ELECTRICAL INSTRUMENT-MAKING FOR AMATEURS

S. R. BOTTONE.

ELECTRICAL INSTRUMENT MAKING FOR AMATEURS.

ELECTRICAL INSTRUMENT MAKING FOR AMATEURS.

A Practical Handbook

BY

S. R. BOTTONE,

LATE OF THE COLLEGIO DEL CARMINE, TURIN; THE ISTITUTO BELLINO, NOVARA. CERTIFICATED SCIENCE TEACHER, SOUTH KENSINGTON.

FOURTH EDITION.

Revised and Enlarged.

LONDON:
WHITTAKER & CO., PATERNOSTER SQUARE

NEW YORK:
D. VAN NOSTRAND COMPANY, 23, MURRAY, AND 27, WARREN STREETS.

1891.

PREFACE.

THE amateur, especially if he be young, inexperienced, and unblest with "filthy lucre," must ever command our sympathy and respect. He, without any hope of reward, except that gratification which follows the acquirement of knowledge, works on, under the greatest difficulties, to the attainment of his end—an end which, in nine cases out of ten, tends directly to the benefit of his fellow-creatures.

Nearly all the really useful inventions and discoveries, which have rendered the 19th century so remarkable as a season of progress, must be attributed to amateurs. For this reason, if for no other, we should render every assistance in our power to the *bonâ-fide* amateur, and for this reason, along with another, have I attempted, in the following pages, to guide the tyro in his attempts at the construction of the more useful pieces of electrical apparatus. The other reason is that "a fellow-feeling makes us wondrous kind," and as I myself felt acutely the need of assistance at the beginning of my amateur-scientific career, so I am pleased to suggest when and how much trouble may be saved, and expense spared by the adoption of certain simple modes of procedure.

In the following pages no attempt has been made to describe the production of such highly finished "brass and glass" instruments as those which adorn the windows of our opticians' shops. Such a high degree of finish requires a technical knowledge of French polishing, lacquering, burnishing, etc., as is not usually possessed by the amateur. The tools used, also, are supposed to be of the simplest description, such as may be found in every home, however humble. Not one of the instruments described necessitates the employment of a lathe or other expensive tool in its manufacture; though, of course, much truer and finished circular work can be done on the lathe than in any other manner. But the instruments produced as described in this book, may be relied upon to *act* efficiently; and this is, after all, the end for which every instrument is constructed. It must be borne in mind that this work does not profess to *teach the science* of electricity: and no attempt is made to enter upon the domain of scientific speculation.

PREFACE TO THE SECOND EDITION.

THE rapid sale and flattering reception accorded to the first edition of this little work prove that it has met a want generally felt. Nearly all the Press criticisms have been favourable. Many kind letters of approbation have been received by the Author, and, in compliance with several of these, he has added a short article on the Telephone, which he trusts will meet the requirements of Amateurs. Any suggestion, either as to matter or treatment, will be gratefully received, and carefully considered in future editions, by the Author.

Carshalton, Surrey.

May, 1888.

INDEX TO SECTIONS.

ELECTRICAL INSTRUMENT MAKING FOR AMATEURS.

§ 1. TOOLS.—The true amateur, as a rule, has not a large assortment of tools. Little by little he gets together, or constructs those which are necessary for his purpose; but he seldom aspires to the complete paraphernalia of a workshop. Still there are certain tools that are indispensable, of which the following is a list in order of utility:—

1 Large pocket-knife.
1 Fine penknife.
1 Archimedean drill and bits.
Pair of cutting pliers.
Pair of large scissors for metal.
Pair of small scissors.
Several files, large and small.
1 Hammer.
1 Mallet.
Bradawl, gimlet, pincers.
Small bench vice.
Small tenon saw.
Soldering iron.
Spirit lamp.
1 Wheel glass cutter or diamond.
Pair of compasses.
2ft. rule.

I should like to have put a lathe at the head of this list, for that is really the king of tools; but I would not deter the student from making electrical apparatus because he has not a lathe, as most may be made well without, though better with one.

Besides tools, the materials mentioned below will be found useful. They need not be procured all at once, but as occasion demands. If the amateur adopts the plan of keeping up a little stock of his materials and tools, as they are worn out or consumed, and more especially if he remembers that, "Order is Nature's first law," and that there should be "a place for everything, and everything in its place," he will turn out better work, keep his temper, and work better than if he allows himself to degenerate into a slipshod style of doing things. Let him never say "that'll do" to anything capable of improvement.

§ 2. MATERIALS.—The following will be found useful in carrying out the instructions given in the ensuing pages:—

Glass rods from ⅛ to ½ in. in diameter.
Ebonite rods from ⅛ to ½ in. in diameter.
Glass tubes from ⅛ to ½ in. in diameter.
Guttapercha.
Glass bottles, preferably green glass.
Sheets of glass; every piece is useful.
Bottoms of broken wine-glasses as stands, &c.
Tinfoil.
Sheet zinc and sheets of tinned iron.*

* Clean beef tins, sardine tins, &c., may be worked up very well and economically.

Sheet copper.
Sheet brass, and brass rod, $\frac{3}{8}$in. diameter.
Solder.
Chloride of zinc.
Rosin.
Needles.
Watch springs.
White hard varnish.
Red lead.
Benzoline.
Burnt umber.
Copper wire of various sizes.*
Prout's elastic glue.
Methylated spirits of wine.

Having these materials at hand, the amateur will find several operations are required so frequently as to render a certain amount of technical skill absolutely necessary if the work is to look neat and act satisfactorily. Among the first of the amateur's requirements must be placed the power of soldering.

§ 3. SOLDERING.—For small work, an iron, shaped as shown at Fig. 1, will be found extremely useful. The

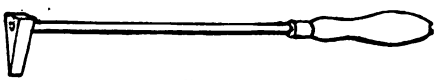


FIG. 1.

amateur can easily construct this for himself by boring a $\frac{\ }{16}$ hole in a copper wedge 2in. long by $\frac{1}{2}$in. thick, and $\frac{1}{2}$in. wide on the base. An iron rod, 15in. long, is straightened out for the handle, and the end of this rod

* This had better be procured as required.

is heated in the fire and hammered up until it can be thrust through the hole in the copper wedge; what projects is then hammered down so as to form a kind of boss or rivet head, to prevent the copper bit from moving. The other end of the rod may then be filed or hammered to a point and driven into a wooden handle. Five inches of broom-handle will answer the purpose, if nothing better can be got at.

In order to solder successfully, four things are essential. Firstly, the portions to be soldered must be made scrupulously clean, either by scraping with a piece of sharp knife blade (kept specially for this purpose), or by sandpapering, or by filing, whichever is most convenient. Secondly the portions that are to be soldered must be raised nearly to the temperature of the melted solder. For this reason the amateur would surely fail were he to attempt to make a good joint, say, between two sad irons, with an ordinary bit, unless he previously heated the irons to nearly the melting point of solder. In ordinary small work, where wires are soldered to wires, sheets to sheets, &c., the heat of the soldering iron itself is generally sufficient, not only to melt the solder, but also to raise the temperature of the surrounding portions to be joined to the requisite point. Thirdly, the nose of the soldering iron must be perfectly clean, and covered with melted solder, or, as it is technically called "tinned."

To insure this result the soldering iron must be placed in a clear red fire until nearly red-hot (if allowed to get too hot it will not take up the solder at all), then quickly and lightly filed on one face, and *at once* plunged into a rod of soft solder, on which a little powdered rosin has been placed. The heat of the soldering iron will cause the solder to melt, and run into globules. If one of these be allowed to run into the lid of a milk tin, or other convenient tinned iron receptacle in which a little powdered rosin is also placed, and the *filed* face of the soldering iron rubbed briskly over the melted solder, the surface of the copper bit will be found to have taken a coating of solder as brilliant as a looking-glass. Should this not be the case, the iron must again be heated and filed and rubbed over the solder until a perfect coating has been obtained.

When once the nose of the copper bit is well "tinned," it is sufficient after each heating (provided it has not been overheated so as to burn off the solder) to rub the iron briskly on a piece of old carpet, kept especially for this purpose, just before touching the solder. Fourthly, the surfaces to be united must be kept perfectly clean and unoxidised during the application of the heat necessary for soldering, by the application of some substance which prevents the access of air, &c., to the heated surfaces.

These substances are various, and some are more adapted to one metal than to another. Thus rosin is excellent for tinned iron and for copper. Hydrochloric acid (spirits of salt) is perhaps the best for zinc. Chloride of zinc (killed spirits of salt), again, is excellent for iron, for copper, and for brass, where the surfaces can afterwards be well washed.

A lump of sal-ammoniac (chloride of ammonia) is also very useful for removing the oxidation from the copper bit by rubbing it against the lump for a few seconds after heating.

§ 4. As an example of the mode of proceeding, let us suppose we wish to solder a wire to the copper plate of a Daniell battery. We begin by cleaning the copper plate at the spot to which we wish to attach the wire, by rubbing it with a piece of glass or sandpaper until the surface is as brilliant as a mirror. In like manner we polish and clean the end of the copper wire. Laying the copper plate flat on the board which we keep expressly for soldering on, we place the copper wire on the desired spot.

We now put the soldering iron into the fire* (it having been previously tinned as described), and watch it until it shows by the melting of the solder on the surface that it is hot enough. We then remove it from the fire, give a rub on the sal-ammoniac or piece of carpet, then take up a globule of solder by touching one with the cleaned nose of the bit, and, lastly, having quickly touched the surfaces both of the copper plate and wire with a feather dipped into the chloride of zinc solution, rub the surface of the plate and wire simultaneously with the soldering iron. As soon as the surfaces become sufficiently heated, the solder will be seen to flow over them. The wire must then be pressed into its desired place, the melted solder rubbed well over the point of

* Care must be taken that the fire is emitting no sulphurous smoke, otherwise the iron will surely *not* take up the solder.

junction, the iron removed, while the wire is held motionless in its position, until a sudden dulling of the surface of the solder shows that it has set and is solid enough to hold the parts together. After soldering with chloride of zinc ("killed spirits," "soldering fluid"), always wash in plenty of water to prevent rusting.

§ 5. SOLDERING WITH A FLAME.—In many instances a better joint and neater-looking work can be made over the flame of a spirit or other lamp than with the soldering iron. This is more especially the case in small work, such as joining wires, soldering pivots, &c. As an example, let us suppose we desire to make a poised magnetic needle out of two similar pieces of needle, joining them together by means of a short tinned-iron junction, in which the pivot is inserted. (It is evident that a pivot could not well be attached to an ordinary sewing needle were the needle in one piece.)

The needles (of which two are required) are broken off of the desired length by means of a pair of nippers. The heads may be the portions rejected, if a very light needle is required; the points, if a heavier needle be not objectionable. Care should be taken that the pieces be of the same weight, to insure a well-balanced needle. A small piece of sheet tinned iron ("tin-plate") about 1 in. square should now be procured and flattened out. With a screw-drill, or small punch, a clean central hole is made a trifle smaller than the largest external diameter of the pivot. (See § 6 for pivots.) The piece is now cut into the shape of a small lozenge, as shown at Fig. 2, A, and again flattened out by a light blow with a flat-faced hammer. The needles are now to be lightly sandpapered at the ends which are to be soldered to the lozenge, then these extremities immersed

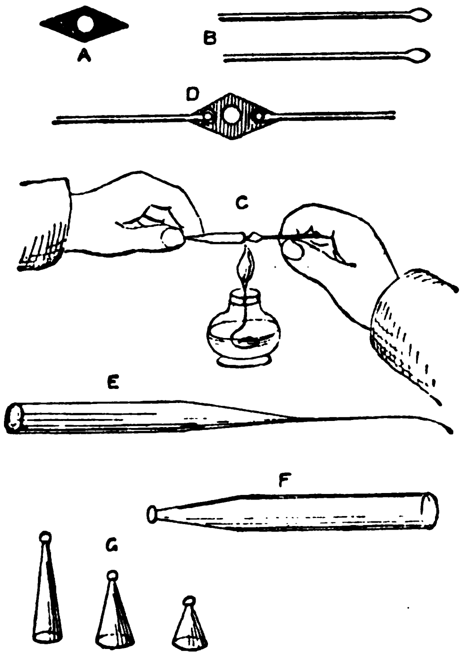


FIG. 2.

in the chloride of zinc soldering fluid. The soldering iron is then to be heated, and a little globule of solder caused to adhere to the prepared extremity of each needle by its aid. The needles should now present the appearance shown in Fig. 2, B. The spirit lamp is now to be brought into requisition. The flame should not be too high for such work, so that the wick need not be raised much. Taking up the lozenge-shaped piece in the left hand, with a pair of tweezers (or longish piece of wire bent to a tweezer shape), and allowing one half to project, we apply with a feather a little soldering fluid to the projecting point. The needle with its adhering solder is now taken up in the right hand (a small piece of paper being wrapped round it, to prevent the fingers being burnt), and both the needle and the lozenge are held for a few seconds over the flame of the spirit lamp, in the position they are desired to remain (See Fig. 2, C). The solder will soon be seen to flow. As soon as this is the case the pieces must be pressed firmly together, and both hands removed from over the flame of the lamp, care being taken to keep the parts constantly pressed together until a sudden *dulling* shows that the solder is set. In like manner the other needle is soldered to the other point of the lozenge. The needle may then be magnetised, and after magnetisation balanced on its pivot, as will be described further on. Fig. 2, D, shows the needle ready for pivoting.

§ 6. PIVOTS.—These are in constant requisition; consequently, it is well to be able to make them of all sizes. The amateur will need only two kinds—viz., in brass and in glass. *Brass* pivots are very easily made from stout, hard, brass wire. The most useful size is about $\frac{3}{16}$th in. in diameter. A short length of this is placed in the jaws of a vice, with its circular section uppermost. A bit, capable of cutting a $\frac{1}{16}$th hole, is placed in the screw-drill, and after being oiled, the drill is worked over the brass rod, the bit resting quite centrally, until the shoulders of the bit just touch the outside of the wire. This produces a good deep and evenly conical hole. The wire can now be removed from the vice, and the outside of the pivot also made conical by filing, while still on the brass rod; when the desired shape has been secured, it can be cut off with a fret-saw or file.

Glass pivots are extremely useful in all electrical experiments. The best way to make these is to soften a glass tube over a spirit lamp, and gradually but steadily pull it asunder. By so doing, two conical pieces are the result. If the extreme hair-like points of these are held over the lamp, they fuse up into a round globule, thus closing up the hole. The pivots thus produced can easily be cut off (when the glass is cold) by making a mark round the tube with a sharp triangular file, at the point where it is desired to break it off. On applying a little pressure between the finger and thumb of both hands, the pivot easily breaks away from the remainder of the tube. The pivots may be made very long and thin, by allowing the glass to soften well, before beginning to pull asunder, and such long thin pivots are very useful for astatic galvanometers, or other cases in which two objects have to be poised on one pivot. Short pivots can be made by pulling asunder as soon as the glass softens in the flame. Fig. 2, C, shows how the glass tube should be held in the hands to soften, over the flame. Fig. 2, E, gives the appearance of the tube after pulling asunder. Fig. 2, F, indicates how the hair-like extremity should be melted into a bead over the lamp, so as to close the capillary aperture, and Fig. 2, G, shows finished pivots.

§ 7. GLASS THREADS.—These are extremely useful as insulators in small work, such as electroscopes, carriers, torsion balances, &c. They are easily made from rather thin glass rod, by heating it carefully over a clear flame (spirit-lamp, or Bunsen burner) until soft, and then pulling asunder rapidly if a very fine thread be desired; more slowly, if a coarser filament be required. Similar threads may be made from shellac; and these, though somewhat more brittle, are even better insulators.

§ 8. STRAWS.—The straws of various grasses, more especially the fine, straight, hair-like terminals of such grasses as *Agrostis spicaventi*, *Alopecurus pratensis*, *Phalaris arundinacca*, and *Aira cristata*, if gathered soon after the flowers are fully matured, cut to the length of about 6 inches, dried, and then boiled in melted paraffin wax, make excellent insulating supports, far stronger than the glass or shellac ones mentioned above. The same straws, *not* paraffined, are, from their lightness, well adapted as pointers for such galvanometers as tangents and others, which require a separate indicator.

§ 9. PITH-BALLS.—These are much used in experiments with frictional electricity. The best piths for ordinary purposes are those of the elder, *Sambucus nigra*. and of the Jerusalem artichoke, *Helianthus tuberosus*, Before being shaped into balls or other figures, the pith should be thoroughly dried. With a penknife, reduced to a razor-like sharpness, the pith can be cut to any desired figure, and is easily rounded to an approximate sphere. When a number of equal size have been made, the final rounding may be given by *lightly* rolling them with a smooth, flat board, on a level table. Care must be taken not to press too heavily, otherwise the balls will be flattened. Having now got together the few things necessary for starting work, we may try our constructive abilities on the simpler forms of electroscopes.

Electroscopes are instruments employed for the detection of the presence (and sometimes of the nature) of electricity; not for its measurement.

§ 10. PITH-BALL ELECTROSCOPES.—These are of two

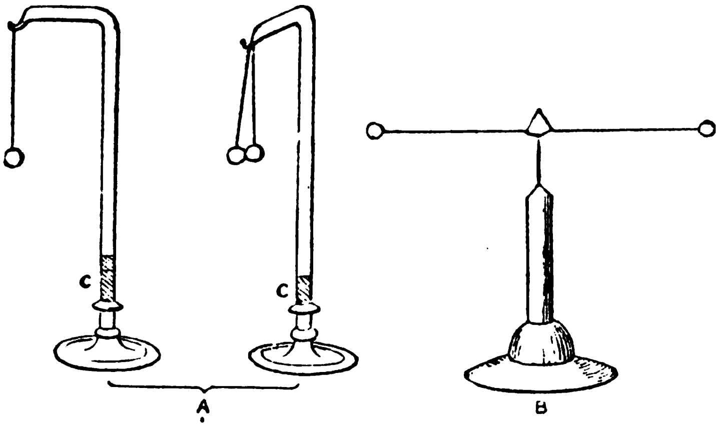


FIG. 3.

kinds—viz., those in which the balls are suspended by a filament, and those in which the suspension consists of a horizontal rod, pivoted at the centre. Fig. 3, A, shows the former; B, the latter form.

To make the former, a glass rod about 8in. long by ¼in. thick, should have one extremity heated over a spirit lamp, and when quite soft, touched with another piece, so as to enable the operator to draw out a filament, which must be bent into the shape of a recurved hook. The rod must then be heated at a point about 2in. from this end, and, when sufficiently softened, bent neatly (not too hurriedly) at right angles. The bent rod must be allowed to cool gradually without touching anything, otherwise it will be liable to fly to pieces. When quite cold it may be fastened to the foot of a broken wine-glass by means of a turn or two of stout brown paper, previously brushed over with good Russian glue, as shown at C. When this is quite dry it should receive (at this joint only) a coating of red varnish, made by mixing a few grains of red lead with a teaspoonful of white hard varnish. (The white hard varnish may be procured at any oilman's.) A single filament of cocoon silk is now to be procured, and a fine needle threaded with it. The needle is passed through the centre of a pith-ball, the end of silk fibre moistened with a drop of glue, and the needle pulled until the ball reaches the glued portion of the silk. This will serve to fasten it to the ball. The other end of the fibre may be tied or glued to the little hook of the bent glass arm. Two balls may be thus suspended, if it is required to show the repulsive effects of similarly charged bodies. To construct the horizontally-pivoted form, it is only necessary to split a straight paraffined straw (§ 8) at its centre, with a sharp penknife, insert a small glass pivot in the split, and fasten it thereto by means of a single drop of hot glue. When quite cold, a pith-ball must be attached to each end of the straw, a small hole being made in each ball with a pin, and the end of the straw (previously touched with glue) inserted in the hole. Care must be taken at this point that the balls balance one another. They may be made to do this by sliding along the straw, until when placed on a needle-point the arms of the electroscope remain perfectly level. Half of an ordinary sewing-cotton reel may be used as the foot of this electroscope. After sawing in half, the upper portion should be filed, rounded, and smoothed, a short length (say 4in.) of cane, glued, and thrust in the central hole; a needle (point upwards) forced into the upper extremity of the cane; and, lastly, the whole wooden portion neatly varnished with the red varnish as described.

§ 11. GOLD LEAF ELECTROSCOPE.—This is a most useful instrument for the detection of minute charges of electricity. If well made, it also serves admirably to show the phenomena of induction. The requisites are a tall wide glass jar, a sheet of gold leaf, a couple of strips of tinfoil, a short piece of brass rod, about ⅛-inch in diameter, a couple of beef tin bottoms, or similar pieces of tinned iron, and an empty cigar box.

For the glass jar, we may either use the straight glass chimneys (about 3 inches in diameter by 7 inches in height), that are used for large gas or paraffin burners, and which may be obtained at any respectable ironmongers for a few pence (see Fig. 4, A), or the bell-shaped chimneys (see Fig. 4, B). Whichever shape be selected, the diameter should not be less than 3 inches

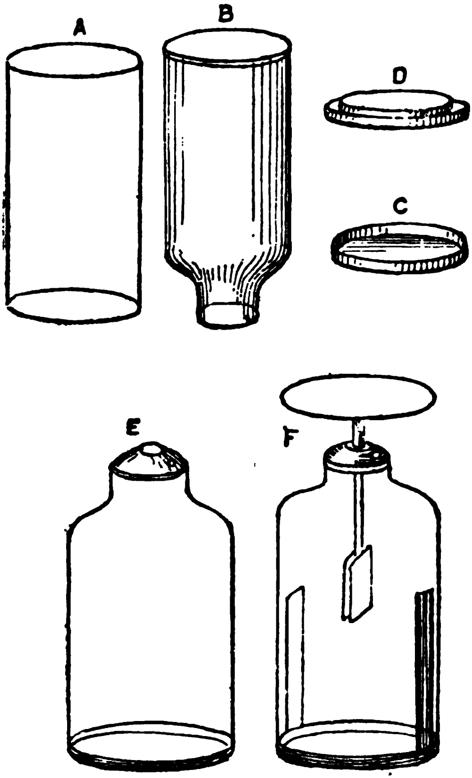


FIG. 4.

nor more than 4 inches. Preference should be given to the bell form, when procurable, as the "cap" is more easily fitted to the narrow neck. Having procured a glass jar, the next step is to fit a cover to both extremities. If Fig. B be chosen, the wider extremity which is destined to form the bottom, should be fitted with a tinned-iron cover. If the bottom of the glass be 3 inches diameter, it will be fitted exactly by the bottom of a Swiss milk tin. The bottom must not fit too tightly, if fitted in winter, or else the slightest increase in temperature will expand the glass and cause it to crack. If a tin "bottom" is not at hand to fit, it may readily be made, by striking out on a piece of thin tinned-iron, a circle of the same size as the outside of the glass jar. Keeping about ⅛-inch outside this line, the circle is cut out, and then the edge turned up square by hammering lightly on the edge of an ordinary iron. The tin disc should now show the appearance sketched at Fig. 4, C. This bottom must not be fastened in until after the gold leaves have been adjusted. The next operation consists in making the cover to fit the other end of the jar or cylinder. If A has been chosen, two circular discs must be cut out of the cigar box wood; one that will just drop into the jar, the other precisely the diameter of the outside of the jar. The two circles had better be measured, struck out with the compasses, and sawn with a fret or band-saw. The two discs, after being well smoothed, should be glued together, as shown in Fig. 4, D. If B is our choice, half a sewing-machine cotton reel will be found to fit with a trifling adjustment. All that will be necessary in this case will be to cut off the narrow portion, leaving one of the coned heads, the rim of which can be trimmed with a rasp, until it just fits the small mouth of the chimney. Whichever form be adopted, this wooden cover must have in it two perforations, one central, about ¼ inch in diameter, wherein will pass the brass rod from which depend the gold leaves; the other near the circumference, which will serve as an exit for moist air. Fig. 4, E shows the glass chimney fitted with its lower "tray" and upper "cap."

At exactly opposite diameters of the glass jar, two strips of tinfoil, about ½ inch wide by 4 inches long, are to be pasted *inside* the jar, reaching from a little above the middle downwards to the metal tray. The object of these is twofold; they increase the sensibility of the instrument by heightening the *apparent* repulsive effect of a charge; and they serve to discharge the gold leaves without tearing, if by inadvertence an overcharge be given. This being done, the brass rod may be fitted to its *table*. Many operators use a brass ball at the top of the gold leaf electroscope; for general purposes, a metallic table will be found more sensitive and more convenient. Having cut a tinned-iron or thin brass disc 3¼ inches in diameter, let the edges be turned in by hammering. To the centre of this metal disc, and perpendicular to it, should be soldered about 6 inches of brass rod, having a small hole drilled in it at half its length—say ¼ inch in diameter. Care must be taken that this rod is quite straight and smooth. The under portion of the disc, as well as the rod to within ½ inch of its extremity, should now be varnished with red varnish (see § 10), and set aside to dry. While this is drying, the upper wooden cap of the cylinder may be immersed in melted paraffin wax, and allowed to remain therein until thoroughly permeated with paraffin. The brass rod may now be passed into the central orifice of the "cap," and tightly fitted thereto by means of a roll or two of paraffined brown paper. (N.B.—When paraffin is mentioned in this work, paraffin *wax* is understood, not paraffin *oil.*) The rod must be pushed down in the orifice until the ¼-inch hole is just level with the top of the cap. A short brad, or similar piece of wire, pushed forcibly into this hole, will effectually prevent the rod sinking through, if any weight be afterwards placed on the table above. A small, flat piece of brass, about ½ inch long by ⅛ inch square section, must now be soldered to the lower end of the rod, transversely to it, so as to form a letter ⊥. It is to this transverse piece that the gold leaves are to be attached. The gold leaves should be about ½ inch wide by about 2 inches long. To cut them neatly is not an easy job for the tyro; still, it may be managed in the following manner:—

Having procured a clean half-sheet of note paper, let it be folded down the middle. This is to be placed *open* close by the side of the book containing the gold leaf. Holding his breath for a few seconds, so as not to blow away the leaf, the operator slides the edge of the note paper under one of the leaves of gold, and assisting operations with a pin point, or perfectly clean camel-hair pencil, coaxes the gold leaf so that it lies flat and square in the centre of the note paper. He then covers it over with the bent half of the note paper, so that the gold leaf lies between the two leaves of paper, forming the half-sheet of note. Then, with a pair of perfectly clean scissors, he cuts the paper into strips, about ½ inch wide by 2 inches long. In so doing, he must take care not to let the papers separate, otherwise his gold leaves will get crumpled, or blow about. Of course, in cutting the paper he cuts the gold leaf into the desired size. He then touches the two sides of the transverse piece of brass (attached to the rod passing through the cap of the electroscope) with the merest trace of gum, then carefully lifting the upper pieces of paper off the strips of gold leaf, takes up, first on one side, and then on the other (of the transverse piece) a strip of gold leaf, being careful that they hang straight down and parallel. Having succeeded in getting the two strips to hang squarely and free from one another, the operator next inserts them very cautiously into the chimney. The cap may now be cemented down on to the neck of the chimney by means of a piece of silk ribbon moistened with thin glue. When this is quite dry, and after the bottom has been likewise cemented to the lower end of the chimney or cylinder, a coating of red varnish is applied, care being taken not to stop up the side air-hole. This air-hole should be fitted with a small wooden plug, furnished with a rounded knob, likewise varnished. A small quantity of Prout's elastic glue, run round the edge of the warmed tin, will be found the most effectual way of fastening the bottom to the lower portion of the glass chimney or cylinder. Care must be taken that the two tinfoil strips are *opposite the width* of the gold leaves.

and that the said strips make metallic contact with the tin bottom. If all has been carefully executed, the electroscope will present the appearance shown at Fig. F, and will be so delicate as to give a large divergence of its leaves, if a rubbed rod of sealing-wax is held at a distance of one foot from the "table," or upper plate.

§ 12. COULOMB'S TORSION BALANCE.—Apart from the actual use of this instrument as an accurate measurer of electric and magnetic force, it is extremely serviceable in calculating the laws of electrical attraction, and repulsion, viz., that these are "inversely as the squares of the distance, and directly as the charges."

To make such an instrument, we select a glass chimney similar to that shown in our last section, Fig. 4, A. This must be fitted with a metal top, precisely like that described for the bottom cover of the electroscope, Fig. 4, C. In the centre of this a small aperture is made to admit of the introduction of about 1 inch of thin brass tube, having about $\frac{1}{8}$ inch bore. This is soldered neatly into the cover, so that the tube projects about $\frac{1}{2}$ inch on either side of the cover. A block of mahogany or deal, about 4 inches square by $\frac{3}{4}$ inch thick, is now planed up and made truly square. A circular channel, about $\frac{1}{8}$ inch wide, and of the same depth, is now cut in this base board for the glass to stand in. If deal, this base should be stained black and varnished; if mahogany it should be polished.

§ 13. An efficient black stain for such pieces of white wood may be made by working upon a slab a teaspoonful of lamp-black, with a tablespoonful of thin glue, until quite smooth, with a muller. This stain may be applied *while warm* to the wood, well rubbed in, and when *quite dry* varnished with "white hard varnish," which will be dry in about twelve hours.

