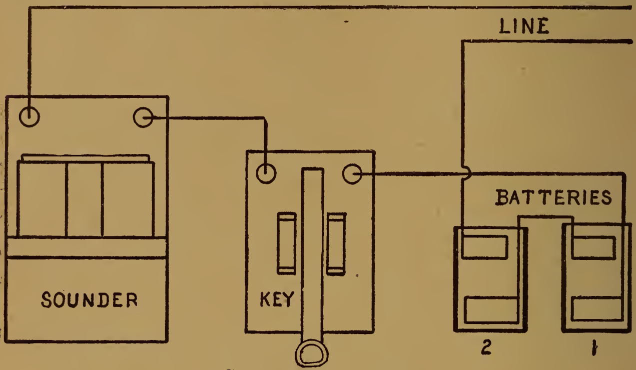
CHAP. XVI —HOW TO WIRE AND USE A TELEGRAPH INSTRUMENT.

PART FOUR.

We are now ready to set up and use the instruments which we have made. Screw the sounder (the instrument with the coils) to a table so that it will give the loudest possible sound. Also screw the device for opening and closing the circuit to the table in such a position that it may be easily grasped with the fingers when the elbow is resting on the table. This last piece of apparatus is called a telegraph key. Then wire up the set in accordance with the accompanying diagram.

For a battery there will be needed two cells of "gravity" or "crowfoot" battery, or in place of these some home made cells, such as have been described in previous chapters. Join the two cells in series, i. e., with the zinc of one connected to the copper of the next. Join the copper pole of No. 1 to one terminal of the key. Join the other terminal of the key to one terminal of the sounder. Join the other terminal of the sounder to one side of the line. Join the zinc terminal of No. 2 cell to the other side of the line. If no line is yet constructed, simply replace it with a short bit of copper wire The connections given are for each end of the line, with the exception of the cells which should all be located at one end.

With the key up, the rubber band holding the armature of the sounder should be just strong enough to pull the armature against its back stop. When the key is pressed down, the current should be strong enough to pull the armature against the front stop with force enough to make a sharp tick. Be sure, however, that the metal strip which was mounted upon the base of the key, does not touch the screw projecting through the base board. Move the key up and down slowly and adjust its movement and that of the armature by means of the screws in each case. The armature should have enough movement to give out a loud sound, but it must not strike against the magnets. The key should move only a little, but should make and break the current



Connecting the Set.

perfectly. When not in use place the metal strip on the base of the key upon the projecting screw. The circuit will then be permanently closed and should always be left in this condition when not in use. Otherwise the person at the other end of the line cannot call the person at this end.

Now as to the signals employed. The regular telegraph, or Morse alphabet, is made up of three characters—dots, dashes and spaces. By a proper combination of these all the letters of the alphabet can be made. The alphabet is as shown.

To make a dot, press the key downward with a quick, yet firm motion, so timing the movement that the two ticks of the sounder against the front and back stops shall come almost together. To make a dash, hold the key down long enough to say "one" between the two ticks. To make the various letters, combine properly accordingly to the letter which it is desired to send. Remember, however, that a space means as much as a dot or a dash, and be careful not to insert one where there is none. Thus, there is no space between the dot and dash in A, and the dash should follow the dot immediately. In making the letter C for example, there is a space between the second

A - —	K — - —	U - - —
B — - - -	L ———	V - - - —
C - - -	M — —	W - — —
D — - -	N — -	X - — - -
E -	O - -	Y - - - -
F - — -	P - - - - -	Z - - - -
G — — -	Q - - — -	& - - - -
H - - - -	R - - -	. - - — — - -
I - -	S - - -	, - — - —
J — - — -	T —	? — - - — -

Morse Telegraph Alphabet.

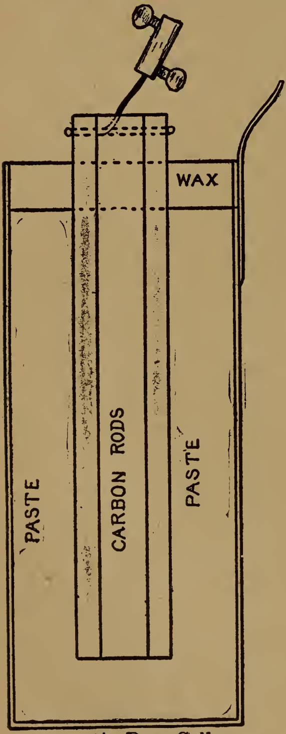
and third dots. Make the first two very close together and leave the shortest possible space between these and the last dot.

The space between words is twice as long as the space between letters. A large amount of practice is necessary in order to become skillful, but in time the letters will become as familiar to the ear as spoken words are, and the operator will not have to stop and think when he wishes to recall a letter.

The instruments described will work with two cells over a line 200 feet long. Using more cells it can work over much longer distances, depending upon the quality of workmanship, and the condition and size of the line. The ground may be used for one wire, provided contact is made with pipes driven deep into the earth, and provided the other wire is perfectly insulated.

CHAP. XVII —HOW TO MAKE A DRY CELL.

Of late years the so-called dry cells have come into common use, chiefly because of their cleanliness and portability. Ordinary liquid cells for ringing electric bells and for similar purposes employ a stick of zinc, and a carbon plate, immersed in a solution of sal-ammoniac. Dry cells use the same material for the two poles of the cell, but instead of a liquid, use a paste formed by the mixing of sal-ammoniac and other salts, with water. They are not then perfectly dry, in the sense that they contain no moisture, but only deserve the name because the paste is thick and cannot spill as a liquid would do.



A Dry Cell.

To make such a cell there will be required first of all, a strip of sheet zinc 8½ inches long and 6 inches wide. Roll this up into a cylinder 6 inches high and 2½ inches in diameter. The zinc will overlap on the side about ⅝ inch, and should be tightly soldered. Also solder a circular piece on to one end of the cylinder, so as to completely close that end, and form a water-tight vessel. This piece should have its edges flanged, and an attempt should be made in soldering to prevent the lead used in the solder from running inside the cylinder so as to make contact with the contents of the cylinder. For this reason, the joints should be painted on the inside with good asphaltum paint. Do not, however, put the paint anywhere except at the joints.

Procure next three carbon rods such as are used in arc lamps. Each rod should be 6 inches long and about ½ inch in diameter, and copper plated. Remove the copper plate from each by means of a file except for a space of ½ inch from one end. Bind them together, the plated ends at the same end, by means of strings. Solder to the copper plate at the ends of carbon rods a wire, which pass around the three rods, making contact with each rod through the medium of the solder, and the ends of which project 2 inches above the rods.

Immerse this end of the rods in a smoking hot dish of melted wax (either paraffine or beeswax), until the pores of the carbon for a space of one inch from the ends of the rods are thoroughly saturated with the wax.

To make the paste take ¼ lb. zinc oxide, ¼ lb. sal-ammoniac, ¾ lb. plaster paris, ¼ lb. chloride of zinc and mix them into a paste by adding ½ pint of water. The first three ingredients at least can probably be secured even by those who have not access to the larger stores. In case of necessity the chloride of zinc may be omitted, and its place supplied by using a little more of the other solid ingredients.

Insert enough paste into the bottom of the zinc cylinder to form a layer ½ inch thick. Rest the end of the carbon rods upon this, with the plated ends projecting from the top, and holding the rods in the center of the cylinder, push the paste into the space between the rods and the cylinder, using a stick for the purpose. Fill the space evenly all around the carbon rods, until the paste is within ¾ inch of the top of the dish.

Pour over the top of the paste a wax made by melting together ½ lb. rosin and 2 oz. of beeswax. This seals the cell, preventing the contents from evaporating and spilling. Connection is made with the zinc by a wire soldered to the outside of the zinc cylinder at the top. Connection is made with the carbon rods by means of the wire soldered to them. In both cases, screw connectors similar to that shown in the figure are very desirable.

Such a cell is very useful when currents are wanted for a very short time, as for example, in the case of the electric bells. This form of cell is, however, wholly unfitted for those purposes where a current is desired for a considerable time, like telegraph work. The cell described gives an electromotive force of 1.3 volts and will easily ring an electric bell through 50 ft. of wire.

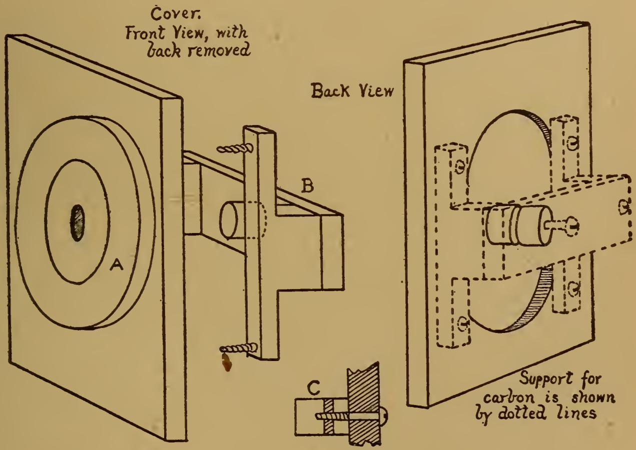
If carbon rods which are plated with copper cannot be secured, they may be plated as described in a previous chapter. Or connection may be made by twisting wires firmly about the upper ends of the rods.

It will improve the working of the cell very much if the carbon rods are surrounded by a layer of black oxide of manganese. If this can be secured it should be used, although those who do not have access to the large cities, may find some difficulty in securing it. It can be ordered sent by mail from any electrical supply house and is not expensive.

CHAP. XVIII–HOW TO MAKE A SET OF TELEPHONE INSTRUMENTS.

PART ONE.

On page 127 a simple telephone is described, designed to be used over a short line. As there described the instrument was designed to be used both as a receiver and as a trans-



mitter. That is, a person using the instrument would talk into and listen to the instrument alternately, no battery being required for its operation. Such an instrument is, however, unsuited for lines of much length, and the purpose of this and the following chapters is to describe an instrument capable of use over a line one mile in length, or even greater distances.

There are three essential parts to every telephone, viz.—a transmitter, a receiver and some form of signalling apparatus for calling. These will be described in the order named.

To make the transmitter, make a wooden box whose length is 4¾ inches, whose width is 3¼ inches and whose depth is 1½ inches, measurements being taken inside the box. This should be made of ⅜ inch whitewood, and one side, the cover, should be fastened on with screws.

In the middle of the cover of this box cut a circular hole 2¾ inches in diameter. Cut out also from a separate piece of whitewood, a circular piece 3¼ inches in diameter, with a ⅝ inch hole in its center. This is shown at A in the figure. On one side the hole is cut away so as to form a mouthpiece as shown in the figure.

This piece is to be screwed to the front of the cover, exactly fitting over the hole cut in the cover. There is ¼ inch margin left all around the hole, and this will be sufficient to hold the screws, if care be exercised. Before screwing it on, however, cut out of a piece of very thin ferrotype iron, a circular piece 3¼ inches in diameter. Bore a small hole through its center, and bore holes near the edges so that the screws holding the circular piece A to the cover, can pass through the iron. Cut out also from a piece of very heavy cardboard, a ring, whose outside diameter is 3¼ inches, and whose inside diameter is 2¾ inches. Now place the circular piece of iron over the hole in the cover, place the pasteboard ring on top of it, next place the circular piece of wood on top of the ring, and clamp the whole firmly to the cover by four screws. The iron is to be the diaphragm of the transmitter. The pasteboard ring is to keep the circular board from touching the iron, so that the latter is held only at its edges.

Make next a wooden frame shown at B. It consists of three pieces. Two of these, the side pieces, are each 2⅝ inches in extreme length, ⅞ of an inch in height, and 1 inch wide at the center. The other piece connecting these two is 1 inch wide, 3 inches long and ¼ inch thick.

Take a piece of carbon rod, such as is used in electric lamps, and cut out two pieces each ⅝ inch long and ½ inch in diameter. Bore half way through each piece lengthwise a very small hole, using a rotating drill for the purpose. If the carbon is held tightly in a vise, and if the boring is done very slowly, using a light pressure, the carbon need not be split in the process. At right angles to this bore another hole passing from one side to the other. In this drive a wooden plug. A section of the carbon is shown at C. Fasten one of these pieces of carbon to the center of the wooden frame B, by a screw passing through the wooden strip and into the hole in the carbon. Fasten the other piece of carbon to the back of the diaphragm in a similar manner.

When the wooden frame B is screwed to the back of the cover of the box, these two pieces of carbon should lie exactly in line, and there should be a clear space of about ⅛ inch between them. Adjust them by filing until this condition is secured.

In fastening the pieces of carbon in place, insert a piece of fine copper wire (about No. 30) under the end of each piece next to the screw, so as to make contact with the carbon. These wires should be about 6 inches long.

The little space between the carbon pieces is to be filled with very finely powdered carbon. Pulverize a quantity of the carbon rod with a hammer, until it is no coarser than fine sugar. Wrap around the two pieces of carbon, after they are both firmly in place, a small strip of thin cotton cloth. Fill the space between the carbon blocks with the powdered carbon, retaining it in place by means of the strip of cloth, which should be bound around the carbons with a thread.

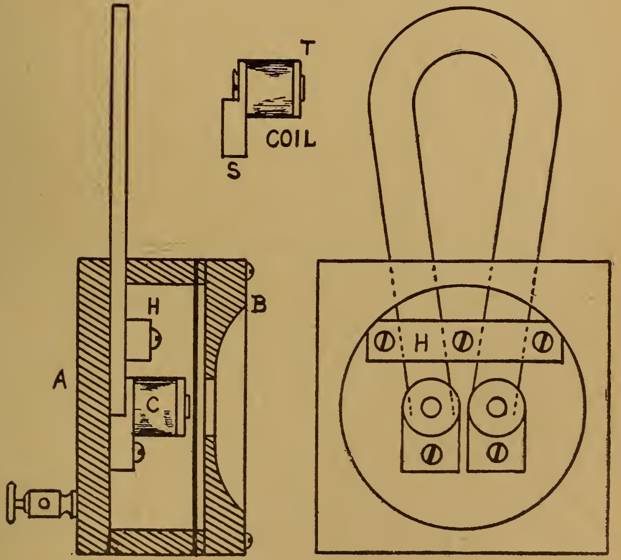
The two carbon blocks are now supported, the one at the center of the diaphragm, the other at the center of the strip at the back, with a ⅛ inch space between them, which is filled with powdered carbon. The cloth, wound around the carbons, holds the powder in place, yet it does not prevent the free vibration of the diaphragm and its attached carbon block.

Connect the front carbon with a binding post on the top of the box, and the back carbon with a second binding post, by means of the wires described. Screw the cover and its attachment to the box, and our transmitter is complete.

CHAP. XIX —HOW TO MAKE A SET OF TELEPHONE INSTRUMENTS.

PART TWO.

Having made the transmitter, we must next make the receiver. This will require the following materials: One six-inch horse-



FRONT VIEW
DIAPHRAGM REMOVED

shoe magnet, one ounce of No. 36 double silk covered magnet wire, two No. 10 flat head iron machine screws one inch long, and a few pieces of whitewood from ⅝ inch to ⅜ inch in thickness.

Cut out a piece of wood, 3½ inches square, and ½ inch thick. Draw a line through its center parallel to two edges. Lay the horseshoe magnet upon this piece, with its ends parallel to the line just drawn, and projecting ⅛ inch beyond the line. This magnet is to be clamped firmly in place by a wooden cleat shown at H. Too much pains cannot be taken to see that the magnet is fixed so firmly in place that it will not work loose. For this reason a wooden wedge inserted between the arms of the magnet, and screwed to the backboard is desirable. Use only brass screws in this part of the apparatus.

Having clamped the magnet in place, make next a piece of wood 3½ inches square and 1¼ inches thick, with a circular hole cut out of its center 3 inches in diameter. It may be built up of two ⅝ inch pieces glued together, and the hole may be cut out by means of a scroll saw, or by the help of a small drill. This piece is to be fastened to the piece upon which the magnet is mounted, and secured firmly in place by means of glue and brads. Of course it must be cut away on the under side so as to fit over the magnet snugly, and also over the cleat which holds the magnet in place. This will make a box, square on the outside, but circular inside, with the poles of the magnet projecting through one side, and resting at the center of the box.

The coils next claim our attention. One of these is shown complete, and is also seen at C. They are made as follows: Cut out a piece of wood 1½ inches long, ⅜ inch thick, and ⅞ inch wide. Cut away one end for a distance of ¾ inch, so that it is only ⅛ inch thick. Through the center of the piece, and 7-16 inch from the thin end, bore a hole the size of the iron screws first mentioned, and push one of the bolts through the hole, from the side that is cut away. Bevel the hole on this side so that the head of the screw will sink down almost level with the surface of the strip. Make a circular wooden piece ⅞ inch in diameter, and ⅛ inch thick, with a hole through its center just big enough to fit tightly upon the screw. The strip first mentioned is to form one end of a spool of wire. The circular piece just described is to form the other end, and is accordingly screwed on to the screw after the latter is in its place in the wooden strip. These pieces are shown as S and T respectively.

The space between them is to be wound full of No. 36 double silk covered magnet wire. Before beginning to wind, cover the iron core with a layer of heavy paper, gluing it in place. Make two coils exactly alike, using the two iron screws for the purpose.

The strip S is made of the shape shown in order that the coils may be screwed to the inside of the bottom of the box, with the heads of the screws resting firmly against the poles of the steel magnet. Their position is shown in the right hand figure. Be sure that they are fastened firmly in place by means of a screw and a little glue. Then connect the terminal of one coil with one terminal of the next so that a current will go around the second coil in direction opposite to that in which it goes around the first. Connect the two remaining terminals to the two binding posts on the back of the receiver.

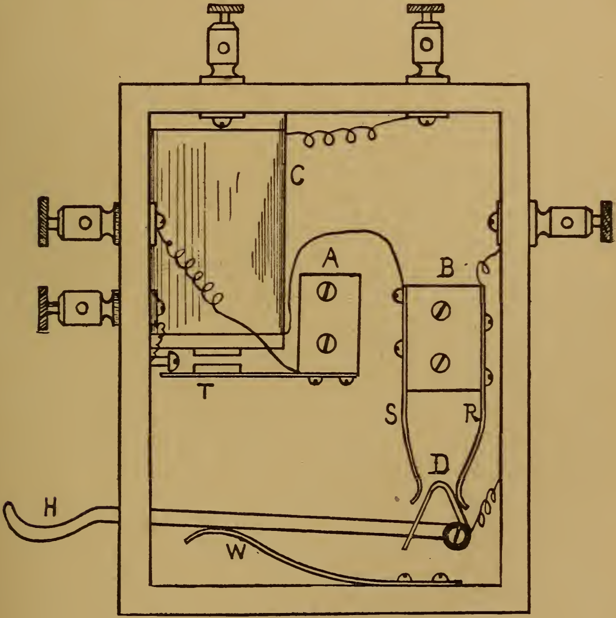
All that remains is to make the diaphragm and to secure it in place. It should be made from a piece of very thin ferrotype iron, such as photographers use. Cut out a circular piece 3½ inches in diameter. Cut out also a piece of wood, 3½ inches square, and ⅝ inch thick, with a hole through its center ¾ inch in diameter. Hollow out one side to form a mouthpiece as shown at B. Cut out a circular ring of heavy cardboard, whose external diameter is 3½ inches, and whose internal diameter is 3 inches.

Place the iron diaphragm over the front of the box containing the coils. It should almost touch the ends of the iron screws. Adjust it so that there will be 1-32 inch between the ends of the screws and the diaphragm. Then place the pasteboard ring on top of the diaphragm, put the wooden mouthpiece on top of this, and screw the whole together by four screws at the corners. The pasteboard ring keeps the wooden mouthpiece from touching the diaphragm except at the edges, leaving the diaphragm free to vibrate.

CHAP. XX —HOW TO MAKE A SET OF TELEPHONE INSTRUMENTS.

PART THREE.

In addition to a transmitter and a receiver, we need some form of apparatus by means of which either party can call up



the other. The ordinary form of electric bell with push button is hardly sensitive enough, unless the line be very short, and the battery used very powerful. We need too, some simple device for cutting the battery out of service when the instrument is not in use, and for cutting the ringing device into service when desired. The apparatus to be described accomplishes these purposes, and is not difficult to make.

Make a wooden box which is 6 inches wide, 8 inches long, and 4 inches deep, measurements being taken on the inside of the box. It should be provided with a cover which may be fastened on by screws. The material used is ½ inch in thickness.

Take a piece of brass or copper rod ¼ inch in diameter, and about 8½ inches long. Bend one end into the form of a hook as shown at H. Take a piece of thin sheet copper or brass about 2½ inches long and ⅝ inches wide. Bend this into the form of a V as shown at D. One arm should be about 1 inch long, and the other arm should be bent on the end so as to form a circular bearing which will just fit nicely on a 1-inch brass screw. This piece of brass is to be fastened to the end of the brass hook just constructed.

Bore a hole through the straight arm of the piece D, push the end of the brass rod through it until its end rests against the circular bearing, and solder the whole firmly together. The brass hook is then to be mounted by means of a 1-inch screw to the back of the box, on the inside, the screw being 1 inch from the lower corner of the box. The curved end of the hook projects through a slot cut in the side of the box, of such a width that the hook may move freely up and down through a slot cut in the side of the box, though a distance of about one inch.

The spring W is easily made from an old piece of clock spring, and pushes up on the hook with considerable force. The springs S and R are made of quite thin brass. The spring R makes contact with D when the hook is up, and S makes contact with D when the hook is down. When D is in contact with one spring, it must not make contact with the other. They are supported by the block of wood B. Be careful that the screws which hold one spring do not touch the screws which hold the other.

At C is shown a coil of wire. Procure a piece of soft iron rod 4⅛ inches long, and ⅝ inch in diameter. Mount tightly upon each end a circular piece of wood ¼ inch thick, and 2 inches square. Wind the iron rod between the pieces with a layer of heavy paper, and then wind the entire space full of No. 30 double silk covered magnet wire. About four ounces will be required. Then fasten the coil in its place in the upper left hand corner of the box.

The spring T should be as thin and flexible as it can be made. Very thin copper or brass will answer. It carries at its outer end a small piece of iron, which serves as an armature, being attracted towards the coil whenever a current goes through the latter. The spring should be long enough so that its end will touch a brass screw inserted in the side of the box, when the armature is attracted towards the coil. When the armature moves away from the coil, the spring should not touch the brass screw just mentioned. In order to make this part of the apparatus as sensitive as possible, the spring T should be as long as possible. It is supported by the block A.

To the sides and top of the box, fix six binding posts, in the positions shown. Connect the upper terminal of the coil to the right hand top binding post. Connect the other terminal of the coil to the spring S. Connect spring R to the binding post on the right hand side. Connect the spring T to the upper binding post on the left hand side. Solder a very small flexible wire to the end of the hook H after the latter is in place. Connect this wire to the left hand binding post on the top of the box. Connect the lower binding post on the left hand side to the small brass screw just below it, and this part of our apparatus will be complete. The cover of the box may be screwed on, and we will be ready next to set up the various parts of our telephone.

CHAP. XXI —HOW TO MAKE A SET OF TELEPHONE INSTRUMENTS.

PART FOUR.

The different parts of our telephone should be supported on a suitable backboard which holds them firmly in place, and enables us to support the whole instrument on the wall. This backboard

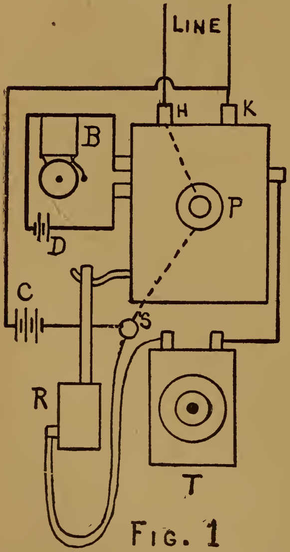


FIG. 1

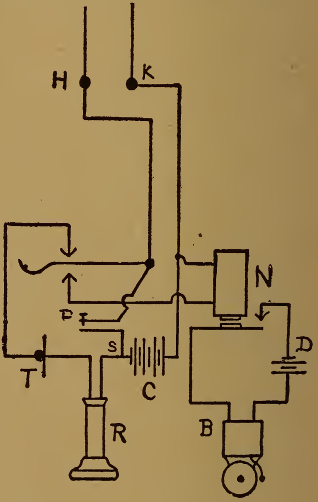


FIG. 2.

should be made from a piece of ⅞-inch board. It should be about 20 inches long and 10 inches wide. Fasten the box containing the movable hook to the upper part of this board by screws passing through the bottom of the box. Fasten the transmitter first constructed at a convenient distance below this in a similar manner. There will be needed, in addition to the apparatus constructed, an ordinary electric bell, a push button such as is commonly used for doorbells, and about five cells of dry battery such as will be described in Chapter XXVIII of this book.

Mount the electric bell in a convenient place near the telephone. Connect one terminal of the bell to one of the binding posts on the left-hand side of the box containing the hook. Connect the other terminal of the bell to one cell of dry battery. Connect the other terminal of the battery to the binding post immediately below the first one just mentioned. Mount the push button on the front of the telephone as shown at P, and run a wire from it to the upper left-hand binding post, and a wire from the button to another binding post screwed to the backboard, and shown at S. Join four cells of dry battery in series, and connect one terminal of the battery to the upper right-hand binding post. Connect the other terminal of the battery to the binding post S. Connect the binding post on the right-hand side of the box to the right-hand binding post on the transmitter.

Provide now two pieces of flexible wire about three feet long and insulated. Connect one end of each to the binding posts on the receiver, and the other end of one to the binding post S, and the end of the other to the remaining terminal of the transmitter. This finishes our connections, and all that remains now is to adjust the different parts and study their action. The connections just described are indicated in Fig. 1. In Fig. 2 is given a diagram which illustrates the principles upon which the apparatus works.

First as to the adjustments necessary. The receiver will require the least adjustment, and if made according to the directions given, should work perfectly. The transmitter should be carefully examined to see if the powdered carbon is still in its place between the two carbon terminals. These terminals should be mounted with the precautions described. The terminal attached to the diaphragm should move freely with the latter. The back carbon terminal should be firmly fixed in place. The hook should next be examined carefully to see if it moves freely up and down. Notice especially if it makes and breaks the circuit between the two contact springs as described. Examine the spring carrying the armature to the ringing coil described in the last number and adjust it so that the armature will be attracted towards the coil with the least possible current. Be sure that the armature makes contact with the screw mentioned in the preceding paper.

Turning now to Fig. 2, let us see how our telephone should work. The line which connects our telephone with that of the person with whom we are talking is connected to the two binding posts at the top. If the receiver be hung on the hook so as to pull the latter down there will be a circuit from H to the hook, to the lower contact point, to one terminal of the coil N, and from the coil back to K and thence to line. If a person at the other end of the line should connect a battery to the line the current would pass through the coil and would draw its armature up, ringing the electric bell.