§ 14. A circular card, graduated to the 360° of a circle, and of the same diameter as the interior of the glass chimney, is now to be glued on to the central circle of the base board; the zero point coinciding with the centre of one of the flat edges, *not* with the diagonal corners. Previous to gluing down the card, a slot about ⅛ in. deep, and ¼ in. wide, must be cut in the upper surface of the base board, reaching from the position of the zero point to the extreme edge of the board. (This serves for the introduction of a soft iron rod, or of different magnets.) The next step is to make a similar but rather smaller graduated circle to slip over the projecting brass tube in the upper cover. This circle should be cut out of a sheet of tinned-iron or zinc, and the degrees of arc (of which there should also be 360°) marked clearly upon it by scratching deeply with a sharp steel point. In the centre of this circle, a hole, just sufficiently large to admit the passage of the piece of brass tube, should be punched. This circle is to be slipped over the tube and lie flat on the cover, *but must not be fastened down.* A short brass rod, about 2½ in. long, and just thick enough to enter freely into the brass tube, is now procured, and fitted with a circular brass head made by filing up a piece of ⅛ in. sheet brass into ¾ in. in diameter, and soldering the rod in the centre of the circle. Or, the pinion of an old paraffin lamp burner.

with the teeth knocked off, may be used instead of this rod, provided it fits the tube. Whichever is used, a short piece of brass wire must be soldered at the upper extremity of this brass rod, near the head.

This index serves two purposes: First, it prevents the rod going too deeply into the tube; secondly, it serves to point out the amount of *torsion*, or twist, given to the wire or fibre which supports the "stirrup" in which is placed the magnetic needle or insulating rod, which is used in magnetic or electric measurements. The lower end of the rod must project just below the lower end of the tube which passes through the cover, and to this lower end of the rod must be soldered a short length of No. 40 German silver wire. To the other end of this German silver wire must be attached, by soldering, a "stirrup," in the form of a wide J. The length of the wire, inclusive of the stirrup, must be such that it just swings clear of the lower graduated circle when a magnetic needle or other rod is placed across the stirrup, and the cover is on the top of the glass cylinder. A well-magnetised needle, a little shorter than the diameter of the cylinder, completes the instrument if it is to be used as a magnetic measurer. The needle may be a piece of a good steel knitting needle, carefully magnetised to saturation. If required for electrical experiments, the magnetic needle must be replaced by a light shellac rod, carrying at one extremity a small disc of thin sheet brass or copper. In this latter case also, the channel in the base board must be fitted with a bent brass wire shaped like the letter L, furnished with a small brass ball at each extremity. This rod must be carefully insulated by being thickly coated with good red sealing wax to the depth of at least ⅛ in. all round, except at the two extremities where the balls are situate.

Fig. 5 illustrates the different parts, and the complete instrument. A is the base board, with the slot and graduated circle attached; B is the tin cover, with its

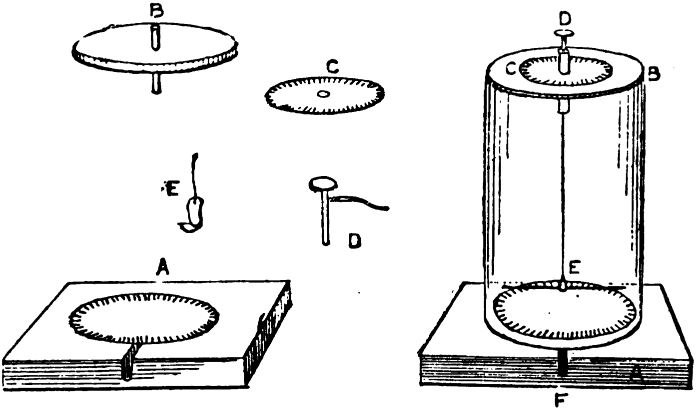


FIG. 5.

brass tube, the whole being cemented to the top of the glass cylinder when once the wire has been soldered to the milled head; C is the upper graduated disc; D the rod carrying the index, and actuated by the brass head; to this rod is attached the wire and stirrup E; F shows the instrument put together, and lettered homologously.

§ 15. VOLTA'S ELECTROPHORUS.—This is essentially the amateur's electrical machine. It is at once the simplest to construct, the most efficient in action, and its theory is most interesting as giving the key to the continuous-action electrophori of the present day. I allude to the Holtz, to the Bertsch, to the Carré, and to the Wimshurst machine.

§ 16. To make an electrophorus will be needed a sheet of zinc, from which are cut two discs; one being about 2ft. in diameter, the other about 4 in. less. The zinc should not be more than $\frac{1}{20}$ in., nor less than $\frac{1}{28}$ in. in thickness. The outer edge of both the discs must be turned up by careful hammering with a mallet, and a round, soft, iron rod, a $\frac{1}{4}$ in. thick, must be run round the edge of each disc, and covered over with the upturned edge of the disc. This operation requires a considerable amount of care and patience to effect it neatly. It is absolutely essential to the efficiency of the machine that the edges should be perfectly round, without any sharp angles; and this end can only be attained by using a steel tool, in shape something like a solid punch, but having a semi-circular concavity at its lower extremity (see Fig. 6, A). By turning the edge of the zinc over the rod by the aid of this tool and a hammer, a smooth border can easily be produced. Should, however, the amateur find any difficulty in performing this operation, it would be advisable for him to have recourse to the nearest

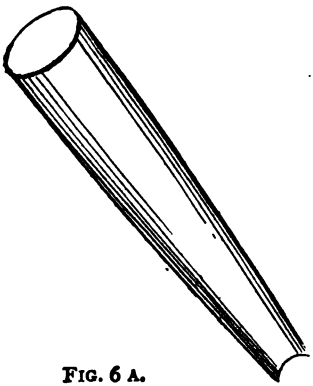


FIG. 6 A.

tinman, who will execute the necessary sleight of hand for a few pence. If well done the two discs should present the appearance shown at Fig. 6, B and C. It will be noticed that from the centre of the smaller disc projects a short piece of tube. This is made of a short length of ½ in. brass or zinc tubing about 1 in. in length,

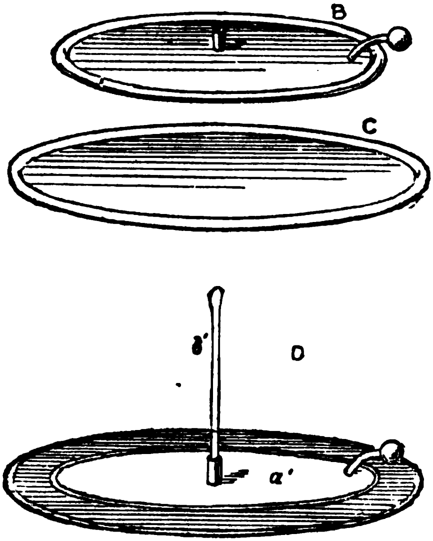


FIG. 6 B, C, D.

which is soldered centrally on the smaller disc. It is into this tube that the insulating handle is to be inserted, so that the amateur may vary somewhat the diameter of this tube to suit that of his handle; but it should not greatly exceed ½ in. in diameter, nor be less than a ¼ in. Near one edge of the smaller disc should be soldered a short length of ¼ in. brass wire—say, about 3 in. in length—bent into the form of a rounded L, and bearing at its extremity a brass ball about 1 in. in diameter. (Such balls may be obtained from most ironmongers at about sixpence each.) If not easily procurable, it may be replaced by a leaden bullet cast on to the end of the wire (see Fig. 6, B). A handle of some insulating material must now be provided. In shop-bought instruments glass handles are generally seen; but these are not nearly so efficient as ebonite, though very much more beautiful. At most chemists ebonite stirring-rods, about 9 in. long and somewhat over a ¼ in. thick, may be obtained for twopence or threepence each. One of these will serve our purpose admirably; and its round end should be cemented into the central tube by the aid of a little guttapercha or Prout's elastic glue, applied hot to the end of the rod, and the extremity of the tube slightly pinched round it to insure its not slipping out. The larger disc must now be filled with some insulation composition. Of these there are several; the best is perhaps *ebonite;* but it is expensive, being about 6s. 6d. a pound; however, it can be obtained in very thin sheets, and this, of course, lessens the expense. If ebonite is used, a disc should be cut that will just fit into the larger zinc disc, and be fastened down to it nicely and smoothly by means of Prout's elastic glue, aided by equal pressure with a warm (not too hot) iron. Another very good material is *gun-paper.* Gun-paper, or *papyroxyline*, is paper which has been immersed for a few seconds in a mixture of nitric and sulphuric acids, and then washed in an abundance of water. A disc of this papyroxyline, cut to reach quite to the bead of the larger zinc disc, may be cemented to the said disc by means of any spirit varnish (say, *white hard*) and when *quite dry*, the surface also varnished with the same, to prevent the paper absorbing moisture, which it would otherwise be apt to do. If papyroxyline is used, it should be made from stout millboard of at least $\frac{1}{16}$in. thick, and $\frac{1}{8}$ will be better still. This material is practically indestructible, and does not deteriorate, as does the ebonite, by the oxidation of the surface, or as the usual shellac composition, by splitting up from the zinc.

The last and most usual composition for the larger disc is a mixture of Venice turpentine, wax, and shellac. To make it of even consistency, it is necessary to proceed as follows :—

Take best shellac	3 parts.
Yellow beeswax	2 parts.
Venice turpentine	1 part.

Place the shellac in an earthen pipkin, and stand it over a gentle fire. Watch until melted. When melted add the beeswax. When well mixed pour in the Venice turpentine. Again stir, and when mixed, pour into the large zinc disc, which must have previously been warmed to nearly the same temperature and placed on a perfectly level table. Should any difficulty be experienced in getting the mixture to flow evenly over the disc, it may be assisted by *ironing* over with a tolerably hot iron. Should this mixture be preferred to the ebonite, or papyroxyline disc, then care must be taken to have a sufficiency to fill the zinc disc up level with the wire beading, because if the coating of resinous mixture be left too thin, it will all split away on being beaten during excitation. Fig. 6, D, shows the electrophorus in its finished form, and in position ready for use.

To put in action, it is only necessary to remove the covering disc *a'*, by its handle *b'*, and to excite the resinous cake (ebonite or gun-paper) by beating it with about half a yard of warm, dry flannel, or better still, a cat's skin. Then if the cover be placed on the centre of the cake, *the upper disc touched with the finger*, and then rapidly raised to a height of 6 or 8 in. by means of the insulating handle *b'*, care being taken not to let any part of the clothes or body touch the disc, a fine 2 in. spark may be drawn from the knob by approaching the *knuckle* or another brass ball to it rapidly. Sparks may be obtained almost indefinitely by again lowering the discs, touching, and again raising. I strongly recommend every student to make an electrophorus, and not to rest satisfied until he has fully mastered the theory of its action. When he understands this, he will have got pretty deeply into the theory of *induction*, and will be prepared to grasp the theory of the Wimshurst machine—a machine which will probably play a very important part in future applications of electricity to the arts.

§ 17. BERTSCH'S MACHINE.—Though this is not the best form of continuous-action electrophorus, yet as its construction is extremely simple, and leads to a thorough comprehension of the principles on which the more efficient forms are dependent, it will be advisable for the student to undertake it. The Bertsch machine may be made with the rotating plate either of glass or ebonite. Both forms will be described, beginning with the glass plate form, as the mode of mounting a glass plate on a spindle is generally regarded as a "poser" by amateurs.

§ 18. MOUNTING A GLASS PLATE.—There are two modes open to the amateur—viz., by drilling a hole through the glass of sufficient size to take the spindle, and screwing or cementing two cheeks against the glass plate; or by cementing two cheeks, one on either side of the glass plate, exactly central, and opposite one another, these cheeks having the spindle (of which there are two halves) inserted at their centres.

§ 19. To drill a glass plate requires more patience than skill, though both are needful. In the first place the glass must be cut to an exact circle, and its centre marked.

To do this the amateur should procure a stout piece of brown paper, and with the compasses strike out a circle of the size of which he intends his glass plate to be. (A very convenient size for most electrical machines is 18 in. in diameter.)

Keeping this marked paper as a template, our student cuts out a similar circle in rather stout millboard. He then places his glass plate upon a *perfectly flat* table, with the millboard disc over it. A small dab of hot Prout's cement applied to the glass, will hold the millboard to the glass so that it shall not move during the cutting of the circle. The operator now traces with a diamond or glass-cutter a circle all round the millboard guide, being careful not to press so heavily as to split the glass, or so lightly as not to cut. To a practised ear the peculiar *whistle* tells when the glass is being cut, and when only scratched. The circle being thus traced on the glass with the diamond, the millboard guide is removed, and the corners of the glass cut so as to permit the curved pieces being pulled asunder. The four diagonal cuts must, of course, come quite close to the periphery of the circle cut on the glass. A cursory examination of Fig. 7 will render this clear. A repre-

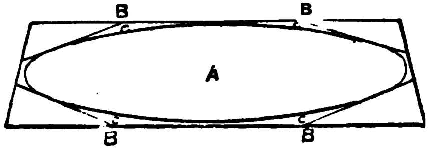


FIG. 7.

sents the circle first traced on the glass; B the four diagonal cuts, which enables the quadrantal segments C to be detached. To insure the glass breaking where it is cut, and nowhere else, a little care is necessary.

Firstly, the operator must see that the glass is *really* cut, and not simply *scratched*. To know this, when he has traced his line or curve with the diamond or cutter, he must turn the glass over and examine the line on the other side. If it looks like a mere white line, not penetrating below the surface, it is but a *scratch*. If, on the contrary, it shows as a glistening *crack* right through, it is a true *cut*. By gently tapping with the cutter on the wrong side of the glass a *scratch* may frequently be converted into a *cut*, but it is necessary to raise the glass from the table at one extremity while tapping, and to tap on the spot only where it is required to decide the fracture. When the line shows as a glistening fracture in its entire length, then, by holding the glass plate between the finger and thumb of the left hand, with the cut side uppermost, and the cut close to the thumb, the operator will find no difficulty in detaching the diagonals, and afterwards the quadrantal segments, by a steady downward pressure of the right hand, applied to the other side of the cut line. Should any pieces refuse to break quite truly, they may be "nibbled" off by means of the wards of a key, or the slots in the glass-cutter. When the circle has been cut to satisfaction, the edges should be smoothed by grinding; but as this is best done when the disc is mounted on its spindle, the directions as to the mode of grinding are deferred until the method of mounting has been described. The glass disc must now be placed on drilling-table, constructed specially for this purpose. It consists, as shown in Fig. 8, in a flat board, A, about 1 in. thick, 20 in. long, and about 12 in. wide. From each extremity of this board rises a standard B B′ about 3 in. wide by ¾ in. thick, and 10 in. or 12 in. high. There are two cross pieces C C′, joining these upright standards together, one at the top, and one within an inch of the bottom. These cross pieces have each a circular hole perforated through the centre, of a trifle over the diameter of the desired hole in the glass (generally ½ in.

in diameter). Through these holes passes a copper tube, D, ½ in. in diameter and 14 in. long. Around the upper extremity of this copper tube is cast a heavy flange of lead, E, weighing, say, at least 2 lb. Before using this tool, the lower extremity of the tube must be "upset"—*id. est*, made irregular—and broadened a little by hammering on its edges. This must be done to prevent the glass being split. To work this drill, the glass being fastened in its place by means of three corks and screws with its marked centre just under the centre of the

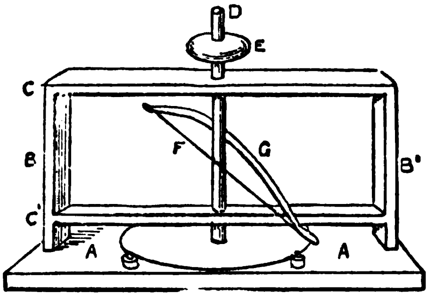


FIG. 8.

copper tube, a small quantity of ordinary emery is poured into the top of the tube, to which are added a few drops of oil of turpentine as a lubricator. A gut-band, F, is now passed once around the tube, and fastened at each end to a tolerably stiff bow, G. Moving the bow backwards and forwards communicates a reciprocating rotary motion to the drill, and this, aided by plenty of patience and a little emery and turpentine, will cut a clean round hole in the glass. This having been effected, the next step is to cement the spindle in its place. The spindle may be from ¼ in. to ½ in. in diameter, and should be furnished with wooden cheeks or washers (consisting of cotton reels cut in half), which fit them pretty tightly. One of the cheeks should be glued to the spindle (nearly at its centre) with Kay's coaguline, or similar acetic glue.* When quite dry and set firm, the surface of the cheek should be painted over with "bicycle tire cement," and the glass plate immediately slipped over the spindle into its place. The other cheek should now be treated in the same manner; that is to

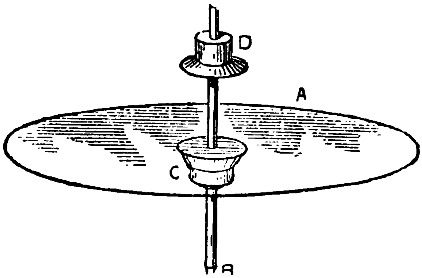


FIG. 9.

say, treated with "bicycle cement" on its face, and the portion of the spindle near the glass plate thickly brushed over with acetic glue. The upper cheek must now be slipped on to the spindle and pressed tightly down upon the glass, the whole being left undisturbed for some hours until quite set and firm. Fig. 9 will

* This useful cement is made by soaking good glue in cold water until quite soft, pouring away the water and adding sufficient glacial acetic acid to cover the glue. A slight heat will render the whole liquid, when it should be poured into a bottle kept corked for use.

illustrate the appearance of the disc when the spindle and lower cheek have been affixed. A is the glass plate, B the lower spindle, C the lower cheek, cemented, D the upper cheek, ready to be pressed down. The length of the spindle and the nature of its attachments will depend on the use to which the plate will hereafter be put. In the present instance, the glass plate being 18 in. diameter, the spindle should be (a steel rod) at least 15in. long, and should have a shoulder turned down at each end to the length of about 1 in.

When the spindle and glass plate are thoroughly cemented together, a small wooden pulley about 1½ in. diameter, similar to those used for roller blinds, must be cemented close to one extremity of the spindle, just before the shoulder. This serves to take the band or gut, by means of which motion is communicated to the glass disc.

§ 20. MOUNTING A GLASS PLATE WITHOUT DRILLING. This method is much simpler than the former, and is in most cases preferable. It is certainly superior, in the case of such machines as the Bertsch, the Carré, the Holtz, the Wimshurst, and, indeed, all "induction" machines; and it is quite equal for frictional machines, except when the plates are very large, say, over 2 ft. in diameter. To mount a plate in this manner all that is necessary is to place the plate on the marked paper which has been kept as a template (§19), so as to be able to find the exact centre. Over this must be pasted (with bichromated paste) circlets of brown paper, one on each side of the glass, of the same size as the wooden cheeks (made, as beforesaid, from a cotton reel sawn in half). The bichromated paste is made as follows:—Flour, two teaspoonfuls; water, four ounces; bichromate of potash, five grains. The flour must be rubbed up to a smooth batter with the water, then placed in a small saucepan over a source of heat, and kept stirred until it boils. The bichromate of potash, in powder, is placed in a jam pot, and the boiling paste poured upon it, with constant stirring. This paste must be kept in the dark. The brown paper used for the circlets should be of a good stiff fibrous texture, such as is used for packing heavy goods, and should be well soaked in the paste, previous to placing on the glass disc. When the circlets have been fastened on, the glass disc, with its paper circlets, must be exposed to good sunlight for an hour or two. This sunning sets up a chemical change in the bichromate, and renders the paste insoluble, so that it does not easily detach from the glass plate. When quite dry, the wooden cheeks (with the spindles) are to be glued to the paper circlets, and the glue must contain a few grains of bichromate of potash, so as to insure that it shall not be affected by damp.

§ 21. As there is no hole through the glass disc, the amateur may find it rather difficult to get the spindle (which is now in two halves) to be exactly in a straight line. The two halves are shown at Fig. 10, where *a a′* are the two half reels, to which have been attached with acetic glue two steel rods, *b b′*, about 7½ in. long. To ensure these being perfectly opposite one another on the glass disc, it is only necessary to glue one on, and let it dry perfectly; then, having placed the disc with the spindle downwards on a block of wood, in which a hole has been drilled of the same diameter as the

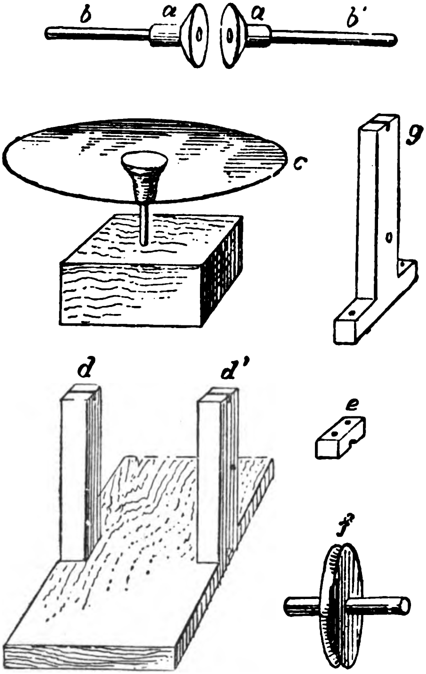


FIG. 10.

spindle (as shown at Fig. 10, *c*), to glue the other on as nearly central as one can judge by eye. On causing the disc to rotate on the lower spindle as on a pivot, it is easily seen whether the upper spindle is in a line with it or not, as it will in this latter case describe a circle instead of remaining apparently motionless. While the glue is still warm, any necessary correction in position can be made. Both spindles being now glued on, the disc should be allowed to dry—if possible—in the sunshine; and then the wooden cheeks neatly varnished (especially round the junction between the glass and the wood) with a varnish made by mixing good white hard varnish with Chinese red.

§ 22. The disc being now mounted in one or other mode, we can proceed to fix it in the standards on which it is intended to rotate. To this end, a base board, about 18 in. long by 12 in. wide, and about 1 in. thick, is planed up, and two uprights, about 10 in. in height and 1 in. square, let into the sides and screwed thereto, as shown at Fig. 10, *d d'*. With a rat-tail file, two semi-circular grooves are cut in the top of these standards, exactly opposite one another, in which the spindles of the disc must run easily. The glass disc having been placed with its spindle resting in these grooves as bearings, two caps are fashioned out of square pieces of wood to fit over the upright standards, and are screwed in their places by means of two screws The use of these caps (of which one is figured at *e*) is to prevent the spindle rising out of the groove during rotation. The standards *d* and *d'* must be such a distance apart that the ends of the spindle that have been turned down (§19, last paragraph but one) rest in the grooves just up to the shoulder.

§ 23. It will be remembered that it was recommended to attach a small wooden pulley to one of the steel rods (§ 19). It will now be necessary to place a driving-wheel below this, which can be turned by means of a projecting handle, and communicate its motion to the small pulley by the aid of a gut. This driving-wheel should be of wood, about 6 in. in diameter, ½ in. thick, and have a groove cut in its circumference about ⅛ in. deep. If our amateur has a lathe, this is an easy matter; if not, he can cut the wheel out of a ½-inch deal board with a handsaw, having first struck a 6 in. circle on it with the compasses, as a guide in sawing it. The bevel in the edge can be cut with a good triangular file. This must be keyed to an iron rod, about ½ in. thick by 4 in. long, as shown at *f*, Fig. 10, where it will be observed that the rod or spindle projects more at the one extremity than at the other. The longer extremity passes through a hole in the standard *d'*, made at such a height as to allow this driving-wheel just to clear the base board. A third standard, of the shape of a letter ⊥, is cut out of ½-inch stuff planed up, reaching, when the head of the ⊥ is on the base board, to the same height as the other two, *g*, Fig. 10. A hole is drilled through this third standard to admit of the passage of the short end of the driving-wheel spindle; and a channel (similar to those in the other two standards) is filed in the top. The driving-wheel having been put in its place, this third standard is placed against it, leaving sufficient room for it to rotate freely. The standard is then fastened down to the base board by means of a screw in each branch of the ⊥. The glass plate is now put in its place, the spindle resting in the grooves on the tops of the standards. The caps *e* are then screwed on. A gut band is attached so as to pass round the driving-wheel, and the pulley fastened to the spindle of the glass disc. A small metal, or, better, wooden handle is screwed to the projecting spindle of the driving-wheel (Fig. 11, H).

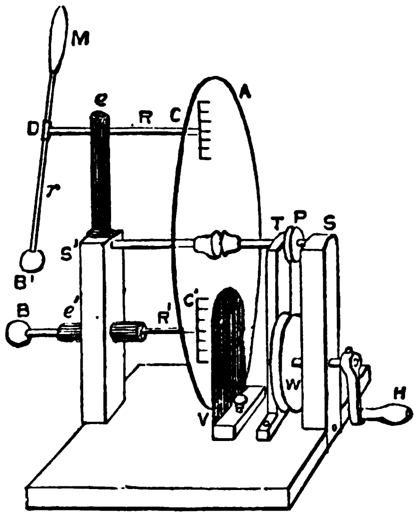


FIG. 11.

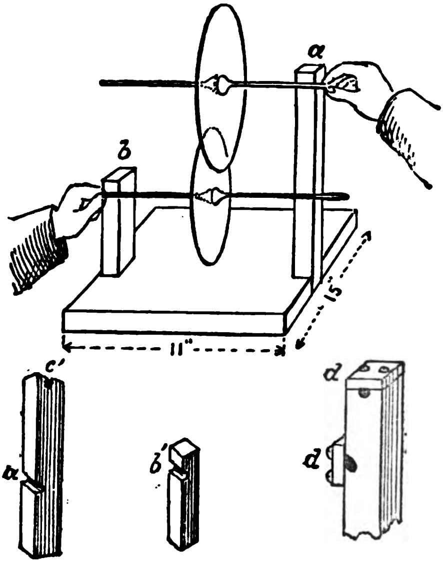
§ 24. A piece of sheet ebonite about 7 in. long by 4 in. wide is cut rounded at the top, and fastened at the bottom to one side of a little wooden stand, which can easily be effected by the aid of a couple of flat-headed screws, the heads of which must be carefully covered over with Prout's elastic glue (Fig. 11, V).

This little piece of ebonite (technically known as the "sector") and its stand must be attached to the base board, parallel with and close to the glass disc, without actually touching it. As it is necessary to remove it for the purpose of excitation, it must not be permanently fastened to the base board, but only held there by means of a small thumb-screw. Opposite this sector, but on the other side of the glass plate, is a "comb," made by soldering half a dozen brass brads to a stout brass rod about 4 in. long. A precisely similar comb faces the plate at its upper diameter (see Fig. 11, C′ and C). These combs are soldered by their middles to stout brass rods R R′. The lower one passes through the top of the ebonite rod E, which must be *solid*, and forms a prolongation of the cap of the standard S′. The lower rod R′ terminates in a brass ball B: the upper one in a short piece of split brass tube D, through which passes with some friction another brass rod *r*, to which is affixed at one end an ebonite handle M, and at the other a second brass ball B′. The split tube D allows this rod *r* to be approached to or withdrawn from the ball B. It is usual, in order to increase the effects, to hang a Leyden jar (or similar condenser) between R and R′, the inner coating being in contact with the one, and the outer with the other of these rods. Contact with earth can also be made at will by hanging a chain to the rod near the ball B, and allowing it to touch the table, D′.

§ 25. CARRÉ'S DIELECTRICAL MACHINE.—The principle of this machine is precisely similar to that of the Bertsch, but it possesses the great advantage of being less affected by the state of the atmosphere. This is owing to the employment of a continuously excited plate of glass or ebonite, instead of the "sector" (§ 24) used in the Bertsch machine. With two plates, respectively 15 in. and 19 in. in diameter, sparks from 6 in. to 7 in. in length may be obtained without a condenser; and if a pair of Leyden jars be added, as in most modern induction machines, this length may be considerably exceeded.

§ 26. With the knowledge acquired in mounting glass plates on spindles (§ 20) the amateur will find no difficulty in constructing an effective Carré machine. The plates may be either both ebonite, or both glass; or one ebonite and the other glass. Personally, I prefer both glass, provided the glass be of the required non-conducting quality. Glass varies very much in its insulating power, and this can only be ascertained by actual trial. Fortunately, this is not a difficult matter. It is only needful to dry the sheet of glass cautiously before a moderate fire; rub it briskly with a silk handkerchief (previously dried) so as to electrify the surface. If with an electrophorus shield of about 12 in. in diameter (§ 16), a spark of about 2 in. in length can be obtained, the glass may be considered sufficiently insulating for our purpose; if much less, it had better be rejected. The suitable kind of glass having been selected, it is cut, precisely as previously directed (§ 19), into two discs, one 15 in., the other 10 in. in diameter. These two discs should be mounted in either of the modes previously described (§§ 19, 20) on spindles, projecting 6 in. on each side of the discs. These spindles should be made of ¼-in. circular iron rod, inserted into the half-reels; and afterwards the rods should be carefully covered with a casing of thick brown paper, which has previously been soaked in melted paraffin wax. This casing of paraffin paper must be neatly glued round the rods, so as to form a smooth surface, and when the whole is dry should receive a coating of the red varnish mentioned at § 10. The next step is to cut out the base board from a piece of inch stuff, which may be either deal or mahogany. In either case, as the size must be 11 in. by 15 in., good, well-seasoned wood must be used, otherwise warping will take place, and spoil the whole instrument. In the centre of the two long sides of this base board are mortised two standards. Both these standards should be cut from planed stuff, 2 in. wide by 1½ in. thick—one (*a*) should be about 16 in. in length, the other (*b*) about 8 in. Previous to being glued into the base board, the necessary bearings, &c., to take the ends of the spindles, should be made in them.

§ 27. As it is very convenient to be able to remove and replace the glass plates at will, it is advisable to make these bearings in the following manner:—Having placed the standards in their sockets temporarily, the smaller glass disc is held with its spindle resting against the two standards at such a height from the base board that the edge of the disc clears it by about 1 in. A mark is made on both standards at the point where the spindles touch the standards. An assistant now holds the smaller disc in this position, while the operator takes the larger glass disc, and holds *its* spindle against the higher standard at such a height that the edge of this clears the edge of the reel of the lower disc by about ¼ in. A glance at Fig. 12 will make this clear. The position at which the two discs must rest on the stan-



FIGS. 12 & 13.

dards to ride clear of the base board and of each other having thus been found and marked, the standards are removed, and a slot cut into them a little higher than the first line, inclining a trifle downwards, and not exceeding in depth (when finished) the thickness of the iron spindle. Fig. 13 shows the position of the two slots in the standards at *a′* and *b′*; while *c′* shows a third slot in the centre of the top of the higher standard, and reaching to the top line, in which the spindle of the larger disc can ride. These slots must all be rounded (where the spindles rest) with a rat-tail file. Square pieces of wood, about ½ in. thick, are made to fit over these slots, so as to keep the spindles from rising out of their slots during rotation; and these squares are held in their places by screws, as shown at *d d*, Fig. 13. At the top of the shorter standard (*b*) must now be cut, with a centre bit, a circular hole, about three-quarters of an inch in diameter, and reaching nearly, but not quite, to the lateral slot in depth. Into this hole is cemented, with marine glue, a solid ebonite rod ¾ in. diameter, and about 17 in. length. This rod serves to insulate the upper and lower combs; and also as a support for the spindle of the large disc. This rod is shown at Fig. 14, *e*. At its lower half is a stout brass ring *e′*, which bears on one side the brass rod, to which is attached the lower comb *f*, and on the other a brass rod carrying a ball *g*, about 1 in. in diameter, also in brass. Three holes are bored in the sides of this ring, two diametrically opposite to one another, which must be tapped and screwed to take the rods; and a third also tapped and screwed to take a small set-screw, to hold the ring and its comb, &c., at the desired height. About half-way up the ebonite rod, exactly opposite the highest slot in the tallest standard, is a wooden collar *h*, preferably of mahogany or other hard wood. This is cemented to the ebonite rod, and has a small orifice in its centre (facing the highest standard), in which the end of the spindle of the longer disc can enter.

A brass ball *i*, caps the ebonite rod, and this ball is provided with a metal comb *j'*, and varnished paper comb *j'*, at one extremity, and a ball through which passes with friction a metal rod and knob *k* at the other. This latter rod has an insulating handle *l*, by means of

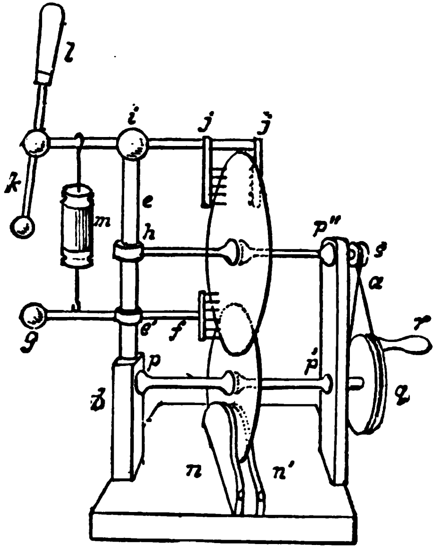


FIG. 14.

which the knob *k* can be approached to, or removed from, the ball *g* at will. These balls may either be in brass, or in lead. In the latter case the amateur may cast them on the brass rods, and drill a hole through the upper one for the sliding rod *k'*, to pass through. A piece of wash-leather glued on one side of the hole with acetic glue will give sufficient friction to hold the sliding rod in any position. If a condenser be used, it should take the form of a double Leyden jar, and can easily be made by coating the inside of two glass pomatum bottles, about 3 in. high, with tinfoil, to within 1 in. of the top. The tinfoil should be cut to the height (about 2 in.), then pasted on one side, and finally slipped into the bottle and pressed into its place. The bottles are covered in like manner, and to the same height with tinfoil on their outsides, care being taken to paste tinfoil on the bottom as well as the side. When quite dry the two bottles should be attached to one another by their bottoms by means of a roll of brown paper glued round both together; but not reaching beyond the tinfoil. When dry, the jars may be varnished all over outside with red varnish. A cork is then fitted to each, and through these corks are forced wires, one end of which touches the tinfoil at the bottom of the jars, the other end terminating in hooks, by means of which the double jar can be hung on the upper rod *i*, and touch the lower one *g*. Two pieces of wood, about 5 in. in height and of the shape shown at *n n′*, are cut out of ½ in. stuff, and the inner sides of these are covered with a wash-leather cushion, stuffed with horsehair and tinfoil. These cushions, which serve to excite the lower disc, are fastened to the base board by two screws, *o o′*. Bosses, made of reels sawn in halves, are geared to the spindles *p p′ p″*. The covering on the spindle (§ 26) must be removed at the points where they ride on the standards.

§ 28. To give the requisite motion to the two discs, a wooden pulley of about 6 in. in diameter, and ½ in. thick, having a handle *r*, projecting from it, is keyed or screwed to the lower spindle; and a small pulley, about 1 in. in diameter, is in like manner keyed to the upper spindle. A crossed gut-band, shown at *a*, completes the driving apparatus. This band must be crossed, as the plates must rotate in opposite directions.

§ 29. HOLTZ MACHINE.—Although this machine is far outdone in point of efficiency by the Voss and the Wimshurst form, yet, as it is historically interesting and presents no particular difficulty in construction, a simple form will be described in these pages.

The first thing to be prepared is a good sound base board, about 16 in. long, by 11 in. wide, and 1½ in. thick. It is not material whether this be of pine or mahogany, but it is essential that it should be thoroughly well *seasoned.* This base board, with the position of the mortise holes to be cut in it, to admit the standard and glass pillars, is shown at Fig. 15, where A is the hole in which is inserted the main wooden standard that supports the rotating disc. B and B′ are two smaller apertures to receive the two shorter standards (also of wood) between which runs the driving pulley. C and C′ are the holes into which are cemented the two glass pillars that serve to carry the combs and conductor rods. Two small cleats are glued on at *d* and *d′*, to hold the stationary "disc" in position; but these had better be left until after the "disc" is in position. I say "disc" because in the older form of machine, the stationary plate really was a *disc*, but in this machine it will take the form of a square plate 16 in. by 16 in.

§ 30. The next operation consists in preparing the wooden standards upon which turn the rotating plate and the driving-pulley. The former should be cut or turned in any hard wood (preferably mahogany), of a circular shape, rather wider at the base, and terminating in a square piece to fit the mortise-hole A, in the base board. The height of this standard (exclusive of the square portion that enters into the base board) should be $7\frac{3}{4}$ in., and it should taper from 2 in. in diameter at the bottom to 1 in. at the top, as shown at Fig. 15, E. A piece of stout brass tubing, $3\frac{1}{2}$ in. long, about $\frac{1}{2}$ in. in diameter (external), and $\frac{1}{4}$ in. bore, is next procured and soldered at one extremity to a stirrup-shaped piece of brass made out of $\frac{1}{16}$ in. stuff. This is first cut into a long oval, $1\frac{1}{2}$ by 1 in., and then bent up in the middle to admit the tube. The straight piece is shown at F, after bending at G, and with the piece of tube soldered in its place at H. Two holes are drilled and countersunk in the projecting brass ears, and these serve to screw the tube to the top of the standard. This tube forms the "sleeve" in which the spindle that supports the rotating disc turns. This main standard, with the "sleeve" screwed in position, is figured at I. Our next step is to make the two lesser uprights which support the driving-wheel. These should be made in $\frac{1}{4}$ in. stuff, planed up nice and smooth, about $1\frac{1}{2}$ in. wide by $4\frac{1}{2}$ in. in height. The top of each standard should be rounded, and a slot, about $\frac{3}{8}$ in. wide and $\frac{3}{4}$ in. deep, cut in each. One of these standards is shown at J, along with the small piece which is placed in the slot, after the splindle has been put there. A little pin, run through laterally

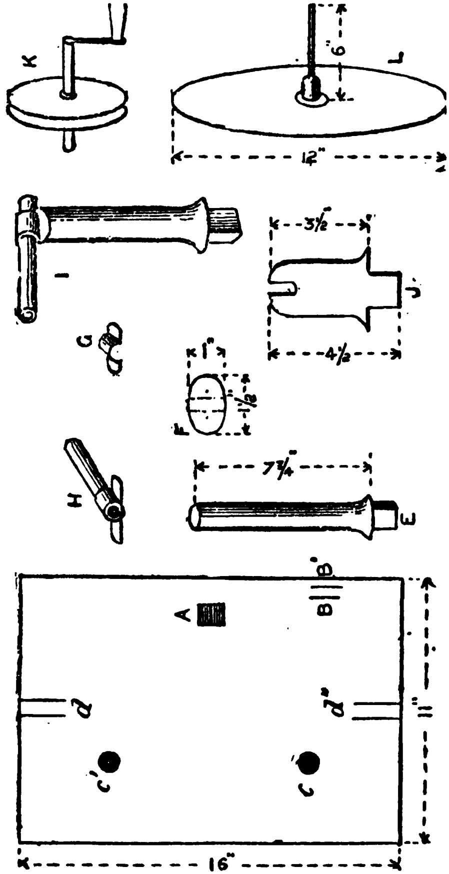


FIG. 15.

retains the whole in its place. These two uprights are placed facing each other, at B and B′, and sufficient space must be left between them for the driving-wheel to turn freely. The driving-wheel should be made of wood, preferably turned up on a lathe, and grooved round its circumference to the depth of a ¼ in. At a pinch, it may be made entirely by hand, without the use of a lathe, by sawing a circular disc, 6 in. in diameter, out of a piece of ½ in. deal, and producing a groove in the circumference by means of a red-hot iron rod carried evenly all round periphery. The central hole should be square, to admit of a square-shouldered wooden spindle being glued therein, the projecting extremities of which must be shaved down and rounded so as to run in the slots of the lesser uprights J. The driving-wheel, with its spindle and handle attached, is shown at K. We may now proceed to mount a glass disc on a half-reel and spindle, in the manner described at § 20. This disc should be 12 in. in diameter, and be fastened at its exact centre to one spindle only, as illustrated at Fig. 15, L. This spindle should be of steel, and should project beyond the half-reel about 5 in.; or, in other words, the distance between the surface of the disc and the extremity of the spindle should be about 6 in. This spindle must run freely (but without play) in the sleeve at the top of the main standard. About 1 in. of the spindle should project beyond the sleeve when the reel end is quite against the sleeve at the other extremity. Over this projecting piece is placed a wooden pulley, about 1 in. in diameter, and this is keyed on to the spindle so as to cause it to rotate rapidly when connected with a gut band to the driving-pulley K.

§ 31. In the older form of machine, as already mentioned, it was customary to employ a *disc* for the

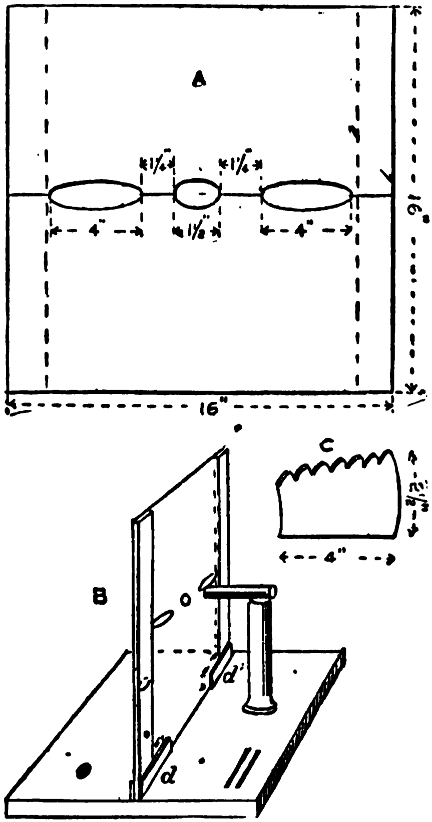


FIG. 16.

stationary plate. In this disc were cut three apertures—one *central*, to admit the spindle carrying the rotating disc, and two *lateral* ones, technically called "windows," in which were placed the pieces of paper that serve as *inductors*. The cutting of these apertures was a serious matter for amateurs. The plan herein recommended will be found equally efficacious and very much simpler in execution. A square sheet of glass, 16 in. by 16 in., is cut straight across the middle, so as to divide it into two equal halves 16 in. by 8 in., as illustrated at Fig. 16, A. When these two halves have been separated, it will be found very easy to cut out two semi-ovals, as shown, large enough to admit the passage of the spindle and reel of the rotating disc. Anyone can cut these semi-ovals with a common "wheel-cutter," or they may be even nicked out with a key under water. Similar, but longer and shallower semi-ovals, are cut out at about 2 in. each side of the central aperture. The length of these cuts should be about 4 in., the depth about half an inch, so that when the two cut sheets are placed in juxtaposition there will be seen a central aperture about 1 in. by 1½ in., flanked on either side by oval apertures, 4 in. by 1 in. The two half sheets are then cemented together in position by means of two glass strips, 16 in. by 2 in., which are glued to the two sides of the divided sheet with boiled and hot Canada balsam, the said sheet being laid on a flat table, the strips loaded with weights, and left until the balsam is set, which will take three or four days. The general appearance of the finished fixed sheet, with its "windows," central aperture, and side strips (the position of which is indicated by dotted lines), is sufficiently well shown at Fig. 16, A.

§ 32. This plate, when quite set and firm, may have any excess of Canada balsam that may have exuded under pressure scraped off and cleaned away with a rag moistened with benzoline. It should then be placed on the base board, as shown at Fig. 16, B, and the cleats

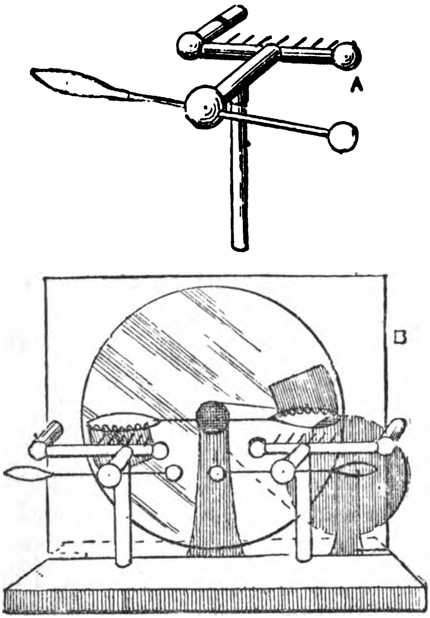


FIG. 17.

d and *d'* fastened thereto by glue and screws, the heads of which must be covered with guttapercha. The plate must not be permanently fixed to the board until after the glass pillars have been inserted; but it is convenient to place it between the cleats (as shown) to try whether the standard carrying the sleeve in which the spindle of the movable plate turns is at the right height and position. This also enables us to try whether the half-reel, which is cemented to the movable glass disc and spindle, allows the said movable disc to come near enough to the fixed plate without actually touching it. The distance between the two plates should be about $\frac{1}{8}$ in. If much more, the brass sleeve may be filed down until the distance is sufficiently diminished; if, on the contrary, the disc runs too near the fixed plate, a brass washer of sufficient thickness may be adjusted between the end of the sleeve and the half-reel. It is, perhaps, as well to point out that the side of the glass sheet facing the rotating disc must be the one on which the strips *are not.*

To insure good effects, the glass plates, as well as the "armatures" or projecting paper combs, which act as "inductors" through the windows, must be carefully coated with good shellac varnish. Shellac dissolved in methylated spirit is the best for this purpose.

§ 33. The *armatures* must now be placed in position. These consist in two portions of the periphery of a circle, cut out of stout paper, as illustrated at Fig 16, C. The scalloped portion must project through the windows, so as to just graze the surface of the movable plate. The armatures are fastened on the "back" of the fixed plate (the side *farthest* from the rotating disc) one *above* one window, and the other *below* the opposite window, by means of good starch paste, and the whole carefully varnished, as above recommended, when dry. This having been satisfactorily performed, two glass standards, about 8 in. in height, and ½ in. thick, are fitted with brass tube tops, to which have been previously soldered two cross arms, shaped like the letter T. The tops can be securely fastened to the glass rods by means of plaster of Paris. Along the top of each T are soldered a dozen brass brads to serve as combs to collect the induced electricity. To the leg of each T, beyond its junction with the brass tube that fits on the glass rod, is soldered a hollow brass ball about 1½ in. in diameter, having a ¼ in. hole right through it. This hole serves for the passage of a sliding brass rod, furnished with a glass handle on the outer extremity, and an inch brass ball at the other. The outer extremity of each head of the T-piece must be furnished with a smooth wooden prolongation at right angles with the T. This has a deep "nick" in its inner surface, and serves to support the fixed plate. The combs at the end T-pieces must be at such a height that they come just opposite the scalloped edges of the paper armature. A glass standard, with its comb, ball, sliding rod, and projecting wooden arm, is illustrated at Fig. 17, A.

After the rotating glass plate has been placed in position, with its spindle in the sleeve, and the small driving pulley keyed or screwed at the other end, the glass pillars may be cemented in position with Prout's elastic glue, care being taken that the nicks in the wooden prolongation of the T-pieces come into firm contact with the fixed glass plate. A stout gut band will be found best to drive with. The complete instrument is shown at Fig. 17, B. It is usual to add Leyden jars to these instruments, as in the Bertsch and Carré machines, in order to increase the capacity of the two conductors.

N.B.—The Canada balsam for attaching the strips to the plates is best thickened by placing in a shallow

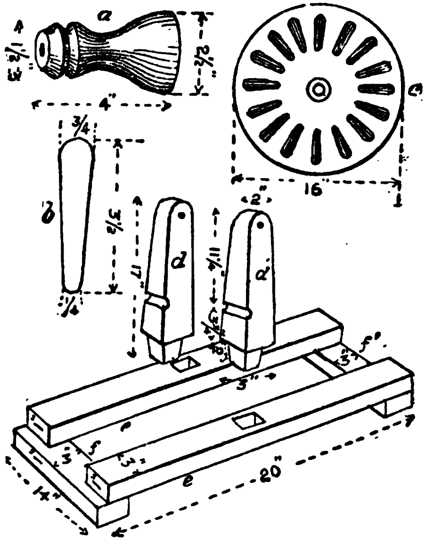


FIG. 18.

saucer in a slow oven, and gently heating it until a small portion withdrawn on a cold iron rod, *sets when cold.* It must be applied while warm, and the glass strips should also be warmed.

It is with considerable diffidence that the author ventures to place before the reader the following instructions concerning the construction of the Wimshurst machine, since the machine has been so fully and ably described by the inventor himself. However, to render this series complete, a brief sketch of the mode of making two simple forms will be given.

§ 34. THE WIMSHURST INFLUENCE MACHINE.—The portions that first demand our attention are the *plates.* These should be of glass—good window-glass—as flat as can be got, and not too green in colour (as it is apt to be poor in insulating power) is to be preferred. This is to be cut into two discs, each 16 in. in diameter. The thickness of these discs should not exceed $\frac{1}{16}$th of an inch. As in the Carré and Bertsch machines, it will be actually better *not* to have holes drilled in the plates, but to fasten the bosses to the plates as described at § 20. These bosses consist in two circular pieces of mahogany or other well-seasoned wood, not less than 4 in. in length. (It is a great mistake to have these too short, as then the glass discs come too near the standards, and much electricity leaks away.) It is best to turn these up in the lathe, of the form and dimensions shown in Fig 18, *a.* While in the lathe, a perfectly central hole nearly $\frac{1}{2}$ in. in diameter must be bored in the small end of the boss (as shown in the cut), reaching *nearly*, but not quite, to the thick end of the boss. This hole must be bushed for its whole length with $\frac{1}{2}$ in. brass tubing, and some stout steel wire which just enters the brass tube, selected and straightened out to serve as spindles on which the bosses are to turn. Mr. Wimshurst, in his directions, says: "I must impress upon those who make a machine that they cannot give too much care in selecting the tubes to fit properly, on the steel wire; it will save trouble throughout the making, and the machine, when made, will work more smoothly." The centre of the glass plates having been obtained as described in § 20, the bosses are attached to the plates precisely as described therein. When quite

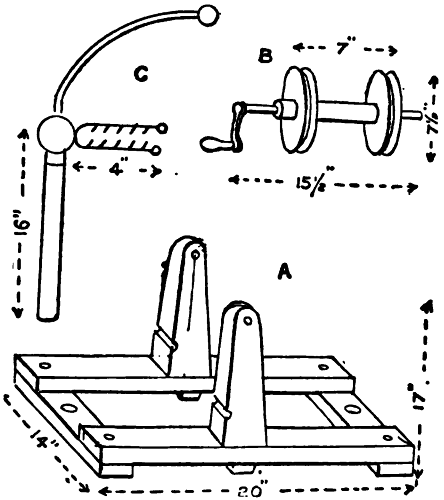


FIG. 19.

set and dry, the plates should be varnished, in a warm, dry room, on both sides, with good shellac varnish, and the varnish dried by the fire.

§ 35. As shellac varnish is in constant requisition for insulating electrical apparatus, I give Mr. Wimshurst's recipe for the preparation and preservation of this useful compound. Take a large, wide-mouthed bottle—say, a pickle bottle—fit to it a soft wooden bung, bore a hole through this bung, and in this hole tightly fix the handle of a rather large brush (the brush end being in the bottle); then about half-fill the bottle with good shellac, cover the shellac with methylated spirits, and shake the bottle occasionally. In about 24 hours it will be ready for use. By this means the brush is always clean and serviceable.

§ 36. While the varnish is drying on the glass discs the operator may strike out on a piece of paper a circle of the same diameter as the discs, and, by means of the compasses, divide the circle into sixteen equal parts, drawing radial lines at each division, from centre to circumference. This divided circle will, if placed on a flat table under the glass discs, enable the operator to fasten down the tinfoil "sectors" or segments, at equal distances from each other.

§ 37. These sectors consist in wedge-shaped strips of tinfoil, slightly rounded at the top and bottom, as shown at *b* (Fig. 18), 3½ in. in length, by ¾ in. wide at top, diminishing to ¼ in. wide at bottom. These sectors are easily attached to the glass plates by placing these latter in turns upon the paper circle (§ 36), and, having rubbed a little *thick* shellac varnish over *one* surface of the tinfoil sector, placing it (shellac side downwards) on to the glass plate, just over one of the lines, care being taken to leave about ½ in. of clear glass between the periphery of the disc and the circle of sectors. The line showing this distance had better be struck out with the compasses on the paper, as the perfect regularity of the circle of sectors adds much to the neat appearance of the machine. One disc, mounted on its boss, and fitted with sectors, is shown at Fig. 18, *c.* When the sectors are firmly stuck down to the glass, and the varnish quite dry, it will be well to run a brush charged with varnish round the inner and outer extremities of the tinfoil sectors. These rings of varnish may extend ½ in. inwards, but not more. They serve to increase the adherence of the sectors to the glass, and also to insulate slightly the extremities. On the centre of each disc, exactly opposite the bosses, must now be fastened with hot marine glue or Prout's elastic glue, a small ebonite washer, punched out of sheet ebonite 1/16 in. thick. These washers are to prevent the rotating glass discs from actually touching during rotation.

§ 38. *The stand* next demands our attention. It should be made of mahogany, walnut, or some other well-seasoned wood. Six pieces will be required—viz., two pieces 20 in. long by 3 in. wide, and 1 in. thick; two pieces 14 in. long by 3 in. wide, and two uprights 17 in. in height, 3 in. square. These two latter must be cut round the lower end to form a square tenon 2 in. long by 2 in. square section, and two of their sides must be made to slope away 2 in., this forming the top end, which must be rounded, as shown at Fig. 18, *d d'*. A hole of exactly the diameter of the steel spindle on which the plates are to run must be drilled through each standard, at about an inch from the top, care being taken that these two holes come exactly opposite each other and at the same *height* in the standards, otherwise the plates will not run opposite each other. At about 3¾ in. from the tenon, and on the same side of each standard, a long semi-cylindrical slot is cut, about ½ in. deep; this serves for the spindle of the driving-wheels to run in. All these pieces are shown in Fig. 18, where *d d'* are the uprights, *e e'* the long cross pieces, and *f f'* the lower pieces of the stand; these pieces must be planed up so as to fit accurately; mortice holes, cut in the centre of the 20 in. strips to take the tenons of the uprights. The whole is then joined together so as to make a strong frame, with glue and screws; the long strips being screwed *over* the 14 in. pieces at each extremity so as to form a square 14 in. by 20 in. As the two short pieces are placed *below* the larger ones, and as the uprights are morticed into these, it is necessary to make the ends of the uprights project 1 in. through the holes, so as to afford a support to the centre of the frame. With a spokeshave, or similar tool, the sharp edges should be taken off the frame, so as to prevent dispersion of electricity. The frame and standard being put together, as shown at Fig. 19. A, it will be well to cut out the holes in the centre of the shorter pieces of the frames, which holes are to receive the glass rods or jars (as the case may be) which support the conductors and combs. These holes may be begun with a centre-bit, and should be 2 in. in diameter if jars are to be used, or 1 in. if glass rods only are to be employed.

§ 39. As the glass discs, when mounted, must rotate in contrary directions, it is necessary to have two driving-wheels on a spindle wherewith to drive them, and to connect one driver with one boss (§ 34) by means of a straight band, while the other transmits its motion by means of a crossed band. These driving-wheels may be turned out of any suitable wood, 7½ in. in diameter; they should have a centre-bit hole, 1¼ in. in diameter, put through the centre; a length of some

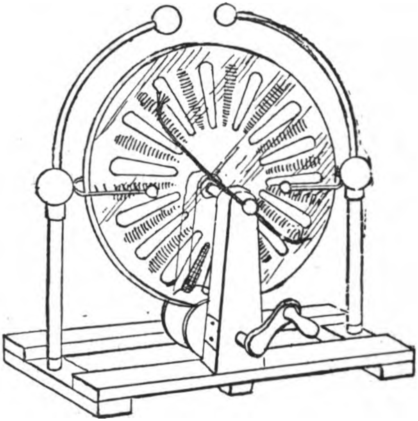


FIG. 20.

good hard wood should then be turned up to make the spindle, on which the two wheels must be tightly fitted and glued. Care must be taken that the edges of the wheels, when glued to the wooden spindle, should come exactly opposite the V groove in the bosses (§ 34) when the glass discs are in their places. These wheels must have a groove turned in their edges, to take the driving-band. The length of the wooden spindle must be such as to just *not* reach from standard to standard, say 7⅛ in. A central hole, about ½ in. in diameter, is now made through the entire length of this wooden spindle, and through this wooden spindle is driven an iron rod 15½ in. in length, ½ in. diameter, projecting 3 in. at one end, and 4 in. at the other. At the longest end this rod is squared up to take a driving-handle. If the wooden spindle does not fit quite tight upon the metal rod, it will be better to drill a hole through wood and iron and drive in a metal pin. The driving spindle is placed in the two semi-cylindrical slots cut in the sides of the standards (§ 38), and is kept in its place by means of two small rounded cleats screwed thereto. These driving-wheels, with their spindles, etc., are represented at Fig. 19, B.

§ 40. The next step is to mount the combs and conductors on to the glass pillars, which are to insulate them. These pillars, of which two are required, should be 1 in. in diameter and 15 in. in length. Good white glass that becomes readily electrical on friction should be chosen. They must be fitted with brass collars 1 in. long, at the upper extremities, and to these collars are soldered brass balls 2 in. in diameter. At the upper portion of these balls is drilled a hole ¼ in. in diameter, into which are fitted, but not *fixed*, brass rods ¼ in. thick, about 16 in. long. These rods are bent into quadrants, and terminate in brass balls. It must be noted that the two brass balls terminating these rods must be of different sizes to obtain the best effects. In the sized instrument under consideration, one should be ⅜ in. and the other 1¼ in. in diameter, and nicely polished. By not having the rods as fixtures in the top of the glass pillars, it is easy to exchange the rods if the direction of the flow of the current in the machine is reversed, either accidentally or intentionally. The combs, which must be screwed to the centre of each 2 in. ball that terminates the glass pillars, consist in ¼ in. brass rods 12 in. long, terminating in brass balls about ½ in. diameter and bent into the shape of a horseshoe, so as to embrace both the plates. In the interior of the horseshoe are soldered, or otherwise affixed, four or five ½ in. brass points. The whole arrangement of the glass pillars, with its collecting comb, large ball, movable end, and terminating ball, is shown at Fig. 19, C.

§ 41. The plates can now be mounted on the standards. To this end, each plate in turn is held with its boss against the small hole at the top of the standard on the steel rod, which was chosen as running freely in the bushing of the boss (§ 34), pushed through this hole and into the hole in the boss as far as it will go. The rod is then cut off, leaving an inch projecting on the outside of the standard. With a file, a nick is cut in this steel rod at about the centre of the portion that is to remain in the standard, then a round-headed screw is driven into the top of the standard to enter this nick and keep the steel rod quite firm and immovable. To the projecting ends of the steel rods are affixed the bent rods carrying the brushes. These rods are technically known as the "neutralising rods." They are made from ¼ in. brass rod, about 17 in. in length. A hole ¾ in. deep and about $\frac{1}{8}$ in. wide, is drilled at the two extremities of each of these rods. A little tuft of about a dozen short lengths of the fine wire used by the gilt lace manufacturers, is made into a brush by binding at the bottom end with a little of the same wire; this same end is pushed in the holes in brass rod, and wedged firmly into place by means of a little wooden wedge. There are two such rods; and each rod must have a brush at each end. A short length of brass tubing, fitting tightly on to the projecting pieces of the steel spindles carrying the plates, is now procured, and cut into two pieces $1\frac{1}{2}$ in. long. With a round file, a slot (sufficiently deep to take the brass neutralising rods just finished) is produced in these pieces, and each rod having been placed in this slot, at its centre, is soldered thereto. At the same point, to give a finish, and prevent dissipation of electricity, is also soldered a small brass ball. Each rod is then bent slightly in the shape of a bow, so that the "brushes" shall come into contact with the sectors, when the neutralising rods are put in their places on the steel spindle.