Suppose, now, that the receiver be taken from the hook so that the latter may move upwards by reason of the spring previously described. Then the hook will break contact with the coil N and will make contact with the upper contact point. This will throw into circuit the transmitter T, the receiver R, the main battery C and the line. We are then ready for talking. When the telephone is not in use the receiver should always be hung on the hook to save the battery.

One thing more needs to be described. The push button indicated at P connects the battery directly across the line. When this is pushed the current from the battery goes directly to line and actuating the armatures of the coils at each end, causes them to ring the electric bells connected in circuit with their armatures. If the line be very short and the armature of the coil N very delicately pivoted, then the act of removing the receiver from the hook at one end will ring the bell at the other end of the line.

CHAP. XXII —THE MEASUREMENT OF RESISTANCE.

It is very often desirable to measure the resistance of various pieces of electrical apparatus, such as coils, and wires of various kinds. It is not at all difficult to construct a piece of apparatus which is capable of measuring resistances with a considerable degree of accuracy. The material needed for the construction of this apparatus is as follows,—a piece of pine board, 42 inches long, 8 inches wide, and ⅞ inch thick, a piece of No.

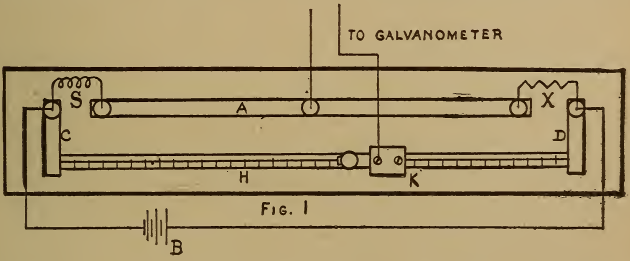


FIG. 1

22 German silver or iron wire about a yard long, an ordinary wooden yardstick, a strip of brass or copper 4 feet long, ½ inch wide, and at least 1-32 of an inch in thickness, and five ordinary binding posts.

Cut the board to the dimensions given above, and smooth it off nicely with sand-paper. It is well to bevel the edges of the board for the sake of appearance. Near one edge of the board, and parallel with the edge, fasten the wooden yard-stick, as shown at H in Fig. 1. Three screws passing through the yard-stick and into the pine board will be sufficient.

Cut off two pieces of the brass strip each 5 inches long. These are to be fastened to the board at the end of the yard-stick, and are shown in the figure at C and D. The thickness of 1-32 inch given above for these strips, was chosen for the reason that this thickness would be easier to work for those possessing few tools. If possible, however, the thickness of all brass strips used should be 1-16 inch.

Now cut off another strip of brass whose length is 32 inches. This strip is shown at A in Fig. 1. It is screwed to the board so that it is in line with the end of strips C and D, and there is a 2-inch gap at S and X, as shown.

Put binding posts at the middle and ends of strip A, and also at the rear end of strips C and D, as indicated.

The next thing is to make the key shown at K in Fig. 1, and

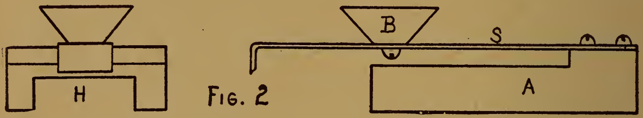


FIG. 2

shown enlarged in Fig. 2. The body of the key is made from a block of wood 2½ inches long, 1¾ inches wide, and ¾ inch thick. It is hollowed out on the under side as shown at H, so that it will fit snugly over the yard stick, and slide easily along the latter. On account of the different width and thickness of various yardsticks, it is impossible to give dimensions for the slot shown at H, but the amateur can easily arrange this.

The top of the block is cut down for a distance of ⅛ inch except for a distance of ¾ inch from one end. This end is left higher than the rest of the block so that the spring S may be fastened to the block in such a manner as to be capable of being moved freely up and down. In order to make it easy to press the spring downward, a wooden button B is screwed to the spring at a point just inside the end of the block. The spring S is made of a piece of 1-32 inch spring brass, and is bent over at right angles at one end as shown. The length of the long arm of this spring is 4 inches, and that of the short arm is 5-16 inch. The latter is beveled on its end to a sharp edge.

Now take a piece of German silver wire of the size already given, and a little longer than the yardstick. Stretch it lengthwise over the yard-stick, drawing it very smooth and tight along the surface of the latter, and clamping it firmly under the brass strips at the end. The wire should be very smooth and straight. Iron wire could be used, if it is impossible to obtain anything else, but it will give trouble, unless it is kept very carefully cleaned.

The key K when placed upon the stick, should slide very smoothly along the latter, and the brass spring should just clear the wire on the stick.

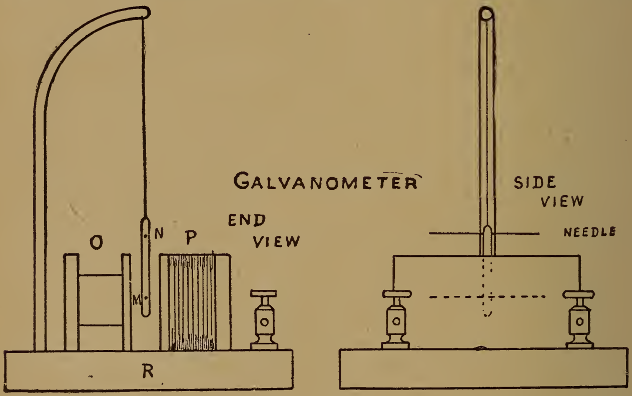
In using the apparatus, some form of sensitive galvanometer must be employed. Such a galvanometer was described in the second chapter of this book. Another form will be described in a later chapter. One terminal is connected to the binding post at the center of strip A, and the other terminal is connected by means of a long flexible wire to the key K.

At S is inserted a coil whose resistance is already known, and at X is inserted a coil or wire whose resistance we wish to determine. A battery of two or three cells is connected across from C to D as indicated at B.

The method of using the apparatus will have to be explained in the following chapter.

CHAP. XXIII—THE MEASUREMENT OF RESISTANCE.

In the last chapter we constructed a piece of apparatus for the measurement of resistance. This apparatus is, however, dependent for its action upon some form of sensitive galvanometer capable of responding to a very weak current. Such an instrument will now be described. A side view and a front view is given in the accompanying figure. R is a block of wood,



3 inches square and ½ inch thick. On this block is to be mounted two coils, shown at O and P. One of these, P, is shown complete while the other, O, is shown without the wire in place. To make the forms for these coils, take a block of wood, 1½ inches long and ½ inch square in cross section. Next make two pieces of wood, 2 inches long and 1 inch wide, one of the pieces being ¼ inch thick, the other ⅛ inch thick. Glue these to opposite sides of the block just mentioned in such a manner that the block will be at the center of the pieces. One or two small brads will help to hold them in place. This will

make a small form, of which the block forms the core, and the two larger pieces the sides. Make two such forms. They are to be wound full of No. 32 double silk covered magnet wire, of which about 3 ounces will be required. They are then to be mounted, as shown in the figure, at equal distances each side of the center of the 3-inch block, the thinner flanges of the coil being turned towards the center. The distance between the coils is 3/8 inch.

Take a very small piece of soft wood, 1 inch long and about 1/8 inch in diameter. A piece of a match will answer. Push through it two small sewing needles, the distance between the needles being 5/8 inch. If the needles split the wood, push them through a longer piece first, and then cut the piece down to the right length.

These needles are to be magnetized by stroking them with a magnet. But the greatest care is necessary in the process. The magnets must be magnetized so that the north pole of one is directly above the south pole of the other. To accomplish this, stroke the end of one needle several times with the pole of a strong horseshoe magnet, and then immediately stroke the end of the needle which is directly below the first with the other pole of the magnet. Magnetized in this way, there is little tendency for the pair of needles to point north and south, as in the case of ordinary magnetic needles.

Near one edge of the baseboard, bore a hole 1/8 inch in diameter, and fit into this hole the end of a piece of brass rod bent into the shape shown. The height of the top of this rod when bent over should be about 3½ inches above the baseboard, although the exact height is not important.

Support the needles just constructed by a very fine silk fibre, made by untwisting a very small fibre from a bit of silk thread. The finer this fibre is, the better. It can be fastened to the needles, and also to the brass rod by means of a bit of sealing wax. The lower needle should hang at the center of the space between the two coils.

Connect the two coils together so that the current will go around them in the same direction. Connect their free ends to two binding posts as shown.

Now we are ready to make use of the instrument in the measurement of resistance. Referring now to Fig. 1, on page 77, the galvanometer is connected to the wires indicated. It is then turned so that the freely suspended magnetic needles hang in the space between the coils and parallel to the coils. If it is difficult to find such a position, a small piece of iron, or a magnet, placed near the instrument, will bring the needles into the desired position.

At S, in Fig. 1, is shown a standard coil. This is made by coiling on a spool about 39½ ft. of No. 24 copper wire. The resistance of such a piece of wire is almost exactly one ohm. It will do nicely as a standard. At X, in the same figure, connect any coil whose resistance we wish to determine. If now the key K be pressed, and its position shifted back and forth, there will finally be found a point where there is no deflection of the galvanometer. At first the deflection will probably be quite violent, but by beginning at one end of the stretched wire, and working towards the other end, a point will finally be reached where pressing the key will not affect the galvanometer needle at all. When this point is found note its position on the yard stick.

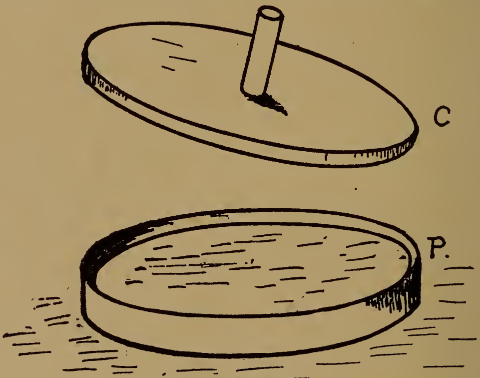
Then, to find the resistance of X, multiply the length of wire to the right of K by the value of S (in this case one ohm), and divide by the length of wire to the left of K.

In case high resistances are being measured, a high resistance coil must be used at S in place of the one ohm coil just described. Having this one ohm coil to start with, the amateur can easily make for himself other coils of 5 or 10 ohms each, and from these still higher ones. In any case the measurement is the easiest made, when the resistances at S and X are the most nearly equal.

As an example, take the following. Suppose a 10 ohm coil be inserted at S, and that with an unknown coil at X, a point is found at 11 inches from the left hand end of the wire, where there is no deflection. Then the resistance of the unknown coil is found by multiplying the length to the right of K (25 inches in this case) by 10, and dividing by 11. The result would be, in this case, 22 7-10 ohms. In order to apply this rule, however, the coils must always have the position shown, that is, S must be on the left-hand side of the apparatus.

CHAP. XXIV—HOW TO MAKE AN ELECTROPHORUS.

Experiments with static or "frictional" electricity are always interesting and instructive. Whenever a substance like sealing-wax or resin or hard rubber is rubbed with a piece of fur or flannel, the sealing wax, or whatever substance is used in place of the wax, is found to be electrified. This is shown by the fact that it will attract pieces of paper or light balls made



The Electrophorus.

of pith. The fur, or flannel, also becomes electrified, as everyone knows who is familiar with the effects produced by stroking a cat in the dark.

The instrument to be described in this chapter depends upon effects produced in the manner just indicated. By means of it, sparks from a quarter to one-half an inch in length may be easily produced, and by means of a condenser, to be described later, quite brilliant effects may be obtained.

There will be needed, first of all, a large shallow tin dish. The cover to a tin pail will answer nicely. If possible, a cover at least 12 inches in diameter and 1 inch deep should be chosen.

In a large iron dish melt together a mixture composed of 2 parts resin and 1 part gum shellac. There should be enough of the melted mixture to nearly fill the tin cover when the mixture is poured into the cover. This cover, with the melted resin inside, is shown at P in the accompanying figure. If the resin cracks a little on cooling, or if subsequent use should cause cracks to occur, it can easily be re-melted and used again.

Next make a circular wooden disc, shown at C. It should be about ½ inch smaller in diameter than the inside of the tin cover. It is provided with a handle at the center as shown, the length of the handle being about 3 inches. The edges of the disc should be rounded off very smooth, and the whole surface sandpapered.

The entire disc is now to be covered with a smooth layer of tin foil. A quantity of this may easily be secured of any dealer in tobacco, as it is used in packing the latter. Paste enough pieces of the tin foil together so that two circular sheets of foil may be cut out, each one being one inch larger in diameter than the wooden disc. Glue one sheet to each side of the wooden disc (cutting a hole in the center of one for the handle to pass through) and smooth the foil nicely over the edges of the disc, so that the lower and upper layers of foil overlap smoothly, and are glued in place.

The disc thus made must be supported by some form of non-conducting handle. The easiest way to do this is to whittle down the wooden handle already provided, until it fits tightly into the neck of a moderate sized bottle. The latter is forced upon the wooden handle, and in using the apparatus, the disc must always be lifted by means of the glass handle thus formed.

To use the apparatus, proceed as follows: Procure a piece of pure wool flannel, and rub the rosin briskly with the flannel. The rosin should become electrified, and should be capable of attracting small bits of paper or cloth.

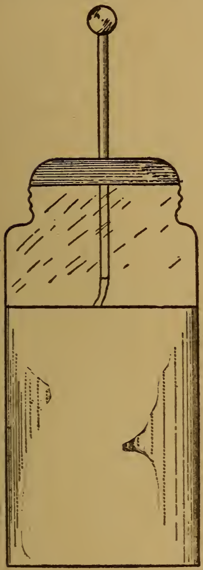
Now place the tin foil disc upon the rosin and touch the tinfoil with the tip of the finger. Then remove the finger, and lift the tin-foil disc by means of the glass handle. Holding it by the glass handle, present the knuckle of the other hand to the tin foil, slowly bringing it nearer and nearer to the disc. When about a quarter of an inch away from the disc, a spark will jump from the disc to the hand, and if the room be dark this spark can be plainly seen.

It is necessary to hold the disc by its glass handle, and the operator must not neglect to touch the disc in the manner described before lifting it from the rosin.

The sparks thus obtained are quite small, especially in warm damp weather. In our next chapter we shall describe a condenser for storing up a large number of charges, producing much more powerful effects.

CHAP. XXV —HOW TO MAKE AN ELECTRIC CONDENSER.

Any piece of apparatus which is capable of storing up electric charges, is generally called a "condenser." The term is hardly a correct one, for the action is not a condensing action in the ordinary sense of the word. What does take place, however, is the accumulation of a multitude of very small charges, until the "condenser" contains a large quantity of electricity. Upon discharging the condenser, this accumulated charge gives up its energy, or nearly all of it, in one sudden rush of charge, so that the effect produced is much more powerful than would otherwise be the case. The term "accumulator" would not be an improper one for such a piece of apparatus were it not for the fact that this term has already been universally applied to another and far different piece of electrical apparatus.



A condenser consists essentially of two conductors of electricity separated by some good insulating substance. Thus two sheets of tinfoil pasted upon opposite sides of a piece of window glass, would make a condenser. Or a sheet of waxed paper might be substituted in place of the glass. The larger the sheets of tinfoil, the more electricity will the condenser contain, other things being equal. Making the glass (or paper) very thin, thus bringing the sheets of tinfoil nearer together will also increase the capacity of the condenser.

The form of condenser described in this article is commonly called a "Leyden Jar." Select a one-pint fruit jar, of as thin glass as possible. Procure two or three sheets of tinfoil, each long enough to go completely around the glass jar, and of a width about equal to two-thirds the height of the jar. Paste one of these on the inside of the jar so as to completely line the latter for two-thirds of its height. The easiest way to do this is to first cover the inner surface of the jar with an even layer of mucilage. Then introduce the tinfoil, rolled upon a stick, into the center of the jar. Then unroll the tinfoil and press it smoothly into place using the stick for the purpose. The bottom of the jar on the inside should also be covered. Then the bottom and sides of the jar should be covered in a similar manner on the outside.

Next a cover should be made for the jar of well-dried wood—pine will answer. It should be carefully sandpapered and shellaced. Through its center insert a brass or copper rod about 1-16 inch in diameter, and 6 inches long. It should project equal distances each side of the cover. The upper end is tipped with a small lead ball soldered in place, and finished smooth. To the inside end of the rod is glued a narrow strip of tinfoil, long enough to reach to the bottom of the jar and make contact with the inner coating.

The jar may be used in connection with the electrophorous described in the preceding chapter. Connect the outer coating to a gas or water pipe. Charge the disc of the electrophorous in the manner described, and bring it near to the knob on the jar. A spark will jump from the disc to the knob. Repeat this operation a number of times, perhaps twenty or more. By this time quite a charge will have accumulated. By connecting the outer coating and the knob by means of a wire, a comparatively large spark will be seen to pass between the wire and the knob. It is necessary in this and similar experiments that the apparatus be warm and perfectly free from moisture and dust.

By making several such jars, and connecting them together, the effects produced are still more powerful. In such case, all the outer coatings are connected together and to earth, while all the inner coatings are connected to the disc of the electrophorous.

CHAPTER XXVI.

HOW TO MAKE A LABORATORY STORAGE BATTERY.

PART ONE.

The most puzzling question which the amateur electrician has to solve relates to the selection of a battery suitable for general use in experimental work. Bichromate cells are powerful while

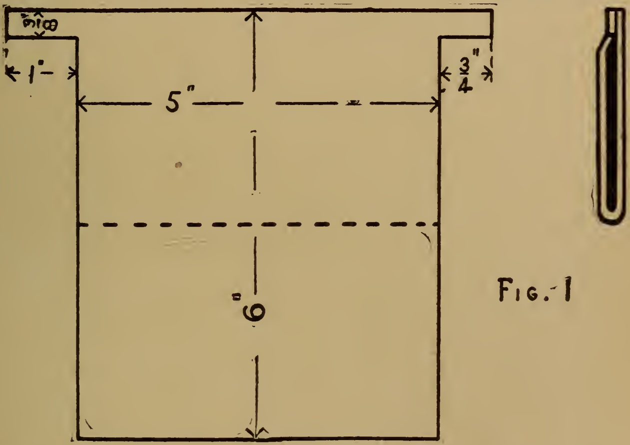


FIG. 1

they last, but they are expensive to maintain and polarize quickly. Other forms of batteries may be purchased, but they are expensive. The ordinary gravity or Daniell cell gives a very constant electromotive force, but on account of its high internal resistance it is not capable of yielding strong currents. Secondary or storage cells are capable of delivering a very strong current and have a very constant electromotive force, but it is necessary to charge them from some other source of electricity. The ideal arrangement would appear to be the use of storage cells in conjunction with gravity cells, the latter being used to charge the former. The present chapter deals with the construction and operation of a small storage cell for the use of amateurs.

The cell will consist of three elements, namely, a series of lead plates, a solution of sulphuric acid into which the plates dip, and a jar for holding this solution.

Make a tight wooden box, which is 5⅛ inches long, 4 inches wide and 3 inches deep, measurements being taken on the inside of the box. The material for this box should be ⅝ inch thick, and the box should be put together in the best possible manner so as to be water-tight. It may be advisable to have the box made by a carpenter in order that it may be more efficiently constructed. It should be put together with screws and glue. Then immerse the box in a dish of hot paraffine wax, or beeswax, leaving it there for at least one hour. If only a little wax is available, a shallow pan may be used and one side of the box immersed at a time. But extreme care should be taken to see that the hot wax penetrates to every fibre of the wood and fills up all corners and cracks. This box is to contain the acid, hence the necessity for the careful boiling in the wax.

Next we will make the lead plates for the cell. At a hardware store procure enough sheet lead to make nine plates of the size and shape shown in Fig. 1. After the plates are cut out each one is to be bent double at the point indicated by the dotted line. Before doing this, however, bore each plate as full of ⅛-inch holes as you can without weakening the plate. The plate is then doubled in the middle and has the shape shown at the right in Fig. 1, there being a space of ⅛ inch between the two sides of the bent plate. It may be well to avoid boring holes near the point where the plate is to be bent, to avoid weakening at that point.

Having prepared the nine plates in the manner above described, procure at a paint shop about two pounds of red lead and the same weight of litharge. These are materials used commonly by painters. In a glass dish mix a stiff paste, made by adding sulphuric acid to water in the proportion of 1 part of acid to 20 parts of water, and then adding red lead so as to make a very stiff mixture. Select four of the lead plates and fill the space in the interior of each full of this paste. It will probably be necessary to solder the plate together at the top where the two edges meet.

In the remaining five plates place a paste made up from litharge and sulphuric acid in the manner just described. Then set the plates aside to dry.

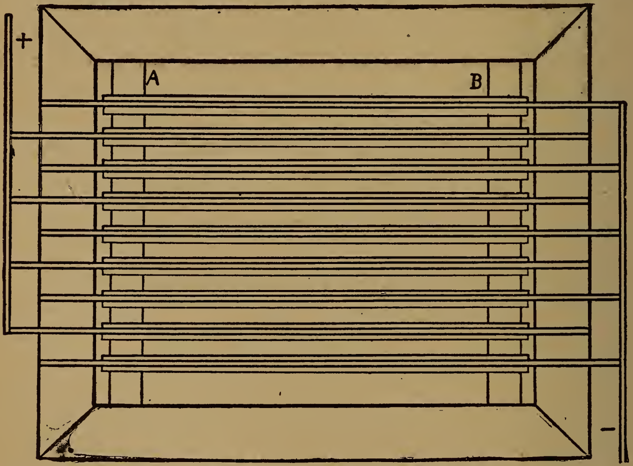
After the plates are dry they are to be assembled. Make sixteen wooden strips 3 inches long, 1/8 inch thick and 3/8 inch wide. Boil them thoroughly in melted paraffine wax; also make four pieces 3/8 inch wide, 7-16 inch thick and 3 inches long, paraffined as just described. These are for separating the plates and for holding them in place.

CHAPTER XXVII.

HOW TO MAKE A LABORATORY STORAGE BATTERY.

PART TWO.

In the preceding chapter directions were given for constructing the separate parts of a storage cell. Beginning with a negative plate (one which contains litharge) place it in the box, with the longer lug projecting from the left hand side. Next insert a positive plate (one which contains red lead) with its longer lug projecting on the right hand side. The



Plan View of Storage Cell.

two plates should be separated by two of the small strips of paraffined wood, these strips being inserted vertically at each end. Next insert a negative plate, and then another positive, and so on, the plates being alternately positive and negative. All the negative plates should have their longer lugs on the left, and all the positive plates should have the longer lug on the right. Since there are five negative plates and only four positives, the outside plates will be negative. The plates should not touch each other at any point.

Next insert the heavier strips of paraffined wood on each side of the plates between the plates and the box, as shown at A and B. These strips should wedge the whole cell firmly together,

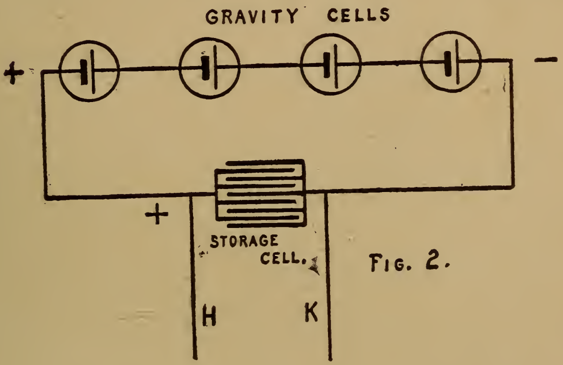


FIG. 2.

so as to prevent the wooden strips from floating when the cell is filled with acid. Yet care must be exercised not to spring the sides of the box, causing it to leak.

Solder a strip of lead along one end, connecting all the negative plates together. Do the same at the other end with the positive plates.

When ready for charging, the cell is to be filled with a solution made by slowly pouring sulphuric acid into water, the proportion being one part of the acid to twelve parts of water.

In order to charge the cell, four gravity cells will be required. The method of connection is shown in Fig. 2. The gravity cells are joined in series, and the positive pole of the storage cell is connected to the copper terminal of the group of gravity cells, and the negative pole to the zinc terminal. There must be no mistake about this, for a reversal of current through the storage cell will spoil the latter.

The wires designated by the letters H and K are supposed to lead to a motor or any other device for making use of the electric current.

The operation of the apparatus is as follows: When no current is being taken through the wires H and K, current flows from the positive terminal of the group of gravity batteries into the storage cell. In its passage through the acid in the latter, it decomposes the acid, and the lead plates are attacked and changed. The red lead in the positive plate is converted into a brown mass, while the litharge upon the negative plate is converted into metallic lead. Of course, it takes time to do this, particularly when the cell is first set up. At first the current should be allowed to flow uninterruptedly for one week without any current being taken from the cell.

Suppose, now, it is desired to use the cell, after it is charged. Connection is made at the wires H and K, and without disconnecting the gravity batteries a strong current can be taken from the cells. Most of the current will be furnished by the storage cell, but a little of it will come from the gravity batteries, the latter being thus made to do continual duty.

It is always necessary to remember that no more energy can be taken out of a storage cell than is put in. For example, if ¼ ampere flows into the storage cell for 20 hours, the cell would have received a charge of 5 ampere hours. Now, if the cell were perfect, we could take out from it just 5 ampere-hours of work. That is, we would take out 5 amperes for one hour, or 2 amperes for 2½ hours, or one ampere for 5 hours, and so on. But no cell is perfect, and we can never take out as much as we put in. As a matter of fact, the present cell, if pushed to its limit, ought to give a capacity of 8 ampere-hours when discharging at a rate of 1¼ amperes, or 6 ampere-hours when discharging at the rate of 1½ amperes.

CHAPTER XXVIII.

HOW TO MAKE AN ELECTRIC BELL.

PART ONE.

An electric bell is not a hard thing to construct, and it is often of great service about the laboratory of an amateur. Certainly the time and money spent will be repaid by the more

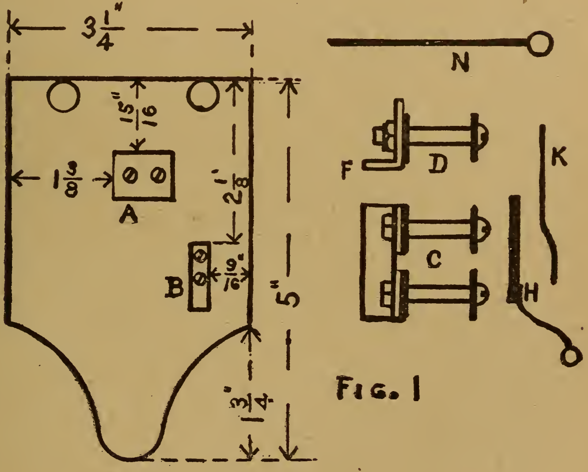


Fig. 1

intimate knowledge of this useful piece of apparatus, which will be gained through constructing it.