The appearance of the complete machine, with the "brushes" in their right position for a right-handed person to drive, is shown at Fig. 20.

§ 42. THE PLATE ELECTRIC MACHINE.—The ordinary frictional machine, although far behind the induction machines in point of efficiency, will always be a favourite with amateurs, owing to the ease with which it may be constructed.

A circular glass plate 12 in. in diameter, having been cut out and mounted by either of the methods described at § 18 *et seq*, is supported by its spindle, on two standards (similar to those described and figured at § 22), standing about 8 in. high, 2 in. wide, and $\frac{3}{4}$ in. thick. These are let in, by mortising, to a base board 14 in. by 9 in. by 1 in., at a distance of about 2 in. from each other, with their flatter sides facing as shown at § 39, with this difference—that they must stand within an inch on either side of the centre of the base board with the glass plate between them. The wood to be used for all the parts of this machine should be thoroughly well seasoned, and if after being planed up it is well rubbed with a flannel pledget dipped in melted paraffin wax, it will be much improved. The spindle on one side should not project beyond the standard, while on the other it should extend about 1 in. beyond the opposite standard, and on this end should be filed up square to take a handle by which it is to be rotated. As in § 19, so here, a shoulder must be turned at each end of the spindle to prevent the plate riding backwards and forwards on the standards. Two cushions are now made by cutting two thin smooth pieces of wood 4 in. long, $1\frac{1}{2}$ in. wide, and a $\frac{1}{4}$ in. thick, and covering these on one side with tinfoil attached with good paste or thin glue. When dry, the tinfoil is covered over to the depth of about $\frac{3}{4}$ in. with horsehair, mixed with some short lengths of very fine iron wire, such as is used by florists under the name of "binding wire." A square of flannel of the same size as the little board is now laid over the packing, and, finally, the whole is covered with good wash-leather, which is drawn tightly round the edges and glued thereto, tacks being used to hold the leather in its place until the glue is dry. N.B.—The corners of the wood to which the leather is attached should be *rounded*, to prevent dissipation of electricity.

In order that the cushions may press firmly against the glass plate, and yet at the same time *give* to any inequality in surface, or want of elasticity, it is well not to fix the rubbers or cushions in any permanent manner to the standards. A mode which works admirably, is to drill two holes at the centre of the edge of each cushion to the depth of about $\frac{3}{4}$ in. A stout piece of brass wire (say $\frac{1}{8}$ in. in diameter) 10 in. in length, is hammered at its centre, to render it springy, and then bent into the shape of a letter **U**, the legs standing at such a distance apart as just to face the two holes just bored in the cushions when these latter are held firmly against the glass plate. The top of each leg of the **U** is then bent sharply at right angles to the rest of the leg for a length of $\frac{3}{4}$ in., the bend in each leg facing and being parallel to its neighbour. The **U** is then squeezed together at its upper extremities until the two bent pieces just touch.

These pieces are pushed into the holes in the cushions, care being taken that the leathers of the cushions face one another. The plate having been placed in its position on the standards, the two cushions (which are held face to face by the **U** spring) are slightly separated, and caused to grip the glass plate between them. They must be pushed so far towards the centre of the glass plate as to clear it by about 2 in. The plate is allowed to turn until the cushions come in a line with the standards, and then, having decided in which direction the plate is intended eventually to be rotated, three cleats of wood are glued to the *inside* of the standards to prevent the cushions from being carried round during rotation. These three cleats or *stops* are put together like a letter **E** without the central stroke, so that the mere act of rotating in the right direction causes the cushions to hold in their right position on the standards, while the **U**-spring pinches them against the plate. When it is desired to remove the cushions for the purpose of amalgamating, etc., it is only needful to give the handle a half-turn backwards, when, of course, the plate being gripped by the spring and cushions, brings these along with it out from between the cleats. A metallic chain should hang from the bottom of the **U**-spring and touch the base board.

A *solid* glass rod 16 in. by $\frac{5}{8}$ in. in diameter must now be procured. This must be cemented into a wooden foot about $\frac{3}{4}$ in. thick by 2 in. wide, and 3 in. or 4 in. long, having a rather long slit through it, so that it can be screwed down to the base board of the electric machine by means of a thumbscrew, the slit being intended to allow of a little adjustment in the way of approach or recession from the plate. It is, perhaps, needless to observe that this glass rod must be placed on that side of the glass plate where the *handle is not*, just in a line with the standards. This glass rod must be surmounted with a brass or wooden ball, at least 4 in.

in diameter (a good skittle ball does admirably). If of wood, it must be carefully and smoothly covered with tinfoil. Besides the hole into which the glass rod enters and to which it must be cemented, this ball has two other holes—viz., one about $\frac{1}{4}$ in. in diameter facing the glass plate; another, also about $\frac{1}{4}$ in. in diameter, at the top, opposite and perpendicular to the one in which the glass rod enters. Into this latter is fixed a rod of metal about $\frac{1}{4}$ in. in diameter, which extends straight upright for a distance of 4 in. from the ball, and is then bent so as to form a ring 12 in. in diameter. This ring, and the rod, except at the extremity, where it enters into the ball, should be carefully and neatly wrapped with good string, $\frac{1}{8}$ in. thick, after the manner in which fencing foil handles are wound. The coating of string should be rubbed over with melted paraffin wax, and lastly, carefully varnished with the red varnish previously described.

The effect of this ring (known as Winter's ring) is greatly to intensify and lengthen the spark.

All that now remains to be done is to make the collectors. To this end, two rings, 4 in. in diameter, must be made out of $\frac{1}{8}$ in. galvanised iron wire, allowing a length of about 5 in. of wire to project beyond the circles. A dozen sharp-pointed brads are now to be soldered at equal distances all round these rings so that when the rings are lying flat on a table the points of the brads stand upright. The projecting wires, or stalks, of these rings are now bent sharply at right angles to the rings, at about $\frac{1}{2}$ in. from the rings, in such a manner that if placed with the stalks in the side hole in the ball, the teeth in the one ring shall face the surface of the glass plate nearer the handle, while the teeth of the other ring shall face that surface of the plate which is nearer the ball.

Having adjusted the rings so that the distance between the teeth of the rings, and the glass plate shall not be more than the ¼ in., nor less than ⅛ in., the operator will solder the two stalks together; cut them off to such a length as to enable them to enter the hole in the ball, and yet retain the correct distance either side of the plate. The stalks should then be wrapped in twine (except at the end that enters the ball), paraffined and varnished as above. This end may now be glued, wrapped in tinfoil, and forced tightly in the hole in the ball. Such a machine, with cushions freshly dressed with amalgam, will give, in dry weather, sparks 2 in. long.

§ 43. CONDENSERS.—These are instruments which owe their peculiar power of retaining charges of electricity to the fact that one conducting surface connected to earth or other large conductor confers, by induction, a greater capacity for charge in a second insulated conducting surface than this latter would have were it not for the presence of the first surface.

Condensers may be conveniently divided into three groups, according to their forms, and the nature of the insulator used between the two conducting surfaces—1st, Bottle formed, or "Leyden jars"; 2nd, Coated glass sheets, also called fulminating panes or Franklin's plates; 3rd, Coated sheets of paraffined paper or other flexible insulator, known as Fizeau's condensers.

§ 44. THE LEYDEN JAR.—Every dabbler in electricity has, at one time or other, made a Leyden jar; not every one has made a good one. The first point to be noted is the *shape* of the bottle or jar to be used. It must have a neck sufficiently wide to allow the inner coating to be easily placed in it and smoothly laid. To this end the mouth should certainly not be less than 2 in. in diameter for a jar 6 in. by 3 in., and so on in proportion. The next point that demands attention is that the bottle or jar should be of nearly uniform thickness, and free from flaw or crack. To ascertain this, it should be made to "ring." The last, but certainly most essential point, electrically speaking, is that the glass of which it is constructed should be really a good insulator. The white, or rosy white glass (which contains manganese) is very deficient in this regard. The greener-coloured glasses are generally good insulators. To test this point clean and dry the bottle. When quite dry, but cold, rub it briskly on the outside with a warm silk handkerchief. Reject all such jars as do not easily and quickly become charged so as to give a distinct spark. Choose all such as retain the charge (once acquired) longer than the others. The jar or jars chosen should now be fitted with a sound bung. This requires cutting neatly above and below, so as to be quite smooth, the upper surface being afterwards rather thickly coated with good red sealing-wax. (N.B.—The coating of sealing-wax should not be applied until the bung has been pierced centrally and a rod fitted.)

It is essential that the bung should be *new*, or at least *unused*, for if it has served for acid or salts, it will be found to attract moisture, and greatly detract from the efficiency of the jar. The *knob* of the jar should be one of those brass balls which can be procured from most of the metal-shops in Clerkenwell, where they are known under the name of "metal beads." A female screw can be made in the orifice of the brass ball, and a thread put on a short length (say 6 in.) of stout brass wire to fit. This wire, or rod, with its accompanying ball is now fitted to the bung. This is effected by making a small central hole in the bung with a bradawl, considerably smaller than the rod. This latter is then forced in until about two-thirds of its length has been pushed through the bung. When this has been done, the upper surface of the bung (that nearer the brass ball) should receive its coating of sealing-wax. Should there be any difficulty in procuring a brass ball, a substitute, quite as efficient, though not so imposing in appearance, will be found in a leaden bullet, cast upon the end of a brass or copper rod of the desired diameter and length. The next step is to coat the jar with tinfoil. It is better to begin with the inside, as when the outside is coated it is not easy to see what is going on inside. A piece of good tinfoil is cut into a circle, a trifle narrower than the outside diameter of the bottom of the jar. One side of this is carefully rubbed over (with the finger) with thin hot glue. It is then allowed to fall in the jar, glue side downwards, and is pressed into its place at the bottom by means of a small mop (similar to those used to clean lamp-glasses). The jar is now measured from the bottom to the bung. Three-quarters of this are marked off as the height to which the tinfoil coating may reach. A strip of tinfoil of this width, and three times the diameter of the jar, is now cut. For convenience of getting in the jar, especially if this latter be narrow, it will be well to divide the strip of tinfoil into two halves, and having glued one half, slip it in the jar, having previously given it a little bend, push it into its place, and smooth it down by means of a tooth brush, then insert the other half in a precisely similar manner. Care must be taken that these side pieces come into actual contact with the bottom circlet. The inside being thus coated, the outside may be proceeded with in precisely similar manner; only the sides may be covered by one entire piece of tinfoil, and this should lap somewhat over the bottom. The coatings should be allowed to dry thoroughly before the jar is used or touched, as otherwise the outer coating will be wrinkled up and spoiled. Very charming effects of a multiplicity of sparks during discharge, may be obtained by coating the inside of the jar with a number of small diamonds of tinfoil, almost, but not quite touching, instead of with one continuous layer. The outside should, in this case, be covered with similar

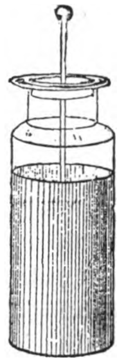


FIG. 21.

diamond-shaped pieces, and this latter should have a circular hole cut in each, so that each hole should stand over the corners of the inside diamonds. By this means not only are the sparks between the outer diamonds seen, but also those between the inside ones. The jar being coated and dry, the bung, with its rod and ball, is fitted to it. It is well to attach a small piece of metal chain to the end of the rod (by soldering), to insure contact between the rod and the inner coating. The *absolute* size of the jar and its parts may be varied at

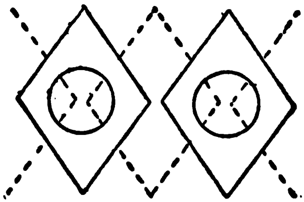


FIG. 22.

will; but, to obtain the best results, the following *relative* dimensions will be found useful:—Let the height of the jar be three times its diameter; the length of rod and ball four times the diameter. With these proportions, and especially if the coatings do not extend beyond three-fourths of the height to the bung, the jar will be found to hold a good charge for some time. A lesser charge, with longer retention, may be obtained by using less coated surface—say, two-thirds, or even a half, of the total height, instead of three-fourths. Fig. 21

shows the relative sizes and shapes of the different portions of the jar ; Fig. 22 shows the inner and outer diamond-shaped pieces of tinfoil to be used if a "spangle jar" be desired.

§ 45. FULMINATING PANES, or "Franklin's plates" as they are also called, are easily made by coating both sides of a sheet of glass with tinfoil, to the extent of half of the entire surface, leaving the margins all round clear glass. The glass should be chosen with the same precautions as to insulating power as in the case of Leyden jars

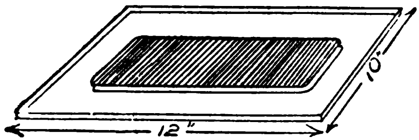


FIG 23.

(§ 44), and the corners of the tinfoil should be *rounded* as rounded ones dissipate electricity less than pointed ones. Good paste or glue (thin) will do very well to stick the foil down to the glass. When *quite* dry, any superfluous glue or paste may be removed from the edges of the foil and glass by means of a slightly damped rag. The tinfoil should be lightly burnished with a bone or ivory knife handle. As a further protection against sparking over, it is well to varnish round the edges of the tinfoil with a coating of good shellac varnish. In charging this condenser, it must be borne in mind that one surface must be connected to earth or other large conductor, while the other is receiving the charge; otherwise its capacity is very limited. A very convenient size and form of the Franklin plate is shown at Fig. 23.

§ 46. Owing to the facility with which these glass plates are broken, they are not much used at present as condensers. Other insulators, having at once the advantages of being lighter, less fragile, more flexible, and of higher specific inductive capacity than glass, are now used in all instruments intended for practical work. Of these, good paper, free from holes, soaked in melted paraffin, stands, if not alone as the first, in the very first rank. Next comes paper soaked in good shellac varnish; then thin sheet ebonite, which can be bent by heat to any shape; and, lastly, good indiarubber cloth. The mode of making a condenser, with either of these insulators, will be the same in each case, so the student will do well to try his hand at a Fizeau's condenser, as being at once the most useful and least expensive.

§ 47. FIZEAU'S CONDENSERS.—These are employed for two purposes: (*a*) to increase the efficiency of induction coils, by taking up the "extra" current induced in the primary; (*b*) to measure electrostatic capacity. Condensers for coils may be of any dimensions between 9 in. by 7 in. and 2 in. by 4 in., according to the power of the instrument with which they are intended to be used; the former size for coils giving from 1 in. to 3 in. spark, the latter for coils giving sparks of ¼ in. or less. In the former case as many as 150 alternations of tinfoil will be needed; in the latter, from 25 to 30 will be ample. Having decided upon the size to be employed, the student will select, at any photographic stores, some sheets of *plain* paper (not salted or albumenised) known as Papier Rive. These sheets run about 22 in. × 18 in. so that each sheet, if cut in half lengthwise, and in three across, will give six sheets 7 in. × 9 in. In selecting this paper it should be held between the eye and the light, so that any holes or imperfections may at once be seen; and any sheet which is faulty in this regard at once rejected. The paper having thus been chosen, and cut to the desired size, should be placed in a square flat dish, a trifle larger than the sheets themselves. The best dish to use for this

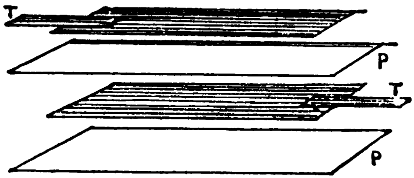


FIG. 24.

purpose is undoubtedly one of the square white earthenware dishes in which photographers sensitise their papers; but if one of these is not procurable, a very fair substitute may be found in a square, flat, tin baking dish made scrupulously clean. The sheets having been placed in the dish, several lumps of good paraffin wax (one requiring a very high temperature for fusion is the best for this purpose) are scattered over the paper, and the whole stood in a gentle oven until the wax is thoroughly melted, and the paper has become semi-transparent by having absorbed it. If there are any patches of unsaturated paper more paraffin wax must be added, until the paper is equally imbued with the melted paraffin. When this is the case, the sheets of paper should be removed from the oven one by one, allowing each one to drain until it drips no longer. The paraffin will *set* almost as soon as each sheet is removed from the oven.

The next operation consists in placing leaves of tinfoil in alternation with the paraffined paper. Supposing we have cut our paper sheets to the size 9 in. by 7 in., we shall require about 150 sheets of tinfoil 7 in. by 5 in.; or, in other words, we must allow a clear margin of 1 in. of paper all round the squares of tinfoil. We shall also need 150 strips of the same tinfoil about 1 in. wide by 3 in. long.

Having procured two thin pieces of board (common deal will do) of the same sizes as the paper, but only $\frac{1}{8}$ in. thick, we proceed to lay upon it a sheet of paraffined paper. In the centre of this we lay a sheet of tinfoil, and on this sheet of tinfoil we place one of the 3 in. strips to the *right* hand, so that the strip projects beyond the paper about 1 in. We now place another sheet of paraffined paper squarely over the first sheet, and then a sheet of tinfoil as before. On this second sheet of tinfoil we put a projecting strip of tinfoil, but this time to the *left*. In this manner the condenser is built up of alternate sheets of paper and tinfoil, with strips of tinfoil projecting alternately in the *right* and *left*. In our case, all the odd numbers, 1, 3, 5, 7, etc., being to the right, and all the evens, 2, 4, 6, 8, etc., being to the left. Care must be taken to end the condenser with a sheet or two of paraffined paper. The other board should now be placed over all, and the whole bound neatly and tightly together by wrapping round crosswise (not lengthwise because of the projecting strips) with rather wide tape from end to end, and then stitching down the ends of the tape. This being done, the projecting strips on each side are folded tightly together, so that the whole 150 strips come into absolute contact. It is to these two projecting lugs that remain after this operation, that the contact pillar and spring of the coil are attached. Fig. 24 shows the disposition of the sheets of

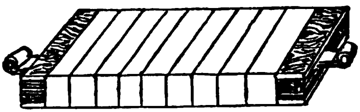


FIG. 25.

paraffined paper and tinfoil, where PP′ are the sheets of paper, and TT′ the tinfoil. At Fig. 25 is shown the complete condenser, with the projecting tinfoil strips turned up and compressed together.

§ 48. MICROFARAD CONDENSER.—Take 37 sheets of good tinfoil, 7 in. by 6 in., with an equal number of strips 3 in. by ½ in. Procure about 76 sheets of very thin, hot-pressed paper 9 in. by 8 in., such as is used for bank-notes, or similar. Choose it carefully, leaf by leaf, free from holes or blemishes. Soak it as above described in hot melted paraffin, drain, and blot off each individual sheet between good blotting paper. A hot iron must be used to do this effectually. Now lay on a perfectly smooth and flat iron plate two sheets of this paper (as shown at P, Fig 24), then a sheet of tinfoil, quite in the middle, then a strip, projecting to the right. Over this are placed two sheets of paraffined paper (as shown at P′), then a sheet of tinfoil with the projecting strip to the left (as shown at T′′). Proceed in this manner, laying the sheets of tinfoil over every *two* sheets of paper until the 37 sheets have been used up. Now, subject the whole in a press between two iron plates to a pressure of half a ton. Solder lightly all the 19 ends on the right-hand side together for attachment to one terminal, and the 18 ends on the left-hand side to attach to the other terminal; place the condenser between two stout boards clamped together by screws, so as to maintain one constant and invariable pressure as the capacity increases by pressure. Two binding screws must be attached to the two soldered ends of the tinfoil strips to serve as terminals. By using two sheets of paper between each pair of tinfoils, any liability to leakage through the holes in the paper is minimised; of course, the instruments should be tested against one of known capacity if great exactitude be required. If too small, increase the pressure, or the number of tinfoil and paper leaves; if too great, remove a leaf or two.

PART II.

DYNAMIC OR CURRENT INSTRUMENTS.

§ 49. THE MEDICAL COIL.—Procure a well-seasoned board of walnut about 21½ in. in length, 3 in. wide, and ⅜ in. thick. From this cut one length 12 in. long for the base board (Fig. 30), and three pieces 3 in. square (like Fig. 29), for the coil heads; when cut, a fillet 8 in. long must be nailed or screwed on the two sides of the base board (as shown at Fig. 30); these fillets should be in. square section. Corresponding square nicks must be cut in *two* of the square heads (as shown at *a*, *a*, *a*, *a*, Fig. 31). All the woodwork when thus squared and finished, should be soaked for a quarter of an hour in melted paraffin wax, and then rubbed dry while still warm.

Procure a thin brass tube (known in the trade as "triblet tubing") about ½ in. diameter, 4½ in. long; turn up a short plug and button to fit one end of this tube and serve as a handle (see Fig. 26). This may be fastened to the tube by driving in three fine brass brads, and filing off the heads flush with the tube.

Now cut up about 100 lengths of straight iron wire (best soft annealed) No. 22 gauge, say, about 4½ in. in length; fill the brass tube with them as tight as you can fit them; cut them all to the same length (they must protrude a little beyond the tube). Now draw out about a couple of inches of the iron bundle, and wrap it tightly round with twine, leaving about ½ in. free. Draw more out, and continue wrapping until you have wrapped to within ½ in. at each end of the bundle. Tie the string, and withdraw the bundle from the brass tube. Melt a little solder in a ladle, dip the ends of the iron bundle into soldering fluid (zinc dissolved in hydrochloric acid), and then at once into the melted solder. Allow the bundle to cool; file off the superfluous solder, so that the bundle will just enter freely into the tube. It should appear like Fig. 27 when the string has been removed.

§ 50. The next operation is to make a good stout paper tube, also about 4½ in. in length, into which the brass tube (Fig. 26) can slide easily. To make this, put a few turns of soaped writing paper round the tube Fig. 26, then roll and glue seven turns of good, stout brown paper, 4½ in. in length, round this writing paper, or else it will be difficult to draw out of the tube. This paper tube (Fig. 28) must be allowed to dry thoroughly while still on the brass tube (Fig. 26). When *quite* dry, it must be slipped off, the writing-paper lining drawn out, and then it must be soaked for a few minutes in melted paraffin wax.

§ 51. The iron bundle should also be allowed to stand in melted paraffin wax for some time, and then stood up to drain in a warm place. This will prevent rusting. When quite cold, all superfluous paraffin having been removed, a strip of brown paper, ½ in. wide, is rolled round one extremity of the iron bundle, until it is of such a diameter as to fit tightly into the paper tube (Fig. 28). This paper strip must be cut off at this point, and glued tightly round the end of the iron bundle. The brass tube (Fig. 26) is then slipped over the iron bundle, until it just reaches the little paper collar just made. The brass tube and bundle together are pushed, button end first, into the paper tube (Fig. 28), and when the paper collar around the iron bundle is just about to enter the paper tube, it is to be well served with hot glue and forced into the tube. The whole must now be allowed to dry and set thoroughly.

§ 52. Taking one of the 3 in. heads (the one which has not any nicks in the sides) we bore a central hole with a brace and centre bit, just large enough for the paper tube (Fig. 28), with its iron core, to fit tightly (see Fig. 29). Putting a little thin good hot glue round the free extremity (the end opposite that at which the brass enters), we push it into the hole in the square head, until it projects about ½ in. on the other side. This must be allowed to dry thoroughly before proceeding to the next operation.

§ 53. We may now proceed to wind the primary coil. To this end, we take about ½ lb. of No. 24 silk-covered copper wire, and wind it round the tube (as shown at Fig. 33), from end to end in continuous layers, taking care to put a sheet of paraffined paper between each layer, and also to baste each layer with melted paraffin wax before winding on another. About four layers will thus be got on, and an even number of layers must be aimed at, so as to get the two ends of the wire at the same extremity, thus rendering it easy to fasten them *under* the binding screws A A (Fig. 33). To effect this, before screwing down the said screws, the ends of the copper wire are stripped of their covering and wound once round the screw of the binder. Free ends of wire, at least 6 in. in length, must be left for attachments, etc. This is shown at Fig. 34.

§ 54. This primary coil, with its iron core, sliding brass tube regulator, &c., may now be fastened to the base board by means of two screws from underneath, as shown at Fig. 32, at 4 in. from one end, and therefore 8 in. from the other. One of the free ends of the primary wire is brought to one of the binding screws A, while the other connects to the clapper, B. A short piece of wire connects the platinum screw pillar C to the other binding screw, which is not visible, as it is behind the platinum pillar. At this point it will be well to try the working of the primary coil. For this purpose couple up the two binding screws on the base board with a good bichromate cell. Connect the two binding screws D D (Fig. 32) with the two brass handles intended for use. Screw up the platinum screw, C, until the clapper, B, begins to vibrate. Now hold the handles in your hand. As long as the brass tube, E, is entirely over the iron core little or no sensation is perceptible. If an assistant pull out the tube, little by little, the current will be found to increase in strength until the regulator tube is quite out.

§ 55. The secondary coil now demands our attention. A paper tube, precisely similar to Fig. 28, but of such a size as to slide *easily* over the primary coil E (Fig. 32), is prepared, and paraffined. This must be cut exactly the length of the coil F, leaving the knob E projecting. The two square pieces of board in which the nicks were cut (Fig. 31) must have central holes cut in them to take this paper tube, and then be glued, one at each end of the said tube, as shown at Fig. 31. Two small binding-screws are then to be inserted in the centre of the upper edge of each square. A bung is now placed in each end of the tube, and a ¼ in. iron rod pushed through both, to serve as an axle. This is then mounted on two standards, as shown on Fig. 35, and beginning by attaching one end of the uncovered wire to the binding-screw A, about ½ lb. No. 36 silk-covered copper wire is now coiled on, being most diligent in avoiding kinks, breaks, or flaws of every description. Each layer must be paraffined and separated from its neighbour by paraffined paper. When the quantum of wire has been laid on, the finishing end is connected to the binding screw A^1, Fig. 35. The last coil should be covered with paraffin paper, and finally covered with a jacket of good silk velvet. The secondary coil is then complete, and may be slid in its place over the primary coil (see Fig. 36). When it is quite over the primary, the secondary current will be at its strongest, if the metal tube regulator is drawn out; it will be weaker as the metal tube

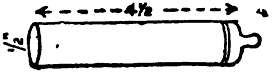


Fig. 26.

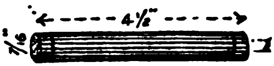


Fig. 27.

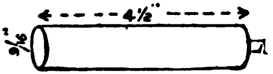


Fig. 28.

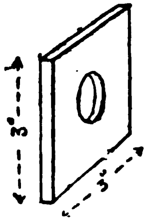


FIG. 29.

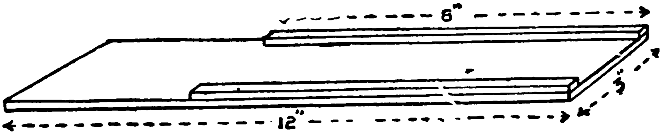


FIG. 32

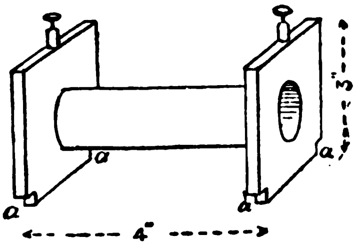


FIG. 31.

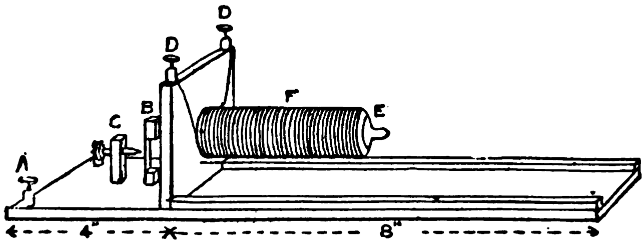


FIG. 32.

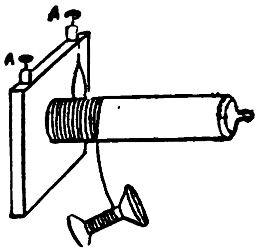


FIG. 33.

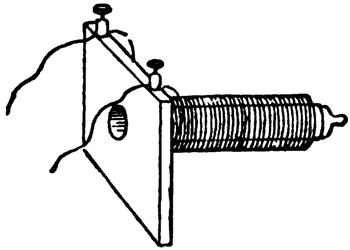


FIG. 34.

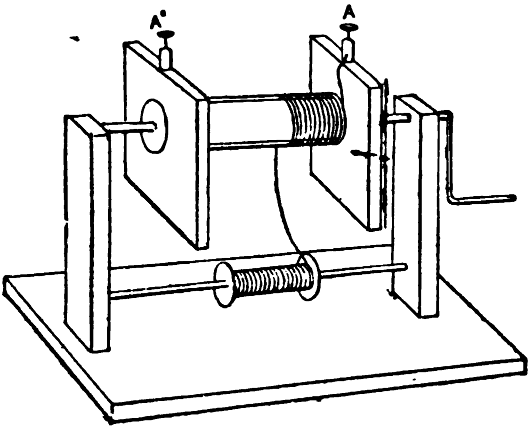


FIG. 35.