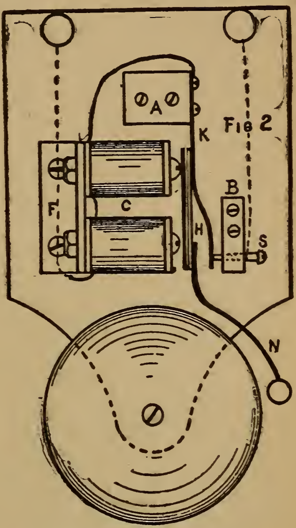
Take a piece of pine board 3¼ inches wide, 5 inches long and ½ inch thick. Cut away one end so that it has the shape shown in Fig. 1. The necessary dimensions are there given. Upon this board mount two wooden blocks shown at A and B. The former of these blocks is 7/8 inch long, 5/8 inch wide and 1/2 inch thick. The latter is 7/8 inch long, 1/4 inch wide and 1/2 inch thick. Fasten them to the board by screws in the positions indicated by the dimension lines. At the top place two small binding posts, as close to the edge as possible. Sandpaper the whole very smooth, and give it a coat of cherry or other suitable stain.

Next take a piece of ordinary sheet iron, such as is used for stove pipes, and cut out four pieces, 1 1/2 inches long and 1 1/4 inches wide. Clamp these four pieces in a vise with their edges even, and with the jaws of the vise lengthwise along the strips. Then with a hammer bend the strips over at right angles, as shown at F, Fig. 1. The portion of the strips held in the vise should be 5/8 inch wide. With a pair of heavy shears cut off their edges even where they have been bent. Bore, or punch two holes in each of the flat faces of these right angled strips, the holes being 7/8 inch apart and on the center line of the faces of the strip.

Procure at a hardware store two round head iron machine screws, 1 1/4 inches long and about 3-16 inch in diameter. The size known as No. 14 is about this size. Each should be fitted with a nut.

Make four very heavy cardboard washers about 5/8 inch in diameter with a hole in the center just big enough to slip upon the screws. Put two washers upon each screw, one being close against the head, the other at a distance of 1 inch from the first. Put the screw end of the screws through two of the holes in the right angled strips, as shown at C and D, Fig. 1. Now wind the space between the pieces of cardboard with three or four layers of heavy paper, cut into strips just wide enough to fill the space between the pasteboard washers, glueing it in place. The strips which were bent at right angles thus serve as a support for the screws when the strip is screwed in place upon the backboard (Fig. 2). Also, because they are made of iron, they serve to connect the two screws magnetically.

Upon each screw, in the space just described, wind about 50 feet of No. 26 double cotton covered magnet wire. This ought to fill the space quite full. Connect the two coils together in the ordinary manner, so that a current going around the coils will trace out an imaginary letter S, going around one coil in a direction opposite to that in the other coil.



At H, Figs. 1 and 2, is shown an armature built up by soldering together three pieces of tinned iron cut from an old can. These strips are 1⅜ inches long and ⅜ inch wide. To one end is soldered a wire 2½ inches long, provided with a small lead ball at its outer end.

To the other end of the tinned iron strips is soldered a strip of very thin hammered brass, shown at K. This strip is 2⅝ inches long. It projects above the tinned strips by ⅞ of an inch, and its lower end is cut narrow and bent out as shown at H.

If difficulty is experienced in attaching this to the strips, a small copper rivet driven through both, may help matters. At any rate its lower end should be bent out as shown, so as to rest against the screw S inserted through the block of wood B.

In our next chapter we shall see how to complete the bell and to wire it up.

CHAPTER XXIX.

HOW TO MAKE AN ELECTRIC BELL.

PART TWO.

Having followed the directions given in the last chapter, the next thing is to mount the different parts of the bell in their proper places. For a bell, the amateur may have to dismantle an old alarm clock, the gongs upon these clocks answering admirably for the purpose. Sleigh-bells are sometimes made of the proper shape, or a suitable bell may be purchased at small cost. To mount the gong, fasten a stout wooden post in the

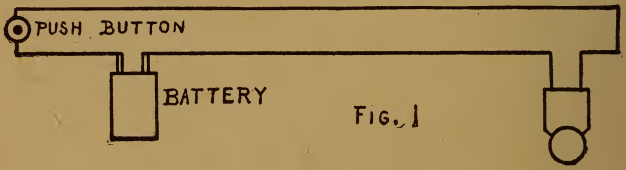


FIG. 1

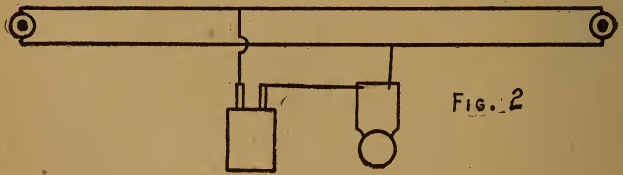


FIG. 2

center of the rounded end of the base board, the post being ⅝ inch in diameter and fastened to the board by a screw passing through the board and into the post. The post should be of such length that when the bell is placed with its center upon the center of the post, the edge of the gong is ¼ inch from the base board. Fasten the gong in place by means of a screw passing through the bell and into the post.

Referring to the diagram given in the last chapter, the spring K is fastened to the block A by two screws. The strip F is screwed to the board at such a distance that the ends of the bolts lie very close to the strip H when the spring is against the screw S. Under these conditions, with the spring K pulling the armature away from the magnets with considerable force, the wire carrying the lead ball should be bent so that the ball is about ¼ inch from the bell. One end of the coil of wire upon the spools is connected to a binding post at the top. The other end of the coil is connected to the spring K. The screw S is connected to the remaining binding post by a wire twisted firmly about it and soldered in place.

The different parts of the bell are now in place, and the bell is ready to work, except for adjusting. See that K presses firmly against S so as to make a firm contact. The armature H should then be about 1-16 inch from the lower limb of the magnet, and 1-32 inch from the upper end. Adjust the position of F until this is attained.

If a current should enter the bell at the upper left hand binding post, it would traverse first the coils surrounding the iron cores, thence to the spring K, to the screw S and back to the right hand post.

The iron cores become magnetized, and draw the armature H with its attached spring K, to the left. This breaks the circuit at S (if the bell is properly adjusted) and the iron cores lose their attraction for the armature, allowing the spring K to fly back against the screw S. This completes the circuit again, causing the armature to be attracted again. This is repeated very rapidly, the ball striking against the bell at each movement.

It is a mistake to make the spring K too weak, as this causes the hammer to move slowly and with little life. At each motion of the armature toward the magnets, the armature should barely touch the iron cores, before the ball strikes the bell.

This gives a clear tone to the bell. Of course a brass or iron ball is better than a lead ball upon the wire N, but some amateurs cannot easily procure a brass ball, while any one can easily make a lead ball.

When it comes to wiring up the bell, the diagram on page 98 may be of help. The push button had better be bought at an electrical supply house. For a short line one cell of battery should be sufficient. Fig. 1 shows how to wire the circuit using one push button. Fig. 2 shows how to wire for two push buttons. A home-made battery may be made from a quart fruit can, a zinc rod and four carbon rods. The latter are tied together and a wire is twisted around them at the top forming one plate of the battery. The zinc rod forms the other plate. The two plates dip into a strong solution of sal-ammoniac contained in the jar. Such a battery is not serviceable, however, except for short experiments.

After the bell is in working order, it is well to make a small box to serve as a cover for the working parts of the instrument. This, of course, must slip on over all parts except the bell, a slot being cut in the lower side to allow the wire N to pass through. This box may be made of pine, sandpapered smooth and stained with cherry or mahogany stain.

CHAPTER XXX.

HOW TO MAKE A RHEOSTAT.

PART ONE.

Electrical conductors, because of an inherent property called resistance, have the power of limiting the value of an electric

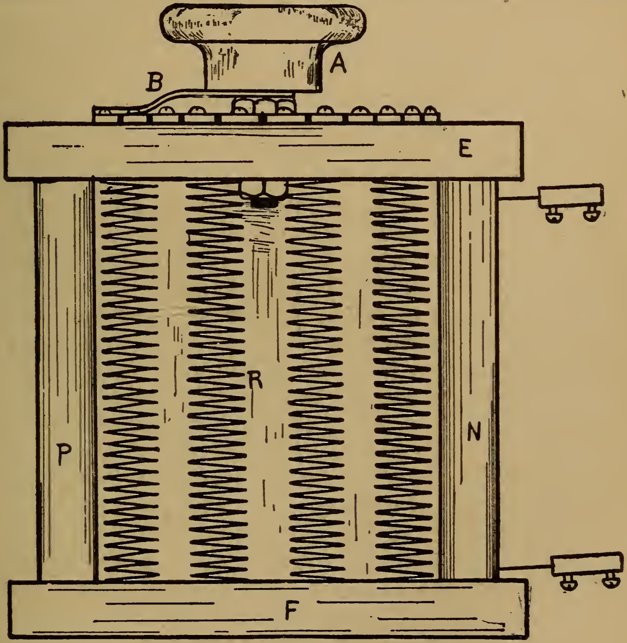


FIG. 1.

current. The greater the resistance in an electric circuit, the less the current, other things being equal. For this reason, resistances are made use of to control the strength of electric currents.

When a resistance is so arranged that its value can be easily and quickly altered, it is called a rheostat.

A very convenient method of arranging such a rheostat is shown in the cut on page 101. It consists of three essential parts—a wooden frame, consisting of two end pieces E and F, supported by wooden pillars N and P, 32 coils of iron wire shown at R, which furnish the necessary resistance, and a dial at the top to which these resistances are connected, so that any desired number of the 32 coils may be connected into circuit.

To make the wooden frame-work, take two pieces of whitewood or pine, 9 inches square, and ⅞ inch thick. Also make four wooden rods 1 inch in diameter and 9 inches long. Near the corner of each of the square pieces bore a hole, whose center is one inch from each edge. The hole is ¾ inch in diameter. Cut down each end of the wooden rods to a diameter of ¾ inch for a distance of ⅞ inch from the end, thus forming a shoulder so that the square blocks of wood may be tightly slipped on to the rods, forming a framework which will support the whole apparatus. Make all joints to fit tightly, and sandpaper the whole off smoothly, and fasten the whole together with screws as shown.

From a piece of sheet copper 1-16 inch thick, cut out a ring whose outside diameter is 7¾ inches, and whose inside diameter is 4¾ inches. The cutting can be done with a pair of tinsmith's shears. Draw lines upon this ring with the sharp point of a knife, dividing it into sixteen equal parts. With a small drill bore two holes in each of the sections, these holes being ¼ inch from the outer edge of the ring. With a hack saw, or the edge of a thin file, cut the ring into sixteen sections along the lines previously drawn. During this process, the ring should be held firmly to an old piece of board, by a ⅝ inch screw passing through each of the thirty-two holes in the ring. The piece of board may be thrown away after it has been used.

On the top of the wooden frame first constructed, draw a circle 7¾ inches in diameter, its center being at the center of the top. Divide it by pencil lines into sixteen parts, and with this circle as a guide, transfer the sixteen copper sections from the old piece of board to the top of the rheostat, arranging them symmetrically around the center. Be very sure that they do not touch each other, and that they lie smoothly and firmly in place. It may be necessary to file their edges a little in order to make them fit into each other well without touching.

In the center of the top bore a ⅜ inch hole. Procure a ⅜ inch stove bolt, 3½ inches long, with a flat head. It should have two nuts, so that it may be clamped in position in the hole just bored, one nut being on the upper surface of the top of the rheostat, the other on the lower surface.

Make a wooden knob shown at A, 3 inches in diameter, with a hole through its center which will allow it to just turn freely upon the stove-bolt, the hole being countersunk at the top to receive the head of the bolt. To the under side of this knob fasten a strip of spring brass shown at B, which is ¾ inch wide, 1-16 inch thick, and about 4½ inches long. It has a hole bored through one end at a distance of ⅜ inch from that end, the hole being ⅜ inch in diameter. The bolt is then slipped through the knob, the spring is slipped over the bolt, and then the spring is securely fastened to the knob by three flat head brass screws.

The bolt with the knob in place is then secured to the top of the rheostat, at such a height that the spring will bear firmly upon the copper sectors already in place. The knob with its attached spring should then turn freely upon the bolt, so that the spring may touch any one of the copper sectors.

There should be inserted between the spring and the upper nut on the bolt, two thin washers made of spring brass. These washers should be bent slightly so as to exact a pressure between the spring and the nut, keeping them always in contact. These washers are very important, and should not be omitted.

CHAPTER XXXI.

HOW TO MAKE A RHEOSTAT.

PART TWO.

Having completed the wooden framework of the rheostat, we will next turn our attention to the coils of wire which are to make up the necessary resistance. Procure about 350 feet of No. 18 annealed iron wire. Take an iron rod ⅜ inch in diameter, and wind tightly and evenly upon it a coil of the iron wire, winding on enough to make a coil 5 inches long.

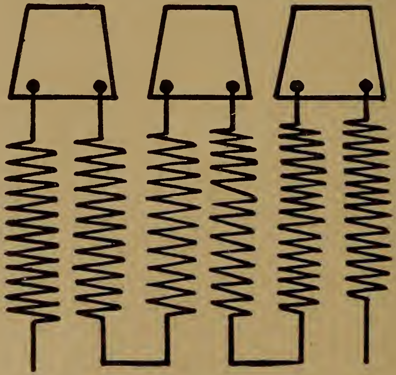


FIG. 2.

Cut off the wire, leaving 3 inches projecting from each end. Remove the coil from the iron rod, and there will be found a spiral of wire, about ½ inch in diameter and 5 inches long. Make 32 such coils. The wire should be very soft, with a very little tendency to spring after being bent. If necessary, the coil may be heated by means of a spirit lamp while in position upon the iron rod.

Now fasten the end of one coil to the inside of the bottom of the wooden framework, at a distance of 4 inches from the center, by means of a double pointed tack driven tightly into the wood. This tack should grip the wire close to the coil, so that the loose end of the wire may project from the rheostat, to make one terminal of the apparatus. Pass the other end of the coil upward through a small hole close to one of the copper sectors, and clamp the loose end of the wire under the

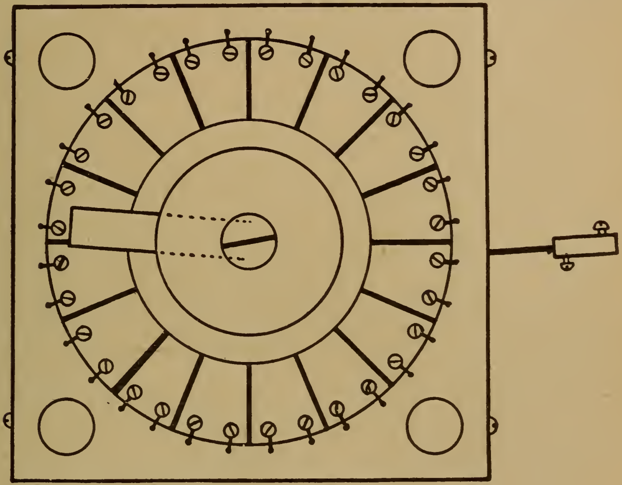


FIG. 3.

screw of one section. The coil should be drawn tightly against the upper board, as this draws the spirals of the coil apart and prevents their touching each other.

At a distance of ⅝ inch from the first hole just bored, bore another, and through this pass the upper end of another coil of wire, securing it to the same sector of copper as the first coil. Fasten the lower end of this coil to the bottom board, in the same way as the first was fastened. However, when the third coil is put in place, the lower end of the second coil is firmly connected to the lower end of the third, by means of a double pointed tack, drawn firmly over the two wires. The upper end of the third coil is connected to the second copper sector, and the upper end of the spiral number four is connected to the same sector.

Proceed in this manner with the whole 32 coils, arranging them in a circle. When the lower end of coil 32 is fastened to the board, cut it off short, without connecting it to any other coil. A diagram showing the principle of the method of connection is given in Fig. 2. It will be seen that the upper point of junction of two coils is connected to a copper sector, while the lower connection of two coils is made by means of a double pointed tack. The coils should not touch each other, except at the ends.

The beginning of the first coil, which was left long, forms one terminal of the rheostat. The handle forms the other terminal. Accordingly, an insulated wire about 8 inches long is bared at the ends, and one end is bent around the bolt at the center, and firmly clamped between the lower nut and the upper board. A copper washer should be inserted between the wire and the board. The other end of this wire is left projecting from the rheostat, and is provided with a connector, as shown in the preceding chapter. This wire should be secured by a double pointed tack to the framework, but must not touch the coils on any account.

By turning the wooden knob more or less coils may be placed in circuit, thus varying the resistance between the two terminals.

Of course, wood is not a very safe material to use in such a piece of apparatus, because of the liability of the wires to overheat. But for an amateur who deals with small currents, the apparatus above described is very useful.

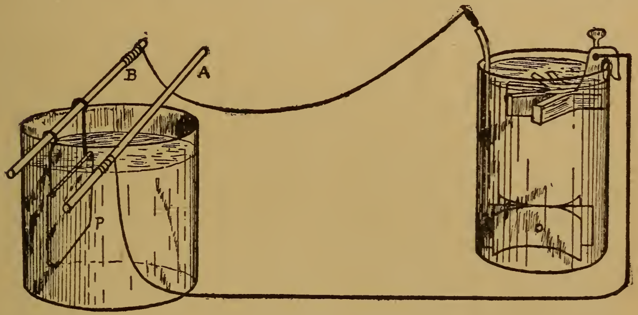
CHAPTER XXXII.

HOW TO DO ELECTRO-PLATING AT HOME.

PART ONE.

Electro-plating is the art of covering metallic bodies with a thin coating of some other metal by the aid of the electric current.

The process may be explained as follows: Imagine two metal plates dipping into a solution containing some metallic salt. If a current be sent through the solution, passing from one plate



to the other, the solution will be broken up by the action of the current, and a portion of the metal formerly held in solution will be deposited upon the plate where the current leaves the liquid. Thus if a copper and lead plate dip into a solution of copper sulphate, and an electric current be sent through the solution from the copper to the lead plate, copper will be taken through the solution, and deposited upon the lead plate.

The process outlined above appears simple, but in practice several points must be looked after. First, the article to be plated must, for the sake of appearance, be rendered smooth and free from scratches, for every line on its surface will be faithfully brought out in the deposit. Next, the surface of the article to be plated must be clean. This is necessary, because otherwise the deposit will scale off. By clean, is meant chemically clean,—that is there must be no trace of grease or foreign substance upon its surface. Even the slight film which would result from touching an article with the fingers will ruin the deposit. Next, it is necessary to secure an even deposit free from streaks and blotches. And finally, the finished article must be polished, as deposits as they come from the plating bath are rarely bright in appearance, but are dull. We will now take up these processes in detail as applied to copper, silver and nickel plating. The amateur is strongly advised to begin with copper plating, as the cost is comparatively slight, and copper solutions are much easier to work.

In the discussion which follows, it is assumed that the articles to be plated are fairly clean and smooth to start with. If not, the ordinary use of file, emery paper, and the finest crocus paper, should make them so. It will also be assumed that the reader has only his hands to work with, although a rotating polisher driven by foot power is almost a necessity for extensive work.

Assuming that the article to be plated has been treated as hinted above, until its surface is smooth, the next thing is to prepare a bath, which will render its surface chemically clean. If the article is of copper, brass, steel, or iron, make up a solution by mixing together two quarts of water, ½ pint (8 ounces) of sulphuric acid, and ½ ounce each of nitric and hydrochloric acids. Be very careful in handling these acids as they will destroy everything they touch, when in the concentrated state. Be sure to pour the acids into the water, when mixing, and not the reverse. Put this solution into two glass fruit jars, and label them "Pickling Solution."

For the sake of definiteness, let us assume that the article to be plated is of lead or pewter, and that it is to be copper plated. Prepare in a large open glass jar, a solution of copper sulphate (blue vitriol), in the proportion of one pound of the sulphate to 2½ quarts of water, with 4 ounces of sulphuric acid added after the crystals are dissolved. Procure a sheet of clean copper about four inches square, and punch two holes at two adjacent corners. The holes are to receive two small copper wires by which the plate is to be hung in the solution. Across the top of the jar containing the solution, lay a brass or copper rod, and suspend the plate from it by two copper wires, so that the plate hangs immersed in the solution, and close to one side of the jar.

For battery power to do the plating, perhaps the amateur can do no better than to use two freshly prepared gravity batteries, connected in series. Connect the copper pole of this battery, to the rod which supports the copper plate in the solution. Lay another rod across the top of the jar, and connect the zinc pole of the battery to this rod. The rod serves as support for the articles to be plated.

Having followed these directions we are ready for plating. The connections are shown in the accompanying figure, where for the sake of clearness, only one cell of gravity battery is shown. Attach a copper wire to the article to be plated, by passing it through any hole that may be in the article. If there are no holes, try to fasten the wire to some unimportant part, such as the bottom, for where the wire touches the article there will be no deposit of copper. Then, holding the article by the wire, immerse it in one jar of the pickling solution. It should be left there for two or three minutes, and then transferred to the second jar. After remaining there for the same length of time, lift it out by the wire, taking care not to touch it with the fingers. Rinse it in a jar of fresh water, and immediately transfer it to the plating bath, hanging it from the rod connected with the zinc pole of the battery.

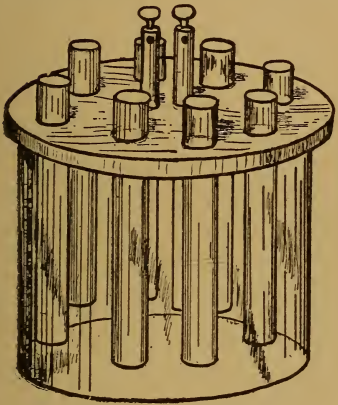
This is indicated by A in the figure on page 107. As soon as the article is hung from the wire, current begins to pass, and copper will be deposited upon the article. The length of time required to secure a good deposit will vary with the size of the article, condition of batteries, etc., but one hour ought to give deposit in most cases, under the conditions indicated. As many articles can be plated at the same time, as can be hung from the rod A. They should be turned around now and then, so as to present different sides toward the plate P, as the side nearer the plate will receive the heavier deposit. The greater the distance between the plate and the articles, the less will be the difference between the deposits upon the two sides. In our next chapter, we will see how to treat the finished article. and how to do nickel and silver plating.

CHAPTER XXXIII.

HOW TO DO ELECTRO-PLATING AT HOME.

PART TWO.

If the reader has attempted to do copper plating according to the directions given in the last chapter, he has at least gained an idea as to the methods employed to obtain a good deposit of any metal. The solution described will not work satisfactorily upon articles made of zinc or iron. For these metals, a solution of cyanide of copper is necessary, but the writer has refrained from describing this solution because it is composed of one of the most deadly poisons known. Those who desire to learn of this solution are referred to any of the numerous good works on the subject.



Home Made Battery.

Nickel plating will have more attraction for most readers, and the method of securing good results with this metal will now be described. The salt of nickel, with which the best results can be secured, is the double sulphate of nickel and ammonium. This salt is commonly used by nickel platers, and there should be no difficulty in procuring it. Dealers in plater's supplies also supply plates of nickel, one of which should be secured about 3 inches square and ¼ inch thick.

The solution is easily made up by dissolving ¾ pound of the double sulphate to one gallon of water. The water should be quite hot in making up the solution, but should not be used until cold. A tablespoonful of ammonia should be added before starting to work the solution, and every now and then, while working, a small quantity of ammonia, say ½ teaspoonful, should be added.

The articles to be plated should be cleaned and polished as before described and dipped in a cleansing solution just before immersion in the plating bath. If of copper, German silver, brass or iron, the article should be dipped in the pickling solution described in the last chapter. If made of tin, lead or pewter, a cleansing solution made by dissolving ¼ pound of potash (bought at any grocer's) in one quart of water. This solution should not be allowed to touch the fingers or the clothing.

For battery power, we need something more powerful than the two Gravity cells described in the last chapter. Four Gravity cells will give electromotive force enough, but the current will be so small that the deposits will be extremely slow. Two or three Bunsen or Bichromate batteries should preferably be used, joined in series. Nickel plating requires much more power than copper plating, and rather large cells should be used.

Let us sum up, then, the process of nickel plating: Smooth and polish the articles with fine emery paper or crocus paper for a finishing touch, hang them by a small copper wire in one of the two cleansing solutions already described, rinse them in clear water, without allowing them to touch the fingers or other bodies and hang them from the proper terminal of the plating bath, in the solution of nickel and ammonium which has been described.

The piece of nickel three inches square, already mentioned, is hung from the other pole of the plating bath, in place of the copper plate used for copper plating. It should be hung up by one corner, by a copper wire, but this wire must not dip into the solution. The article to be plated should be kept in motion, and if there are projecting parts upon it, these should not be too near the nickel plate. Failure to observe these precautions may result in a "burned" deposit.

Whatever battery is used, care must be taken to connect the article to be plated to the zinc pole of the battery, the square piece of nickel being hung from the rod connecting with the other pole.

The author recently constructed a cell which appeared to give excellent results for this line of work. Procure about a dozen electric light carbons about eight inches long, and three zinc rods. Procure a glass jar about six inches deep and six inches in diameter. Having removed all copper from the carbons, arrange them in a circle which will just fit the jar, thrusting them through a piece of pine board ½ inch thick. In the center of the board mount the three zinc rods. A wire twisted around the carbon rods forms one pole of the battery. Another wire connecting with the three zinc rods forms the other pole. For a solution dissolve ½ pound of potash in two quarts of water.

Two of these cells in series ought to give excellent results.

In our next paper we shall study the matter of nickel plating further, and also take up silver plating.

CHAPTER XXXIV.

HOW TO DO ELECTRO-PLATING AT HOME.

PART THREE.

When a body which has been nickel plated comes from the plating bath, it does not have the brilliant appearance so common to nickel plated articles. This brilliant appearance is only secured by careful polishing. Sometimes, too, the deposit is marred with blotches and "burned" spots. This is caused by

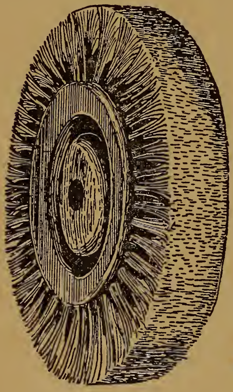


FIG. 1.

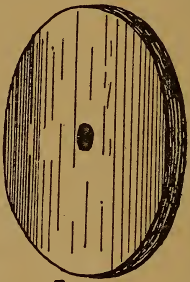


FIG. 2.

FIG. 3

too strong a current, or by leaving the articles immersed too long, or perhaps by allowing one portion of the article to remain too near the immersed plate of nickel.

The process of polishing is quite easy, if the plater be provided with a polishing lathe, or with any suitably mounted polishing wheel, driven by foot power or otherwise. The polishing brush shown in Fig. 1 is commonly made of bristles, mounted in a suitable hub, so as to revolve at a high rate of speed. The work to be polished is held against this revolving brush. Often, too, a polisher, or "buffer," is made by clamping upon a spindle a large number of circular discs cut from muslin or canvas, or thin leather. When revolved at a high rate of speed, the discs which ordinarily are soft and yielding, stand out stiffly because of centrifugal force, making a stiff wheel against which the work is held.

To aid in the polishing various compounds may be applied to the surface of the revolving buffer. These are usually called by the general name of "rouge." They may be bought in sticks at dealers in plating supplies. There are hard and soft rouges, for coarse and for delicate work, as well as dry rouges and greasy rouges.

But the amateur without special tools will have to polish the articles as best he can by hand, unless he can improvise a lathe. A great deal can be done with a piece of soft canton flannel upon which rouge or whiting has been rubbed. Both these substances are common in the market under the name of "silver polishes." Begin with a coarse rouge, and after the roughest part of the work is done, use a finer rouge. Then, using a clean piece of flannel, rub to a final polish with whiting. An old soft tooth brush is excellent for getting into corners, or a piece of flannel mounted upon a smooth stick.

Silver plating can be done very nicely without the use of a battery. A simple immersion of the article to be plated in the proper bath will give an excellent deposit. A solution for this purpose will now be described. The solution is especially applicable to such articles as watch chains, teaspoons, brooches and other small articles of jewelry.

Procure four ounces of chloride of silver, twelve ounces of common washing soda, and five ounces of common salt. Mix these together with warm water so as to form a paste about as thick as heavy cream. The mixture is applied to the surface of the article to be plated by rubbing it upon the article by means of a piece of cork, or a piece of flannel tied upon a stick. All parts should be uniformly silvered. Of course the article must be cleaned and washed as explained in the first paper, and the paste is applied while the article is wet. Soft tooth brushes are useful in this work also. The work when done should be dried by rolling in sawdust and wiped dry.

In replating old articles which have already been plated, care must be taken in the preliminary polishing and cleaning, to see that all rough edges are smoothed down. Ordinary hand scrub brushes, Fig. 3, are not at all bad for rough cleaning, and a bristle brush with crocus powder, or dry rouge, will do for the final polish.

For extensive work, a small dynamo built for electroplating is necessary. For copper plating an electro motive force of two or three volts is sufficient, with moderate current. Nickel plating requires from four to six volts, and a much stronger current.

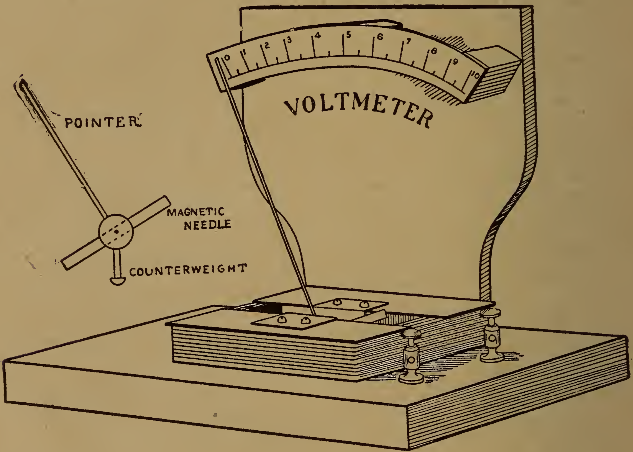
CHAPTER XXXV.

THE CONSTRUCTION AND USE OF A SIMPLE VOLTMETER.

In the preceding chapter three electrical units were explained. One of these, the volt, is the standard by which we measure electrical pressures. An instrument designed to measure electromotive force (electrical pressure) is called a voltmeter. There are several ways of constructing such an instrument, but nearly all depend for their action upon the mutual effects produced between a magnetic needle and a coil of insulated wire carrying a current. The instrument now to be studied is a simple one, yet it is one which may be easily constructed by an amateur with profit to himself in the knowledge thereby gained.

A base board should first be secured 5 inches long, 2½ inches wide and ½ inch thick. In its center cut a slot ⅜ inches wide and 1½ inches long, with the slot running lengthwise of the board. At each side of the slot glue two blocks, each 1½ inches long, ½ inch high and ¼ inch in thickness, the blocks being even with the sides of the slot. Around these, as a support, is to be wound in a horizontal coil 225 ft. of No. 32 double silk-covered magnet wire. The length and size of this wire are both very important.

A magnetic needle is next to be made, whose position is to be inside of the coil. The best material of which to make this needle is a piece of watch spring, such as may be obtained for the asking at an obliging watch repairer's shop. Select a piece 1⅜ inches long and ⅛ inch wide. Straighten it by bending it with the fingers. Heat the center of it in a small alcohol flame, taking care to keep the ends cool by holding wet cloths upon them. Then bore a small hole through the center big enough to allow an ordinary sewing needle to pass through. This sewing needle should be ½ inch long and with very sharp points at each end. It may be made by breaking off an ordinary needle until it is of the proper length, and then grinding the ends to a sharp point. Insert the needle through the hole in the piece of watch spring, and fasten the latter in the center of the needle by two small pieces of wood, circular in shape, which slip tightly on to the needle, and clamp the piece of watch spring tightly. A little glue will help make everything firm. Then magnetize the piece of watch spring by rubbing it with a strong magnet. If the spring has not been softened at the ends it will keep its magnetism to a large degree.



To the magnetic needle thus mounted a pointer 3 inches long is to be attached at right angles to the needle. The best material of which to make this pointer is a firm, hard straw taken from an ordinary broom. Straighten it by rubbing between the fingers, bore a very small hole in one of the wooden clamps which hold the piece of watch spring to the piece of needle, insert the pointer in this hole, and fasten with a bit of glue. The pointer should be straight, and should be at right angles to the piece of watch spring. Take a small brass screw and screw it into one of the pieces of wood which hold the watch spring in place, in such a position that the pointer, magnetic needle and screw (counterweight) will have the relation shown in the figure. The purpose of this screw is to bring the pivoted needle and its pointer back to a certain position whenever the pointer is moved.

To mount the needle take two pieces of thin sheet brass, each 1 inch long and ½ inch wide. In the middle of each and ¼ inch from each end make a deep dent by means of a pointed nail and a hammer, but be careful not to punch a hole completely through the metal. Bend each strip over at right angles in the middle. These straps can now be slipped down in the slot in the middle of the coil first made, and by a little patience the piece of sharp pointed sewing needle, with its pointer, magnetic needle and counterweight will just slip down into the dents punched in the sheet iron and swing freely there. It may be necessary to do a little filing and bending, but the needle and its supports can finally be adjusted so that it swings very freely and easily in its place. The counterweight (screw) should be heavy enough and in the right position to bring the pointer into the position shown in the figure.

At the back of the board fasten an upright piece of thin wood, of the shape shown, and 4 inches wide at the top. To this, at the proper height, attach a piece of thick cardboard, circular in shape. It should be supported by blocks in such a position that the pointer will move close to it, but not touching it.

Be sure that the parts of the moving system have the relation shown in the figure, and that the needle swings very freely.

Our instrument is now complete, except for the matter of marking the scale. We shall have to leave this until a later chapter, however, when, in addition to completing our instrument, we shall learn something regarding its use.

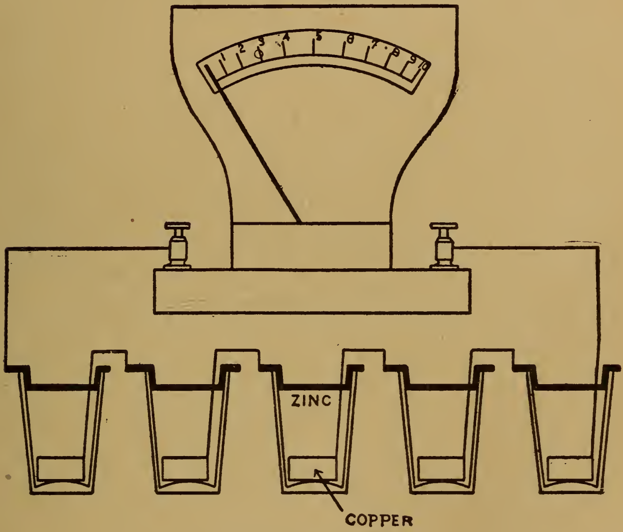
CHAPTER XXXVI.

ADJUSTMENT AND USE OF A SIMPLE VOLMETER.

The voltmeter whose construction was explained in the previous chapter is not ready for use until it has been calibrated. By calibration we mean the fixing of points upon the scale, so that we can tell instantly the value of the voltage which causes a particular deflection. To do this there will be required a battery of special form. The cells composing this battery can be made in a very temporary and easy manner, and will answer the purpose perfectly. They are made as follows:

Procure five ordinary tumblers and in the bottom of each place a strip of copper one inch wide and three inches long with a copper wire attached to it, projecting from the cell. In the top of each tumbler hang a strip of zinc a little longer than the copper strip, supporting it in the manner indicated in the figure below. Connections should be made to the strip, outside the tumbler, by a piece of wire firmly twisted around it. Place in the bottom of each tumbler a handful of blue vitriol (copper sulphate) and fill them with water so as to cover the zinc strip. Connect the zinc and copper terminals of each cell by a short piece of wire, and let them remain this way for twelve hours, at the end of which time the connecting wires should be removed. Then join the cells in series—that is, connect the zinc of the first cell with the copper of the second and so on through the series. Be sure that the wire leading from each copper strip does not touch the zinc in the same cell. The electromotive forces of the cells are then added together. Connect the terminals of the battery, that is, the copper of the first cell and the zinc of the fifth cell, if they are joined as above described, to the terminals of the voltmeter. The needle of the latter should move part way across the scale. If it does not reverse the connections of the wires leading to the instrument.

Now adjust the counterweight by making it heavier or lighter, as the case may require, until the pointer stands exactly at the middle of the scale. Make a line here and mark it 5 volts. Disconnect one cell, leaving only four in series, and again mark the position of the pointer. This will give very nearly the position corresponding to 4 volts. Again disconnect one cell, leaving only three in series, and noting the position, mark it 3. Proceed



SIMPLE VOLTMETER.

thus until five points are marked upon the scale corresponding to 1, 2, 3, 4 and 5 volts. It will be found that the spaces between the various points are not quite equal, that at the center being the longest. On the other side of the middle point the spaces should be marked like those already found, with the longest space at the center, gradually decreasing in width until the tenth line is drawn. These lines should then be plainly numbered from 1 to 10, as in the figure.

The reasons for the process just gone through are not difficult to understand. Each cell constructed as described gives on open circuit an e. m. f. 1.08 volts. The five cells in series would give us five times this amount or 5.4 volts, on open circuit. But as soon as they are attached to the voltmeter their voltage falls, due to the current through themselves, so that their combined voltage is then very close to five volts. Similarly, four cells give us very nearly four volts and so on. Beyond the middle point of the scale the points would be found to be similar in their position to the first five found, so we can mark their position without the necessity of actually constructing the cells necessary to cause the corresponding deflections. It must not be understood that the cells described are suitable for practical work. They will probably give out entirely after a few days, but for the purpose of adjusting the voltmeter they will answer as well as an expensive battery.

A voltmeter is always connected directly to the points between which it is desired to measure the difference of potential. This is done without disturbing the connections of the rest of the circuit. Thus, when we wish to measure the difference of potential across the terminals of a motor, the terminals of the voltmeter are connected to these points, without disturbing the rest of the circuit. The instrument and the motor are then connected in parallel, or in shunt, these two terms being used to designate the same thing.

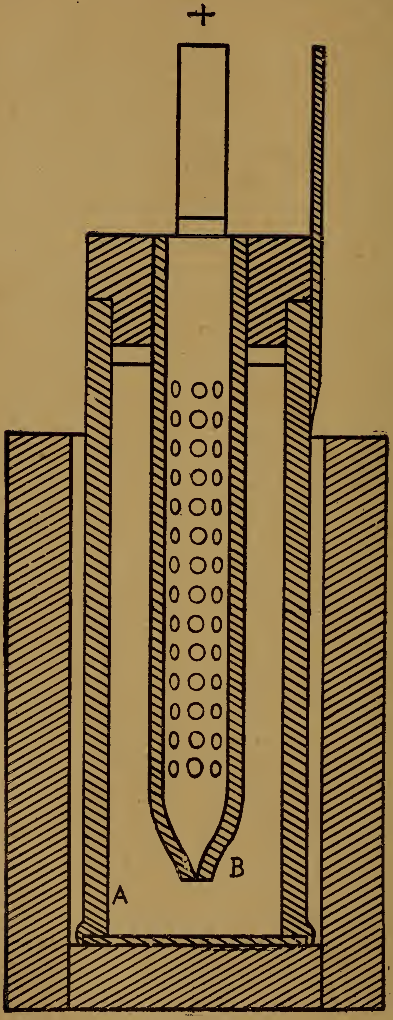
CHAPTER XXXVII.

HOW TO MAKE A STORAGE BATTERY.

A storage cell consists of a positive plate and a negative plate, both made of lead, and dipping into a dilute solution of sulphuric acid. For large cells there are always a large number of positive and negative plates, all the positives being connected to one common terminal and all the negative plates to the other terminal. The storage cell described below is one that is suitable for the amateur's use, and is the proper size to be readily charged by a few gravity cells.

Procure a piece of lead pipe 1¾ inches in external diameter, and 5 inches long. Having squared off both ends, solder to one end a circular piece of sheet lead so as to form a lead cup of the size just mentioned. This cup is to hold a solution of sulphuric acid, and must, therefore, be free from all leaks. Procure another piece of lead pipe, of the same length as before but ¾ inches in external diameter. With a ⅛-inch drill, bore this as full of holes as is possible, except for a distance of one inch from each end. Hammer the lower end of this tube together as shown at B in the figure. It need not be water tight at this point, but only sufficiently tight to hold a paste which will be described later.

The tube B is to form the positive plate of one cell. The negative plate is the lead cup first mentioned. To support the positive plate so that it will not touch the negative, make a wooden cover for the cell of the same external diameter as the outer tube and ⅞ inch thick. Cut away its lower portion, so that it will fit snugly into the outer tube. Through its center bore a hole ¾ inches in diameter, so that the smaller lead tube will just fit into it snugly. Solder to the upper end of this tube two lead strips, one of which is one inch long, the other three inches long. If these are bent over at right angles and screwed to the top of the wooden block after the smaller tube is in place, then


+
A
B

the latter will be held firmly in the block. Now immerse the wooden block after the smaller tube is in place, in smoking hot paraffine wax, leaving it there until the wood has become thoroughly saturated with the hot wax. This is to protect the wood from the action of the acid. Do not get any wax on the lower part of the lead tube.

Make a paste for the positive plate as follows. In an old tumbler make a weak solution of sulphuric acid, by pouring the latter slowly into a half tumblerful of water. Be very careful in handling this acid as it destroys everything it touches, including the skin of the hands. Never pour water into the acid, but pour the acid into the water slowly as directed. Procure at a paint shop a pound of red lead, and mix a sufficient amount with the half tumblerful of diluted acid to form a very stiff dry paste. Stir the mixture with a stick. Then ram the paste into the inside of the smaller tube until the later is nearly filled with a solid mass of paste. Scrap off any paste that may have oozed through the holes and set the tube aside to dry. Meanwhile solder a lead strip to the outside of the large tube, at the top, to serve as a connector.

Fill the large tube two-thirds full of a solution of sulphuric acid, made by pouring acid into water, until there is 1-12 as much acid as water. A glass graduate such as amateur photographers often use for measuring chemicals is of great assistance in this case. Then insert the wooden stopper with its attached tube into the larger tube. Our cell is now complete, except that a wooden box ought to be made in which to set the cell, to prevent its being overturned. This box can be made square in shape with inside dimensions a little larger than the cell. The latter may be set into the box, and held firmly there by filling all waste space with sawdust.

To charge this storage cell three "gravity" or "crow-foot" batteries will be required. These had better be purchased at an electrical supply store, and it is probable that most amateurs have them already. Join them in series, that is, join the zinc of one cell to the copper of the next, and so on. To charge the cell, connect the terminal marked positive in the figure to the copper pole of the three gravity batteries, and connect the negative terminal of the storage cell to the zinc pole of the battery.

The first time this storage cell is charged, the connections should be left undisturbed as above for one week. At the end of this time it will be found to have acquired quite a charge. After the first charge, it is not necessary to charge it so much, 10 to 12 hours being sufficient.

CHAPTER XXXVIII.

HOW TO MAKE A SIMPLE TELEPHONE.

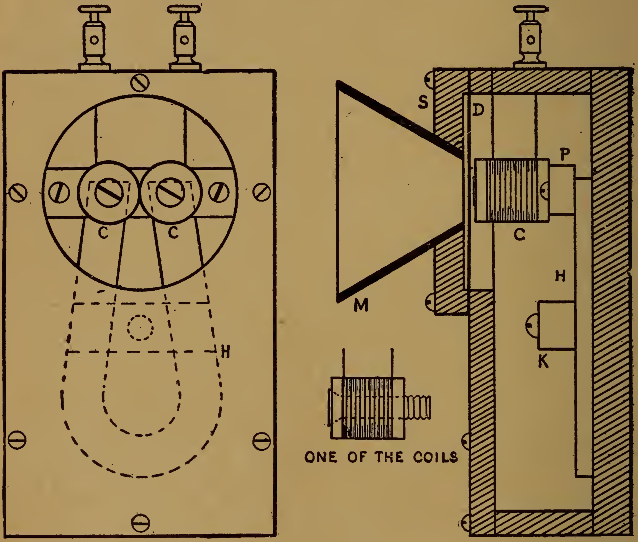
A telephone is a source of never failing pleasure to one fond of experimenting. Oftentimes, too, a telephone is of great convenience in affording easy communication between two widely separated points. The instrument is excedingly sensitive, even when rudely constructed, and so simple that nearly every boy should be able to make one.

There are three things that must enter into the construction of a telephone. These are (1) a permanent steel magnet; (2) a coil or coils wound upon the poles of the magnet, and (3) a diaphragm of very thin soft iron held firmly by the edges so as to vibrate back and forth very close to the poles. These three things are shown in the sketch below, when H is the magnet, in this case of the horseshoe form, and C represents the coils wound upon two iron screws as cores, and D is a circular diaphragm of soft iron. To the above mentioned parts, essential to any telephone, we might add a fourth, namely, a mouthpiece shown at M, whose purpose is to concentrate any sounds uttered near the telephone upon the diaphragm.

In the construction of such a telephone, first make a shallow wooden box, 4¼ inches in length, 2¼ inches in width and 1 inch deep, all measurements taken inside the box. The bottom of the box should be of ⅜-inch whitewood, the sides of ¼-inch wood. Fasten the box tightly together with glue and brads. Make a cover for the box, ¼ inch thick, and at one end cut out a hole 2 inches in diameter. This hole should be midway between the long edges of the cover and its outer edge should be ¼ inch from one end of the cover.

The magnet used is a 3-inch horseshoe magnet, which can easily be purchased at a hardware or electrical store for fifteen cents. It is clamped to the bottom of the box just constructed by a wooden cleat shown at K, held by a screw at its center. The ends of the magnet should project a little above a line drawn through the center of the hole in the cover.

The two coils are wound upon cores formed from two iron machine screws. The size used is what is known as No. 10, and they are about 3-16 inches in diameter by 1 inch in length, and



FRONT VIEW
MOUTHPIECE REMOVED

VERTICAL SECTION
THROUGH CASE

with flat heads. They can be purchased at a hardware store. The screws should be covered with a layer of stout paper, glued on, and then two circular wooden discs are slipped on each screw, whose outside diameter is ⅝ inch. They are for the purpose of forming heads for the coils of wire to be wound upon the core. They should be ⅛ inch thick and should fit tightly upon the screw. Make a hole in a block of wood of such a size that the screw will fit tightly in the holes. Screw it into the block until it projects ¾ inch from the block. The block simply serves as a handle by which to hold the coils while winding and will be thrown away after it has served its purpose. Place the wooden heads in position upon the screw, and place them at such a distance apart that there is a clear space of ½ inch between them. Wind this space full of No. 36 double silk covered magnet wire. Remove the coil from the block which has served for a handle, and there should now be a coil whose outside diameter is ⅝ inch, and whose extreme length is ¾ inches with an iron core made of a screw which projects ¼ inch from one end. Proceed in a like manner with the other screw, forming a second coil exactly like the first one.

These coils are to be held with the projecting end of the cores firmly clamped against the poles of the horseshoe magnet. This can easily be done by screwing the projecting ends into a strip of hard wood, which is 2¼ inches long, ½ inch wide, and a scant ¼ inch thick. Bore two holes in this, ⅝ inch apart and equally spaced each side of the center of the strip. These holes should be of just the right size so that the iron screws will fit them tightly. The screws should project a little through the back of the wooden strip. The strip is then screwed to the base wood board forming the back of the box first constructed, in such a manner that the screws are each held firmly against the poles of the magnet. Connect one end of one coil to one end of the next in such a manner that if a current should flow through the coils it would go around one coil in a direction opposite to that in which it goes around the other. Connect the free ends to the binding posts shown.

The diaphragm D is of thin soft iron called ferrotype iron, such as is commonly used by photographers. It can be purchased of a photographic supply store. Cut out a circular piece 2½ inches in diameter. Clamp it to the front of the cover covering the hole cut in the latter. It is held firmly all around its edges by a circular block of wood S, but this block must not touch the disc except at its edges. Hence it is cut away on the under side as shown. The diaphragm should be free to vibrate at its center, and so it must not touch the ends of the iron screws around which the coils are wound, although it should be as close as possible to them.

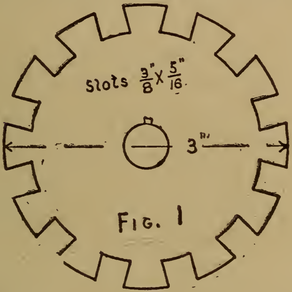
The mouth piece M is made of heavy cardboard. The stiff cover of a blank book is excellent material. It should be 2 inches in diameter at the large end, and 5/8 inches in diameter at the small end. The cover of the box is fastened on by means of small brass screws.

CHAPTER XXXIX.

THE DESIGN OF A SMALL DYNAMO.

PART I.

One of the most common problems that the amateur meets is the problem of the proper design of small dynamos and motors. In the following chapter an attempt will be made to explain the methods and principles involved, and the various steps in the calculation will be gone over. It will be assumed, however, that the reader has a fair knowledge of electrical terms, and a familiarity with the essential parts of a dynamo or motor.



First of all we must assume that we are to build a machine that will give us, when run as a dynamo, a certain output in watts. The machine to be described will have a maximum output of 75 watts at a pressure of 50 volts. We are obliged to rely for our starting point upon the experience gained by others. It has been found that for this type of machine a speed of 2400 revolutions per minute is a good value to use; also that a velocity of the conductors upon the armature of 30 ft. per second is about the highest we can go with safety. Knowing these two things, it is easy to calculate the size of our armature. If we multiply the speed at which the conductors move (30), by 12, and divide the product by 3.14 and again by the number of revolutions per second (40), the result will be the diameter sought. In this case the product of 30 and 12 is 360. Dividing this by 3.14 gives 114.6. Dividing again by 40 gives 2.865 as the diameter of the armature we are to use. This is very nearly the same as 2⅞ inches, and is the average diameter of the armature, measured to the center of the conductors. The outside of the armature should be a little larger than this. To use even figures, let us assume the outside diameter of our armature to be 3 inches.

In the design of armatures for large machines, a less number of revolutions per minute must be chosen. A machine of ½ horse power (373 watts) should have a speed of about 2200 revolutions per minute. A one-horse power dynamo should run at about 2000 revolutions per minute, and a two-horse power dynamo is usually run at about 1800 revolutions per minute.

The armature which we will use will be of the toothed type, shown in Fig. 1. The actual number of slots used is immaterial, if it is only an even multiple of the number of commutator segments to be used. We will choose twelve slots and twelve teeth for our armature. The number of commutator segments varies with the voltage to be employed; and also with the current generated. Of course, the number of segments should be an even number, and is almost always some multiple of 3 and 2; e. g., 12, 18, 36, etc.

Since ours is a low voltage machine a very few segments will suffice, as far as insulation goes. But it must be remembered that the greater the number of segments the smoother will be the current generated. On general principles, not less than six segments should ever be used, and for machines of 110 volts and upward, twelve or more segments should always be used. Because of ease of construction, we will choose six commutator segments for our machine. The above remarks apply to machines with one pair of field poles. Machines with two pair (4 poles) will require double the number mentioned.

The conductors wound upon the armature will lie closely packed in the slots. Imagine that we have built our armature, and could cut it open directly across the conductors. How many conductors could we count? This is the next question we shall answer.

Their number depends upon their size, of course, and their size depends upon the current they are to carry.

Now if the output of our dynamo is to be 75 watts at 50 volts, the current generated must be 1½ amperes. Usually we have to allow also for the current which supplies the field coils, assuming the latter to be in shunt with the armature. In this case we will assume that the field current has a value of ½ amperes. It is usual to allow in small machines an area of 400 circular mils per ampere, in determining the size of wire on the armature. On larger machines (1 to 2 kilowatts), at least 600 circular mils per ampere should be allowed. Our machine will have a drum armature and will therefore have two parallel circuits through the armature. So that each conductor carries one-half the above current, or one ampere. Therefore the conductors on our armature must have an area of 400 circular mils. This means that we must use No. 24 magnet wire upon the armature. This, when insulated with double cotton covering, has an outer diameter of .03 inches.

The width of our slots if they are to take up one-half of the circumference of the armature is ⅜ inch, and if they are 5-16 inch deep, it will give us a well proportioned tooth. Assuming these dimensions, we can have eight layers of wire in each slot. This allows 1-32 inch for insulation at the bottom of the slot, and 1-16 inch clearance at the outside, which will be necessary for binding wires. Assuming the same thickness of insulation on the sides, we can get 11 turns in each layer. So the number of conductors in each slot is the product of 11 and 8, or 88; and the total number of conductors in all slots is 88 times 12, or 1056.