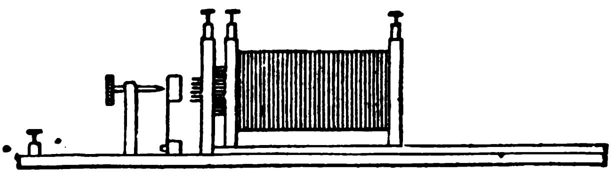


FIG. 36.

regulator is more and more inserted; or may be even more delicately regulated by sliding the secondary coil itself more or less over the primary. The secondary coil, while the primary is being excited with a freshly made pint bichromate, will give a $\frac{1}{2}$ in. spark, when the regulator is out, and the secondary coil right over the primary. This will pass easily through a dozen persons.

§ 56. THE INDUCTION COIL.—If, in the construction of the coil described in the last eight sections, the following modifications be made, the result will be a coil capable of giving with 6 chromic acid, or Bunsen cells, a good inch spark.

In the first place, a brown paper tube should be made, 9 ins. long, $\frac{3}{4}$ in. in internal diameter, and about $\frac{1}{16}$ in. thick by rolling and gluing the brown paper as recommended at § 50, round any cylindrical rod of the desired diameter.

This tube should be treated with melted paraffin wax as described at § 50, and then filled with straight iron wires, No. 18 gauge, as tight as they can be made to fit. (These wires will not require soldering, &c., as they are to remain permanently in the paper tube.) The wires should protrude about $\frac{3}{8}$ in. on end side of the paper tube.

§ 57 The wooden heads should be only two in number, and 4 ins. square, instead of 3 ins. as directed at § 49. In one of these heads (the one intended to be near the vibrating hammer), two $\frac{1}{16}$ in. holes are drilled, close to the central hole through which the paper tube is passed. The two heads are to be glued on to the paper tube, precisely as recommended for the secondary coil tube at § 49. When dry, the whole affair, wires and all, should be soaked in melted paraffin wax.

It should be then set up between standards, and wound carefully with four layers No. 18 double silk covered wire. The ends of this wire should be brought out, at the hole just made in the wooden head. When this, the primary wire has been well, and evenly laid on, it should be well basted with hot melted paraffin, and then surrounded by a layer of paraffined brown paper, pulled very tight and smooth, and made to adhere by means of melted paraffin.

Over this layer of paper may now be wound the secondary wire. This should be 1 lb. of No. 39, in one continuous length: and should be tested electrically for continuity before laying on. The whole reel of wire should be soaked in melted paraffin wax, and allowed to drain while still hot, before being wound on; each separate layer should be basted with hot paraffin wax before being covered with the next layer of paraffined paper. The ends of the secondary should be attached to the binding screws marked A and A^1 at Fig. 35, § 55. The coil may now be fitted to a stand, with the vibrating hammer and platinum screw, as described at § 54; but the stand should take the form of a shallow box inverted, and in the bottom must be fastened, by means of catches, a Fizeau's condenser § 47, and the hammer pillar and the platinum screw pillar, each separately connected to one of the projecting lugs. A false bottom is now put in the stand, to hold all in its place. The *condenser* is essential to obtaining a good long and dense spark. *Careful* insulation is also another important, if not the most important item, in a successful coil.

§ 58. THE MAGNETO-ELECTRIC MACHINE.—This is the first form of *dynamo* which the inventive genius of Faraday placed before the scientific world. It had its origin in the discovery "that a conductor moving before the poles of a magnet, in such a direction as to cut the lines of force of the said magnet, had its electrical condition upset, so that a flow of electricity was produced within it"; and this could be rendered evident by suitable means. Two forms of magneto-electric machines will be described: *firstly*, the ordinary "medical" or "shocking" machine; and *secondly*, a rather more scientific instrument, which can be used for many experiments, for which the former would be totally useless.

§ 59. THE "SHOCKING" MACHINE.—The amateur will need a pretty powerful horseshoe magnet, as shown at Fig. 37 M, about 8 in. long, made of ½ in. steel. Each limb should be about 1½ in. wide, and should at the polar extremities stand about ¾ in. from the other. If the amateur is able to work in steel, he may make these magnets himself, and magnetise them by passing magnetising coils of wire round each limb, and sending a powerful current of electricity through the coils, until the magnet is sufficiently strong. For the purpose required, the magnets should pull easily a weight of 10 lb.; but it will, in most cases, be found cheaper to buy these magnets ready made. The armature can be readily constructed at home. It consists in two iron bobbins, F F', screwed on to an iron yoke, or cross-piece, Y; these bobbins should be turned up out of the very best soft iron circular rod, about 1¾ in. diameter.

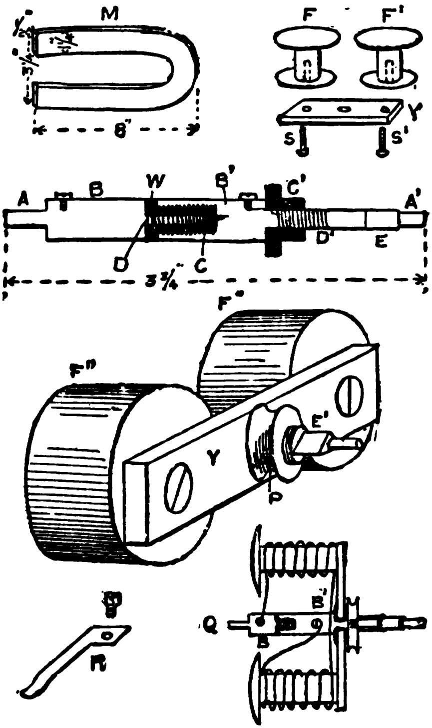


FIG. 37.

The centres, or cores, should be turned down to about ½ in. in diameter, a flange about $\frac{1}{16}$ in. in thickness being left at both erds. A hole must be drilled up the centre of each bobbin, and this hole must be tapped to receive an iron screw about 1 in. long, 3/16 in. diameter. These screws serve to clamp the bobbins to the yoke. Owing to the weight of the coiled bobbins, and the high speed at which they must be driven, it is needful that these screws should be strong to resist the centrifugal tendency. The length of the bobbins, including flanges, is 1⅝ in. If the operator has not a lathe, he may make a fair substitute for the turned bobbins by putting a screw-thread on the top and bottom of two pieces of ½ in. iron rod, 1⅝ in. in length, and screwing thereto discs of soft iron, 1/16 in. in thickness, 1¾ in. in diameter, having holes drilled and tapped in their centres to take the extremities of the rods. The yoke Y has in its centre a ⅜ in. hole, which must be carefully bushed with some good, hard insulator, such as ebonite, ivory, or boxwood, soaked in paraffin wax.

§ 60. The shaft or spindle on which the armature revolves constitutes the distinguishing feature of this particular form of magneto machine. It must be compact, easy to construct, strong, and well insulated in its two halves. It must also have some device whereby contact can be made and broken two or three times during each revolution. To this end an iron rod, about 5 in. long and ¼ in. in diameter, is turned down at both ends for a length of ¼ in., to about 3/32 in. in diameter. This is to produce a shoulder at each end for the spindle to rest in its bearings. These thinner ends are shown at A and A′. Another, 1/32 in., is taken off at one end for about ½ in., say, at the end A′. Then a screw-thread of about ½ in. in length is run on at D′. The rod is then cut in two at D, and a length of about ½ in. is turned down to about ⅛ in. in diameter. A screw must be formed on this thinner portion, as shown at D. The portion B′ has then a hole about ¾ in. in depth drilled in it, and about 3/16 in. in diameter. A female screw must be cut in this, and the hole bushed with ivory or ebonite, as shown at C. Great care must be taken in tapping this to receive the screwed end of D, that the two halves of the divided rod are perfectly insulated from one another. To this end an ebonite washer is placed at W. It is well to test for insulation by inserting the spindle at this point, in the circuit between a galvanometer and a battery. If any current passes so as to produce a deflection, the hole C must be cleaned out and replugged, until perfect insulation has been effected. Two small holes, to take short screws about 1/16 in. diameter by ⅛ in. in length, must be drilled and tapped, near B and B′. These are intended to make connection with the two ends of the wire coming from the bobbins, as shown at Q. The next operation is to turn up a small brass pulley, about 3/16 in. in thickness, by about ½ in. in diameter, which must have a female screw put in it to fit over D′, as illustrated at P. This pulley serves at one time to clamp the yoke Y in its place on the spindle, and to communicate the motion from the little driving-wheel to the armature spindle. All that now remains to be done to the spindle is to file about ¼ in. of its length, just beyond the screw-thread D′, into a triangular form, like the

Grecian letter Δ, as shown at E′ and E. The length of the finished spindle should be 3¾ in.

§ 61. A brass frame, of the form and dimensions figured at Fig. 38 A, must now be provided. In substance it should be ¼ in. wide by ½ in. deep. At the point *d* the frame expands both above and below, so as to form a lug, projecting about ½ in. on either side, against which can be clamped the magnet, M (Fig. 37). The amateur should construct a pattern of this frame in wood a trifle larger than it is intended to be (to allow for shrinkage), and after having carefully smoothed and bevelled the edges, send it to the brass founder's to get a similar one cast in brass. When cast, the frame will require careful cleaning and trueing up with a file. Holes to take 3/16 in. diameter screws must then be drilled and tapped at *c c*. These serve to fasten the frame into its box. At B and B′ rather larger holes must be bored, the former being carefully bushed with ivory or hard ebonite, the latter fitted with a metal screw, through both of which a hole is put, sufficiently large to serve as bearings for the end, A and A′, of the spindle (see Fig. 37 AA′). At *e* and *e*′, precisely opposite one another, are drilled two 3/16 holes, which serve as bearings for the driving-wheel. At *f*, a small hole about ⅛ in. and ¼ in. deep, is drilled and tapped, to receive a small screw. This is intended to receive the small contact spring R (Fig. 37.)

§ 62. The next thing needed is a small brass driving-wheel about 4 in. in diameter and ¼ in. thick, with a groove cut in the periphery, to take a gut band. The tyro need not make a pattern for this, for nearly every toy-engine shop keeps brass flywheels of about this size. If it have not a groove when bought, one can easily be

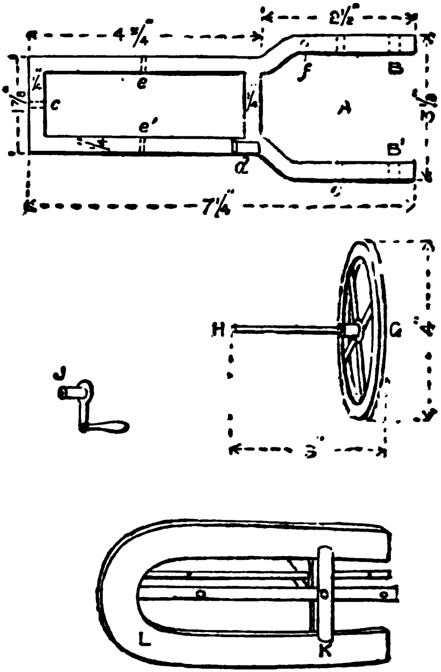


FIG. 38.

put in it on the lathe. This wheel is shown at Fig. 38, G, mounted on an iron shaft, 3 in. long, H. This fly-wheel may be keyed or brazed to the shaft. Just beyond the fly-wheel at I, the shaft is turned down so as just to enter freely into the holes *e* and *e'*. At the extremity, G, a screw thread is put on the projecting end of the rod, to take the female screw of the driving handle, shown at J. At the opposite extremity, H, the shaft is drilled and tapped to take a rather large-headed screw, which serves to prevent the shaft from riding to and fro.

§ 63. The operator may now proceed to wind the bobbins. For this purpose he will need about 1 lb. of No. 26 or 28 double silk-covered wire. Having ascertained, by testing with a battery and galvanometer, that the wire is continuous, it will be well to soak the coil of wire for a few minutes in hot melted paraffin wax, allowing the paraffin afterwards to drain off, by suspending the coil for a few minutes in a rather warm place. The iron bobbins, F F' (Fig. 37), are then wrapped round with one layer of brown paper, which is fastened down to the cores with good glue. Two semicircles, with hole cut in the interior to fit the iron cores, are also glued inside the flanges, so that the whole of the inside of the bobbins is entirely covered with brown paper. When the glue is *quite dry*, the bobbins may be warmed, and plunged for a few seconds in hot melted paraffin. Each bobbin is then to be wound, *in the same direction*, with the wire above specified, until the bobbin is filled to the top of the flange. To prevent unwinding the finished ends may be tied down to the bobbin with a bit of silk, leaving, however, about 2 in. of the wire *free* for attachment to the spindle. The commencing ends of the wire must also be allowed to protrude beyond the flange for 2 in. or 3 in. for connection. The two bobbins are then screwed firmly to the yoke, the yoke afterwards being put on the spindle. When this has been done the four ends of the wires are joined, as shown at Q (Fig. 37); that is to say, the two lower ends (after their covering has been removed), are twisted together, soldered, and rubbed over with Prout's elastic glue, to insure insulation; while the two top ends are screwed each one down to the shaft, one at B, and the other at B′, the covering having been previously removed from the wire at these points to insure perfect electric contact with the two halves of the shaft. In order that the machine may work, the relation between the winding and connections of the lower ends of the bobbin wires (as seen from the yoke end), must be like this—ɷ. A thin ebonite washer is now placed over the yoke, and the little pulley, P, screwed tightly in its place. This must be screwed down very firmly, as upon this depends the stability of the armature. The armature is now *finished*, as far as actual work goes, but the bobbins may be covered with any pretty-coloured silk velvet, if appearance be studied.

§ 64. The brass frame is now clamped by means of a stout brass cross-piece K (Fig. 38) to the magnet; and if necessary a second cross-piece (also of brass) is screwed to the frame at L. The back end of the armature spindle (the end farthest from the pulley) is passed into the larger hole B, of the frame A. This will allow the other end of the spindle being inserted into the opposite hole B, without strain. When the spindle is in its place the hollow screw is place in B^1, and screwed home, until the armature spindle can just turn freely, without too much play, before the poles of the magnet. In like manner the driving-wheel G is put in its place by passing the long end of spindle through the holes *e* and *e'*, and then fixing it in position by means of the larger headed screw already mentioned at the end of § 62.

The small spring R is then screwed down to the frame at *f*. It must *just rest* on the projecting corners of the triangle E^1, during rotation, and *just clear* the flattened portions. On careful attention to this point a great deal of the efficiency of the machine depends. The shock is felt, not *while the current is continuous*, but at the instants of *breaking* and *making* contact. The instrument can now be placed in any suitable box, which must be sufficiently long to allow the armature to rotate without striking against the ends, and just a trifle—say ⅛ in.—wider than the frame. The frame is attached to the box by means of screws which pass through the box into the holes *c* and c^1 of the frame. The screw at *c* should be hollow, so as to take a small pin, or metal hook, which is intended to make connection with the metallic cords and handles, that are used for giving shocks. Another similar screw is put in the side of the box almost opposite the armature, and to this screw, in the inside of the box, is fastened a rather stiff brass spring about ¼ in. wide, bent into the shape of L, the longer end of which must press firmly against the end of the armature spindle which projects through the hole B Fig. 38. This latter screw forms the other terminal of the machine, the other cord, etc., being affixed thereto. It is usual, though not essential, to place a soft iron keeper at the back of the magnet's poles, which may be partially or wholly removed at will. This enables the operator to regulate somewhat the strength of the shocks by increasing the inductive effect of the magnet on the armature, consequent on the removal of keeper from near its poles. There must also be a hole in the box, to allow of the insertion of the driving-handle, J.

§ 65. THE UNI-DIRECTION CURRENT MACHINE.—At § 59 we studied the construction of the magneto specially designed for physiological effects. Here we shall direct our attention to one that may be used for heating, lighting, chemical, and electro-magnetic experiments generally.

The first thing to be procured or made, as described at § 59, is a horse-shoe magnet, having a clear space of 1 in. between the poles, 8 in. long, ½ in. thick, and 1½ in. wide. This should be capable of lifting at least 10 lb.

An armature, or iron core, 3 in. long, $\frac{15}{16}$ in. diameter, with a channel all round its length, ⅝ in. wide, ⅜ in. deep at the sides, ½ in. deep at the ends, as shown at Fig. 39, must next be made. It may be cast in good malleable iron, and carefully annealed; but it will give better results if cut out of a soft piece of circular wrought-iron rod, which, with a good file and a little patience, may be filed up to the desired shape. Should, however, a casting be preferred, the pattern for the purpose may be cut out of a common broom stick, nicely sand-papered to the desired size, the channel being cut out with a sharp chisel.

Whichever plan may be adopted, the armature, previous to winding, must be fitted with two brass or gun-metal heads, wherein the spindle is affixed. For this purpose, the amateur who has no lathe must strike two circles $\frac{15}{16}$ in. diameter on a piece of hard sheet brass, $\frac{1}{8}$ in. thick, great care being taken to get the circles true, and the centres distinctly marked. These circles can be cut out roughly with a hack-saw, and finished up carefully to the line with a file. A perfectly central hole is to be drilled in each disc with an Archimedean drill, to take circular iron rod $\frac{3}{16}$ in. diameter. Two smaller holes,

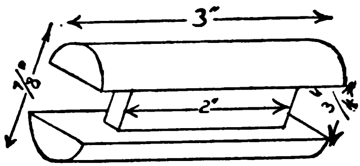


FIG. 39.

one on each side of the central aperture, are also drilled through the brass circlets. These are to take the screws which hold the heads on to the armature. Holes corresponding exactly to these in position, must now be drilled in the two extremities of the armature, the greatest care being taken that the heads are fitted truly, so that the armature may run without wobbling. These holes in the armature must be tapped so as to take the screws.

On the brass circlet which will afterwards be placed nearer to the commutator, must be drilled yet two more holes, through which the ends of the wire, with which the armature will be wound, must protrude. When the armature and heads have thus been fitted, two pieces of the $\frac{3}{16}$ in. iron rod before-mentioned should be cut, one for the back and the other for the front or commutator end, the former being about $1\frac{1}{2}$ in. long, the latter 2 in. A thread must be put on the end of each of these rods where they enter the brass circlets, and after being screwed in, the end must be burred over by hammering, so as to prevent the rods (which serve as the spindle for the armature) from working loose during rotation.

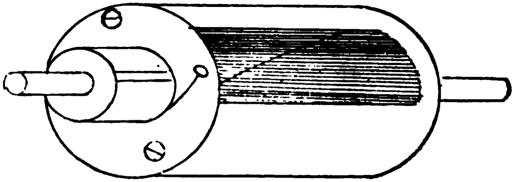


Fig. 40.

§ 66. A small piece of boxwood about 1 in. long is now to be cut or turned into a perfect cylinder about $\frac{3}{4}$ in. diameter. A hole $\frac{3}{16}$ in. diameter, is put centrally through this, so that it can be made to fit tightly on the spindle. A piece of brass tubing, about $\frac{1}{16}$ in. thick, 1 in. long, and $\frac{3}{4}$ in. in internal diameter, is now driven on to the boxwood cylinder. Two short brass screws, not reaching to the iron spindle, must now be procured, and, holes having been drilled at two opposite points in the diameter of the ring, and countersunk, the screws are inserted and tightly screwed down so as to hold the ring in its place. The brass tube or ring is now cut into two halves by giving two fine saw cuts across the ring at two points equi-distant from the screws just inserted. This completes the *commutator*, which is now ready to be slipped on the longest end of the spindle when required.

§ 67. The next operation is to wind the armature; and here the amateur must use his own discretion as to whether he will wind it for a large current of low E.M.F., or for a high E.M.F., but little current. If he desires to have both he will do well to make *two* armatures precisely as described, and wind the one with coarse wire, say No. 14, for large currents, and the other with No. 22, for smaller currents of higher E.M.F. Previous to winding, however, the armature must be *taped*, as it is technically called, to insure perfect insulation.

To this end the brass heads, with the spindle, etc., are removed, and a piece of silk ribbon, ¾ in. wide, glued right round the central portion of the channel of the armature so as to entirely cover the iron. In like manner, the sides of the channel are also covered with silk. When the glue is *quite* dry, the armature may be immersed bodily in melted paraffin wax, so as to saturate the silk thoroughly with paraffin. It should then be taken out, allowed to drain, and set.

§ 68. The armature may now be wound. The operator takes the armature in his left hand, with that end which is to be against the commutator nearest to him. Holding in his left hand also, about 6 in. of spare end of the wire with which he intends to wind the armature, he grasps the reel or hank in his right, and winding always in the same direction, fills up the channel with the wire, taking care to wind tightly, smoothly, and evenly, and being most careful not to abrade the covering of the wire, so as to produce leakage. About 3 oz. can be laid on without extending beyond the sides of the channel. (See Fig. 40.)

It will be well, before finishing the armature to test the wire for insulation. This can be done by connecting one end of the wire to one pole of a single-cell chromic acid battery, the other pole of which is connected to one terminal of a galvanometer. A short length of wire is attached to the other terminal of the galvanometer. If with this wire the iron part of the armature be touched *no deflection* will ensue if the insulation between the coiled wire on the armature and the iron body of the armature *is good:* but if it be *defective*, the needle will swing round and indicate the fact. It is needless to point out that the iron of the armature should be sand-papered at the spot where it is to be touched with the wire, as otherwise the paraffin wax adhering to it might falsify the results of this trial.

Both the beginning and ending portions of the coiled wire must be brought out at the commutator end of the armature. The heads of the armature can now be permanently screwed on, the ends of the coiled wire pushed through the two holes left in the head, the wire pulled very tight, the holes bushed with melted gutta-percha to prevent any chance contact of the wires with the brass head, then the commutator pushed on to the spindle (a drop of *white hard varnish* having been previously applied thereto to insure adhesion); and lastly the two projecting ends of the wire, cleaned from their covering, and soldered, one to each brass cheek of the commutator, as shown in the cut at Fig. 40, which also shows the position the slits on the commutator should occupy with relation to the channel of the armature. N.B.—Only one slit is shown, as also only one wire, since the other is hidden by the spindle.)

§ 69. The magnet should now be mounted on a stained wood or mahogany base board, about 14 in. long, by 8 in. wide, and 1 in. thick. Two pieces of well-seasoned wood (deal will do) 1¼ in. in square section and about 6 in. long are to be glued one each side of the centre of the base board, so that the magnet can lie with each pole supported on one of these strips, leaving a clear place for the armature to lie between without touching anything.

A piece of square brass rod ¼ in. in section and 4¼ in. long is next procured. A ⅛ in. hole is drilled at each extremity to take a long screw. At the centre, another piece of similar brass, ½ in. square, but only ¼ in. thick, is soldered, and through this is drilled a 3/16 hole to serve as a bearing for the back spindle of the armature. This piece of brass serves a double purpose. It acts as a strap to hold the magnet in its place when screwed down by the two side screws; it also serves to carry the bearing. The exact distance of this brass strap, from the poles of the magnets, depends on the length of the armature; it should be so placed that when the spindle is in the bearing up to the brass head, the front head should just be flush with the poles of the magnet. The appearance of the magnet, supported on the two wooden blocks and held down with the straps, is well shown at Fig. 41.

For the front bearing, a piece of stout sheet brass about $\frac{1}{8}$ in. in substance is cut into the shape of an angle about $1\frac{1}{4}$ in. wide at the base, 2 in. high, rounded at the apex. The base of this triangle is bent at right angles to the rest to the depth of about $\frac{3}{8}$ in., in order to form a

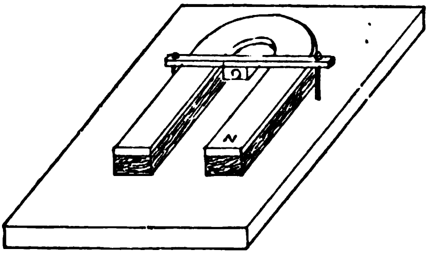


Fig. 41.

foot. Two holes must be drilled into this reverted portion, into which are passed two screws to attach it to the base board. The armature having been placed in the back bearing, is supported by a cork and side wedges, so that it stands equi-distant from either pole of the magnet, touching at no part. The front bearing is then rested on the base board, and pushed against the front spindle. A mark is made where it touches, and a $\frac{3}{16}$ hole drilled through the bearing at this spot. This must be cleared out, so that the armature can rotate freely between the poles of the magnet, supported on the back and front bearing, without any strain, twist or bind.

A keyway must be filed on the back spindle, and a small ½ in. grooved pulley keyed thereon.

§ 70. In order to collect the electricity set up by the rotation of the armature, two "brushes" are needed. These consist in two strips of sheet copper, about 1/50 in. thick, hammered until quite springy, and then cut about ½ in. wide, by 2½ in. long. At about ¼ in. from one end of each strip is punched a circular hole, wide enough to take the tang of a binding screw. Two little blocks of boxwood, about ¾ in. in square section, one being ¾ in. high, the other about 1½ in. in height, are now to be glued on to the base board, one on each side of the commutator (§ 66) at a distance of about 1¾ in. from it. To insure rigidity and strength, these two blocks should be made longer than they are intended to stand above the level of the base board, a corresponding square hole being cut into the base board with a chisel. On gluing these blocks in their places, there will be no fear of there becoming detached.

When quite dry, a small hole (a little less than the tang of the binding screws which are to be used) is drilled centrally and perpendicularly in these blocks. Each copper strip or "brush" is now bent, so that when lying on its block it just touches the commutator ring; that on the higher block resting on the commutator above, while the one on the lower block can be just caused to touch the commutator underneath The binding screws are then inserted in the holes through the brushes into those in the blocks, and then screwed down tightly, so as to hold the brushes firmly in their place, pressing lightly against the commutator above and below. These two binding screws, as shown at Fig. 42, serve as the *poles* or *terminals* of the machine, and to these the wires, etc., may be attached to lead the current where desired.

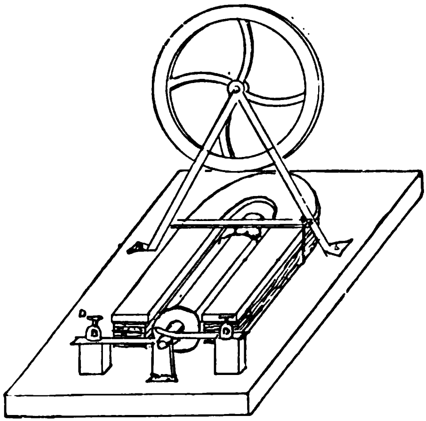


FIG. 42.

§ 71. The only thing now needed is a bracket and hand-wheel, wherewith to drive the armature. The simplest, and at the same time the strongest mode of affixing these, is to have a Λ-shaped bracket cast in iron at the nearest foundry. This should be 9 in. in height, and should stride over the magnet, clearing it on each side by about 1 in. Holes must be drilled in the feet to screw it to the base board, and at the top a hole must be put through it to take a bolt and nut. A 12 in. wheel, either of iron or wood, and furnished with a wooden handle, is put on this bolt, and a back-nut screwed on to keep it against the bracket. A gut or leather band connects the hand-wheel to the pulley at the rear of the armature. The complete machine is shown at Fig. 42.

With this machine a variety of instructive experiments can be performed. Small lamps can be lit, an arc light can be shown, coils worked, water decomposed, etc. The direction of the current can be changed by changing the direction of rotation; and by sending the current from a battery into the armature the machine gives a proof of its reversibility by running as a motor.

§ 72. THE DYNAMO.—In another work* the author has gone pretty fully into the theory and practice of the construction of dynamos of the Siemens' type. It is proposed here to give a general outline of the mode of calculating the winding of dynamos of the *ring armature* type, along with such instructions as will enable the amateur to decide upon the size of the armature and field magnets required to produce a given effect. Machines of the "ring" class may be conveniently constructed either of the A Gramme form, as shown in the annexed Fig. 43, or of the form Fig. 44, now generally known as the "Manchester" type, due to Mather, Hopkinson, and Platt. Wooden patterns should be made of the fields, from which good malleable iron cast-

* The Dynamo: How made and how used.

ings can be obtained from any founder who knows his work. The castings *must* be *soft*, or else quite 40 per cent. of the efficiency of the machine will be lost.

The ring (which should be of the *toothed* or *Pacinotti* form shown at Fig. 44, may be also cast, but will be better in every respect if built up of laminations in sheet iron, of the same shape as shown, and strung together by pins running through every alternate tooth, which pins, if screw-headed, serve to bolt the armature firmly to

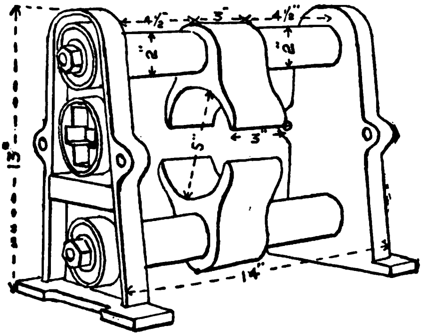


FIG. 43.

the brass star-wheel, or "spider," by means of which it is affixed to the shaft. As these laminations or "punchings" can be had ready made in many convenient sizes of the makers of electrical instruments, the manufacture of such is not advised here, as a punching tool costs from £3 to £4 to make; whereas the punchings can be had for a few shillings per gross.

The amateur, having decided on which patterns he intends to employ for the fields, has next to consider the purpose to which he intends to put the machine when complete, and the power he has to drive it. It is really the former of these data which will decide the size of the armature, and, consequently, of the machine itself.