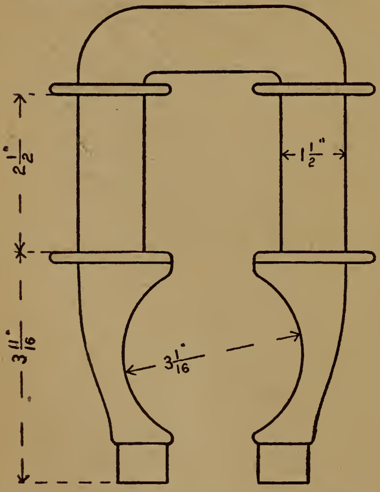
We will continue the design of our machine in a following chapter.

CHAPTER XL.

THE DESIGN OF A SMALL DYNAMO.

PART II.

Having calculated the number and arrangement of conductors upon the armature, as described in the preceding chapter, we will next take up the necessary calculations for the field magnet. We will assume that it is to be of the bi-polar form, of the general shape shown in the accompanying figure. First, as to diameter of armature space. The outer diameter of armature is three inches. Allowing 1-32 inch clearance, the diameter of the armature space should be 3-16 inches. Next, how large should the core of the field magnet be? This will depend upon the strength of magnetic field that we are to force through it. There is a definite relation between the strength of magnetic field, the speed, the electromotive force and the conductors on the armature. In every dynamo, the product of the number of conductors on the armature, multiplied by the strength of field, is equal to the electro-motive force in volts multiplied by 100,000,000 divided by the number of revolutions per second.



In one machine, the voltage at full load is to be 50. But allowing for an inevitable loss in the armature, we will assume voltage to be 55. This means a loss of 10 per cent, which is none too much for a small machine. Applying the rule just given, we multiply this by 100,000,000 and divide by 40 (the revolutions per second), getting as an answer 137,500,000. This represents the product of the number of conductors on armature by the strength of field. But we have already calculated the number of conductors (1,056). Consequently we have but to divide 137,500,000 by 1,056, giving us 130,200, the strength of field necessary to give us 55 volts at a speed of 40 revolutions per second.

Now how large shall be our field magnets? That depends on their material. If they were of cast iron they will be quite large. If we make them of cast steel, they will be much smaller. Consequently, we will make them of soft cast steel. This material will carry easily 88,000 lines of magnetic force for every square inch of cross section.

Since there will be a large amount of leakage of magnetism in so small a machine, the 130,200 lines of force will have to be increased considerably. Multiplying this by 1.2 gives us 156,240 as the number of magnetic lines to be sent through the field magnet.

Dividing this by 88,000 gives 1.77 square inches as the area of one field magnet core. Further calculation shows that the diameter must be 1.5 inches to give us this area. These dimensions are shown in the figure.

The next important dimension of the field magnet is its length parallel to the shaft of the armature. This length is determined solely by the allowable density of magnetism in the air gaps between armature and field. The magnetism has to cross a gap of 1-32 inch on each side of the armature. If we make the field magnet poles too short, the density in this gap will be too great. If we make them too long, we shall waste material. Their proper length is determined by allowing one square inch for each 20,000 lines of magnetic force that cross the air gap.

So our air gap will have an area of 6.51 square inches, obtained by dividing 130,200 by 20,000. If we should take a string and measure the length of arc on field magnet, we should find it to be 3½ inches. Measuring the same arc on surface of armature, its length is 3⅜ inches. But since only half the surface of the armature is iron, the effective length of arc on armature is 1 23-32 inches. Taking the average of 1 23-32 with 3⅜ gives 2 18-32 inches as the effective length of arc across which the magnetism must cross. Knowing this length, and knowing that the area of air gap measured parallel to shaft must be 6.51 square inches; dividing the latter by the former, gives us a length a little in excess of 2½ inches. In order to make dimensions an even number, will call the length of pole piece parallel to shaft 2½ inches exactly.

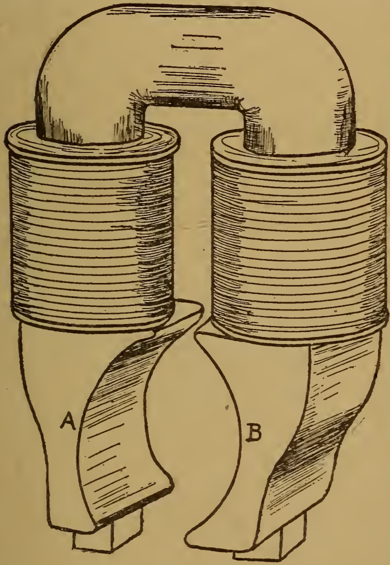
Our next chapter will be taken up with a calculation of field winding, and a consideration of practical details. The theoretical work thus far is simply to fix dimensions and shape, and the practical side will now be emphasized. The dimension given in the figure as 3 11-16, was derived from a consideration of diameter of armature and of clearance necessary to top and bottom of armature. At the bottom are two projecting lugs ¾ inch square for fastening field frame to base. The casting shown in figure is in one solid piece.

CHAPTER XLI.

THE DESIGN OF A SMALL DYNAMO.

PART III.

Final calculations must now be made to determine the size and amount of wire upon the field coils. The latter have to furnish enough magnetic force to send 156,240 magnetic lines through the iron frame, across the air gap and through the armature. Let us begin with the air gap between armature



and field. It is 1-32 inch wide on each side of the armature. That is, the magnetism has to cross a layer of air equivalent to 1-16 inch thick. To calculate the ampere turns required for this, multiply the density of magnetism in the air gap (20,000) by the width of gap (1-16 inch) and by .313. This gives as a result 391. Next find how many ampere turns will be required for the field magnet. The total length of steel traversed, beginning at A and extending around to B is about 11 inches. Multiply this by the density (88,000) and by .313. This gives us 240,384. This would be the amphere turns required if steel were no better a conductor of magnetism than air. But as a matter of fact soft steel. under the above conditions, has a conductivity 800 times greater than air. So we will only need one eight-hundredth as many ampere turns as above calculated. This gives us 300 as the ampere turns required for field. For the armature teeth, which are 5-16 inch deep and of an average width of 5-16 inches, there will be needed 26 ampere-turns. And for the body of the armature core there will be needed 75 ampere turns. Adding these all together gives a total of 792 ampere turns. To this we will add 25 per cent. to make up for armature re-actions, giving a total of 990. Let it be decided that our field current should be ½ ampere. So we will need 1,980 turns of wire on our field magnet. We find the size of wire to be used in just the same way that we found the size in the armature —namely, by allowing 400 circular mils per ampere. This shows us that No. 27 magnet wire must be used. Calculating the length of 1,980 turns of No. 27, we find that it would take about 990 feet, and have a resistance of about 60 ohms when hot. Now this would give us a current of 1 1-5 amperes, which is too much. Our assumption of ½ ampere then was too high, and we cannot use No. 27 wire. Let us assume a field current of ¼ ampere. This would require 3,960 turns of No. 30 magnet wire, whose total length would be 1,980 feet, with a hot resistance of 210 ohms. This gives us the right value of current, assuming an e. m. f. of 52½ volts. The wire will be wound on the core in 14 layers on each spool of approximately 135 turns each.

The weight of wire required is about one pound.

The accompanying figure shows the finished field magnet with windings in place. The cores are first wound with several layers of heavy paper glued in place. Then four heavy split washers of cardboard or fuller board are slipped on the core, protecting the ends of the coils from contact with the iron. The wire should be wound evenly, and the two coils connected in the usual manner.

Castings similar to the above may be bought of dealers in electrical supplies, or may be made from patterns. If made of cast iron, however, the cross section will have to be doubled, and the field windings recalculated.

The armature of our dynamo is to be made up of a large number of discs, cut from thin sheet iron. These may also be bought of the form and dimensions given in a previous chapter. About 60 of them make a pile one inch high, so that 150 discs will be required.

Directions will be given in the following chapter for winding the armature, building commutator, and finishing up the machine.

CHAPTER XLII.

THE DESIGN OF A SMALL DYNAMO.

PART IV.

The armature of our dynamo is to be of the well known drum type. The armature core, the shape of which was shown in Chap. 1, is made up of a large number of toothed discs punched from thin sheet iron. These discs may be bought of the dimensions given, at various electrical sup-

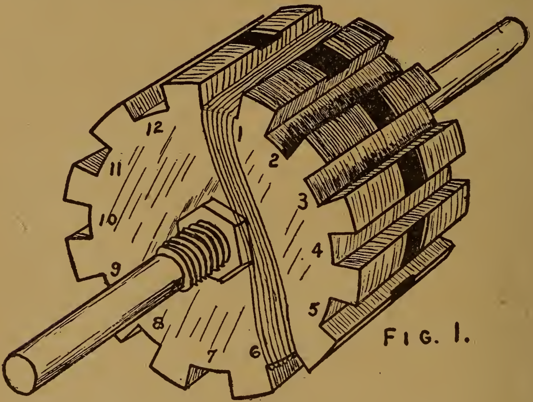


FIG. 1.

ply houses. About sixty of them are needed to make a pile one inch high, so we will need 150 such discs. They are mounted upon a shaft of soft steel, which is 5-16 inch in diameter at the ends and ½ inch in diameter in the middle, and should be at least 9½ inches long. The central portion is threaded as shown in Fig. 1, and two nuts, clamping against two stiff washers, bind the whole very tightly together. The discs must be held very firmly and cannot be clamped too tightly. When threading them on cut the ends of the teeth of those discs which occupy a position ¼ inch each side of the center, so that they are 1-16 inch shorter than the teeth in remaining discs. This makes a slot which will be filled with binding wires as explained later.

Having mounted the core upon the shaft, in the position indicated by the dimension lines in Fig. 2, it must next be carefully covered with an insulating covering to keep all wires from contact with the iron. First go over every corner and sharp bend in the slots and on end nuts, covering these places with a layer of thin cotton cloth, fastened in place with shellac. Then apply a layer of the cloth to the sides and bottoms of the slots, the ends of armature, and other places where the wire is especially liable to touch the iron, using shellac as a glue. Wrap two or three layers of cloth around the shaft, for a distance of two inches from the ends of core.

In winding the coils in place proceed as indicated in Fig. 1. There are twelve slots on armature, and we are to have only six coils. So each coil will occupy two slots. This is an advantage, as it lets the wires clear the shaft with little difficulty. Begin at slot number one, and wind in eight layers, carrying the wire around the armature across the end at the back, and returning through slot number six. There should be eleven turns in each layer, using number 24 double cotton covered magnet wire. This completes coil number 1, and the wire may be cut off leaving a projecting end six inches long. Its beginning should be tagged with a small tin tag marked B-1, and its end tagged 3 E-1, and the two ends twisted together temporarily.

Coil number 2 begins in slot number 3, and occupies slots 3 and 8. Its ends should be tagged B-2 and E-2, and twisted together. Coil number 3 occupies slots 5 and 10. Each coil is put on in this manner, skipping one slot between each coil. Of course they all overlap on the ends, but this can be made to present a neat appearance, if pains be taken.

When all are in place, stout brass binding wires are wound tightly in the slot left vacant at center of core, and soldered in place. These keep the copper wires from flying out when armature rotates rapidly, and are absolutely necessary. About one pound of magnet wire is required for armature. The whole armature should now be given a coat of shellac, and then placed in a warm oven to thoroughly dry.

A six section commutator is easily made by mounting a piece of brass tubing 1¼ inches in external diameter and 1¼ inches long upon a wooden hub which may be driven tightly upon the shaft. Before doing this, divide the surface of the brass tube into six sections by lines parallel to its axis. In the center of these sections and at either end, bore two holes through which pass two 3-8 inch brass screws. Then with a hack saw cut the tube into six portions, sawing along the lines first drawn. The screws already inserted hold sections in place. After sawing remove each section and file off all sharp edges. If a lathe is available, the surface of commutator should be turned down smooth and circular, after sections are again in place.

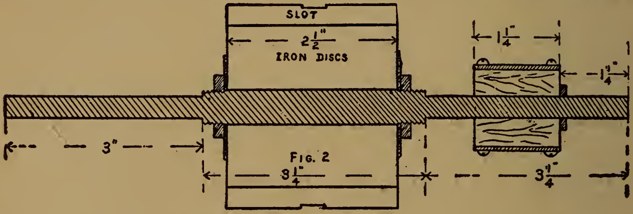


FIG. 2

Connect the end of coil number 1 (E-1) and beginning of coil number 2 (B-2) to a section of commutator. Connect E-2 and B-3 to next section, E-3 and B-4 to the next, and so on around the armature. These connections should be made smoothly and uniformly. It is best to make connections by soldering, as this throws less strain upon the screws in commutator. A little copper ear may be clamped under each screw to which connections may be soldered.

CHAPTER XLIII.

THE DESIGN OF A SMALL DYNAMO.

PART V.

Having made the armature and field magnets as previously described, the next thing to be done is to provide suitable means for mounting them in proper relation to each other. For this purpose a bed plate must be provided of a shape shown in Fig. 3. The general dimensions are there given, although details regarding the machine are left for the amateur to work out for himself. The bed plate should be of brass. It cannot be made of iron, for the ends of the field magnets are to rest upon it, and if made of iron much of the magnetism would pass through the iron base, instead of through the armature. In the center are two holes, ¾ inch square, which are to receive the projecting lugs on the polar ends of the field magnets. (See Chap. II.) The amateur will have to see that the dimensions on field magnet and on base, are so adjusted that the former will fit the latter. The base should be about 1 inch high. The projecting lugs slip down into the holes provided, and bolts screwing up into the lugs, provided with large washers, clamp the base and field magnet frame firmly together.

Next, bearings must be provided for. They should be made of brass castings also. The two bearings are not alike, for one of them must be made so as to serve as a support for brushes, while the other one is a plain simple bearing. The former is shown in plan in Fig. I, and in elevation in Fig. 2.

Measure the height of the center of the circular armature space above the top of the base. This is the height of the center of the shaft, and is therefore the height of the center of bearing above base. In making patterns for these bear-

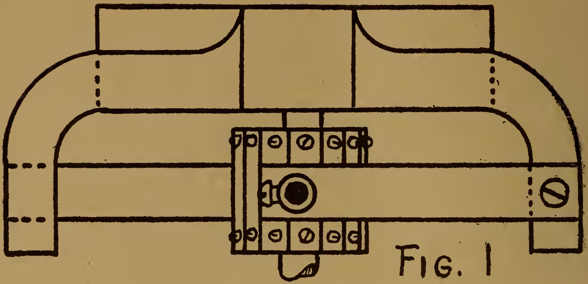


FIG. 1

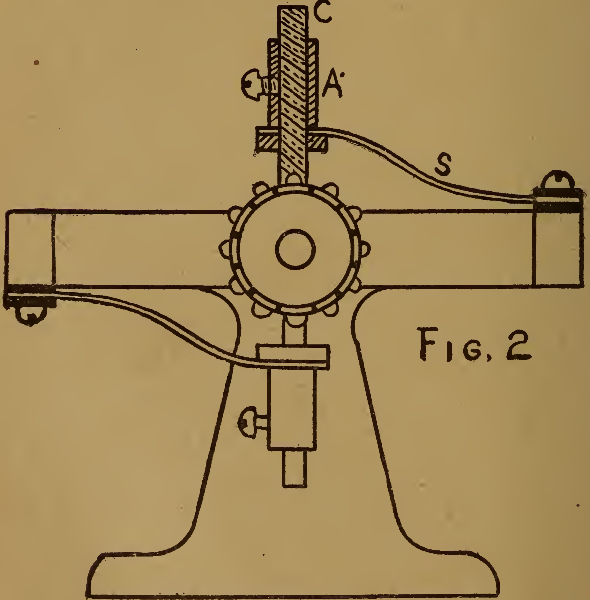


FIG. 2

ings, allowance should be made for loss of metal in finishing, which will amount to at least 1-16 inch.

The brush holder shown in Fig. 2 is very simple, and fairly efficient. Each brush holder consists of a brass spring S, a brass ferrule A, and a carbon rod C. The ferrule A is provided with a shoulder as shown, and a hole is drilled through the spring to receive the smaller part of the ferrule. The latter and the spring are then soldered together. The carbon rod C should be about 3-16 inch in diameter, and should fit the hole in ferrule snugly. A screw passing through the side of ferrule clamps carbon rod firmly. The springs are so adjusted that the carbon rods are pressed firmly against the top and bottom of commutator. They should slant a very little to the back, imagining the eye

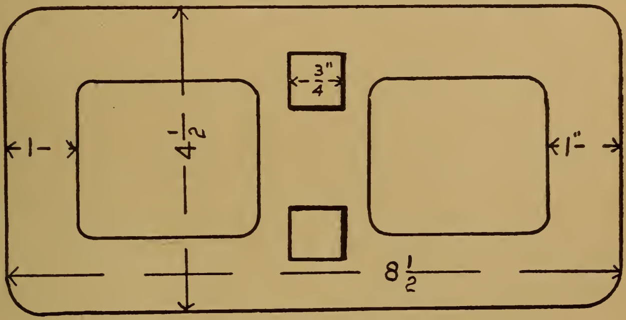


FIG. 3

to be looking in direction that commutator is to revolve. The springs should be about 3¼ inches long, 1-32 inch thick, and ½ inch wide. In Fig. 2 the upper holder is shown in section, and the lower holder in elevation. Each spring must be carefully insulated from the brass supporting arm. This is done by putting pieces of hard rubber or hard fibre above and below the spring and by also providing a washer of the same material surrounding the screw which clamps the springs to the support.

The field coils, after being joined in series, are then connected directly to the brushes. The brushes also serve as terminals for the machine, making the field coils to be in shunt with the external circuit.

When run at 2,400 revolutions per minute, the machine will give 60 volts on open circuit, and will give a voltage of 50 when delivering a current of 1½ amperes. Many details regarding construction have been left to the amateur to work out, as the purpose of this series of articles has been to teach the main principles of dynamo design, rather than the mechanical details which any ingenious amateur may work out for himself.

CHAPTER XLIV.

HOW TO MAKE AN ELECTRIC GYROSCOPE.

PART I.

The gyroscope has long been known to physicists as an interesting scientific toy. In an elementary form it has been used probably by many of the young readers of this book. The form usually sold in toy shops, consists of a lead wheel with an extremely heavy rim mounted in a pair of pivots supported on a ring. When set into extremely rapid rotation by means of a string wound around the axis, the wheel may be made to perform numerous interesting feats such as hang-

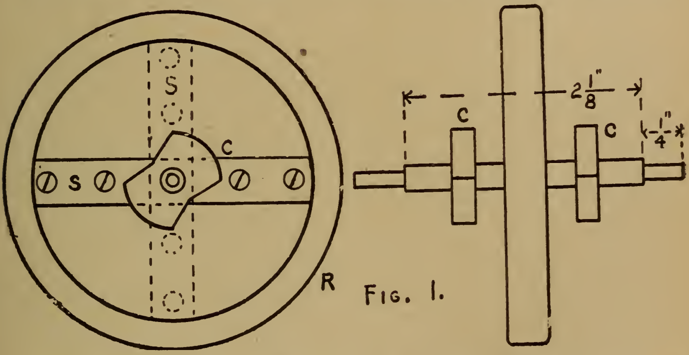


FIG. 1.

ing by one side from the edge of a table or other convenient support. The common top so dear to every boy's heart is only a special form of gyroscope. Every one knows that as a top spins rapidly it will stand upon its point in apparent defiance of the law of gravity, and if displaced from its position will tend to assume an erect position again. If we take a bicycle wheel from its frame and grasp the supporting axle in the two hands, we may tilt the wheel easily to any angle provided the wheel be at rest. If however, we set the wheel spinning quite rapidly and then try to change the direction of rotation of the wheel by grasping the axle, we shall find that it is almost impossible to suddenly wrench the wheel out of its normal position.

In all these cases, it is apparent that a body in rapid motion possesses properties which a body at rest does not possess. They are only specific illustration of the important law of motion which states that a body once set in motion cannot of itself change either the direction or the value of its own motion.

In the case cited the motion soon ceases and the effect is, therefore, only a temporary one. In the instrument to be described in this paper electrical means are employed to keep the body in constant rotation, thus making possible the demonstration of many interesting physical facts. One of these which is of especial interest is the visible demonstration of the rotation of the earth upon which we live. We ordinarily accept as true that the earth rotates on its axis; the gyroscope makes this rotation a visible fact.

We will need first of all, a heavy brass wheel such as is shown in Fig. 1. This wheel is 3 inches in external diameter and has a heavy rim ¼ inch thick, the width of this rim being ⅜ inch. The wheel may be turned from a ⅜ inch plate of brass. Especial care should be taken to accurately center and turn the wheel. The central portion of the wheel should be turned down to a thickness of ⅛ inch, the rim being of the dimensions already given.

On one face of the wheel and within the rim, is to be mounted a piece of soft iron shown at S which is 2½ inches long, 7-16 inch wide and 1-16 inch thick. It is fastened in place by four flat head iron screws counter sunk flush with the surface. On the other side of the wheel and at right angles to the first piece of iron is mounted a second piece indicated by the dotted lines.

Having done this, bore through the exact center of the wheel a hole which is a scant ¼ inch in diameter. Through this hole is to be driven very tightly a shaft whose total length is 2⅝ inches, the wheel being in the exact center of the shaft. The shaft is turned down for ¼ inch from each end to a diameter of ⅛ inch thus forming two shoulders to fit in bearings to be described later. If any doubt exists as to the shaft being exactly in the center of the wheel a test should be made at this point and the wheel turned down by taking a very light cut until both inside and outside of rim run perfectly true.

At C are shown two contact wheels made of 3-16 inch brass driven tightly upon the shaft. These contact wheels are so made that they will make contact with a brush which is to press upon them for one-eighth of a revolution, then break the contact during the next quarter revolution, then make contact during the next quarter and so on. Accordingly they have the shape shown in the left hand part of the figure, the diameter measured between circular portions being ⅞ inch. They should be placed in the position indicated in the figure, the discs on opposite side of wheel being twisted around so as to be at right angles to each other. This point will be explained more fully later, after we have built the remaining parts of the machine.

CHAPTER XLV.

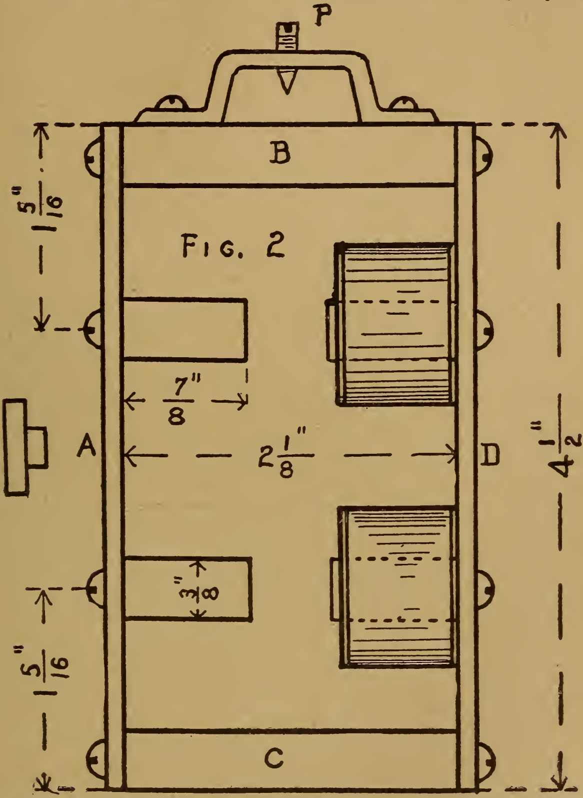
HOW TO MAKE AN ELECTRIC GYROSCOPE.

PART II.

In the last chapter the rotating part of our instrument was described consisting of a brass wheel with an extremely heavy rim supported on suitable shaft. The field magnets and supporting frames of this motor will now be described.

A view of the frame is given in Fig. 2 with two of the four coils composing it in place. It consists of two side strips of iron marked A and D which are 4½ inches long, ⅝ inch wide and ⅛ inch thick; the end pieces of the frame C and B being made of pieces of brass ⅜ inch square and 2⅛ inches long. At a distance of 1 5-16 inches from the end of the iron strips, bore two holes 3-16 inch in diameter. These are to support the circular iron cores shown at H. These circular iron cores are of the dimensions given in the figure and are drilled and tapped at one end so as to be fastened to the iron strips by round headed machine screws passing through the holes already drilled. The frame is fastened together at the end by iron screws passing through the strips of iron and into the ends of the brass strips. Extreme care must be taken to see that the frame is rigid, and perfectly balanced throughout. To secure these qualities care should be taken to finish the various strips carefully. After the frame is screwed together bore with a small drill a hole close to the end screws and passing through the iron strips into the brass strips to a depth of ⅜ inch. In these small holes drive a tight fitting pin which will help to prevent racking of the frame.

Coils are next to be wound upon the four inwardly projecting cores. Two of these are shown in the figure, the other two being omitted to make the diagram clearer. Turn out from a piece of brass, eight pieces 1-16 inch thick, and 15-16 inch in diameter, with a hole in the center just big enough so that the disc may be driven tightly upon



the circular iron cores, to form heads to contain the wire to be wound upon the cores.

About four ounces of number 30 double silk covered magnet wire will be required. Wind each core with a layer of paper, fastened on with shellac, and cover the inside of the brass head with a paper disc, so that the wire cannot possibly come in contact with the core. Then wind the coils on the four iron cores, so as to make a coil 15-16 inch in diameter. Connect all the coils in series when they are complete, connecting them in such a manner that a north pole of one coil will be opposite to the south pole of the coil opposite.

Before fastening the cores in place to the side strips A and D, bore a hole in the exact center of the two strips A and D, the holes being ¼ inch in diameter. To these holes are to be fitted brass bushings of the shape shown at the left of the figure. These brass bushings are to form bearings for the support of the revolving wheel described in the last chapter, and accordingly must be flush with the surface of the iron on its inner face. The bushings had better be threaded into the iron and fastened by means of a set screw.

We must provide means for supporting the apparatus when it is completed. It is to be supported by being hung upon the steel pivot P. This pivot is threaded into a brass strip ⅜ inch wide bent into the shape shown. In order to exactly balance the machine it will be necessary probably to shift this piece of brass a little so that the screws which fasten it to the frame pass through slots cut in the brass instead of through holes.

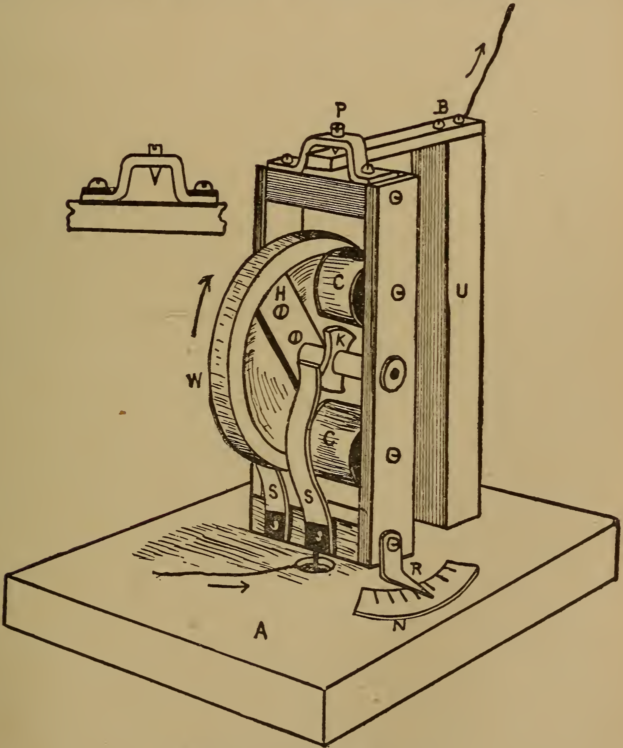
We are now ready to put the apparatus together, but the description of this will have to be left to the following chapter.

CHAPTER XLVI.

HOW TO MAKE AN ELECTRIC GYROSCOPE.

PART III.

The rotating and the fixed parts of our instrument having been completed, they can be assembled together after the



THE ELECTRIC GYROSCOPE.

manner indicated on page 153. It will be seen that the wheel W is mounted so as to swing freely in the center of the frame already constructed. It is essential that this wheel should run very smoothly and evenly and should be perfectly balanced. The iron armatures fastened to its sides should pass very close to the poles of the electro magnets C of which there are two on each side of the wheel, without touching the latter. For this reason the wheel can have hardly any side motion. The strip of brass into which the pivot P is fastened, must be insulated from the frame. To acomplish this strips of hard rubber are placed between it and the frame and also under the head of the screws which clamps it, the latter being provided as well with an insulating bushing.

At the bottom of the frame are attached two springs marked S which are also insulated from the metal frame but are connected with each other and to a piece of wire hanging from the bottom of the frame to a distance of about one inch. The four coils are connected in series in the manner previously described and one terminal of the wire is connected to the insulated pivot P. The other terminal of the coils is connected to some part of the metal frame.

A suitable base shown in the figure is provided with an upright post U which carries at the upper end the heavy strip of brass B. The height of this post should be such as to allow the frame to swing clear of the base by about ½ inch. Directly under the middle of the frame a hole is to be bored in the base to a depth of ½ inch into which is to be poured a globule of mercury. The projecting wire already mentioned should dip into this mercury when the frame is suspended in position. The pivot P should be very sharp and hard and should bear upon a piece of hardened steel fastened to the brass strips B so that the gyroscope may turn with very little friction into any position.

Its action is as follows: Current is led into the lower mercury cup by a wire as indicated, thence to the insulated springs S, to the contact maker K to the frame of the machine, through the coils C to the pivot P and thence out of the wire shown at B. The action of the contact maker K is as follows. When the iron strip H is ⅛ of a revolution from the poles of C, K should make contact with S, closing the electric circuit through C which causes H to be attracted. This should continue until H is exactly opposite to the poles, when the contact should be broken. Now for ⅛ of a revolution, the circuit will be open, but after this interval the strip on opposite side of the wheel should be ⅛ of a revolution from the magnets on that side. The contact maker on that side should now close the circuit and act in just the manner that K acts when it comes in contact with S. If three or four strong bi-chromate cells be used the wheel ought to revolve at a high rate of speed.

Its gyroscopic action, that is, its resistance to any change in the plane of its rotation is very marked. If no force were acting on the wheel it would be impossible for it when once started to change the plane of its rotation. If the pivot P be without friction the base may be turned about in any direction without altering the position of the wheel H. Suppose the wheel to be started so that its plane points exactly north and south. It will continue to run in the direction in which it is pointed even though the base A and the earth under A should change their position. Now the earth is constantly rotating and what is north for a person in one place is not north for a person in another place, for the reason that the meridians of longitude converge at the pole and are therefore not parallel. If the wheel be started to rotating in a north and south meridian at a given time, it does not mean that the wheel will continue on this meridian but it will always continue to rotate towards some fixed point in space. After a time, therefore, the wheel will apparently have changed its direction of motion and will no longer point north and south. It is not the wheel which has changed, however, but the earth. By making a small sphere and drawing lines upon it to represent the meridians, it will be very easy to understand this matter. Of course it is understood that the force of gravity will make the wheel to always rotate in a plane passing through the center of the earth, but this can in no wise affect the horizontal direction in which the wheel points.

CHAPTER XLVII.

AN ELECTRICALLY LIGHTED LAMP.

The electric spark is quite commonly used to ignite gas, as all readers are doubtless aware. For this purpose either the spark from the secondary of a rather powerful induction coil, or the direct spark caused by the breaking of an electric circuit in proximity to the stream of gas, may be used. The former plan has the advantage that the apparatus may be worked at a distance by the mere pressing of a button, while in the latter case the apparatus must be worked at the place where the light is desired. It has the advantage, however, that the apparatus required is simpler and cheaper than in the first case.

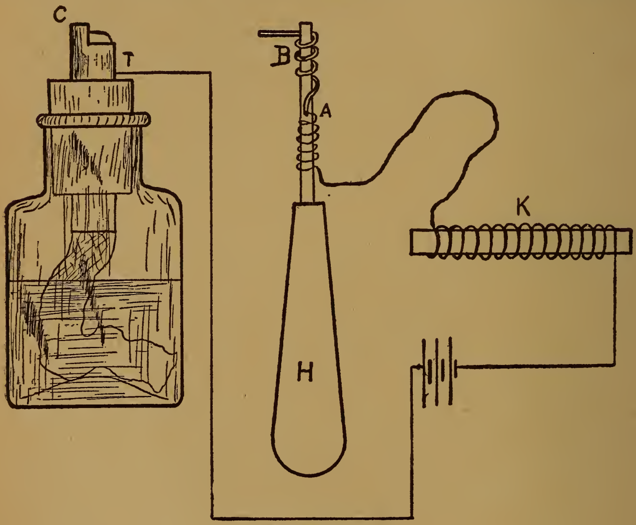
Not only may illuminating gas be thus ignited, but the vapor from highly inflammable liquids, like gasoline and alcohol is also easily lighted. Electric cigar lighters are made containing alcohol, and a wick, so arranged that the wick will burst into flame when a spark occurs near it.

The small alcohol lamp described in this chapter cost but little to make, and illustrates the principles involved very clearly, and may be of some practical use as well.

There will be needed first of all, a small wide-mouthed bottle, something like a horseradish bottle, but smaller. Those in which glue and paste are often put up are about the right kind. Fit to this a smooth cork. Through the center of this cork is to be fitted a brass or iron tube, long enough to project ½ inch above and below the cork, and about ⅜ inch in diameter. The brass tubes of which curtain fixtures are often made will answer the purpose. At the bottom the tube is cut square across, but at the top a lip is left projecting, as shown at C in the accompanying figure. Through the tube is to be thrust a circular wick such as are commonly used in torches.

At H is shown a wooden handle into which is fastened a metal rod, about 3-16 inch in diameter. An old button hook with the end cut off will answer very nicely. On the end of this rod is slipped a rather stiff metal spring, shown at B, with one end straightened, and projecting about ½ inch. The other end is coiled about the rod and is soldered to the latter at A.

At K is represented an ordinary spark coil, such as may be bought at dealer in electrical supplies. It can be made very easily however by an ingenious boy. Make a bundle of soft iron wires, the bundle to be about 12 inches long and ⅝ inch in diameter. The wires themselves should be not larger than No. 20, and should be very straight and uniform in length, so



Lights a Lamp.

as to form a very compact bundle. On this as a core, and carefully insulated therefrom, wind six layers of No. 14 double cotton covered magnet wire. The coil thus made is represesented merely at K.

Now connect one terminal of the coil to one terminal of a battery of three sal-ammoniac cells, the other terminal being connected to the brass tube at T. The remaining terminal of the coil is connected to the metal rod at A.

Now if the handle H be held in the hand, and the spring B is drawn firmly across the projecting lip at C, a heavy spark will be produced very close to the end of the wick. If the wick be saturated with alcohol this spark will be sufficiently heavy to ignite the alcohol. The bottle should be kept well filled.

In order to keep the wick moist, and to prevent waste of the alcohol, a small brass cap should be provided which fits tightly over the end of the tube when the apparatus is not in use.

CHAPTER XLVIII.

A SIMPLE ARC LAMP.

There are two kinds of electric lamps—incandescent lamps and arc lamps. The former are operated by sending a current of electricity through a very small thread of carbon contained in a glass bulb from which the air has been exhausted. The passage of the current through the carbon thread heats it very hot, so that it is capable of giving out light.

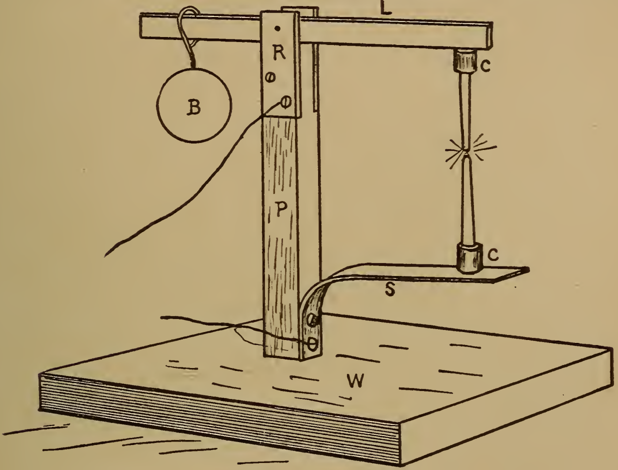
Arc lamps are operated by causing a current to pass between the tips of two carbon sticks, which are separated by a short space, usually about one-half inch in length. Ordinarily it is impossible to make an electric current pass from one body to another, unless the pressure be very great. But if two sticks of carbon connected to an electric circuit of proper strength be touched together and then separated by a short distance the space between them becomes filled with the vapor of carbon, through which the current will pass, at the same time heating the tips of the carbons to an intense white heat, which gives off a dazzling light.

As the carbons burn away it is ordinarily necessary to provide means for feeding them toward each other as fast as they are burned. This calls for a rather complicated arrangement of magnets and other devices. The amateur can construct a very simple arc lamp, however, which will illustrate the principles involved very nicely.

The arrangement of the lamp is shown in the accompanying figure. W is a wooden baseboard about 5 inches square. Near one end and on the center line of the base mount a square upright post P, 3 inches high and ½ inch square. To the upper end of this post is to be secured two flat pieces of brass shown at R, about 1 inch long, and projecting above the top of the post about ½ inch. These pieces are to form a support for a brass lever L, which is swung on a pivot which has a bearing in the strips R. This lever is 3½ inches long and the pivot is 1½ inches from the left-hand end of the lever. It may be made from a piece of sheet brass 1-16 inch thick and ¼ inch wide.

In order to support the carbons there will be needed two small brass sockets shown at C. These are made by taking a piece of very thin brass and curling it up into the form of a very short tube ⅜ inch long and ¼ inch in diameter.

At S is a piece of brass 1/16 inch thick, bent into the shape



The Arc Lamp

shown, and secured to the post at the bottom, so that the outer end of the spring projects 2 inches from the post.

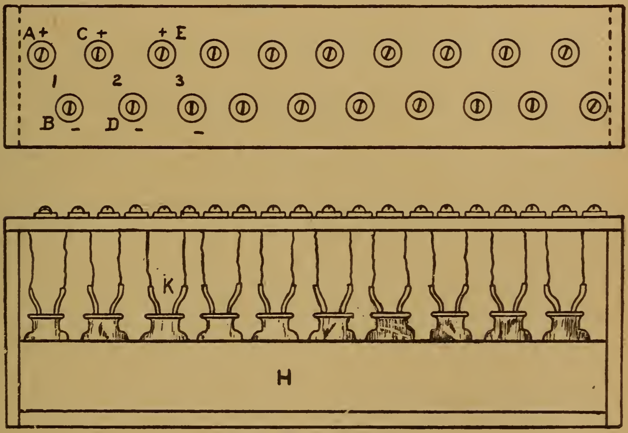
Near the outer end of the lever L and the spring S solder one of the little brass sockets just described. They should be equal distances from the post P when the lever L is horizontal.

Make a small lead weight, preferably in the form of a ball, as shown at B, provided with a hook so that it may be hung on the outer end of the horizontal lever. The lever should be so nicely pivoted that it swings very freely up and down. Take a piece of ordinary electric light carbon such as may be picked up in the street and break off two pieces about 1½ inches long. Put these pieces in a vise and file them down until they are each about ⅛ inch in diameter. Then insert them in the two sockets and the arc lamp is complete. The weight B should be so adjusted that it almost balances the weight of the carbons and lever, but not quite. Connection is made by wires running to R and S. A suitable battery for use with this lamp will be described in the next paper.

CHAPTER XLIX.

AN EXPERIMENTAL BATTERY.

In order to run the arc lamp described in the previous chapter, a battery will be required capable of giving a rather high electro motive force and a considerable current. At least ten cells ought to be used, and if we try to construct bi-chromate or similar cells we would find it a costly and troublesome task. A simple storage battery may be easily



Simple Storage Battery

constructed which is capable of doing a number of interesting experiments and the cost is insignificant.

The jars for containing the fluid for our storage battery are made of empty horseradish bottles. The amateur can arrange to make as many cells as he sees fit, but at least ten will be required for our experiment. They are arranged in a long wooden trough shown at H in the accompanying figure. This trough is provided with upright strips at the end about ten inches high, across the top of which is a smooth flat board. The material of which this trough is made should be at least ⅞ inch thick.

Each cell is composed of two strips of thin sheet lead immersed in a solution of sulphuric acid. The strips of lead are about ½ inch wide and are long enough to project 2 inches above the top of the bottle. These are shown at K. To the upper ends of these strips are soldered pieces of copper wire such as bell-hangers ordinarily use. These wires are for the purpose of making connections with the various cells. The strips of lead are prevented from touching each other by a strip of wood which fits tightly in the center of the neck of the bottle and is long enough to touch the bottom. The liquid used in the cell is a solution of sulphuric acid in water. The proper proportion is one part of acid to twelve parts of water, and the mixture should be made by pouring the acid slowly into the water. The bottles should then be filled about ¾ full of the liquid, the lead strips inserted, and the wooden strips pushed into place between them.

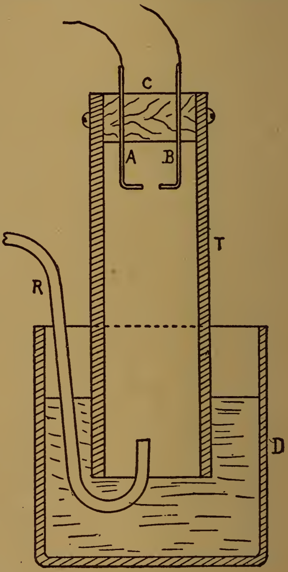
We are now ready to arrange the connections of our battery. On the top of the wooden strip are mounted small copper washers as shown at A and B. These copper washers are arranged in two rows of ten each, and are secured by a small screw passing through the washers into the wooden strip. The terminals of cell No. 1 are connected to A and B. The terminals of cell No. 2 are connected to C and D, and the other cells are connected in a similar manner. When all connections are made the cells are ready for charging.

In connecting the cells for charging, all the copper washers in one row should be connected together by a strip of thin sheet copper and this strip is then connected to one terminal of a battery of three gravity cells connected in series. The other row of washers is similarly connected together by a second strip of copper, and this strip is connected to the other terminal of the gravity battery. An inspection will show that the cells are then all connected in parallel, and three gravity cells ought to give them a sufficient charge in one week, at the start. After this first charge they will charge enough over night to do considerable service the next day. After the cells are charged, the cells are all connected in series. This is done by removing the two copper strips just mentioned, and by connecting posts B and C, D and E, etc. When the cells are thus arranged in series, the electro-motive force of each cell is added to its neighbor, and the combined electro-motive force of the whole battery is considerable. The capacity of the cells as constructed is not very great—that is, they will not yield a current for a great while at a time, but nevertheless, many interesting experiments may be performed by their aid.

CHAPTER L.

HOW TO MAKE AN ELECTRIC BOMB.

When a mixture of an inflammable gas is ignited there results a violent explosion. This is made use of in the gas engine, so common at the present time. There must always be both air and gas present in the mixture, or there will be no explosion, on the same principle that a fire will not burn unless it can have air. Moreover, it is found that there must be a definite relation between the amounts of air and gas, to secure the best results. It is found that with ordinary illuminating gas, the proper proportions are 7 parts of air to 1 part of the gas. A mixture differing slightly from the above will explode fairly well, but no great variation from the above proportions is possible.



The mixture may be exploded by contact with a flame, or better still, by passing through it an electric spark. Both of these methods have been made use of in the gas engine, although the use of the electric spark is fast superseding all other methods. The present chapter deals with the construction of a small electric bomb, which illustrates many important principles.

Take piece of ordinary iron pipe, 4 inches long and 1¼ inch in outside diameter. Turn the ends off smooth and true, and fit to one end an ordinary wooden plug, about ¾ inch thick. This plug should fit tightly, and should be turned out in a lathe, and it is well also to turn out the inside of the pipe where the plug is to fit in, in order to ensure a perfect fit.

Through the plug insert two short pieces of stiff brass wire, about two inches in length, bending the inside ends of these pieces toward each other, so that there is about ¼ inch clear space between them. Then insert the plug in place, first brushing it over with a layer of shellac, and fasten it in place by means of screws passing through the pipe and into the plug.

The bomb is now ready for filling with the explosive mixture. The surest way of doing this is indicated in the accompanying figure. Fill the pipe with water, and holding a piece of paper or the palm of the hand over its mouth, invert it in a dish of water, the mouth being submerged. Then remove the piece of paper, and if the plug at the top fits tightly, the bomb will remain filled with water, even though inverted. Attach a rubber tube to a gas jet, and place the open end of the tube in the water, and directly in the mouth of the inverted pipe.

Upon turning on the gas, bubbles of gas will rise through the water, the level of the latter will fall in the tube, and of course the outer containing dish will fill up. These operations cannot be seen through the pipe, and it may be well to take an ordinary horse-radish bottle, and experiment with that, just to see what takes place.

When the pipe is ⅛ full of gas, the latter should be turned off, and air forced into the pipe. The experimenter can tell how full the pipe is, by observing the rise in level in the water in the outer dish. A preliminary trial will enable the experimenter to tell just how much the level must rise in order to fill the pipe to any given height.

When forcing in air, use a bicycle pump, as the use of the lungs will force in a lot of carbonic acid gas, which will hinder combustion.

Having filled the bomb, hold it with its mouth still under water, and insert a rather tight fitting cork. It may then be removed from the water, but if the cork does not fit tightly, it must still be kept bottom side up.

If the two wires A and B are connected with the terminals of an induction coil capable of giving a ¼ inch spark, the passage of the spark will ignite the mixture, producing a violent explosion. The experiment can be varied by using powder instead of gas, but of course the explosion of a bomb of this size filled with powder would be exceedingly dangerous.

The two terminals, A and B could be connected by a piece of very fine wire, so small that it would be heated very hot by the passage of a current from a battery. In this case no induction coil would be needed, but considerably more labor is involved, as the wire will have to be replaced each time. Both of these methods are made use of in the construction of submarine mines in time of war.

CHAPTER LI.

HOW TO MAKE AN ELECTRIC ENGINE.

The present chapter deals with the construction of a small electrical engine, which, while it is a toy, will be a source of amusement to the mechanically inclined youth. All the difficult parts of the machine may be obtained by dismantling an old brass clock. A wealth of material is available from such a source in the form of wheels, pinions, shafts and strips of brass and of steel.

A side view of the engine is given in Fig. 1, and a plan view is given in Fig. 2. At the left in Fig. 1, is shown an electromagnet. This is made from a round piece of iron rod, ½ inch in diameter, bent into the shape of the letter

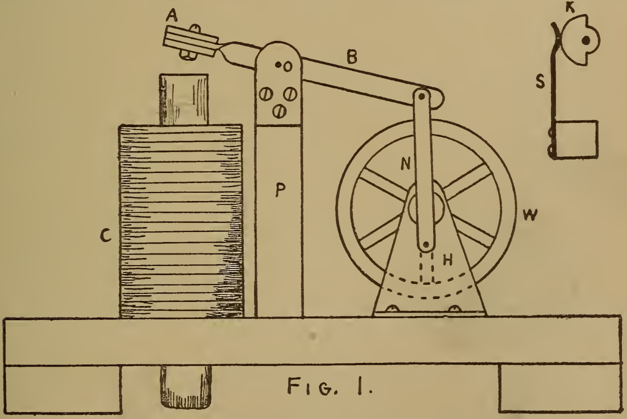


FIG. 1.

U, each of the arms being 3½ inches long, measured from the extreme bottom. On each arm wind a coil of insulated wire, so as to form a bobbin 2 inches long and 1¼ inches in diameter. These had better be made of number 24 double cotton covered magnet wire of which about 4 ounces will be required. Carefully insulate the iron core by a layer of paper, before winding the wire, and provide also circular wooden ends for the coil, which fit tightly upon the iron core, and hold the wire in place. The end of core should project ½ inch beyond end of coil.

Make a base board by taking a piece of smooth pine, or whitewood, ½ inch thick, 6½ inches long and 3⅝ inches wide. Across each end screw two strips to keep the base from warping. Mount the magnet so that its center is 1⅞ inches from the left hand end of the base, securing it in

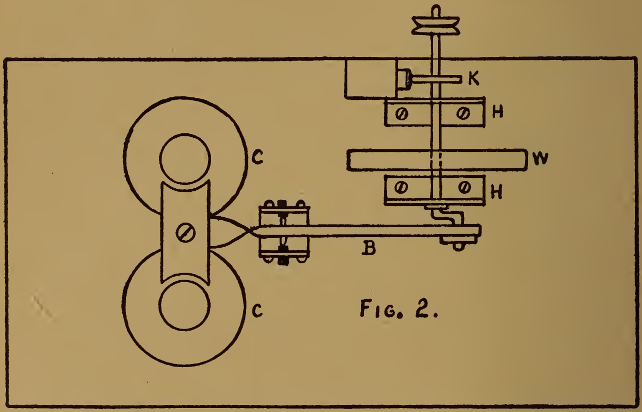


FIG. 2.

place by a block screwed to the base, the lower part of the iron core being fitted into a slot cut in the base.

At a distance of 2⅞ inches from the same end of the board, and in the center, mount very firmly a post, 2½ inches high and ½ inch square. This is shown at P.

Having procured an old clock, cut with a file, two strips of brass, these strips being cut from those portions of the frame which hold the little steel bearings upon which the balance wheel rests. These strips should be one inch long, and cut so that the bearing is ¼ inch from one end. Screw these strips to the opposite sides of the square post, so that the bearings are exactly 2⅝ inches above the base board, and exactly in line.

The beam shown at B is 3 inches long, and ¼ inch wide. At one end, the strip is twisted around at right angles, by clamping securely in a vise, and twisting it with a wrench, placed at a distance of ½ inch from the end.

At a distance of 1¼ inches from this end, is to be fixed a pivot which is to fit exactly into the two bearings in the top of post P. Possibly a strip of brass may be cut out from the frame of the clock, which will have a hole in it at just the right place. Drive the balance wheel off from its shaft, and drive the latter tightly into place in the hole B, and adjust by filing, until the beam may be mounted in its bearings and swing very freely up and down.

At the twisted end is to be mounted strips of soft iron shown at A, cut so as to fit as closely as possible into the space between the two limbs of the magnet, when the beam moves up and down.

At the right hand end of the beam is to be pivoted an arm N, which is to take hold of the crank upon the shaft of motor. This arm is 1¾ inches long and should move very freely. The pivot which holds it should be very freely fastened to B, soldering it if necessary.

The wheel W may be made by taking one of the larger wheels of the clock, and casting a lead rim around it. Because of lack of space the amateur will be left to his own devices to accomplish this.

The shaft upon which the wheel is mounted turns in two upright pieces of brass shown at H. The center of shaft should be 1⅛ inches above the base, and is at a distance of 4 7-16 inches from the left hand end of the base. The crank has a throw of ⅜ inch.

At the back side of the shaft is mounted firmly a piece of of brass cut in the shape shown at K. This piece has bearing upon it a spring S, so adjusted that the electric circuit through the coils is closed while the armature A is moving downward, but opens the circuit as soon as the armature reaches its lowest point and begins to move upward. Thus the magnets are excited, and pull on the armature while it is moving downward, but cease to pull while it moves upward. Some adjustment of the contact strip K may be necessary at first, but it may then be soldered permanently in place. Three cells of gravity battery ought to run the motor at a good rate of speed.

CHAPTER LII.

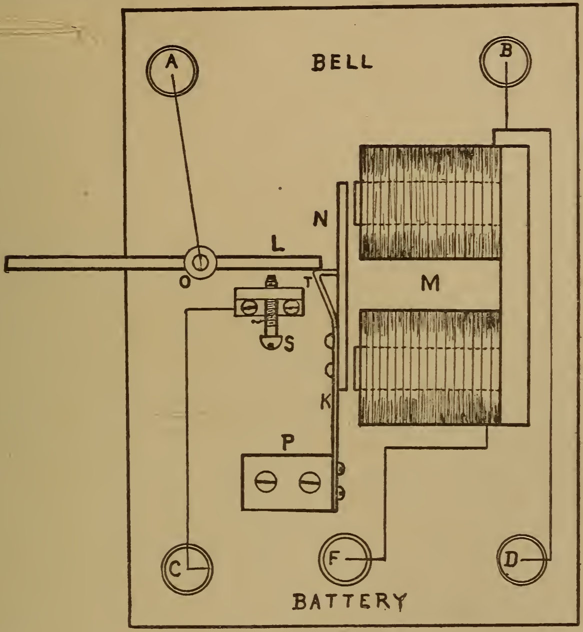
AN AUTOMATIC CIRCUIT CLOSER.

Sometimes it is desirable to so arrange a curcuit, normally open, that when once closed it shall stay closed even though it be opened again at one point. For instance, an electric door bell may be so arranged as to ring continuously when once the push button is pressed even though the pressure is but instantaneous. Or, an electric alarm clock may be desired to work in conjunction with an ordinary electric bell so that the alarm once started will ring continuously unless stopped by some one.

One way of accomplishing these results is to use an automatic circuit closing device such as is shown in the accompanying sketch. Take a piece of ¾-inch board 4 inches wide and 5½ inches long. Upon this board is to be mounted an electro magnet shown at M. This magnet is so simple that directions for building it will not be given. Its principal dimensions, however, are as follows. The length between centers of cores is 1½ inches, the length of core is 1¼ inch, the diameter of the latter is ⅜ inch and the outside diameter of coils is 1 inch. They are wound of No. 32 double silk covered magnet wire. Fine wire is used so that the magnet will have a high resistance for a reason that will be explained later. The center of the magnet is 2½ inches from one end of the board and about ½ inch clear space is left between the back of the magnet and the edge of the board.