First, then, as to power. The best modern dynamos return about 95 per cent. of the energy spent upon them, as electricity. Theoretically, 1 h.p. is equal to 746 watts. The *watt* is 1 ampère multiplied by 1 volt, so that we are at liberty to take our "watts" out

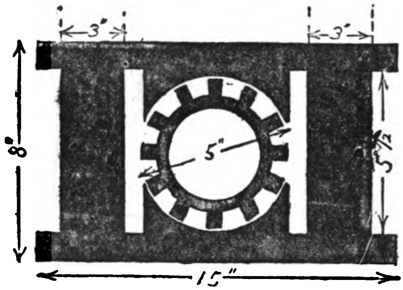


FIG. 44.

of our dynamos as we please. We can have, for instance, a low tension machine of only 2 volts E.M.F., but giving a current of 373 ampères, or we may have a small current, of 2 ampères only, with an E.M.F. of 373 volts; in either case 746 watts would be generated by the dynamo, and rather more than 1 h.p. needed for its evolution.

The next question to be considered is, what number of volts is the machine to give? Having decided this point, the length of the wire to be employed is immediately found;

since large, well-constructed machines, give on an average 1 volt for each yard of copper coil in the armature. Therefore, so many volts as are desired as the E.M.F. of the finished machine, so many yards of wire on the armature. If the machine is a small one, *i.e.*, does not greatly exceed 2 cwt. in weight, it will be well to allow more than a yard per volt, as small machines are *not so efficient as large ones.* In calculating the voltage, the desired current must also be considered, and allowance made both for the internal and external resistances, as also for the amount of current required to keep up the requisite intensity of the magnetic field. Remembering Ohm's law that the current will be equal to the E.M.F. in volts, divided by the R in ohms, we can easily (knowing what resistance we are going to have in the outer circuit) calculate from a table of wire resistances, what gauge copper wire we may use on the armature, so that the length desired to produce the desired number of volts shall not exceed in resistance the margin left from the outer circuit, to allow of the passage of the desired number of ampères. In making this calculation, it must always be borne in mind, that even in the best made shunt dynamos, it is usual to allow 4 to 5 per cent. of the current to be shunted off through the field magnet coils. The annexed table of sizes, weights, lengths, and resistances of the usual covered copper wire found in commerce, will enable the amateur to calculate at once the desired gauge and length of wire to be used to furnish a given E.M.F. and current:—

§ 73. Table showing relative resistances, weights and length, of different gauges of covered copper wire.

B. W. G.	Decimal of an inch.	Equivalent in m/m	Yards to the lb., approximate.		Ohms per lb. approximate. Copper.
			Silk covered.	Cotton covered.	
No.					
10	·134	3·35	6	6	·01150
12	·100	2·45	9	9	·03417
14	·080	2·03	15	15	·08500
16	·062	1·58	25	24	·22342
18	·048	1·21	45	41	·69000
20	·041	1·04	64	59	1·2100
22	·032	·802	119	109	3·1000
24	·025	·650	167	156	7·0000
26	·019·7	·482	266	244	26·219
28	·016·0	·406	414	383	52·137
30	·014·0	·353	542	500	88·493
32	·010·0	·276	870	800	126·00
34	·009·6	·248	1,170	1,080	402·00
35	·008·7	·221	1,475	1,360	596·41
36	·007·9	·200	1,660	1,530	877·23
38	·006·8	·183	2,480	2,280	1177·0
40	·005·8	·158	3,050	2,805	2300·0
	·005·0	·125	3,090	3,585	6000·0
	·004·0	·100	5,700		14000·
	·003·0	·075	9,800		42812·

In calculating from this table, it must be remembered that the resistance of any wire coiled on a Siemen's I girder form of armature, is proportional to the length of wire used: but in the ring armature form where the winding is continuous, the resistance is only ¼ that of the entire length of wire employed. There is still one consideration to be made in deciding upon the gauge of wire to be used in the armature, and that is, that the current carried must in no case be so great as to *heat* the wire. It is usual to allow 1 square inch section for each 2,000 ampères to be carried; and this rule holds good in the smaller diameters.

Based on these rules, the armature may be constructed *as small as will hold the requisite amount of wire.* The dynamo figured at 43, is capable of working up to 120 c.p., say six lamps of 50 ohm's, cold resistance, requiring one ampère each = 6 ampères. The E.M.F. of this machine should be about 50 volts. In Fig. 44, owing to the fact that the armature is made deeper, as many as ten such lamps may be put on. In winding as a shunt machine, it will be well to put the following rules into practice. 1st. Let the resistance of the armature coils ($\frac{1}{4}$ the entire length of wire) be $\frac{1}{20}$ of the resistance of the outer circuit, including, lamps, leads, baths, accumulators, etc. 2nd. Let the resistance of the field magnet coils be 20 times that of the outer circuit. 3rd. Let the diameter of the wire chosen to fulfil this latter condition be such, that the diameter of the *wound field magnets* does not exceed, nor fall greatly short of, *twice* the diameter of the *bare iron cores.*

One example, worked out in full, is here given to show how these data are to be employed in practise. Let it be desired to construct a gramme dynamo to light five twenty c.p. lamps of 50 ohms cold resistance, each requiring about one ampère to light it to the full. Supposing the resistance of the "leads" (cables, connections etc.) to be one ohm. The highest resistance we shall have to overcome in the outer circuit will be when only one lamp is used, and this will not exceed

50 ohms for the lamp, and one ohm for the leads = 51 ohms. In this case one ampère only will be needed. When all the lamps are on, in parallel circuit, the resistance falls to $\frac{1}{5}$ of 50 for the lamps = 10 ohms, and one ohm for the leads = 11 ohms. In this latter case, however, we shall need five ampères to feed the five lamps. Hence in the former case, if the armature be wound so as to give 51 volts, we shall get

$$\frac{E = 51 \text{ volts}}{R = 51 \text{ ohms}} = 1 \text{ ampère};$$

and in the latter, if the armature be wound to give 55 volts, we shall have

$$\frac{E = 55 \text{ volts}}{R = 11 \text{ ohms}} = 5 \text{ ampères}.$$

Hence, as far as the outer circuit is concerned, an E.M.F. of 55 volts will be ample. It will be well to allow a trifle more than this, because of the resistance of the armature. Therefore, allowing one yard per volt, 56 or 58 yards of No. 18 wire will be sufficient on the armature. As the current will never exceed five ampères, the diameter of the wire need not exceed No. 18 gauge, as this will carry safely five ampères of current. Hence 56 to 58 yards of No. 18 wire will suit our purpose very well. On measurement it will be found that a ring of about 5 in. diameter will take this amount of wire, the resistance of which ($\frac{1}{4}$ of 56 yards = 14 yards = 0·25 of an ohm) falls considerably within the limit of $\frac{1}{20}$ of the outer circuit resistance. An armature of this size will admit of field magnets having cores presenting 12 inches length by 2 inches diameter, on which the magnetising coils may be wound. Since the armature resistance is only 0·25 of an ohm, we must put on a wire having 400 times this, or $400 \times \cdot 25 = 100$ ohms; and yet shall not, when wound on, greatly exceed the original core diameter. It will be found that 13 to 14 lbs. of No. 24 gauge will fulfil the requirements. In the above example, the very best soft iron is supposed to be employed. Any deviation from this will entail the employment of more wire, both in the armature and in the field magnets.

§ 74. As to the mechanical part of winding the cores and armature, the following points must be observed to obtain the best results. 1st. The cores of the F.M. must be carefully *taped and varnished* to insure insulation. 2nd. The armature must also be *most carefully* taped and varnished. *No part* of the iron, where the wire has to be wound, *should be left uncovered.* 3rd Having decided into how many sections the armature is going to be wound, the wire needed to go round one section must be measured off, and the whole series of sections cut off to the same length. 4th. The wire, both on the F.M's. and on the armature, must be wound as tightly and smoothly as is possible. 5th. After winding, the armature coils should be soaked in a thin shellac varnish (French polish does admirably), and then baked in a slow oven at a heat not exceeding 212°, until the varnish is quite hard and dry.

In both the Gramme and the Mather-Hopkinson type of dynamo, the field magnet bars must be wound so as to produce consecutive poles at the top, and consecutive poles at the bottom of the machine.

The *commutator* must have as many divisions as there are *sections* in the armature.

The *brushes* should be self-regulating by means of spring and swivel, for pressure; and should be capable of adjustment by means of a set screw, for the best angle of commutation.

In the shunt wound machine, the two ends of the field magnet coils are each connected to one of the brushes, and these latter again connected to the two binding screws, which form the terminals of the dynamo.

On no account should the armature be mounted on a wooden hub. This was a favourite mode with the older makers, but it is to be condemned, in view of its mechanical inefficiency, and more so, because of the resistance it opposes to the escape of the heat generated by the Foucault's currents. Brass or gun metal spiders only are admissible. Iron or any other magnetic metal must not be used, either for the spiders or for the bearings of the shaft, as they short-circuit the magnetic field, to the great detriment of the inductive effect of the field magnets or the armature coils. The collector bars of the commutator should be as massive as possible, and separated from each other by air spaces, as in the Hochhausen form.

§ 75. AMMETERS.—These instruments are intended to measure the amount of current in ampères passing through any given circuit. One ampère of current, passing through a solution of sulphate of copper, is capable of depositing 18·35 grains of copper per hour.

To make such an instrument, suitable for the general purposes of the amateur, and capable of reading from 1 up to 5 or 6 ampères, the following mode of procedure may be adopted:

§ 76. Procure a square piece of deal 4 in. × 4 in. × ½ in., smoothly planed up; also a glass-capped circular cardboard box, 3 in. diameter by 1½ in. deep, inside measure. (Such boxes are sold by mineralogists, etc., for preserving specimens.) Push the cardboard bottom out of the box. This bottom may be used as the "dial" whereon to inscribe the degrees of current. Stain the wood black, or any desired colour, and varnish it. Now trim the edges of the bottom of the box into an exact circle, capable of entering *easily* into the box from which it was removed. Describe near its circumference three circles in ink, with a pair of compasses. Let these circles stand about ⅛ in. from one another. Describe also a small circle about a ¼ in. diameter in the centre of the card, to serve as a guide for a central hole, which must be punched out with a ¼ in. circular punch.

§ 77. Now make a small glass pivot, as described at §§ 5 and 6, about ⅝ in. long, and not more than ⅛ in diameter at its base. When made, test it for freedom and absence of friction by poising it on the point of a very fine needle, the head of which is stuck in a bung. If it spins round quite freely without any hitch, well and good; if not, make others until you get one *perfectly freely suspended.* This is most essential.

Procure a strip of copper sheet, about $\frac{1}{20}$ in. thick, 4 in. long, and ½ in. wide. Punch three ⅛ in. holes in it, one at each extremity, wherein to pass the binding screws, and one in the centre. Lay this strip on the little wooden square, across its centre, and screw it down to the square by means of two small binding screws, taking care that there is space left for the cardboard box to stand between them without touching either. Now stick a fine, bright, and sharp No. 8 needle, point upwards, into the centre of the square, just where you have punched the central hole in the copper slip. Care must be taken that this be perfectly perpendicular, and clears the glass top of the capped box by about ⅛ in. when this latter is placed over it.

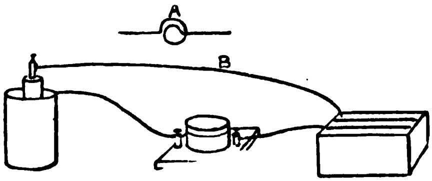


FIG. 45.

§ 78. With a pair of round-nosed pliers, make, from a short piece of No. 16 pianoforte wire (steel), a single coil to fit tightly round the base of the glass pivot, having a straight ½ in. prolongation on either side of the central loop or coil, as shown at Fig. 45, A. This must be thoroughly magnetised by rubbing with a good horse-shoe magnet, and then fastened with a drop of glue to the base of the pivot, extreme care being taken that no glue touches the rim of the pivot, otherwise it will not swing freely. The pivot must now be placed on the needle in the centre of the square; and the punched circle, which is to serve as a dial, held over it, and lowered down over it until the point of the pivot protrudes about $\frac{1}{8}$ in. above the central aperture, and the magnetised needle below clears the card also by about $\frac{1}{8}$ in. The dial is to be fixed in this position by gluing three corks of the right height to the square, and then gluing the card on to them. Here, again, care must be taken that the pivot does not touch the card dial at any point, and also that the magnetic wire needle below is clear of the dial.

A small *pointer* in black paper, straw, or any other very light rigid material, about $1\frac{1}{4}$ in. long, is to be lightly glued to the top of the pivot *at right angles to the needle* below. The glass-capped box may now be placed over all, and glued to the square by running a little thin glue round its bottom edge. When quite dry, the grading may be proceeded with.

§ 79. To grade correctly, at least 10 quart Daniell cells will be needed. These must be freshly made up, and filled to about half their capacity. A decomposition cell (a stoneware basin or foot-bath will do), capable of containing two squares of copper sheet, facing one another, at least 6 in. × 6 in., must next be provided, and filled with a strong solution of copper sulphate slightly acidulated with sulphuric acid.

The copper plate which it is proposed to attach to the negative pole of the battery (the zinc end), having been carefully weighed in a balance capable of turning to the $\frac{1}{100}$ of a grain, and its exact weight noted, a

Daniell cell, the ammeter, and the decomposition cell are arranged in series, as shown at B, and allowed to work for one hour exactly. At the end of that time the copper plate is withdrawn, washed (not rubbed), and dried. When dry, it is weighed, and the increase noted. If exactly 18·35 grains, well and good; if not, the following alterations must be made until the deposit reaches exactly this amount.

Should the deposit be *less*, approach the plates in the decomposition cells, and add more fluid to the battery cell, until the deposit reaches exactly the 18·35 grains per hour. If the batteries are less than quart cells, two, coupled for quantity, may be needed to produce the desired result. Should the deposit be *greater*, remove the plates in the decomposition cell farther apart, in either case carefully noting the distance. Once the desired result attained, the greatest care must be taken to maintain all *in statu quo*, and the exact position of the two copper plates in the decomposition cell being marked, the temperature of room taken, the height of the fluids in the battery cell, or cells noted, etc. One pole of battery is now detached from the ammeter, and this latter moved round until the magnetic needle lies quite parallel with the copper strip, hence the pointer exactly at right angles to it. The spot at which the pointer stands is marked with O. The battery is again attached to the ammeter, and the deflection, when the needle comes to rest, noted. This deflection corresponds to one ampère of current, and should be marked as such on the dial. To get the corresponding deflection on the other side, the poles of the battery must be reversed.

All the other degrees may be got in precisely similar manner, multiples of 18·35 gr. of copper being considered and counted as so many ampères, more cells being connected up, *in parallel*, to obtain the desired weight of deposit per hour.

§ 80. THE VOLTMETER.—This instrument serves, as its name implies, to measure the *voltage*, or *electro-motive force*, of any source of electricity. Perhaps there is no subject so puzzling to the electrical student as the difference between *electro-motive force* (E.M.F. as it is generally abbreviated) and *current*. As it is essential to have clear ideas on these points, in order to grasp the principles on which the construction of the voltmeter is based, I shall deviate somewhat from the plan hitherto followed in these pages, and devote a few lines to the consideration of what E.M.F. really is.

§ 81. According to the present state of our knowledge, the phenomena which we group together under the name of "electricity" are simply manifestations of a peculiar mode of motion in the ultimate particles of bodies, called *atoms*. What the nature of this motion may be, whether rotary, undulatory, vibratory, etc., we are as yet utterly unable to say. We have, however, at our disposal, many means of setting up this motion, such as, for instance, *friction* (and many other mechanical movements), *chemical action*, the application or abstraction of *heat* (itself a mode of motion), or of *light* (another form of motion), etc. I purposely leave out *magnetism* as a source of electricity, since magnetism is itself but a manifestation of electricity.

Whichever of these means be employed as sources of electricity, we find (other things remaining the same) that an increase in the means employed is followed by an increase in effect. Now the means employed, whether they be friction, motion in the field of a magnet, chemical action, or heat, are called, when viewed under this aspect, "electro-motive force," or that which sets up an electrical condition. In the same way as we can only measure the power of a man, or of a steam-engine, by the work performed by them when they exert their force, so we can only measure the E.M.F. of any given battery, dynamo, frictional or induction machine by the electrical work it can perform. It is optional whether we use as measures the chemical, the magnetic, or even the mechanical work which the electricity set up by the given means can perform. As a matter of convenience, the magnetic work performed is generally preferred as a means of measurement.

§ 82. From a study of Ohm's law, we learn that the amount of current set up in any given circuit is equal to the "electro-motive force divided by the resistance in that circuit." This simply means that, with any given force setting up electricity, the current will be *greater* as the resistance is *less*. This is usually expressed $\frac{E}{R} = C$. From this it is equally evident that if we know the value of R (the resistance), and of C (the current), we can always calculate the value of E, by multiplying

R by C. Moreover, it will be equally evident that, if R be constant, E will always be directly proportional to C. To prove this, let us give an actual value in figures to the E.M.F., the R and the C. Let us suppose, for example, that we are working with a battery having a known E.M.F. of two volts, and we get a current of one ampère when working through a total resistance of 2 ohms. This would actually be the case, since $\frac{(E = 2)}{(R = 2)} = (C = 1.)$. Now, let us imagine that using another source of electricity, pitted against a precisely similar total resistance, we found we obtained a current of 10 ampères. What would E.M.F. be?

Simply— $(C = 10) \times (R = 2) = (E.M.F. = 20)$. Here we see that as the current is ten times as large as in the first instance, so also is the electro-motive force. But it will be perfectly evident, that as the *current* would be altered in amount by any alteration in the resistance, it is essential that any resistance in circuit should be kept as nearly as possible invariable, if we desire to have results that are even approximately correct.

§ 83. Unfortunately, no two batteries or sources of electricity have precisely the same resistance; and even if they had at one instant, this would be found to vary during work. On the other hand, the internal resistance of most batteries does not often fall below 0·0016 of an ohm, nor rise above 2 ohms per cell. It follows from this, that if we make the resistance of the voltmeter very large in proportion to the possible resistance of the battery, we can reduce the possible error to within any desired limits. In practice, it is usual to allow a resistance of 50 ohms for every volt to be measured. This gives sufficient accuracy for most purposes, as the error is then within 3 per cent. of the total readings.

§ 84. From the above, it follows that a *galvanometer* having a resistance large in proportion to the current to be measured, if graded to indicate the current deflection which corresponds to a given voltage, can be used as a *voltmeter*. Certain precautions are necessary in order to obtain deflections at all parts of the scale, sufficiently distant from one another to be easily read. The following instructions will enable the amateur to construct an instrument, which, if used intelligently, and far from masses of iron or other magnetic bodies, will give results which for the measurement of low E.M.F., say from 1 to 5 volts, far exceed in accuracy those given by more pretentious apparatus. As there are several points of resemblance between the ammeter and the voltmeter, the student will do well to refer to § 75, previous to making the voltmeter.

§ 85. The first thing needed is a light cardboard or chip box, 2½ in. long, by 1½ in. wide, and ⅝ in. in height. There must be no ends to this, which exactly resembles in size and shape the sliding cover of a Swedish "Tandstick" box. Indeed, such a cover may be used for the purpose with good results. If the amateur desires to make this himself he need only take a strip of stoutish millboard, 4½ in. long, by 2½ in. wide, fold it three times on itself, and glue the top and side edge, as shown in figure 46. A circular central aperture, about ¼ in. in diameter, is to be cut in the bottom of the box with a sharp penknife, while a central strip, also about ¼ in. wide, but extending the whole width of the box, is cut away from its upper portion. This being done, the box is slightly moistened with thin glue, and then quickly, but carefully, wound with about ⅛ oz. of No. 40 silk-covered German silver wire. This should be about ·0058 of an inch in diameter, and have

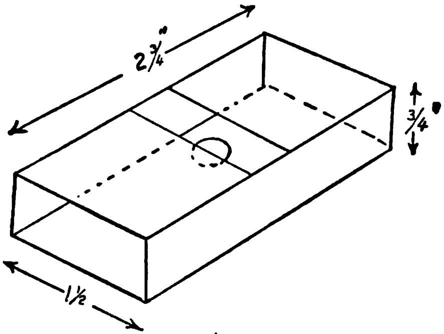


Fig. 46.

a resistance of not less than 2570 ohms to the ounce. Care should be taken to wind this wire evenly, closely, and without kinks, leaving about 3 in. wire free at each end. Having started winding at one end, the operator proceeds to wind continuously across the box, coil after coil, till he reaches the central hole and slit; these he leaves open, crossing over to the other half by letting the wire pass diagonally across one side. He continues the winding on to the other side, in the same direction, till he reaches the end of the box. If the glue gets dry during the winding he may apply a little more fresh glue as he nears the end, so as to ensure that the wire should not uncoil when released. When the box has been wound from end to end, as shown at Fig. 47, it must be allowed to dry thoroughly in a warm dry place, and when *quite* dry soaked for a few minutes in hot melted paraffin, until permeated with it, and then hung up to

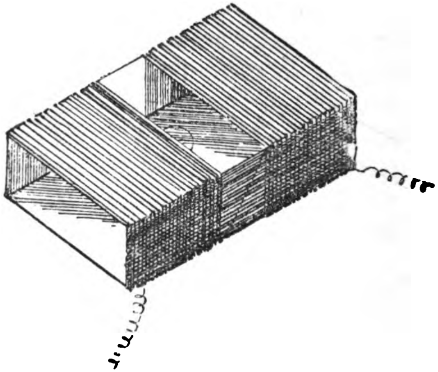


Fig. 47.

drain and set. While this is taking place, a small base board of ½ in. deal or mahogany is planed up and stained or polished as desired. This piece should be 4 in. square. The exact centre of this having been found, a needle 1½ in. in length is forced head downwards in the board at this spot so that the pointed end stands perpendicularly upwards at a height of 1¼ in. from the surface of the base board. A small 1 in. magnetic needle is now made out of a short length of piano wire, and fastened to a glass pivot precisely as directed in the case of the ammeter (see § 77 and 78). This is carefully tried for freedom of motion, equality of magnetism, etc. The box, coiled with wire, is now placed over the upright needles on the board (this latter being made to pass through the central apertures, without touching them, so as not to blunt or grease the needle point, which would be fatal to free movement), and while in this position, the pivoted magnetised needle placed on the point, so as to see whether the magnet swings freely without touching any part of the inside of the box, of which, in fact, it ought to stand in the centre. It may require raising a trifle, which may be done by means of thin slices of cork. When this has been duly adjusted, the cork slices (if any) and the box are fastened down to the base board with a little good, hot glue. Care must be taken that the coiled box stands squarely on the base, with its longest edge parallel with one side of the base board, and with the poising needle passing up the middle of the central circular hole. When this has been arranged, the glue is allowed to set firmly. The next operation is to bore two small holes right through the base board—one at each extremity of the coiled box—to allow the projecting ends of wire to pass through. These holes, as well as one at each of two corners of the base board in which are to be inserted the terminal binding screws, are best made with a small Archimedean drill. With a sharp penknife, two little channels are cut in the under surface of the base board leading from the first two holes to the latter two. The ends of the wire on the coiled box are then passed through the more central hole, and the extremities, having been stripped on their silken covering, pushed through the corner holes so as to return to the upper surface of the board. They are held in this position while a binding screw is screwed in each of the two corner holes. This having been effected, any excess of wire above is cut off, and the portion below caused to make perfect contact with the tang of the binding screw by a touch with a drop of solder on a hot iron. The channel in which the wire ends lie, under the base board, should now be filled in

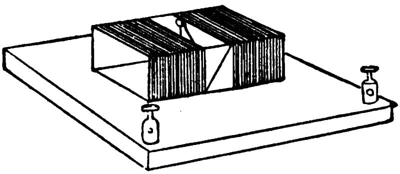


FIG. 48.

with a little hot guttapercha, or Prout's glue (see Fig. 48). The pivoted needle may now be definitely placed on the point. A circle of about 3 in. in diameter is now cut out of a clean stout white card, and two inner circles described with the compasses and good black ink, within. One should be ⅛ in. less all round than the card, and the other ¼ in. all round less than the former. For convenience of grading, a central line should be drawn across the card, so as to divide it into two equal semicircles. One end of this line should be marked o.

A perfectly round central ¼ in. hole should now be punched in this card, which must then be glued on to the coiled box, great care being taken to have the central 0 line *parallel with the wire* coiled round the box, and therefore parallel with the centre slit. Care also must be taken that no glue, etc., be allowed to touch the glass pivot, the apex of which must protrude centrally through the hole in the card, and stand above about ⅛ in. To insure the card drying flat, it is well to place two or three half bullets, or similar weights, on it until dry.

A small pointer, made either of stout glazed black paper or of blackened straw, about 1¼ in. in length, is now glued to the top of the pivot, care being taken that it is *exactly parallel* with the magnetised needle below. It is not difficult to secure this parallelism if the magnetised needle be held *perfectly at right angles* with the zero line by means of a bar magnet inserted inside the coiled box, while the pointer is being glued on outside, also at right angles to this zero line.

The pointer must be allowed to dry thoroughly before any attempt at grading, etc., be made. When quite firm in its position, a 3 in. glass-capped box (§ 76) about 1½ in. deep, must be selected, and glued on to the base board, the bottom of the box having previously been removed, as described in the case of the ammeter. This box, with its movable glass-capped lid, serves to keep the instrument free from dust, and unaffected by currents of air.

To grade this instrument, it is necessary to have access to five freshly-charged clean Daniell cells. (See § 79.)

These give a current of about 1·079 volt per cell, and before using them definitely they should be separately coupled up to the voltmeter, to see if the deflection given by each cell is sensibly the same. Supposing this to be the case, the voltmeter is allowed to come to rest, turning the instrument until the pointer stands exactly at zero. (The instrument should be held firmly in this position during the following trials.) When this takes place one cell of the Daniells is to be coupled up to the terminals of the voltmeter, and the deflection noted. With a sharp pointed HB pencil (the glass cover having been previously removed), a dot is made on the end at the spot where the pointer indicates. This is one volt, and very nearly 1-12th over; more exactly, $1\frac{78}{1000}$, if the battery be in perfect condition; but it may fall as low as $1\frac{20}{1000}$ when the copper solution works through the porous cell. Having made this mark, the battery is uncoupled from the terminals, and the connections *reversed*, so as to get a deflection in the opposite direction. When the needle has come to rest (with the glass cover over), the deflection is noted as before, and, as before, a dot made on the card where the pointer stands. Two cells are now coupled in series, and the same operations gone through to get a second set of dots, which stand for 2 volts and, say, $\frac{1}{6}$. In like manner, one after the other, the whole 5 cells are coupled in series, and connected to the voltmeter, and the relative deflections noted. Lines can then be ruled from the circumference towards the centre of the card, in ink, allowing for the one-twelfth excess on each dot, and these lines may be numbered 1, 2, 3, 4, 5, and they will indicate, with very fair accuracy, the deflection given by a corresponding number of volts. At Fig. 49 is shown the mode in which the card dial is divided, centred, and finally graded. Each instrument will vary a little in its degrees owing to the different resistance of the wires, their distance from the magnetic needle, etc.;

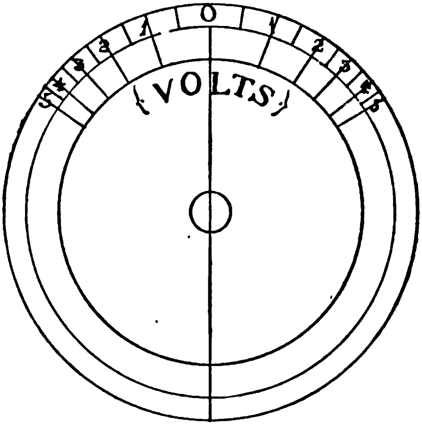


FIG. 49.

but once graded, they will be found to remain very fairly constant in their indications as long as the pivot remains uninjured.

§ 86. GALVANOMETERS.—Besides the ammeter and voltmeter described in our last sections, there are two other forms of galvanometer which, although giving no absolute measure in current or voltage (unless calibrated) are extremely useful for the purposes of detecting weak currents, or comparing their forces. These are the ordinary single and double needle galvanometer (also called multiplier and galvanoscope), and the tangent galvanometer.

§ 87. A very convenient form of single needle galvanometer may be constructed on precisely the same lines as given at § 85 for the voltmeter; the only difference being, that silk covered copper wire should be substituted for the German silver wire, therein suggested. The diameter of the wire, and the quantity to be employed, will depend entirely on the use to which it is intended to put the galvanometer when completed. If it is to be used for large currents of very low tension (such as thermo currents, etc.), it will be better to use a few turns of No. 16 wire. If on the contrary small currents of higher tension are to be detected, then wire as fine as No. 40, may be coiled round the frame or box. A very useful all round instrument may be constructed, by winding about 200 turns of No. 36 silk covered copper wire round the frame, or box. This will produce a galvanometer that will give a deflection of about 20°, with the current set up by heating the junction of a 6″ length of copper wire, twisted to a similar piece of iron wire. Of course, instead of using a card dial as shown at § 85, graded to volts, the divisions of the circle should be in 360°, numbered from 0° to 90° on either side of the zero line.

§ 88. If, instead of poising the needle on a point and pivot, it be suspended by a single fibre of silk, depending from a brass rod, bent at right angles like an Γ, the short arm standing about 6 in. above the centre of the coiled box, a very much more sensitive instrument is the result. In this case the magnetised needle had better be a well magnetised sewing-needle, broken off at its point to the length required. This should be thrust half through a fine straw, about 1 in. long, at right angles to the length of the straw, and nearly at one extremity of it, similar to a ⊥. The silken fibre can be attached to the opposite end of the straw by means of a drop of sealing-wax. A similar needle (not magnetised) is now thrust through the opposite end of the straw, perfectly in the same plane, and parallel to the lower needle, so that the combination presents the appearance of a letter I. This arrangement, hanging from the bent brass rod over the central slot in the coiled box, must be fixed to the brass rod by the silken fibre, at such a height that the magnetised needle enters the slot, and hangs equi-distant from the top and bottom of the box. The upper needle, or "pointer," should clear the upper surface of the coiled box by nearly a half inch. Since it would be impossible to fasten the graded circle on the box when the needles are in position if the circle is entire, we must cut the circle into two halves down the zero line, and glue the two halves together again on the box by the under side. A glass shade placed over the whole will protect the needles from air currents.

§ 89. If in either of the two last-described instruments the "pointer" be replaced by a carefully magnetised needle, of the same size and "moment" as the under one, placed with *its north pole* over the *south pole* of the lower needle, and *vice versâ*, we have the "astatic galvanometer." Owing to the (almost) complete neutralisation of the earth's pull on the magnets, and to the increased effect of both upper and under surface of coiled box on the two magnets, the sensitiveness of this instrument is much greater than that of any of the preceding.

§ 90. The *tangent* galvanometer presents no difficulty in construction. A small lozenge-shaped "needle" is made from a thin piece of watch spring, about 1 in. long and $\frac{1}{8}$ in. wide. This is "let down," or softened, by being held over the flame of a spirit lamp until of a dull red, and allowed to cool gradually. When quite cold a small hole $\frac{1}{16}$ in. in diameter is drilled through the centre. The "needle" is then straightened out, and tested for centrality; and, if defective, filed until the hole corresponds with the centre of gravity. It is then *hardened* by being made nearly red hot over the flame of a spirit lamp, and being dropped into cold water. It must then be carefully magnetised by being rubbed at each extremity with the opposite poles of a good horseshoe magnet. When fully magnetised it must be fitted with a small glass pivot, made as described at § 6, small enough to enter the $\frac{1}{16}$ in. hole in the needle, and about $\frac{1}{4}$ in. in length. Great care must be exercised in the choice of a pivot, which must be very perfectly shaped, so as to allow great freedom of motion in the poised needle. This point being settled, the pivot is attached to the needle by means of a mere trace of good glue, applied to the hole in the needle only. The needle must now be poised by its pivot on a fine steel sewing needle (No. 10 will do), and any want of perfect horizontality must be remedied while the glue is still moist. When the above is quite dry, a very fine straw, about 2½ in. long, has a small hole made in its centre (half way between its two extremities) with a rather coarse pin; then the head of the pivot is pushed through this hole in the straw, so as to cause the straw to lie exactly at right angles over the needle. The merest trace of glue will now cause the straw to adhere to and retain its position on the glass pivot. This can now be set aside to dry. While this is drying the base board and standard can be fitted up. A piece of good dry wood, either deal or mahogany, is planed up and cut into a slab 6 in. × 6 in. × ¾ in. In the centre of this is inserted a circular wooden rod, 1 in. in diameter, and 6 in. in length. To the top of this rod is glued one of the glass-capped boxes mentioned at §76; which in this case should be at least 3 in. in diameter, but need not exceed ¾ in. in depth. This should stand squarely and centrally on the top of the rod, like the cap of a mushroom on its stalk. When the glue has dried, and the box is firm in its place, the exact centre of the bottom of the box is found by a pair of compasses, a small hole being made with a sharp needle to mark the spot. A No. 10 needle is then driven (head downwards) through the centre of the bottom of the box into the wooden rod below, until the point of the needle is out ⅛ in. below the glass of the cover when the cover is put on; more exactly, the point of the needle must stand at such a height that when the pivoted magnetic needle and straw pointer is placed on it the whole system shall ride clear of the glass cover when this is placed on the box. Before placing the magnetised needle permanently in position, a white paper circle of the same diameter as the interior of the box, and graded from 0° to 90° on either side of the zero line, should be pushed over the needle point and glued to the bottom of the box. (The greatest care must be taken that no glue gets on the needle or pivot, as all freedom of motion would thereby be destroyed.)

§ 91. A band or strip of copper, about 1 in. wide by $\frac{1}{16}$ in. thick, and 3 ft. 4 in. long, is bent so as to form a circle, 1 ft. in diameter, with side extensions, like the Greek letter Ω. Two holes must be put through the extended extremities, to allow of two binding screws being inserted, which binding screws serve at one and the same time to make contact with the copper ring, and to hold this latter to its place on the base board. The position of the ring, with regard to the graded dial at its centre, should be such that the 90° line lies parallel to the plane of the ring; so that, in fact, when the magnetised needle is parallel with the ring, the straw pointer stands at zero. This constitutes all that is *necessary* to the efficient action of the tangent galvanometer. Of course, the stand may be polished, or stained and varnished; if required more sensitive, a few turns of No. 16 copper wire (single silk covered), may be substituted for the copper ring. If currents of high tension are to be measured, the copper band must be replaced by a light wooden frame (like a tambourine frame), on which must be wound several hundred coils of fine insulated copper, or even German silver wire. When well made, the tangent galvanometer indicates the force of the current, as the "tangent of the angles of deflection." As this may not be quite clear to the non-mathematical amateur, I append a table, in which the relative values of the angular deflections are approximately expressed in degrees of force:—

Amount of Deflection in degrees of Arc.	Relative forces of Currents producing deflections.
1	1·000
5	5·012
10	10·118
15	15·347
20	20·847
25	26·814
30	33·076
35	40·114
40	48·066
45	57·290
50	68·275
55	81·818
60	99·220
65	122·857
70	157·398
75	213·836
80	324·867
85	654·824
89	3281·871
90	Infinite.

If one semi-diameter of the graded circle be divided into degrees of arc from 0° to 90° on either side of the zero line, and the other semi-diameter divided in the same manner, but *numbered* with the *integers* showing the corresponding amounts of force, the readings may be taken from this latter scale, without appreciable error, and without necessitating a fresh calculation for each experiment. When absolute accuracy is required, reference must be made to a table of "Natural Tangents." A glass shade to cover the whole is essential, if the glass capped box be not used.

§ 92. The previously described galvanometers are frequently required in testing the resistances of different

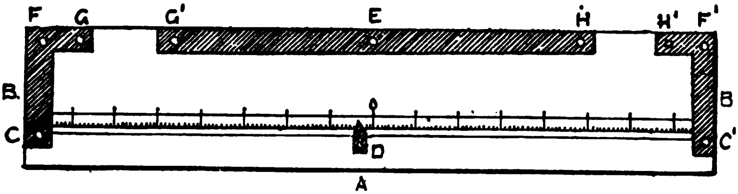


FIG. 50.

lengths of *line*, or of different samples of *wire*, *lamps*, etc., in which case some means by which these unknown resistances may be compared to a known one must be adopted. The instrument usually employed for this purpose is the "Wheatstone Bridge" or balance.

The Wheatstone Bridge consists in a dry seasoned piece of wood, nicely planed, stained, and varnished, 2 ft. long, 4 in. wide, by ½ in. thick, as shown at Fig. 50. Two strips of thin copper, B B, of shape of the letter ┐, are fastened, one at each end of the base board. These strips are cut ½ in. wide, and are 3½ in. long in their longest arm, and 2 in. in their shortest. Another straight strip, of the same width, but 16 in. long, is placed between these two short arms, leaving 2 in. gap on either side. These strips are fastened down in their places by nine telephone binding screws, as shown at C C′, E, F F′, G G′, and H H′. A thin German silver wire (No. 30) connects the binder C, to C′, and a small wooden block, carrying a spring contact piece, runs along the wire. A tenth binding screw, D, serves to connect this to one pole of the battery, E being connected to the other. The galvanometer is connected to F and F′, while the known and unknown resistances are placed between G G′ and H H′. Just below the wire which is stretched between the two binding screws is gummed a piece of white paper about ½ in. or ¾ in. wide. In the exact centre is marked the zero line, and the portions to the right and left of this are divided into 10, 20, 100, or 500 divisions, according to delicacy required.

§ 93. THE THERMOPILE.—This instrument depends in its action on the fact that when the point of junction between two pieces of metal is heated, or cooled, a current of electricity is set up. It is not necessary to this effect that the metals should be of different nature; but they must be in different molecular states, so that they oppose different resistance to the passage of heat and electricity. As, however, the greater the difference in these respects the greater the force called into play, it is usual to employ dissimilar metals, or metallic alloys, etc., in which these differences are highly accentuated.

§ 94. A very convenient form of thermopile for the amateur, and one which, with a little care in the management of the heat, gives a very constant current, adapted to delicate and long-continued experiments, such as grading delicate galvanometers, etc., may be constructed as follows: Cut 25 or 30 pieces of No. 16 German silver wire into 6 in. lengths; do likewise with a similar number of pieces of No. 16 copper wire. With a pair of pliers twist tightly about 1 in. of the extremity of one copper wire to the extremity of one German silver wire,

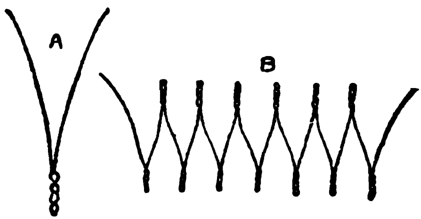


Fig. 51.

so as to join them firmly together, as shown at Fig. 51 A In a similar manner join the remaining pairs of copper and German silver wires; clean the junctions with a bit of sandpaper, and solder the junctions with as little hard solder as you possibly can. Now twist and solder the opposite extremities of the joined wires, each German silver to the copper of the next pair (not its own), leaving the first copper and last German silver as terminals (see Fig. 51 B). Now procure two wooden cornice-pole rings, about 3½ in. in diameter (such as are used to suspend curtains from the pole), and with a coarse rasp, file one surface of each ring *flat*, so that if laid upon one another, after filing down, they form one thick ring, as shown at Fig. 52. To the lower ring, at equi-distant points, should be affixed three wooden rods, about 6 in. long, spreading out somewhat, so as to admit of the insertion of a spirit lamp between them. For the sake of stability, these rods, which form the feet on which the thermopile rests, may be inserted into a heavy wooden or leaden base as shown at D in Fig. 53. The next step is to place the joined wires in a radiating fashion on the ring,

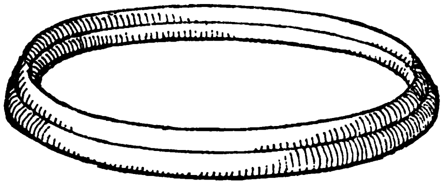


FIG. 52.

and clamp them in their place by covering them with the upper ring, which must be screwed tightly down to the lower one, care being taken that the screws do not touch the wires, and also that the wires do not touch each other, except at the soldered junction. The inner circle of junctions must not touch, but must stand at equal distances all round the centre of the circle described by the ring, leaving a space of about ½ in., in which the flame of the spirit lamp can burn and heat these junctions simultaneously. The two unsoldered ends (of copper and German silver wires) are then to be attached to binding screws, which serve as the poles or terminals of the thermopile. Fig. 54 illustrates the appearance of the finished instrument. On placing a lighted spirit lamp on the base, so that the flame plays against the junctions pointing to the centre, a current will be found to flow from the two terminals. The electro-motive force of these little instruments is about one-twelfth of a volt

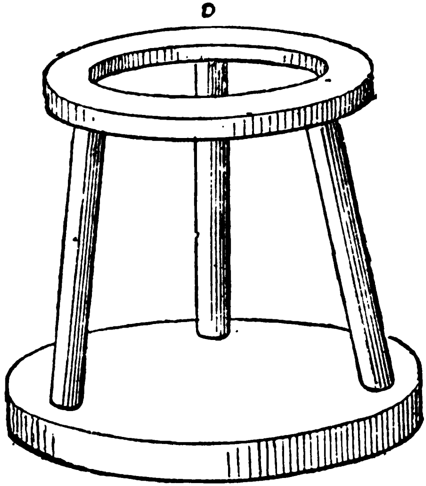


FIG. 53.

for each pair of wires, so that a dozen pairs of wires give very nearly one volt. On the short circuit *each pair* is capable of giving about one-third of an ampère. Coupled up in series (as shown), this remains, of course, the same. To increase the current, the elements must be made larger, or, what amounts to the same thing, coupled up in parallel instead of in series. For the benefit of those amateurs who may be desirous of attempting something on a larger scale, the following account of a thermopile which was made on the plan of Clamond's pile, with some slight modifications, is subjoined:—288 strips of tinned iron, 1 in. wide by 5 in. long, were cut out. A mould of plaster-of-Paris was prepared

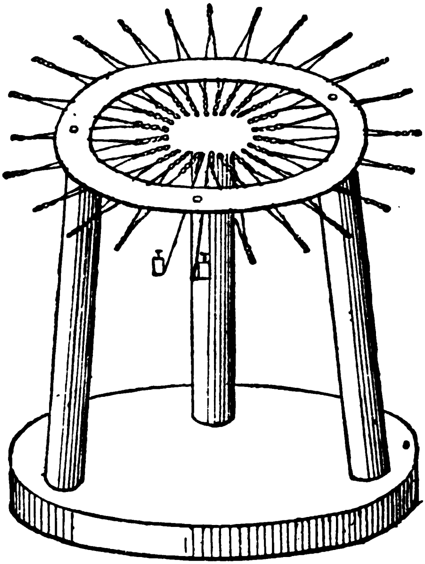


FIG. 54.

in which could be cast oblong squares, $2\frac{1}{2}$ in. long by 1 in. in square section. At end of the two extremities of the mould were placed, standing upright, a tinned iron strip. The mould was then filled with a molten alloy, consisting of two parts of antimony, melted with one part of zinc (as this alloy expands considerably on cooling, it must be withdrawn from the mould as soon as set). By this means were obtained 144 castings, having a tinned iron lug at each end, looking something like a letter E, without the central stroke. An iron ring, about 1 in. wide, ¼ in. thick, and 1 ft. in internal diameter, was supported on four stout iron rods, screwed to it, at a distance of about 10 ins. from the ground. On this ring was placed a coating of good Portland cement, about ⅛ in. thick. The castings, with their lugs previously bent, as shown at

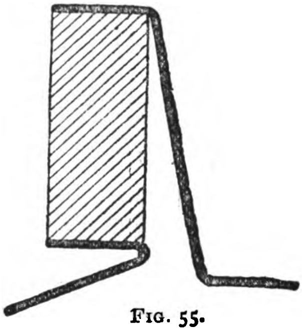


Fig. 55.

Fig. 55, and having a thin piece of mica (talc) inserted between the inner strips and the alloy, to prevent contact, were then arranged in a circle on the iron ring, each one being separated from its neighbour by a thin piece of mica, and the whole held together by means of a little Portland cement put in between as each casting was placed in position. Several such layers of circles of castings were thus arranged, care being taken that the faces of the castings projected about ⅛ in. inward beyond the iron ring. When the entire series of castings had been thus arranged in circles, and set in cement, a final layer of cement, about ¼ in. thick, was spread over the upper layer, care being taken in each layer to leave quite 1 in. of the castings projecting outwardly, free from cement. A second iron ring, precisely similar to the first, was now laid over the top, and when the cement had set, clamped to the lower one by means of

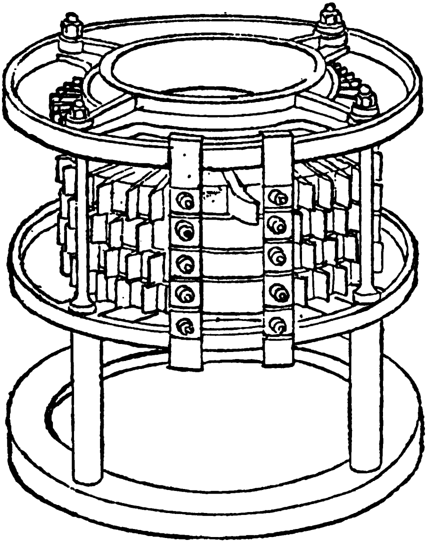


FIG. 56.

three long screw clamps. The iron strip attached to the inner end of one casting was then soldered to the iron strip attached to the outer end of its neighbour (previously cut to the required length), and so on all round each circle, except at one point of each circle only, where, of course, the projecting strips were left free, to be afterwards attached to binding screws as terminals. Each circle had its own pair of terminals, and these could be coupled up to the neighbouring circles either in parallel or in series, as the case might demand. This pile was used with a large paraffin burner having an iron chimney nearly touching the interior ends of elements. It has been also tried with a charcoal brazier (with a similar iron chimney), with gas, and with a small coke stove. For steady currents of low E.M.F., but considerable quantity, the 6 in. paraffin burner answered admirably.

The following table will give a fair idea of the force developed with the said paraffin burner, the elements being in all these cases coupled up for tension—*i.e.*, in series :—

No. of Elements.		E.M.F.		Ampères on a short circuit.
36	......	2	......	0·6
72	......	4	......	0·6
108	......	6	......	0·6
144	......	8	......	0·6

Fig. 56 is reproduced from a photograph of the identical thermopile (of four circles of 36 elements) with which the above trials were made. By using more powerful sources of heat (up to a certain point) correspondingly more powerful effects were obtained.

§ 95. BATTERIES.—For the convenience of classification, batteries may be divided into two great families—viz., *single fluid* and *double fluid*. To the former class belong all such as do not require a partition of any kind (whether porous cell, septa, sawdust, sand, difference of specific gravity, etc.) between the fluid surrounding the *negative* and the *positive* plate or element.

To the latter class belong all those, in which, either for the sake of obtaining constancy of effect, overcoming polarisation, etc., the fluid or fluids surrounding the negative and positive elements respectively, are kept from mixing, by any of the means just mentioned.

Few amateurs would care to manufacture their own jars, or porous cells, so no attempt will be made here to describe the construction of such, except to point out that where great lightness and strength is required, as in the case of small batteries to drive model yacht motor, or pocket coils, very efficient and perfectly acid proof cells, of any shape, may be constructed by gluing together with good tape, stout brown pasteboard, of the size and form required. The cells thus formed, after being allowed to dry thoroughly, must be immersed for a few minutes in hot melted paraffin wax until thoroughly permeated, and then allowed to dry and set. Cells of this kind will stand any acid, and even a solution of sulphate of copper.

Small porous cells may be made out of bowls of tobacco pipes, the small hole being stopped with Prout's elastic glue. Larger ones for any experimental purposes, had much better be bought, but can be made by the amateur from any good clean yellow clay kneaded so as to free it from stones, etc. This may be moulded of the desired shape, allowed to dry *perfectly* and then *gradually* heated to redness in any ordinary fire. Greater porosity may be imparted to the clay by the addition of powdered graphite or even charcoal.

Zincs may be cut to any shape by making a pretty deep line with a file at the spot where it is desired to divide, and then running a little quicksilver in the furrow thus produced. In a few seconds this permeates through the zinc at this place, rendering it brittle and rotten, so that the least pressure suffices to cause the zinc to break at the line.

Amalgamation is best effected by making up a mixture of 1 part oil of vitriol with 19 parts of water, placing this in a large flat shallow dish, in which a little mercury is also placed. The fingers having been rubbed with a greasy rag to prevent the acid affecting the skin, the zinc plates or rods are one by one immersed in the acid and quickly rubbed over with an old tooth brush so as to carry the mercury all over the surface. The excess of mercury should be allowed to drain off by rearing the plates on end, in a plate or other earthenware vessel. In separating the positive and negative elements from each other, *ebonite* will be found of the highest value for *small batteries*. In larger ones, teak, mahogany, or boxwood strips, previously boiled in hot melted paraffin wax, give excellent results, and are impermeable to the acid used.

Binding screws, though very convenient, are not absolute necessities. In many cases the negative plates (even if of graphite) can be held in their places by ordinary wood screws, by being screwed to the wooden bar which separates them from the zinc. Connecting wires can be soldered to the zinc, or twisted tightly round the shoulders of the screws. For coupling up a number of elements or circuits, strips of copper, about 1 in. wide, 1½ in. long, about $\frac{1}{20}$ in. thick, made perfectly clean and bright, and then rolled contrariwise at each end, so as to present the aspect (in section) of an ∽, will be found very convenient. It is not proposed here to give details for the construction of all the batteries which have been from time to time "invented," patented, or described, for their name is legion, and their utility in many cases, highly problematic. General outlines will be given for the construction of a single fluid, and double fluid battery; the student can then use what excitant he may fancy, or circumstances dictate.

§ 96. THE SINGLE FLUID CELL.—For the containing vessel, a Westall salt jar, or one of the 2 lb. plum bottles, will do very well. For very small cells, the smaller sizes of Liebig's "extract of beef" pots, answer admirably. The zinc and copper (or graphite) elements having been cut of the right size to enter the vessel, and yet leave a good ⅛ in. clear between the zinc and negative element, two strips of paraffined wood, ⅛ in. thick, and from ½ in. to 1 in. wide, according to the size of the battery, are cut, a little longer than the diameter of the containing cell. A small strip of clean sheet copper, to one end of which the wire which is to form one pole of of the battery is soldered, is placed in contact with the upper end of the zinc plate. Over this is to be placed one of the paraffined wooden strips: then the negative element. If the amateur is content with a single negative element (be it copper, graphite, silver, or platinum), he need now only place the second strip of paraffined wood, over the top edge of the negative plate with a little copper strip and wire (as before, to form the other pole of the battery) between the negative plate and wooden strip. The whole is now clamped together between the jaws of a clamping binding screw, or, if the larger elements are used, between the jaws of a sewing machine clamp (these can be got at 1d. and 1½d. each). Care must be taken, that the binding screw or clamp, does not make contact between the negative *and* positive elements. As much better results are obtained when the negative elements are double, the amateur will probably prefer to have two carbons, or coppers, to each zinc. In this case, after having placed the copper piece, to which the wire is attached, against the top end of the zinc, he will put a paraffined wooden strip on each side of the top end of the zinc, then a negative element on each side of the zinc. If the negatives are graphites, a wide copper band should encircle both graphites, and the clamp should grip the band against the graphites; care being taken as before, that the graphites, neither through the clamp, nor through the copper band at any place make contact with the zinc.

§ 97. MOUNTING GRAPHITE RODS AND PLATES.—In cases where the negative elements are graphite, and more especially if the plates are to stand long in the fluid, as in the Leclanché, the bottle bichromate, etc., it is advisable, owing to the porosity of the graphite, to adopt some other means of making connection with the terminal. It is usually recommended to *electroplate* the upper end of the carbon with copper, and then solder connection to it, but a better plan, is to make several nicks round the plate or rod, with a file, or even to drill a few holes in with a screw drill, and then to *cast* a leaden cap round the top end. If the lead have a little antimony added to it during fusion, it will set much harder, and fit closer. This is hardly acted on by the usual acids of the battery. To prevent any chance access of acid, the top end of the graphite may be painted round with hot paraffin wax. This treatment is specially useful in the case of bichromate or chromic acid cells.

§ 98. It is a well-known fact that the remarkable fall in current strength which takes place in the single fluid batteries of this class depends to a great extent on the absolute immobility of the exciting fluid. This is due to the fact that as the hydrogen is absorbed by the oxidant (chromic acid, bichromate of potash) as fast as it is generated, no mechanical movement is produced in the mass of the liquid, so that the liquid near the zinc plate becomes quickly charged with sulphate of zinc, thus protecting the plate from the farther action of the acid. Many schemes have been proposed to avoid this, such as setting up circulatory currents in the fluid by the external application of heat (Sprague), or by means of an aspirator (Courtenay), etc., etc. These methods are excellent in their way, but are rather inconvenient of application by the amateur, who has only to deal with a few cells—and fewer shillings.

A very simple mode, which is quite effective, which gives no more trouble than snuffing a candle, and which could be made automatic if desired, is one which the author adopted in his own 4-cell batteries for temporary lighting purposes, etc.

The battery (shown below, Fig. 5) consists essentially of four glass cells, A A A A, about 2½ in. in diameter,

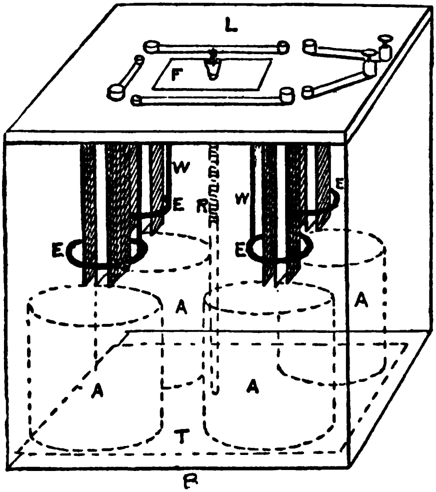


FIG. 57.

standing on a tray, T, from the centre of which rises a screwed and jointed rod, R, by means of which it can be raised or lowered, along with the four cells in the box B. These cells are filled to about two-thirds of their height with the excitant (chromic acid 3 parts, sulphuric acid 3 parts, water 17 parts). The zincs and carbons are attached, by means of long binding-screws, to the lid L, and each element is connected in series to its neighbour by means of metal straps, the first and last, of course, forming the electrodes. The rod R, passing through the lid, enables the operator to raise the cells to the plates; and this in practice will be found a great advantage over lowering the plates into the cells. The arrangement for setting up movement in the fluid consists simply in ebonite rings, E E E E, which encircle the plates, and which are attached to the ends of guttapercha-covered wires, W W W W, the upper extremities of which pass through the lid of the box, and are soldered to the four corners of a flat square of wire, F, which, on being raised and depressed, agitates the fluid in the cells, and thus prevents the accumulation of zinc sulphate round the plates. For the convenience of carriage etc., the lid L is fastened to the box by means of two rings and catches, and is furnished with a central handle, not shown in the sketch.

§ 99. THE DOUBLE FLUID CELL.—Differs from the single fluid cell only inasmuch as a porous cell, or substitute, is employed to separate the fluid acting on the zinc from that in contact with the negative element.

As before, the containing vessel may be a stoneware jar or glass wide-mouthed bottle. A porous cell is chosen, a little taller than the containing or outer cell. The bottom of this porous cell, and also ½ in. round the top, should be immersed in hot melted paraffin wax. This prevents "creeping" and is specially serviceable in the case of the Daniell cell. The zinc may take the form of a cast rod, and this obviates the necessity of a binding screw, as a copper wire may be cast in as a terminal. At one time "cast" zinc was regarded with suspicion; but now it has been pretty well proved that cast zinc, even if it contain a certain amount of tin and lead, is quite as efficient, if not even more so than the rolled metal. But in any case it must be well amalgamated. A little wooden lid or cover should be fitted to the porous cell, through the centre of which should project the wire coming from the zinc. The negative element, if copper, may be bent into the form of a circle to fit the inside of the jar, and the other terminal soldered to it. Also a little shelf or ledge should be soldered inside the copper, at the top edge, to hold crystals of copper sulphate, if the Daniell form be preferred. If carbon be chosen as the negative, then it will be well to take a sufficient number of carbon (graphite) pencils, such as are used for electric lights, about ¼ in. thick and a little longer than the outer cell, and having tied them all round a bottle or other cylindrical body, of such a size that they will then freely enter the outer vessel, cast a leaden ring round one extremity, to which the other electrode can be attached. This forms a very excellent negative, presenting a very large surface. Annexed is a table of the names, elements, fluids, and E.M.F., etc., of the most useful batteries:—

Name of Cell.	Positive Element.	Negative Element.	Exciting Fluid.	Depolarising Fluid.	E.M.F. in Volts.	Internal Resistance in Ohms.*
Bunsen	Zinc	Graphite	Sulphuric Acid dilute	Nitric acid	1·8	·08 to ·11
Do.	,,	,,	,,	Chromic acid	1·8	·1 to ·12
Chromic Acid, single fluid	,,	,,	Sulphuric acid and chromic acid, dilute mixed	None separate	2·2	·001 to ·08
Daniell	,,	Copper	Zinc sulphate solutn	Copper sulphate sol.	1·079	2· to 5
Fuller	,,	Graphite	Chloride of zinc solution	Potash bichromate and hydrochloric acid	1·5	0·5 to 0·7
Gaiffe	,,	Silver	Zinc chloride	Silver chlorid	1·02	0·5 to 0·6
Grove	,,	Platinum	Sulphuric acid dilute	Nitric acid	1·96	·1 to ·12
Lalande Chaperon	,,	Copper or iron	Caustic potash solution	Oxide of copper	0·98	1·30
Latimer Clark	,,	Pure mercury	Sulphate of mercury	None separate	1·457	0·3 to 0·5
Leclanché	,,	Graphite	Ammonium chloride sol.	Manganese dioxide	1·6	1·13 o 1·15
Maiche	Zinc scraps, in bath of mercury	Platinized carbon	Common salt solution	None separate	1·25	1· to ·2
Mariè Davy	Zinc	Graphite	Sulphuric acid dilute	Paste of sulphate of mercury	1·52	·75 to 1·
Niaudet	,,	,,	Common salt solution	Chloride of lime	1·5 to 1·6	5 to 6
Poggendorf	,,	,,	Saturated sol of potash, bichromate, and sulphuric acid	None separate	1·98	·001 to ·08
Schanschieff	,,	,,	Mercurial solution	None separate	1·56	·05 to 0·75
Skrivanow	,,	Silver	Caustic potash	Chloride of silver	1·5	1·5
Smee	,,	Platinized silver	Sulphuric acid dilute	None	0·47	0·5
Walker	,,	Platinized graphite	,,	,,	0·66	0·4
Warren de la Rue	,,	Silver	Sal ammoniac solution	Silver chloride	1·	0·4 to 0·6

* The resistances were measured in cells standing 6″ × 4″.