At N is a soft iron armature about 3-32 inch thick. It is fastened to a thin brass spring shown at K. As will be seen, this spring projects about 1⅛ inches beyond the armature and is supported at its outer end by being screwed to the wooden block P. At its upper end the brass spring is bent up into a peculiar hook projecting about 3-16 inch outward from the middle of the armature.

Next provide a brass lever shown at L, about 2¾ inches long, ⅛ inch thick and ¼ inch wide. This lever is pivoted at O, at a distance of about 1⅛ inches from the nearer end of L. This is accomplished by boring a small hole through the piece and passing a screw through this hole into a block supported upon the wooden base. The lever should be so located upon the base that its end rests upon the hook shown at T when the armature N is farthest from the magnet core. When the armature is drawn toward the core, however, the lever L should slip from the hook and strike against a screw S which



The Automatic Circuit Closer

is supported by a strip of brass bent over at right angles and fastened to the base board.

Five binding posts are provided in the position shown and the connections for the various parts of the apparatus are shown by lines. The bell to be rung is attached at the top, the battery is connected to the posts C and D, and the push-button, or other circuit closing device is connected to posts C and F. It is assumed that the apparatus is to be supported in a vertical position. If connections are made as just indicated, the pressing of the button connecting C and F will send a current into the binding post D, from there through the magnet to the binding post F, thence to C, and to battery again. This will draw the armature N toward the magnet and allow the lever to fall against the screw S. The current will then have another path from the post D to B, through the bell to A, from A by means of the lever L to S, thence to the binding post C and battery. This will cause the bell to ring continuously, even though the connection between C and F be broken. The ringing can be stopped by pulling down on the projecting part of the lever L.

An ordinary alarm clock may be easily arranged to close an electric cuircuit when its own bell rings, and this in turn may start another bell by means of the device just indicated, which will ring until stopped by some one.

The device might also be applied in a very simple manner to a burglar alarm system.

CHAPTER LIII.

A MODEL FIRE ALARM TELEGRAPH.

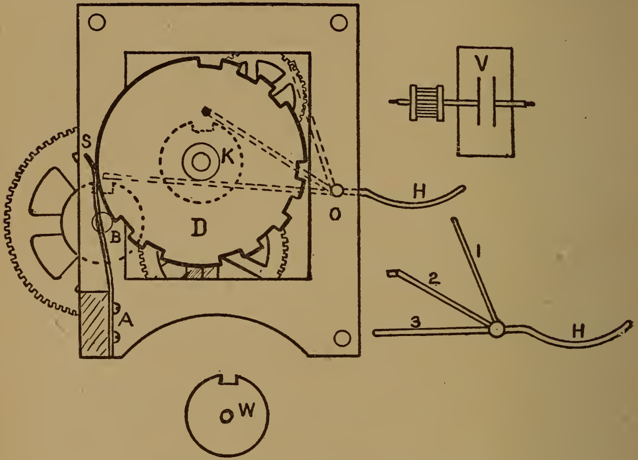
PART ONE.

All modern fire alarm systems depend for their action upon some form of clockwork, which in connection with the electric current, operates the bells or whistles which give the alarm. This might be done in two ways—either by causing the clock-work to close an electric circuit in a special manner, causing the bells to sound each time that the circuit is closed, or by employing the clock-work to break an electric circuit, normally closed, the breaking of the circuit causing the bells to strike. This is the method usually employed in modern systems, for the reason that if a wire breaks or any part of the circuit is accidentally opened, the break is noticed at once, and can be immediately repaired.

It is easy to make a model fire alarm system using the works of an ordinary brass clock. This chapter and the following, will describe now to make such a model. On account of the varying sizes met with in different clocks, it is hard to give exact dimensions, but the ingenious reader will easily grasp the main principles, and modify his model to suit the material on hand. A diagram is given below. In this diagram the frame-work and wheels of a simple clockwork are sketched. It is better to use a clock which is provided with a spring and train of wheels for striking the hour, but the description given assumes that this is not available.

Carefully remove the balance wheel and escape lever from the clock. As soon as this is done, the clock will immediately run down at high speed unless care be taken to secure the wheels so that they cannot turn. The first thing to do is to fasten a vane to the shaft of the smallest wheel remaining, such as is shown at V in the figure, the action of which is to prevent the clock from running down too fast. This vane may be made of very thin copper or brass, and need not be fastened very firmly to the shaft, the only requisite being that it shall not slip on the shaft when the latter turns. It should be of such size that the shaft which carries the minute hand of the clock, (that is the long hand), shall make one revolution in about half a minute.

Remove the gear wheel which carries the shorter hand of the clock, and fasten to the shaft which ordinarily carries the minute hand, a brass disc shown at D in the figure. This disc is 2 inches in diameter, and at least 1-16 inch



Clockwork Mechanism of Fire Alarm

thick. Notches are cut in this disc as shown, the notches being 3-16 inch wide, and the space between them is of the same width. Starting at the part of the disc which is uppermost, cut three such notches, properly spaced, then leave a space of ⅝-inch and cut four notches, then another space of ⅝ inch, and finally cut two notches, giving the disc the appearance shown.

Cut out two discs like that shown at W, ¾ inch in diameter, and 1-16 inch thick. One of these is to be secured to the main driving shaft of the clock, the other to the shaft of the clock, the other to the shaft which carries the disc D. They should be so fastened that the notches which are cut in them shall stand exactly vertical above their respective shafts, at the same instant of time. These discs must be firmly fastened in place, preferably by soldering.

A hook shown at H must now be made, from a piece of rather stout brass wire. This hook is secured by soldering, to a straight piece of brass rod, which is cut of such a length that it may be pivoted in the frame work of the clock, as shown at 0. To this shaft are secured three other arms, which may be of light brass wire, in substantially the position shown.

The object of the three peculiar arms is this. Arm No. 1 is designed to strike against the vane V on the small wheel of the clock, preventing the wheels from turning. Arm No. 2 is designed to drop into the slot on the middle wheel of the clock, when the slot is in a vertical position relative to its shaft. Arm No. 3 is designed to fall in a like manner into the slot on the main shaft. Now if the two discs have their slots vertical at the same time, the arms No. 2 and No. 3 will fall into their respective slots, and arm No. 1 will strike against the vane, preventing the clock work from turning. If, however, the hook H be pulled down, arm No. 1 should clear the vane V, the wheels should turn, and arm No. 2 will ride on the edge of its disc, while the shaft K turns.

When the shaft K has made one revolution, the arm will try to drop into its slot, but will be prevented from doing so because arm No. 3 cannot fall. The clockwork will turn until both slots again become vertical.

At A is secured a block of wood, and fastened to it is the spring S which bears firmly against the surface of the wheel D, except when a slot passes under the spring, when the latter should break contract with the disc.

The remainder of our apparatus will be described in the following chapter.

CHAPTER LIV.

A MODEL FIRE ALARM TELEGRAPH

PART TWO.

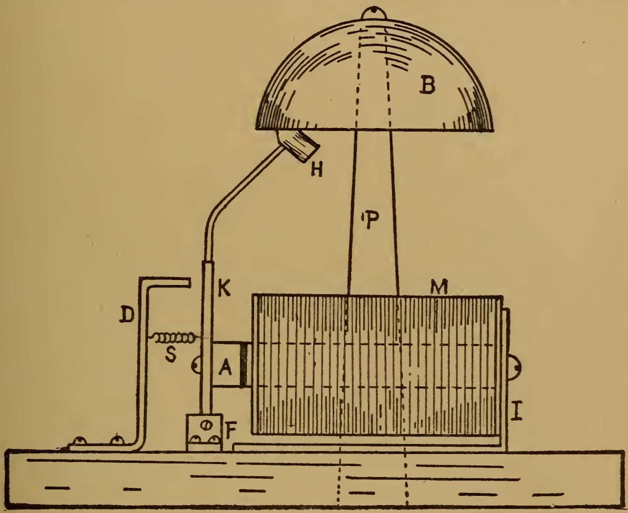
In the preceding chapter we described the arrangement of train of clockwork, so designed as to interrupt an electric circuit in a regular manner. This clockwork was arranged to be set into motion by means of a hook, which was to be pulled down in a manner similar to the fire alarm boxes used in all cities. The amateur can easily design a box for himself, to hold this clockwork, with the starting hook protruding from one side. In this chapter we shall see how to make a bell to work in conjunction with the clockwork.

First of all we shall need a piece of thin sheet iron, very soft, whose length is 3¾ inches, width 3 inches, and whose thickness in 1-16 inch or thereabouts. This is bent over at right angles at a distance of 1¼ inches from one end, as shown at I in the accompanying figure. This piece of iron serves as a support for two coils of wire upon iron cores, forming an ordinary electro-magnet. A side view of this magnet is shown in the figure. The iron cores are ⅜ inch in diameter, 2¼ inches long, and are spaced so that their centers are 2 inches apart, and at a height of ¾ inch above the bottom of the iron strip first mentioned. Drive tightly upon the iron cores some circular brass heads, one close to each end, to hold the magnet wire in place which is to furnish the exciting power to ring the bell by means of an electric current. The brass heads are 1¼ inches in diameter. Having carefully covered the iron cores and the brass heads with heavy paper, so as thoroughly insulate them, wind each bobbin full of No. 24 double cotton covered magnet wire. About ½ pound will be required for the two spools.

An iron armature shown at A must be provided, consisting of an iron strip 2¾ inches long, ⅜ inch wide, and of any convenient thickness. It is fastened transversely at its center to a small strip of brass, shown at K, whose length is

1⅝ inch, and is thick enough to be quite stiff. This strip is pivoted between two small upright supports one of which is shown at F. When exactly vertical, the strip K should leave a clear space of 1-64 inch between it and the iron cores, this space being left so that the ends of the cores may be covered with small pieces of paper glued in place with shellac. These pieces of paper are to prevent the armature from touching the cores.

At D is a stiff piece of brass, which serves two purposes.



Fire Alarm Telegraph Bell

First it serves as a support for the spiral spring S, which draws the strip K toward the left. Secondly, it serves as a stop for strip K, preventing it from going too far toward the left.

To the upper end of K is fastened a wire, which carries at its upper end a rather heavy piece of brass, to serve as a hammer for the bell B. The amateur will be able to secure an old gong of some kind, perhaps from a clock. As the dimensions of these bells will vary, the reader will have to adjust the position of the hammer H, and the gong, to suit his individual case. When the strip K moves to the left, and brings up against the end of D, the hammer H should just barely clear the inside of the bell. Then when the hammer moves swiftly, its momentum will be sufficient to cause it to strike the bell sharply, and then bound back, allowing the bell to give a sharp, clear tone.

The supporting base for the whole arrangement is made of a piece of smooth pine or whitewood. The post P is mortised firmly into the base, passing between the coils of wire. The post is about 4¼ inches in height.

The bell and clockwork are to be joined in series with three cells of gravity battery. Connection is made with the insulated spring on the clockwork, and to the brass frame of the same. As arranged, the number of the box to be struck is 243. When the circuit is closed by the clockwork, the armature A should be drawn against the cores. When the circuit is broken, it should spring away, striking a sharp blow on the bell.

CHAPTER LV.

HOW TO MAKE A LARGE INDUCTION COIL.

PART ONE.

While the induction coil to be described in the following chapters would not be classed as a large coil by manv manufacturers, yet it is much more powerful than the amateur ordinarily meets with. It is capable of furnishing a spark four inches in length, representing an electromotive force of something like 160,000 volts. Such a coil will excite an X-ray tube quite well, and will operate satisfactorily in wireless telegraph work also.

It is assumed that the reader is already familiar with the essential parts of an induction coil. As is well known, such a coil consists of a primary, surrounding an iron core, and a secondary coil surrounding both the primary and the core,

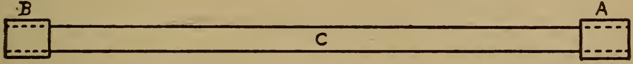


Fig. 1.

but securely insulated from both. In our coil, the principal difficulty will be to properly insulate the secondary coil, against the high voltage generated within itself.

To make the primary coil, we shall need first, a smooth, firm core composed of a bundle of soft iron wires, 12¾ inches long and ½ inch in diameter. The separate wires composing this bundle should be about No. 20 B. & S. gauge, and should be very soft and straight. Fit tightly to the ends of this bundle two wooden ends, made by turning from maple or other tough wood, two thimbles of the shape shown at A and B in Fig. 1. Each end-piece is 1 inch in length, ¾-inch in external diameter, and ½-inch in internal diameter. They should slip tightly upon the iron core. As this involves quite a stress upon the ends, it may be well to turn two or three grooves in the outer surface of each, in which strong binding strings may be wound, to prevent splitting.

Now cover the central portion of the core with a layer of paper, fastened on with shellac. Then wind in this space two layers of No. 16 double cotton covered magnet wire. This will make a primary coil whose external diameter is ¾-inch, and whose length is 12¾ inches.

Secure from a stationer, one of the ordinary tubes used for sending pictures through the mail. This tube should be 1¼ inches in external diameter, and of the same length as the core. We wish to secure the primary coil, with its core, in the center of the pasteboard tube, and there to fill the intervening space with an insulating mixture. Accordingly the tube should be closed at one end by a piece of heavy pasteboard glued in place, and then held in a vertical position, with the closed end downward.

Carefully insert the primary coil into the center of the tube, while vertical, and then pour into the tube, a mixture made up of melting 4 pounds of rosin with 1 pound of beeswax. This mixture should be poured in hot, and the tube left undisturbed until it is cold. However, when the mixture cools it contracts, and as fast as it contracts mor mixture must be poured in so as to keep the tube full. When these operations are complete, we shall have a primary coil completely encased in a layer of wax, except at the ends, the whole being encased in a pasteboard tube. The latter should be given a thorough coat of shellac, and set aside to dry. A section of the finished primary is shown in the lower part of Fig. 1. The ends of the coil should project from one end for a distance of about six inches.

In our next chapter we shall describe how to make the secondary of our coil.

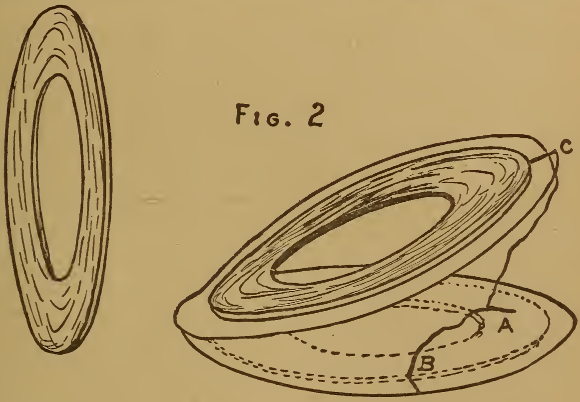
CHAPTER LVI.

HOW TO MAKE A LARGE INDUCTION COIL.

PART TWO.

In the previous chapter directions were given for the construction of the primary of our coil. The secondary will next receive our attention. The primary consists of a comparatively few turns of coarse wire, while the secondary consists

Fig. 2



of a very great number of turns of fine wire. Each turn of the secondary has generated within it an electromotive force, and as the latter must be very high, this necessitates a large number of turns.

The secondary cannot be wound in one large continuous coil. If we did this, the electromotive force would be so great as to strike through the silk insulation upon the wire, rendering the coil inoperative. The coil is made up of a number of disk-like sections such as is shown at the left in Fig. 2. The sections are placed side by side, with insulating material between them, and each section is connected in series with the next, so that the effect is the same as if the coil were wound in the ordinary manner.

In order to wind the sections a special winder will be required. A suggestion as to the method of construction is given in Fig. 3. A and B are two circular pieces of wood, 3¼ inches in diameter. Between them is another circular piece 1⅝ inches in diameter and 3-16 inch thick. The three pieces are tightly screwed together, with their centers coincident. The inner faces of A and B, and of the center piece, must be smooth and true, so that when the screws are tightened up the three pieces will fit perfectly together. They are to be mounted upon a shaft supported in suitable bear-

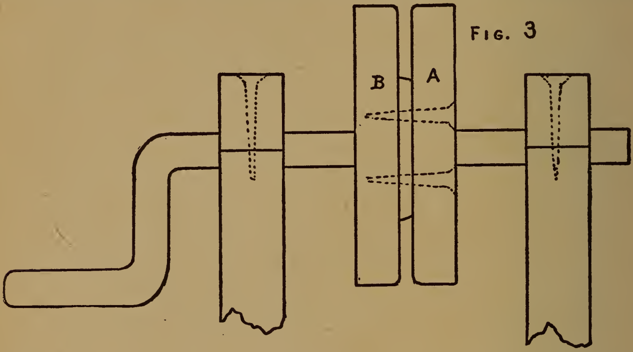


FIG. 3

ings and provided with a crank, so that wire may be wound upon the central portion. The disc A may fit loosely upon the shaft, but B should fit tightly so as to turn with the shaft. For this reason B should be rather thick and should preferably be of hard wood. The disc in the cutter should be tapered, the smaller end being next to A, so as to permit the coil, after it is wound, to be easily removed.

Having made this rather crude winding device, we are ready to wind the sections of the coil. For this purpose we shall need about 6 pounds of No. 34 single silk covered magnet wire. Each small section consists of 1,500 turns, wound as tightly and as evenly as possible.

In winding, support the spool upon which the wire is bought in some convenient place, and arrange it so that the wire, in passing from this spool to the winder, shall dip into a dish containing melted paraffine wax. This can be done by using a rather deep dish for melting the wax, with a spool immersed in the melted wax, under which the wire runs in passing to the winder.

Using the apparatus shown in Fig. 3, wind eight sections, each having 1,500 turns. Each section as it is wound can be carefully removed from the winder without damaging the turns of wire. To prevent the coil from sticking to A and B, two thin disks of paper may be placed against the inner faces of the pieces, and may be lightly glued to A and B at three or four points around the edge.

After each section is removed wrap a strip of thin tissue paper around the coil at three or four points, fastening the strip by a bit of wax to prevent the coil from unwinding or losing its shape.

Having made eight sections of the dimensions given above, remove the disc in the center and substitute therefor another disc two inches in diameter and slightly tapered as before. This will make a section with a larger hole in the center, but exactly like the preceding in general shape. Then make 18 of these sections, each section being of 1,000 turns.

We will continue our discussion in the following chapter.

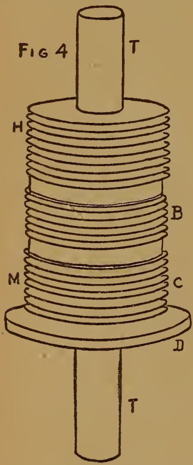
CHAPTER LVII.

HOW TO MAKE A LARGE INDUCTION COIL.

PART THREE.

After the various sections of the induction coil are wound, as described in the last chapter, they must be connected together or "stacked." Each section is connected in series with its neighbor, and the turns are so connected that the current will go around each section in the same direction. Between the sections are two rings cut from heavy manila paper, the outer diameter of the rings being four inches. Three rings separate the sections, and prevent a spark from passing between the sections.

Fig 4



Take a piece of board about ⅞ inch thick, and cut a circular piece 4¼ inches in diameter. Through the center bore a hole, which shall be large enough to admit the pasteboard tube containing the primary, and make a tight fit. This piece of wood is seen at D in Fig. 4, with the tube projecting at T for a distance of three inches.

The method of stacking the sections is indicated in Fig. 3 of the preceding chapter. Beginning with the bottom section, lay upon it one of the paper rings already mentioned. The bottom section should be one of the eighteen sections of 1,000 turns. Cut a little slit in the edge of the paper ring, in as far as the wire, and through this slit pass the terminal of the wire. Now on top of this lay another paper ring, with its slit turned around so as to be 90 degrees from the first slit. On top of this place the second section, passing its terminal through the proper slit, and connecting it to the terminal of the first section with a small, soldered joint. Proceed in a like manner with all the sections, taking care to have two paper rings between each section, and to have the joints between the wires as far from each other as possible.

The "stacking" is to be begun upon the board D, Fig. 4, as a base, the sections being piled up around the primary. Between the first section and D is to be placed a wooden ring whose outside diameter is 3⅜ inches, and whose thickness is ⅝ inch. After piling up nine of the smaller sections, insert another wooden ring whose thickness is ⅜ inch. Then put the larger sections (those containing 1,500 turns) into place. Above these place another wooden ring ⅜ inch thick, and above this the remainder of the 1,000 turn sections. The

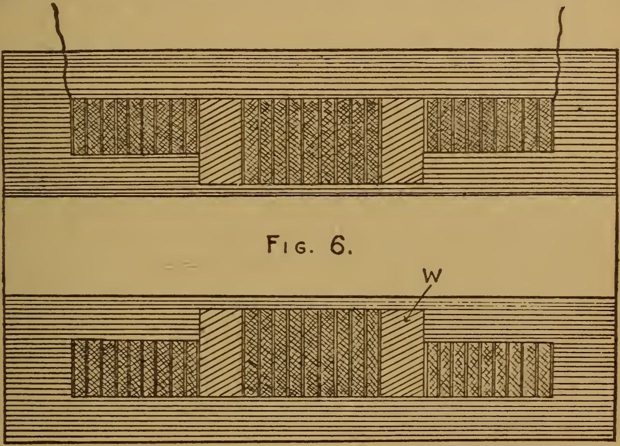


FIG. 6.

wooden rings used should be thoroughly dried in an oven and then well soaked in boiling hot paraffin wax before being used.

The two terminals of the finished secondary may be brought out at the ends, one through a small hole in D, the other being left sticking straight upward. Now select a piece of heavy wrapping paper, and of it make a stiff tube which shall surround D and the coils which it supports. This tube is to be filled with melted wax, so it must make a tight joint with D. A string wrapped tightly about it will help make the joint tight.

Now make up a mixture by melting together four pounds of rosin and one pound of beeswax. When this mixture is hot, pour it into the tube containing the sections. A heavy weight should be placed on the sections to keep them from floating, which may be removed when the wax is nearly solidified. The wax should extend above the top of the sections for a distance of ⅝ inch. As the wax cools it contracts, and more hot wax must be added from time to time.

A section of the finished secondary is shown in Fig. 6, the primary being removed. The outer paper tube, as well as D, is removed, as they are only temporary. Also the wooden ring nearest D is removed by chipping away the wax, and its place filled by pouring in hot wax.

One of the interior wooden rings is indicated at W.

CHAPTER LVIII.

HOW TO MAKE A LARGE INDUCTION COIL.

PART FOUR.

Having made the primary and secondary coils, they must next be mounted in a suitable framework and provided with some form of interrupter for making and breaking the primary current.

The supporting framework should preferably be made of well-seasoned mahogany, although any wood capable of taking a good finish will do. A base should first be made whose length is 18 inches, and which is 8 inches wide. To prevent warping, it is best to dovetail a strip of wood across each end, or else make the base of two boards glued and screwed together, with the grains of the pieces at right angles.

Two upright pieces of wood will be needed, each five inches square and three-fourths of an inch thick. Through the center of each bore a hole which will just fit the primary tube. Then the latter may be slipped into the upright pieces, one at each end, and the uprights screwed to the baseboard, thus securing the coil firmly to the base. The position of the coil is shown in fig. 7.

The binding posts should be provided to receive the terminals of the secondary. They should be mounted on two hard-rubber blocks, as shown at R, and then the latter are fastened to the upright strips.

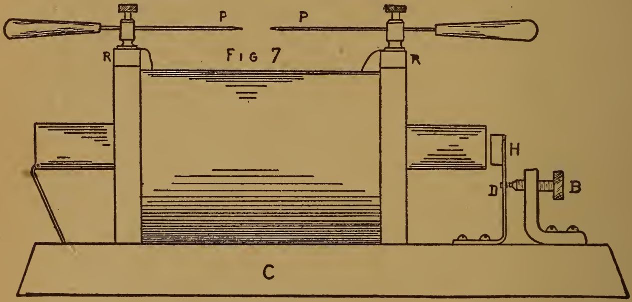
Two straight pieces of brass wire about 6 inches long, shown at P, should be made. They should slip easily through the holes in the binding posts, but should not be loose enough to "wobble." Each must be pointed at one end and provided with a handle of hard rubber at the other.

An interrupter of the well-known hammer type is shown at the right. A rather limber brass spring is provided with an iron armature, H, the spring being of such a length that H is directly opposite the end of the iron core of the coil. The end of the latter should just come flush with the end of the tube. There should be about one-eighth of an inch space between H and the core.

At D, about one inch below the center of H, a small hole is drilled in the brass spring, and a piece of small platinum wire riveted into the hole. The screw, B, which rests against D, is also tipped with platinum, and it is supported by a very stiff piece of brass.

One end of the primary coil is connected to a binding post (not shown), and the other end to the spring which supports H. Then B is connected to a second binding post on the base.

When a battery of five bichromate cells (large size) is



connected to the instrument, the hammer, H, should fly rapidly back and forth, breaking the primary circuit at D.

In order to work well, however, a condenser must be bridged across the spark gap at D. This condenser may be made by taking about 100 sheets of tin foil 5 inches by 7 inches and stacking them up with a sheet of paraffined typewriter paper (thin) between them. Every odd numbered sheet is connected together, forming one terminal of the condenser. The even numbered sheets, connected together, form the other terminal. The condenser should be clamped tightly together.

When provided with a condenser as described, the coil should give a four-inch spark without difficulty.

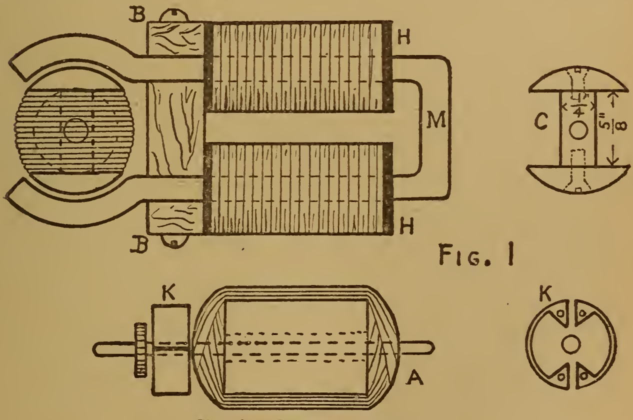
CHAPTER LIX.

HOW TO MAKE AN ELECTRIC LOCOMOTIVE.

PART ONE.

Any ingenious boy can readily construct a model electric locomotive which will be the source of much pleasure and instruction as well.

The main outlines of the motor to be used are shown in



Showing Outlines of Motor.

the accompanying figure. It consists of three main parts, the field magnet M, the field coils H, and the armature A. The field magnet M is made up from strips of thin sheet iron, such as may be bought at any stove dealers. This iron is cut into strips about 9 inches long and 1⅛ inches wide, and about eight strips of this size will be required. In order to bend these strips into the shape shown in the figure, it is best to make a wooden form the shape of which is exactly the shape of the interior space between the limbs of the magnet. This space is circular at one end as shown and the diameter of this circular space is 1⅛ inches. The length of the interior straight portions is 2¼ inches. Clamp the wooden form in a vise and bend the iron strips around it one at a time, until they all conform exactly to the shape shown in the figure. Provide blocks of wood shown at B, of which the upper is 2¼ inches long, the middle one being of the same length, and the lower one being 3½ inches long. By means of brass screws passing from the upper and lower blocks into the middle block, the strips of iron may be tightly squeezed together into a solid mass.

The field coils shown at H are 1½ inches long and surround the iron core to a depth of ¼ inch. It is best to make up a small form from thin sheet brass or copper which shall have the dimensions of the finished coil, and upon which the field coils may be wound and afterwards slipped into place. If this is done, however, the coils must be finished and slipped on before the circular space at the end of the magnet is formed. The wire used should be No. 24 double cotton covered, and about 4 ounces will be required. Be very careful to insulate all metal parts by covering them with a layer of paper before winding on the wire. The coils are connected in series in the ordinary manner.

Passing now to the armature, we come to a more difficult matter. The shape of the iron part of the armature is shown at C. It consists of three parts—a rectangular central portion ¼ inch thick, ⅞ inch long and ⅝ inch wide. To the narrow faces of this block are to be fastened the two circular end portions, by means of flat-head iron screws passing through the outer pieces into the central block. These circular pieces of iron should be of such dimensions that when bolted together the armature should have an outside diameter of exactly 1 inch, and the length of these outer sections is 1⅛ inches. Thus an iron core will be formed whose length is 1⅛ inches, whose diameter is 1 inch and which has a groove ⅝ inch wide running lengthwise around the core. In the exact center bore a hole lengthwise through the core, ⅛ inch in diameter. Into this drive tightly a shaft 2⅜ inches in length and perfectly straight. Now wind the slot in the armature core full of No. 24 magnet wire carefully insulated from the iron core.

A commutator must now be made, shown at K, and consisting of a circular hardwood block ⅝ inch in diameter and 5-16 inch thick, on the outer surface of which are fastened two semi-circular pieces of thin copper. The method of fastening these is shown in the small figure at the right. The pieces of copper may be cut from any thin sheet, with the little tongues projecting as shown in the figure. The pieces of copper may then be bent into circular form so as to fit closely the wooden block, and may be fastened to the latter by bending the tongues down over the ends of the block, and secured by a pin driven through the tongues into the block. The block has a hole in the center just large enough so that it will fit very snugly upon the shaft when put into the position shown in the figure. Care must be taken that the two sections of the commutator do not touch each other, nor the iron shaft of the motor. The slot should be in the position shown—that is, at right angles to the groove on the iron part of the armature. Outside the commutator and separated therefrom is driven on a small gear wheel taken from an old clock. Each end of the armature winding is connected to one of the sections of the commutator.

It will be noticed that no bearings or supports for the armature are described, as this will be left for a following chapter.

CHAPTER LX.

HOW TO MAKE AN ELECTRIC LOCOMOTIVE.

PART TWO.

The motor for our model locomotive was described in a preceding chapter. This motor must be mounted on a suitable truck, the construction of which will now be described. A general view of the truck and motor is shown in the accompanying figure. The wheels shown at W are perferably turned from hard rubber, but may be turned from a piece of hard wood. The material required is ½ inch thick, the running face of the wheel being ¼ inch wide, the flange ⅛ inch and the small hub ⅛ inch thick. The diameter of the running face of the wheel is 1⅝ inches, the diameter of the flange is 2 inches and that of the hub is ⅜ inch. They are mounted upon shafts made of a piece of 5-32 inch brass or iron rod threaded at each end so as to screw tightly into the wheels. The total length of this shaft is 3½ inches, and the distance between the hubs of the two wheels is 2½ inches.

The front and rear axles of the truck are connected by two brass strips E and D which are 5 inches long, ¾ inch wide and ⅛ in thick.

The motor which was described in the previous chapter is mounted in the frame thus formed by screws passing through the brass strips and into the wooden block which is clamped between the limbs of the magnet. A similar arrangement of wooden blocks at the end of the magnet shown at M securely fastens the magnet in place. The long strip F should be on the lower side of the truck.

Connection is made between the armature and the front shaft by means of the train of gears indicated at A, H and B. These gears may be taken from an old brass clock, and since the size of the wheels used must necessarily be different in each case, the exact distance between the shafts supporting these gears cannot be given. The amateur will have to begin by first locating the gear A, then the shaft which carries the gear H, then the shaft which carries B and the armature of the motor, and the location of this last shaft will determine the location of the field magnet frame in the frame of the truck.

If the locomotive is to run on a straight track, the axles may be rigidly fixed as already described. If, however, it is run on a circular track, especially if the latter be of rather short

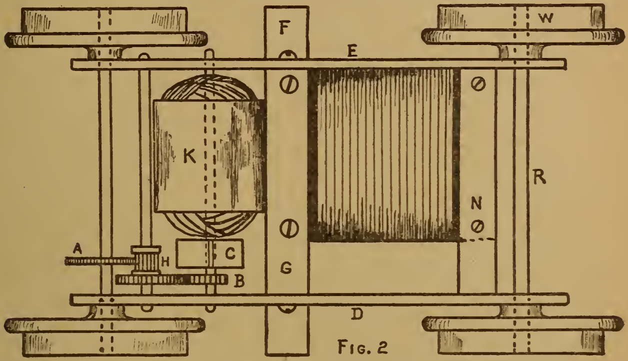


Fig. 2

Plan View of Truck

radius, one of the axles will have to be so fixed that it may swing in one way or the other to allow the locomotive to go around the curves. The amateur can easily arrange this for himself.

The springs which convey the current into the armature are made of very thin spring copper or brass and are fastened to the wooden blocks so as to bear rather lightly upon the commutator C. They are omitted in the diagram for the sake of clearness. The armature and fields of the motor are connected in series, and the terminals of the motor are connected to two brass springs which are screwed on to the terminals of the wooden strip F, and are bent downward so as to bear upon the rails upon which the wheels are to run. The track may be made of strips of thin copper, cut into convenient length about 1 inch wide and bent over at right angles so as to form a suitable bearing surface for the wheels. The rails serve as conductors for the currents of electricity and must therefore be fastened to some non-conducting support such as wood.

The amateur may follow his own devices in the construction of the body of his model locomotive, the form shown in Fig. 3 being a model of some of the large locomotives now in use. If the reader possesses a scroll saw, he may cut the parts nec-

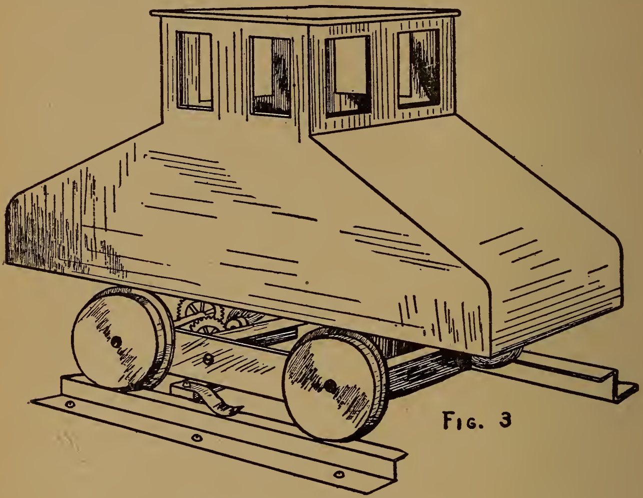


FIG. 3

Electric Locomotive Complete

essary to construct his model from pieces of thin wood which may afterward be glued together, and painted black, presenting a very neat appearance. Four cells of bichromate battery ought to run the locomotive at a good rate of speed.

CHAPTER LXI.

A PORTABLE VOLTMETER.

PART ONE.

Voltmeters are instruments for measuring the voltage, or electrical pressure, between two points of an electric circuit. Some voltmeters are designed to be used in one position, while others are designed to be carried about, and to give essentially correct readings in any position. The latter are harder to construct than the former, but as may be readily seen, they have a wider range of usefulness. In the following chapters directions will be given for constructing a portable instrument, the form of construction adopted being one that has been proved by experiment to be perfectly practical, and easily constructed by a person with few tools. There will be needed for the base of the instrument, a piece of well dried cherry 6¼ inches square and ⅝ inch thick. It is well to take considerable pains in finishing this up so as to make it perfectly smooth and true. The edges should be beveled, as shown in Fig 1. To this base is to be fastened, on its upper side, a block of wood 1¾ inches long, 1¼ inches wide and ⅞ inch high. This block is fastened by two heavy screws, as shown at W, and is so placed that the center of the block is on the center line of the base, and the outer edge of the block is ⅞ inch from the edge of the base.

Now procure an ordinary 3-inch horseshoe magnet. This is to be secured firmly to the upper side of the wooden block by a clamp made from a piece of stiff sheet brass through which a screw passes into the wooden block, securely clamping the magnet in place, as shown at M.

We will now proceed to construct the movable part of our instrument. There will be needed first of all a large-sized sewing needle about 2 inches long. The eye-end of this needle should be broken off and ground to a fine point so as to make a needle 1½ inches long. We wish to secure to this needle a small thin piece of soft iron, as shown at I in Fig. 2. A very simple way to do this is to cut out a long narrow strip of thin sheet brass, such as is shown at P in Figs. 1 and 2. By means of two holes through this piece near one end, which are just big enough to allow the needle to pass easily, the piece of iron may be secured firmly in place and by forcibly bending the brass strip, the latter will bite the needle hard enough to prevent the whole from turning easily upon the needle. The upper end of this strip

Fig. 1

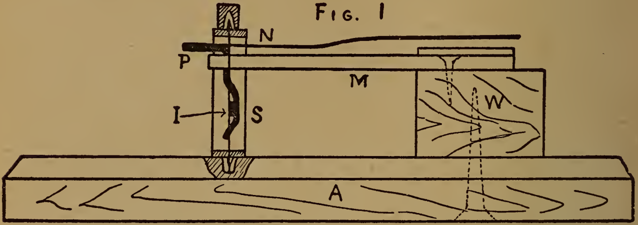
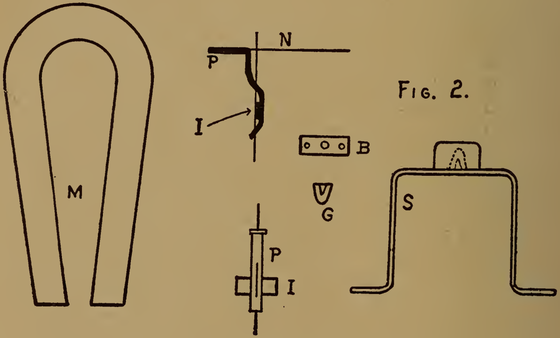


Fig. 2.



is bent over at right angles at a distance of 5-16 inch from the upper end of the needle. The object of this bend is two-fold. First, it is to be used to support the pointer N by being bent around the latter, and for this reason the strip at this point should be cut rather wide, say $\frac{1}{8}$ inch. Second, the weight of the projecting part of the strip is designed to counteract the weight of the pointer so as to form a moving system which will be nicely balanced.

To support the needle we will need a piece of brass about 5-16 inch wide bent into the shape shown at S. The height of the under side of this brass support is about 1 3-16 inches above the base. A small block of brass is shown fastened to this strip. This block serves as a support for a bearing made of glass which greatly diminishes friction.

To make these glass bearings procure a piece of very small glass tubing such as chemists use. Insert one end into a gas flame and heat it until the end softens and runs together. If the tube be held vertical and allowed to cool, the outer end of the tube will be rounded and the inner end of the tube where it is closed up will taper down to a point. If now the end of the tube be cut off so as to form a piece about ¼ inch long there will be formed a piece of glass something like that shown at G, Fig. 2. The glass tube may be cut by making a deep incision on one side of the tube with a sharp file. If the tube be held in the hands, with the thumbs held on each side of the scratch, the latter being on the opposite side of the tube, then the tube may be easily snapped off. Two such bearings will be required, one held in the brass block as already described, the other fastened into a recess in the wooden base, and held in place by a small piece of brass, B, screwed to the base. Of course holes must be bored through the brass strips, B and S, so that the needle may pass through them, but not large enough to allow the glass bearings to slip out of place.

The needle should be supported in such a position as to pass vertically between the poles of the horseshoe magnet at a distance of ⅛ inch within the latter. The needle N is made from a slender straight piece of broom corn taken from an ordinary whisk broom, and is secured as has been explained by bending the end of P over until it clamps the needle. The needle may be made about 4 inches long at first.

We will continue the discussion of this instrument in our following chapter.

CHAPTER LXII.

A PORTABLE VOLTMETER

PART TWO.

In the previous chapter a description was given of the moving parts of our voltmeter. It consists of a straight steel needle at the center of which is mounted a small thin bit of soft iron about ½ inch long, and ⅛ inch wide, and of a pointer attached at the top of the needle, made of a strand from a broom. The piece of iron and the pointer are secured by a small strip of brass as previously described, and the whole moving system suitably mounted in glass bearings so as to turn very freely. The strip of iron should be at such a height above the base board that it is half way between the latter and the horizontal steel magnet. The magnet will then turn the iron strip around until it points along a line parallel to the pole pieces. The pointer should now be turned toward the left by bending the strip of brass until, with the iron strip in the position just described the pointer is bent away at an angle of about 30 deg. Referring to Fig. 4 the strip of iron can be seen at I, and the ends of the magnet pole at M with the needle passing vertically between them. In Fig. 3 the position of the pointer relative to the rest of the instrument is shown at P. Having completed these adjustments the pointer and moving armature should be counter-balanced by filing, or bending the brass strip until tipping the instrument produces little change in the position of the needle. Care should be taken to see that the needle moves very freely and that the pointer P always returns to the same position after being deflected.

In Fig. 3, there can be seen at C two coils of wire. These are made by winding the coils upon two brass frame works each of which consists of a rectangular spool with heads of the shape shown at C in Fig. 4. These heads are 1½ inches long, ⅞ inch high and are made of thin brass. The shank of the spool is likewise made of thin brass and has an opening through its center ⅝ inch long and 3-16 inch wide. The purpose of this opening is to allow the coils to be supported close to the moving armature and yet to allow a free space in which the strip of iron I may turn. The ends of the spools are soldered to the shank and together make up a spool which is ⅜-inch wide. On one side of each spool a lug is left pro-

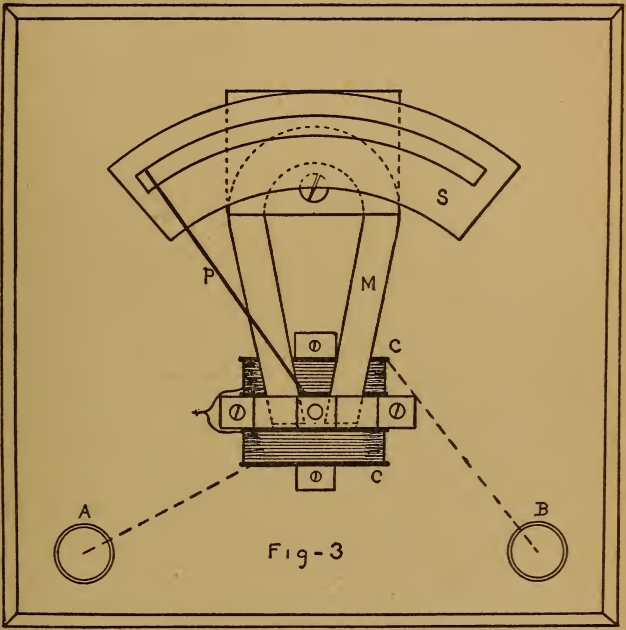


Fig-3

jecting by means of which the spool may be screwed to the baseboard.

Carefully insulate the whole interior surface of the spool and wind the same full of No. 36 double silk covered magnet wire. The spools are then mounted in the position shown in Fig. 3. They are connected together in such a way that the effect of one is added to that of the other and their free ends are connected to two binding posts A and B. The purpose of these coils is to receive the current to be measured. The effect of the current in the coils is to cause the pointer to move in one direction or the other against the pull of the magnets. The greater the current strength in the coils, the more will the needle be deflected. The current strength in the coils is dependent upon the voltage between A and B and by proper calibration, therefore, the instrument may serve as a

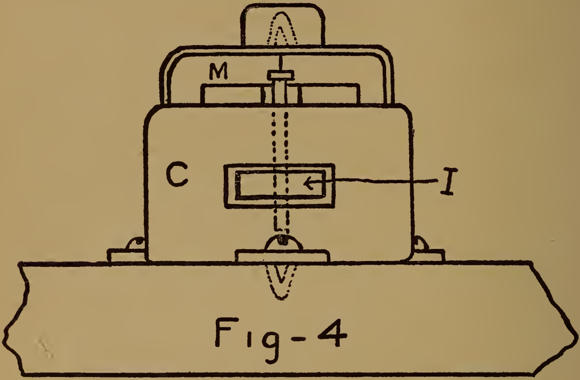


Fig-4

voltmeter. In order to measure the deflection of the pointer a circular scale cut from a piece of stiff Bristol board is mounted at S, by being glued firmly to the top of the magnet, the pointer being so adjusted that it is about 1-16 inch above the scale. In our next chapter an explanation of the method of calibration will be given.

CHAPTER LXIII.

A PORTABLE VOLTMETER.

PART THREE.

It will be necessary to make some sort of a case to cover the working parts of our voltmeter in order to protect them from mechanical injury and to shield the pointer from currents of air. A very nice case may be made from a piece of smooth sheet copper cut in the proper shape and soldered wherever necessary. The general shape of the case is shown in Fig. 5, which also gives an idea of the appearance of the finished instrument.

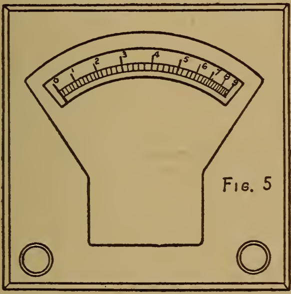


Fig. 5

The instrument as described may be used as a voltmeter or as an ammeter according to the method of connection. In either case, for the purpose of calibration, a standard instrument is almost necessary—that is to say, some instrument whose readings are known to be approximately correct. Let us suppose that our instrument is to be used as a voltmeter. The method of connection is shown in Fig. 6. Here A is the instrument described and B is the standard instrument, connected in parallel with A. A battery shown at C must be provided sufficiently powerful to deflect the needle to its fullest extent. An adjustable resistance shown at P will also be required. Insert in series with A, a coil of wire represented merely at R. This is to be made of the same sized wire as is wound upon the coils of the voltmeter, and is a loose coil of wire. The process of adjustment is as follows: Suppose it is desired that A should give a full scale deflection on 30 volts. Make connections as shown and adjust P until the standard reads at 30. Then insert enough resistance at R so that A will give the proper deflection. Probably this will cause a slight change in the reading of the standard so that P must be again adjusted. By alternately adjusting P and R the proper deflection of A will finally be reached. After this R is to remain unchanged and lower points upon the scale of A are obtained by adjusting P until the standard reads at the desired value when the position of the needle of A can be marked with a pen. After calibration the resistance R may be fastened inside the case of the voltmeter and connected in series with the coils. It is then out of the way.

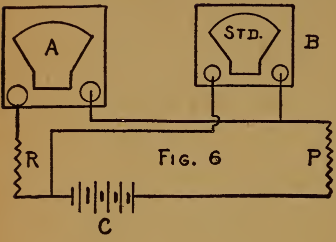


Fig. 6

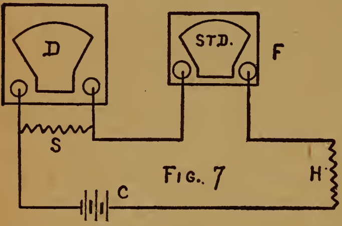


Fig. 7

Suppose, however, that the instrument is to be used as an ammeter. Then it will be necessary to connect across its terminals a low resistance as shown at S, Fig. 7. The instrument D is connected in series with a standard ammeter F, an adjustable resistance H, and a storage battery C. H is adjusted until the standard reads at the desired value when S is adjusted until D gives the proper deflection. This will cause a change in the reading of the standard, necessitating a readjustment of H and another adjustment of S. Having once fixed S, however, it is not to be changed. It can be soldered permanently to the terminals of the instrument and coiled up inside the case. The various points upon the scale of D may be obtained by adjusting H until the standard reads the proper value when the position of the pointer D is marked with a pen as before.

The instrument may, therefore, be set up either as an ammeter or a voltmeter and ought to be of considerable value to the amateur.

CHAPTER LXIV.

A PORTABLE BATTERY AND SWITCHLESS LAMP.

A very convenient and durable portable battery and lamp can be constructed as follows:

The details of construction are shown in Figures 1 and 2. The lamp requires no switch, this result being obtained by means of a specially designed battery jar.

The design of this jar is such that the electrolyte can act upon the plates of the battery only when the container is placed in a certain position, and this position also places the lamp at the proper angle for the diffusion of light to the best advantage. The outer casing is wood.

The dimensions of these pieces may be 9 in. x 9 in. x ¾ in. Each piece should be thoroughly sandpapered, and the joints, which are to be mitred, should be put together with glue and secured by flat head wood screws. Four screws should be used at each joint.

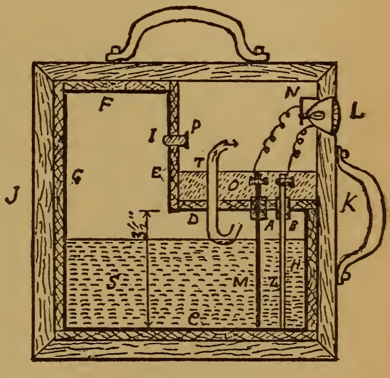


Figure 1.

The inside container, or battery jar proper, consists of eight pieces of white wood indicated by the narrow edges of darker shade and designated by the letters C, D, E, F, G and H.

The dimensions of these pieces are as follows: C—7 in. x 7 in. x ½ in.; D—7 in. x 4 in. x ½ in.; E—7 in. x 3½ in x ½ in.; F—7 in. x 3 in. x ½ in.; G—7 in. x 7 in. x ½ in.; H—7 in. x 3½ in. x ½ in.

Before assembling the parts of the inside container a one-inch hole, I, should be bored in piece E for the purpose of filling the interior with electrolyte. When the device is in use, this hole is closed by the plug P. Three holes are also to be bored in piece D.

Two of these holes are designed to receive the lugs of the battery plates A and B as shown, and the distance between them is one inch, while the distance between hole B and piece H is one inch also. Two pieces of soft rubber tubing, or old rubber hose should be snugly inserted into these holes in order to properly insulate the electrodes passing through them.

A third hole about one-half inch in diameter is also to be bored in piece D into which a glass tube T with ends bent as shown is to be inserted. This is done to permit the gas generated by the battery to escape through the tube when it is in use. The two sides of this L-shaped container are of the same size and should be cut to the shape of the jar when completely assembled. The corners should be carefully glued with a liquid glue and all parts should be secured in substantial position by ⅞-inch flat-head iron screws. Having secured all parts in their proper places the next step to be taken in the construction of the container is to make the interior surface absolutely acid-proof. To prevent the acid from leaking out of the container, the cracks can be filled by applying a thin coating of melted pitch or asphalt to the inside surface as shown by the heavy black line. The best method of accomplishing this is to melt a few pounds of asphalt in a kettle and then after pouring in a sufficient quantity through the rubber tube holes at A and B, plug all holes and tilt the container in such a manner as to cause the melted tar to run into all corners and cracks, after which it may be permitted to cool. This process should be repeated until the entire surface of the interior is thoroughly coated with the insulating and acid-proof material. In order that the battery plates and glass tube T may be put in their proper locations after the coating of asphalt has cooled it will be necessary to remove one of the sides of the container. Figure 2 shows the shape of the battery plates, one of which, M in Figure 1, is the carbon plate, and Z is the zinc plate.

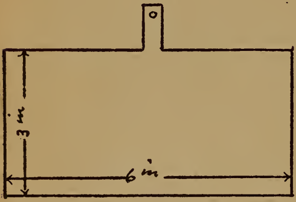


Figure 2.

Each plate measures 6 in. x 3 in. x $\frac{3}{16}$ in. and is fitted with a lug of the proper size to pass through the insulated holes at A and B. In each lug a hole is to be drilled as shown in Figure 2 for receiving an 8-32 binding post screw for connections. After the battery plates and tube T are in position, the side of the container may be replaced and permanently secured.

In order to produce a complete joint when putting this side in place it should be coated with the melted asphalt while exposed, and again warmed when closed.

The mixture composing the electrolyte for the battery is made up as follows:

Potassium bi-chromate	1
Concentrated sulphuric acid................	3
Distilled water	10

By placing the cabinet on its side J, and removing plug P, a sufficient quantity of this solution may be poured through hole I to fill the bottom chamber up to the proper height to cover the plates when the cabinet stands in the position shown in Figure 1, which is the proper position for supplying current to the lamp at L, which is a two-volt incandescent lamp enclosed in a metallic reflector, the opening of which may be fitted with a condensing lens.

The dimensions of this reflector is a matter of choice and the size of the opening to be cut in the outside casing depends upon the dimensions of the reflector.

Connection is made with the central terminal of the lamp by means of a short copper strip N, secured as shown in Figure 1, while the other connection is made from the reflector. Flexible conductors are used from these terminals to the battery terminals. Having made all connections, sufficient melted paraffine should be poured on top of part D to cover the binding posts. This when cool will form an insulating compound O, which will protect the parts. With the apparatus in the position shown in Figure 1, the electrolyte solution S covers the battery plates to the proper height, and current is being supplied to lamp L. When the lamp is not needed, the generation of current may be instantly stopped by simply turning the cabinet on its side J. This will cause the solution to occupy the other compartment of the container, thus leaving the battery plates bare; the result being that the lamp is extinguished, and all unnecessary eating away of the zinc plate by the acid solution is also prevented.

When the lamp is again needed, all that is necessary is to replace the cabinet in its former position, allowing the solution to again cover the surface of the plates, when the generation of current will begin at once and the lamp will be lighted. No switch is required, hence the name "switchless" lamp.

An extra handle can be attached to the side K of the cabinet to be used in carrying the device from place to place when current is not needed, side K at such times being the top and the extra handle will be found to be a great convenience.

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