§ 100. THE TELEPHONE.—Although the effects produced by this instrument are at once among the most beautiful and astounding in the whole range of physics, nevertheless the apparatus necessary to their production is of the simplest description. In the form patented by Graham Bell (see fig. 60), which embodies all the essential points of a serviceable working instrument, we have a bar-magnet, around one pole of which is coiled about a hundred feet of fine insulated copper wire. The extremities of this coil of wire are attached to two binding screws, by means of which connection can be made to the transmitting lines, etc. In front of the coiled pole of the bar-magnet, but not in actual contact, is a circular plate of very thin sheet iron, gripped at its edges, but free to vibrate centrally. This arrangement is all that is really necessary in the construction of the telephone. In order to carry on a conversation by the aid of the arrangement described, two precisely similar instruments are employed, one at the speaking or "transmitting" end, and the other at the hearing or "receiving" end. The two binding screws belonging to each instrument are connected together by means of separate insulated wires. An individual speaking near the thin iron disc of one of the telephones, causes the air to enter into vibration. These vibrations are taken up by the thin iron disc, which performs, in consequence, oscillations, "excursion and incursions" to and from the pole of the magnet. By virtue of the well-known law, that "motion before the poles of a magnet sets up currents of electricity" (see § 58), and that the currents flow in one direction when the movement is one of *approach*, and in the contrary when the motion is one of *recession*, it follows that during speech a number of waves of electricity, now in one direction, now in another, flow around the wire encircling the coiled pole of the magnet, and, traversing the lines leading to the farther instrument, flow round the coiled pole of that magnet. When these flow in one direction, the magnet is strengthened by their advent, and pulls down the disc before it more forcibly. When the flow is in the opposite direction, the magnet is correspondingly weakened, its pull on the disc is lessened, and consequently the disc performs an excursion from the magnet by virtue of its elasticity; and every trifling modification in the strength and direction of current set up by the vibrations in the disc moved by the speaker's voice at the transmitting end, is faithfully reproduced in vibrations of corresponding amplitude and strength, in the disc at the receiving or hearing end.

To construct a pair of telephones for experimental purposes, capable of transmitting to a distance of two or three miles, the following materials will be needed :

1st. A pair of square bar-magnets, about ¼ in. by 3 in. such as may be procured from the ironmongers from 1½d. or 2d. each. These should be capable of sustaining each other if the marked end of the one be presented to the unmarked end of the other.

2nd. A pair of wooden tooth-powder boxes, 2½in. diameter by about 1½ in. deep. These may be obtained at any chemist's shop.

3rd. A pair of ferrotype plates, 4¼ in. by 3¼ in. These are to be bought from the dealers in photographic goods, being the thin iron plates on which the cheap "ferrotype" pictures are taken.

4th. Two pairs of small binding screws, of any pattern, so long as they are small.

5th. A piece of cylindrical white wood, similar to a broom-handle, about 1 in. diameter, and 12 in. long.

6th. A quarter of an ounce of No. 36 silk covered copper wire.

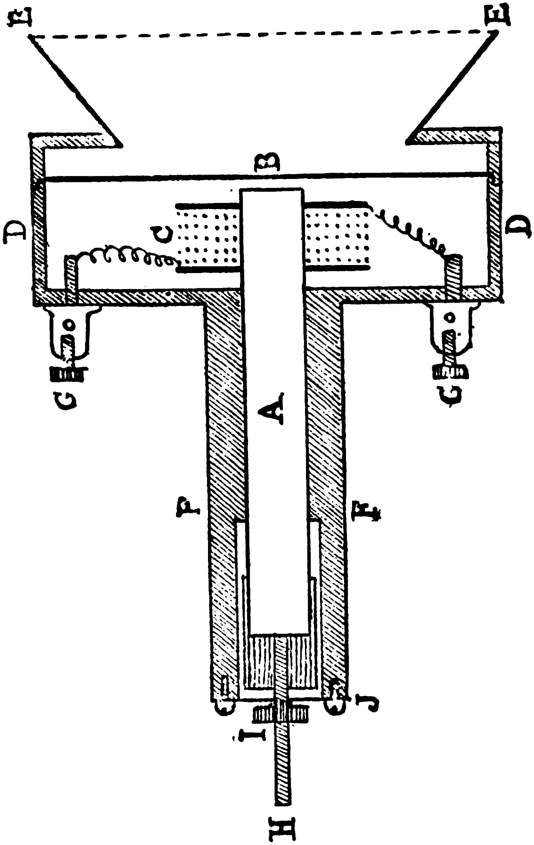
§ 101. The operator begins by cutting off two pieces of the cylindrical wooden rod, 4¼ in. in length, and, with a sharp knife, splits each one down the middle, into two semi-cylindrical halves. Taking care to keep each pair of halves so as to be able to fit them together again when required, he cuts, with a ¼-in. chisel, a channel in the flat face of each half-cylinder, to such a depth that the bar-magnets can lie between the two halves when these are fitted together. The channels should extend from end to end of the cylinders, and should just allow the magnets to slide in them, without any lateral play. At one end, for a depth of about 2 in., the channels should be made a trifle wider than the bar-magnets, say $\frac{1}{16}$ in. When the channels have been thus satisfactorily cut, the half cylinders must be glued together, so as to form two cylinders with a square channel running up the middle. The next step consists in cutting a circular hole (of exactly the same diameter as the wooden cylinders just prepared) in the centre of the bottom of each tooth-powder box. A little good glue is now rubbed round the edges of this hole, and also round the top end of each cylinder. (The top end is the end at which the channel is smallest). This end is then thrust into the bottom of the box, from the *outside*, until it is just flush with the *inside* of the bottom of the box. The boxes, with their cylindrical handles, are now set aside to dry. Whilst these are drying, the student may cut a circular aperture 1¾ in. in diameter, in the centre of the lid of each tooth-powder box. He then proceeds to glue a cone of stiff pasteboard, shaped something like the bell of a clarionet, into this hole. This cone, or bell, must open and extend outwards for about 1 in., and be cut off flush with the inside of the lid of the box. Its only service is to collect and re-enforce the sounds which are to fall on the vibrating plate. The next step is to cut two circles out of the ferrotype plates of such a diameter as to fit exactly, without binding, or without any shake, into the inside of the lids of the boxes. As any dent or buckling in the ferrotype plates would prove fatal to their action in the telephone, it is not permissible to use a compass, or any similar instrument, wherewith to strike the circles on them; but the following mode of procedure must be adopted: Having measured the exact diameter of the inside of the lids, the operator strikes out, with the compasses, a corresponding circle on a stout piece of cardboard; cuts out this circlet with the scissors, and then, laying this as a template over the ferrotype plate, scratches lightly a line all round with the point of a pin. It is easy then, with a sharp pair of scissors, to cut a circle of the desired size in the ferrotype plates, without any buckling or denting.

Two pieces of brass wire, about ⅛ in. in diameter and 2 in. long, are now run through a screw plate, so as to produce a thread on them for their entire length. Two small hexagonal nuts are cut out of a piece of sheet brass ⅛ in. thick, and a corresponding female screw produced in them.

A piece of brown paper, ½ in. wide, is glued around one end of these screwed wires, until this end is of the same thickness as the sealing-waxed end of the bar-magnets. When this is the case, the screw wires are each respectively glued, as prolongation, to the sealing-waxed ends of the bar-magnets, one to each, and further strengthened in their attachment by having a roll or two of brown paper glued tightly round, of such a length as to embrace about ¾ in. up the bar magnet and ½ in. of the screw. The thickness of this paper must not, however, exceed the width of the channel at the lower end of the cylinder.

A small bobbin of cardboard is now made to fit the polished ends of the bar-magnets. These bobbins should be about 1 in. in diameter by about 1 in. wide in the channels ; they should be made to fit pretty tightly on to the poles of the magnets. When made and glued together, they should be allowed to dry, and then soaked for a minute or two in melted paraffin wax. After this they may be wound with about 1 drachm (60 grains) of No. 36 silk-covered copper wire, particular care being taken to wind in one continuous direction only, and to avoid all breakages or even kinks in the wire, as being fatal to success. Each bobbin, after being wound (and it should be wound while on the pole of the magnet), should be removed from off the pole of the magnet and dipped for an instant in melted paraffin wax. About 3 in. of each end of the wires should be left free, for attachment to the binding screws.

This being done, the nut is removed from the screwed tailpiece of each magnet. Two small circlets are cut out of thin sheet brass or zinc, of the same diameter as the lower ends of the cylinders. A central hole is bored in these circlets, to admit of the passage of the screwed tailpieces of the magnets ; and two lateral holes, by means of which they can be fastened to the ends of the cylinders with two screws. The bar-magnets are then pushed up the central channels until their polished ends are very nearly flush with the edges of the boxes, before the lids are on. The little brass circlets just prepared are then screwed on to the ends of the cylinders, leaving about ¾ in. of the screwed tailpieces projecting. (Should the magnets play too loosely in the channels, a thin sheet of paper may be wrapped round them, to increase the friction). The nuts may now be replaced on the tailpieces Each wound bobbin is now to be slipped in its place over the pole of its respective magnet, and, if too loose, retained there by touching the inside of the bobbin with a brush lightly dipped in white hard varnish. The free ends of the wire proceeding from each bobbin are soldered to the prongs of the binding screws, which are driven into the bottom of the boxes, at opposite points in its diameter, near the edges. The ferrotype plates are now placed



inside the lids, with the glossy side outwards, and the lids pressed firmly on to the boxes. The lids should fit tightly ; if they do not, they should be made to do so by gluing a strip of paper round the edge of the rim of the box. The boxes, handles, and cardboard bells may be stained and varnished if desired.

The distance of the magnets from the ferrotype plates can be regulated to a nicety by means of the nuts and screwed tailpieces of the magnets. In practice, I find that the best effect is obtained when the magnets are only just clear of the plates. To secure this result, it is only necessary to screw up until the magnet just touches the plate. This can be told by the dull blocked sound which is given on tapping lightly the ferrotype plate with the finger nail; then, if the nut be turned gradually in the opposite direction until the tapping gives a clear sound instead of a dull thud, the magnet will be just clear of the diaphragm. The annexed cut will make the general disposition of the parts clear: A is the bar magnet, attached by means of the brown paper roll to the regulating screw H; this is controlled by the nut I which is rotated against the circlet J. The coiled bobbin is shown at C, with its free ends of wire attached by a drop of solder to the binding screws G G. At F F, we have the channelled cylinder, in which lies the magnet. D D., represents the tooth powder box, which forms the case and resonant box ; B is the ferrotype plate, and E E the conical mouthpiece made of stout cardboard.

§ 102. Electro-motors.

A very efficient little motor for driving model boats or locomotives, and for producing rotation of vacuum tubes, etc., may be constructed in the following manner: Procure a piece of soft hoop iron about $\frac{1}{8}$ in. thick, $\frac{3}{4}$ in. wide, and 1 ft. long; cut this into two equal pieces 6 in. in length; drill a $\frac{1}{16}$ in. hole through the centre of each one; then bend each piece of the iron into the shape of the letter U, having the limbs $1\frac{3}{4}$ in. apart, and therefore about $2\frac{1}{2}$ in. in length from the middle of bend to the end of limb. In one of these pieces, which is to be the fixed magnet, two other holes, in a line with the first, but near the edges of the iron, should be drilled, in order to enable the operator to fasten it to the base board when finished. A piece of sound mahogany or well-seasoned pine about 3 in. wide, $\frac{5}{8}$ in. thick, and 10 in. long, should now be procured; and a piece about 3 in. square cut off one end and glued and screwed to the remaining 7 in. at right angles to it, similar to a letter L. This piece, which forms the base board, may be stained, varnished, or polished, at the option of the maker. The next step is to wind the two U-shaped electro-magnets previously produced; great care, of course, being taken to cover the iron first with a dressing of paper or tape, as described at §§ 67 and 74, to insure that no electricity shall leak through from the wire, with which the magnets are wound, to the iron below. Each magnet will require to be wound with 6 layers of No. 24 silk-covered wire; that is to say, between 6 and 9 oz. of the said wire; the exact amount got on depending on the skill and neatness of the operator. The connection between the windings must be in the direction shown in our last paragraph, viz., like a letter ᔕ. It will be well, in order to avoid joins, to measure off one-half of the wire intended to be laid on one electro-magnet, and without cutting it off from the remaining half, to wind one limb with the first half, the other limb being wound with the other half. In both electro-magnets, the winding should be begun near the bend; just at those portions where the limbs of the U begin to straighten. If, as directed, 6 layers of wire are got on, the finishing, or free extremities of the wires, will be found near the bend of the U's. At this point they should be carefully tied, with silk of the same colour, to prevent uncoiling. If the operator prefers appearance to efficiency, nothing further need be done to the coils; but if, on the contrary, efficiency be the first consideration, it will be well to soak the coils in white hard varnish, and let them dry in a warm place. Of course, in either case, the electro-magnets should be tested for insulation, before anything else be done as described at § 68. The next step is, to fasten one of these electro-magnets (the one with the three holes drilled at the bend) to the upright piece of the base board, with the limbs parallel to the base itself, and at such a height that the other electro-magnet shall be able to rotate freely in front of it without touching the base; that is to say, the height from the base to the central hole of the fixed electro-magnet must not be less than 1¼ in. The fixed electro-magnet must be fastened to the upright of the base-board by means of two screws, one in each of the lateral holes previously drilled in the electro-magnet. In the central hole of this same electro-magnet is passed a piece of stout brass wire about ⅛ in. diameter and ¾ in. long, and which has been filed down for about ¾ of its length to such a size that it can enter the hole in the centre of the electro-magnet, leaving a head about $\frac{3}{16}$ in. protruding from this hole. In the centre of the head of this piece of brass is drilled a conical depression by means of the Archimedean drill. This depression is to form one of the bearings in which the shaft or spindle which carries the movable electro-magnet will rotate. We will designate this the *back bearing*. The next operation consists in making a little pillar about 2 in. in height, from a piece of brass wire about ¼ in. in diameter. About ½ in. of one extremity of this pillar should be reduced by filing to ⅛ in. in diameter, and a thread put on it by means of a screw plate. At the upper extremity a hole must be drilled and tapped; at right angles to the length of the pillar, and at such a height that when the pillar is screwed into the base-board the said hole shall be exactly in a line with the conical depression in the back bearing. This hole should be about ⅛ in. in diameter, and be fitted with a short length (about 1 in.) of brass screw, to serve as the *front* bearing. The face of this screw must also have a conical depression drilled, corresponding to, and facing the one in the back bearing. The pillar may now be screwed into the centre of the base-board at a distance of about 6¼ in. from the back bearing, with the screw which forms the front bearing in a line with and perpendicular to, the back bearing. If necessary, a small nut may be put at the lower extremity of the pillar screw which passes into the base-board, so as to insure rigidity. In this case a hole must be countersunk at the under surface of the board, so as to allow the nut to lie flush with the board. A piece of steel rod, such as a stout knitting needle, is now procured, and cut so as to be a little longer than the distance between the back and front bearings. This is to form the shaft or spindle of the motor, and must be lowered in temper by holding over the flame of a spirit lamp at its two extremities, which are then to be filed to fine conical points, so as to run freely in the conical depression of the front and back bearings. These points can then be hardened again by making red-hot and plunging in cold water. The free electro-magnet is now to be fitted to this spindle. For this purpose the spindle is pushed through the central hole at the back of the bend; should the existing hole not be large enough, it must be rimed out until the spindle will just enter. The spindle with the electro-magnet on it is then placed between the bearings, the screw of the front bearing being then tightened up to hold the spindle immovable. The movable electro-magnet is then placed with its poles facing, but not touching those of the fixed electro-magnet, a piece of stout cardboard, $\frac{1}{16}$ in. thick, being placed between the poles to prevent actual contact. The magnet being held firmly in this position by the left hand, a file-mark is made with a sharp triangular file, at the point at which the bend of the electro-magnet touches the spindle. The spindle with the electro-magnet is now removed from between the centres, and the electro-magnet soldered to the spindle at the point just marked with the file. In order to solder effectually, the back of the bend of the electro-magnet, as also the inside of the bend, must be filed perfectly clean, and run over with the tinned soldering-iron, so as to get a coating of solder, before attempting to solder the spindle thereto. When this has been done, the movable electro-magnet should be again placed between its centres to see whether it runs freely before the poles of the fixed magnet, without either touching it on the one hand, or being more than $\frac{1}{16}$ in. away from it on the other. If it should not do so, the soldering must be repeated until this result has been attained. A commutator, precisely similar in form, but somewhat smaller than that described in § 66, is now made, and fitted to the spindle. It should be $\frac{1}{2}$ in. long, and $\frac{1}{2}$ in. in diameter, the central hole being a tight fit on the spindle. As the brass cheeks of this commutator must be carefully insulated from each other, from the spindle, and from the iron of the electro-magnet, very short screws must be used; and a small paraffined paper washer put over the spindle, against the electro-magnet, before the commutator is put on the spindle, and pushed up into its place, which is close against the outside of the bend of the movable electro-magnet.

A drop of white hard varnish, painted over the spindle where the commutator is finally to remain, will prevent the commutator from slipping round. The commutator *must be so placed on the spindle, that when the limbs of the movable electro-magnet are exactly opposite the limbs of the fixed electro-magnet, the slits* of the commutator are *in a line* with the limbs; that is, they should find themselves at the two sides of the com-

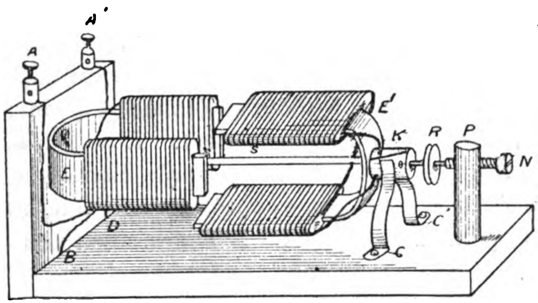


FIG. 61.

mutator, and *not* above and below. A small pulley, either of brass or wood, may be keyed or soldered to the spindle, to serve as a driving wheel, wherewith to communicate the motion wherever desired. The free ends of the movable electro-magnet wires should now be cut a convenient length and soldered, one to each cheek of the commutator. Two L shaped springs (to serve as brushes) are now to be made out of a piece of very thin and springy brass, about 1½ inches in length beyond the bend, and ¼ inch wide. These are to be screwed down to the base-board in such a position that they press squarely, firmly, yet not too heavily on the opposite side of the commutator. Finally, one of the ends of the wires coming from the fixed electro-magnet E (see fig. 61) is connected to a binding screw A. The other end D is carried in a groove under the base-board to the screw of the brush C, to which it is soldered, or otherwise electrically connected. The other brush C is connected by another wire passing under the board (and shown at B) to the terminal A. The spindle carrying the movable electro-magnet and its attachment may now be put in its bearings, the brushes carefully adjusted, and the back screw N screwed up until the spindle can rotate *freely*, but without too much play on its two centres, which should be kept oiled. If well made, this little motor will run well with a single Leclanché, better with a pint bichromate, or chromic acid cell, and at a furious speed with the four cells described and figured at §98.

§ 103. THE PHONOGRAPH.

Although the phonograph cannot by any stretch of the imagination be called an electrical instrument, yet it is so closely allied to the telephone in its mode of acting that a short description of the manner of making a simple form may not be out of place here. The following directions are due to Mr. Shelford Bidwell, and were originally published in the *English Mechanic*:—

"The most important part is the cylinder. This in my phonograph is a hollow brass casting, 4½ in. long and

4½ in. in diameter. It is mounted upon an iron spindle ¾ in. in diameter and 16 in. long, at one end of which is a winch-handle. Upon that part of the spindle which lies between the handle and the cylinder a screw is cut, having eight threads to the inch. The other end of the spindle is left plain. The cylinder having been turned perfectly true, a screw is cut upon its surface of exactly the same pitch as the screw upon the spindle, *i.e.*, eight threads to the inch. The depth of the spiral groove thus formed is $\frac{1}{16}$ in., and its breadth is $\frac{1}{16}$ in. It is better to cut it square, and not **V** shaped. Two brass bearings for the spindle are made of the following dimensions:—length, 2¼ in.; thickness, 1⅛ in.; height, 1½ in. One of these has an inside screw corresponding to the screw upon the spindle. Each bearing has two holes for

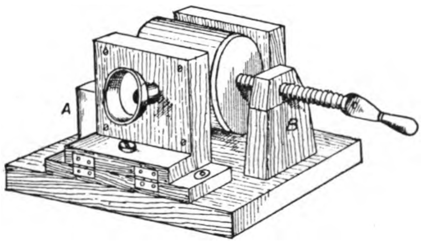


Fig. 62.

screwing it to the support, as may be seen in Fig. 62, which is engraved from a photograph of the instrument. The cylinder, spindle, and bearings being completed, ten pieces of wood must be prepared as follows:—

A is 12 in. × 9½ in. × 1⅛ in.

B is 3 in. × 3 in. × 1⅛ in.

C is similar to B.

D is 5½ in. × 5½ in. × ½ in., and has a circular hole 2¾ in. in diameter, cut in its centre.

E is similar to D.

F is 5½ in. × 5½ in. × ½ in., and has a hole, 1 in. in diameter, in its centre.

G is 5½ in. × 2½ in. × ½ in.

H is similar to G.

I is 8 in. × 2½ in. × ½ in.

K is similar to I.

B and C are the upright supports for the bearings, one of them being shown in Fig. 62. The position of the others is indicated by the letters corresponding to them

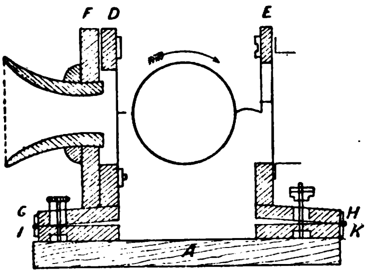


FIG. 63.

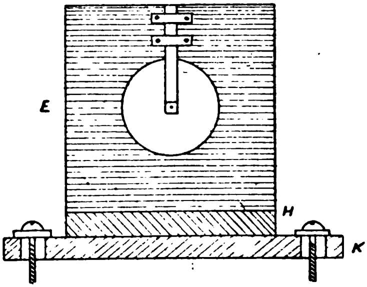


FIG. 64.

in Figs. 63 and 64. The uprights B and C are fixed near the ends of the base board, **A**, by means of 2½ in. screws. D and F are screwed together (see Fig. 63) and the two are then fixed perpendicularly upon G. G is joined to I by a pair of hinges. The two ends of I are screwed to the base-board, but two holes in I are ⅛ in. larger in diameter than the screws which pass through them. The heads of the screws are effectively enlarged by iron washers ¾ in. in outside diameter. The object in this arrangement is to allow a certain amount of play in the board I for purposes of adjustment. When properly adjusted the screws may be tightened, and the board firmly fixed in position. E is attached perpendicularly to H, and made rigid with two small triangular pieces which are not shown in the figure. H is hinged to K, and K is fixed to the base in exactly the same manner as I. Through the middle of I is passed a brass screw bolt, the square head of which is fixed in I. The screw goes through an elongated hole in G and is fitted with a round milled brass nut. It is well to place a washer under the nut. Screw-bolts of this description are used for fixing the expanding bodies of ordinary photographic cameras, and may be had of any optician. H and K are fitted with a similar bolt. Two rather stiff pieces of steel spring are attached to the ends of I and extend for a little distance underneath G. These springs tend to separate G and I, or rather to cause G to turn backwards, like the lid of a box when opened. One of the springs may be seen in Fig. 63.

"The nut, of course, works against the springs. When the nut is screwed up tight G and I approach, and may be made almost to touch each other. When the nut is loosened the spring causes G to rise. Very delicate adjustment is thus rendered possible. H and K are fitted with similar springs, for a similar purpose. We come now to the diaphragm and points. The diaphragm, which receives the voice, is fixed over the circular hole in D, as shown in Fig. 63. It consists of a circular plate of very thin iron 4 in. diameter. Ferrotype plate will answer the purpose very well, but thin charcoal iron is better. It is, however, possible to have the iron too thin. I should say that about two-thirds the thickness of an ordinary ferrotype plate is the best. The point is made from a knitting needle about $\frac{1}{20}$th of an inch in diameter, which must be very hard—one which can be bent is no use. The original point had better be broken off, and a new one ground upon an oilstone. For this purpose, the needle is held at an angle of about 30 degrees with the stone, and is constantly turned round. The point, having been made tolerably sharp, is polished and cut off with a file. The part so cut off is $\frac{3}{16}$ths of an in. long. This has now to be attached perpendicularly to the centre of the diaphragm, and the method of doing so is as follows:— The diaphragm is laid upon a sheet of glass, and a little spot in its centre—about $\frac{1}{8}$ in. in diameter—is scraped clean with a knife. This must be done carefully and gently, or a bulge will be produced. The fragment of knitting needle is then taken up with pliers, and its blunt end, having been moistened with soldering fluid, is held above the flame of a spirit lamp, and touched with a piece of tinfoil. With a little manipulation a small bead or globule of tin may thus be made to adhere to the end. The scraped spot on the diaphragm is now moistened with soldering fluid, and the diaphragm is supported at some distance above a small spirit flame. The ring of a retort stand forms a convenient support. The butt end of the point, with tin globule attached, is then applied to the scraped spot with pliers. In a few seconds the globule melts, when the lamp is instantly removed, and the point manipulated with the pliers, so as to be perfectly upright when the tin hardens, which will take place in a few seconds more. The point will then be found to be firmly attached. The diaphragm and point must, after this operation, be thoroughly washed with soap and water, and slightly oiled, otherwise they will rust. The only precaution to be observed is to apply no more heat than is just necessary for melting the tin. Too much heat wiil warp the disc and, if it is a ferrotype, blister the japan. The soldering fluid consists of equal parts of hydrochloric acid and water, in which is dissolved as much zinc as possible. A pile of books will be found useful for steadying the arm while manipulating the point. The diaphragm is fixed in its place by means of a brass flange (like a camera flange), 4 in. in outside diameter, with a $2\frac{3}{4}$ in. opening. Four screws are used. The second diaphragm is made of parchment paper, like that used for covering jam pots. It is 4 in. in diameter, and is gummed over the hole in E on the side remote from the cylinder (see Fig. 64). When the gum is dry the diaphragm is moistened, and again allowed to dry, when it will be found to be as tight as a drum. The second point is exactly like the first, though it may, with advantage, be a trifle sharper. It is not attached directly to the paper diaphragm, but to a steel spring, which may be seen in Figs. 63 and 64. This is a piece of main spring $\frac{5}{16}$ in. wide and $2\frac{7}{8}$ in. long. It is fixed above the hole in E, by means of two strips of brass, as shown in Fig. 64, and is just so much bent that the end of it, when free, is ⅝ in. distant from the plane of E. The power of this spring may, however, be varied within considerable limits without appreciable difference in its performance. The point is fixed to the spring in the same manner as to the iron disc, but the same care as to overheating is not requisite, and the operation is consequently easier. Before the spring is screwed in its placed, a loop of sewing silk is attached

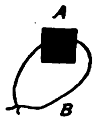


FIG. 65.

to the centre of paper diaphragm by means of a piece of court plaister, ¼ in. square (see Fig. 65, where A is the piece of plaister, B the loop). The length of the loop must be such that when it is drawn over the spring just above the point, the end of the spring may be nearly in the plane of E. The spring is thus caused to draw the paper drum even tighter than before, and its inner surface is rendered slightly convex. Another flange carrying a short rim or spout is now screwed round the paper drum. A paper resonator is made to slip over the short rim or spout. It is a cone made of two or three thicknesses of stout drawing paper. Its length is 18 in.; diameter at small end 2⅞ in., and at large end 7 in. The resonator greatly reinforces the sound when the phonograph is speaking. A wooden mouthpiece, like those used for speaking tubes, is inserted into the hole, F (see Figs. 63 and 64). The instrument is now complete, but it will require careful adjustment before it can be used. In the first place the screws which attach it to the base must be loosened. The milled nut on A screwed up tight, and the piece I, shifted about until the point on the iron disc is exactly in the middle of one of the grooves on the cylinder, and barely touches the bottom of it. Then the screws must be tightened, and this part of the apparatus finally adjusted. The same process is repeated on the other side; but in this case the adjustment is not quite final, as will hereafter be seen. The next thing is to procure suitable tinfoil. This should be rather stout—about 15 square feet to the lb.—and should be cut into pieces 14½ in. by 4½ in. Before putting a tinfoil on the cylinder the two nuts are removed, and the diaphragms turned back out of the way. A little gum brushed along one end of the tinfoil will be sufficient to keep it firmly in its place; the join must be carefully smoothed.

"The diaphragms are then turned back to their places, and the nuts screwed on. The nut on G is screwed up just far enough to cause the point on the iron diaphragm to touch the tinfoil very lightly. The handle is then turned about a quarter of a revolution, causing the point to make a short scratch on the tinfoil. The nut on G is thereupon loosened, withdrawing the point from the tinfoil, and the nut on H being screwed up, another turn is given to the handle. If the scratch thus produced exactly coincides with the former one, well and good; if not, the screws attaching K to the base must be loosened, and K shifted about until absolute coincidence is attained. The utmost accuracy on this point is essential. The instrument may now be considered fit for use. Loosen the nut on H, so that the point on the spring may be well away from the tinfoil, and screw up the nut on G, so far that the point on the iron diaphragm may score a well-defined furrow on the tinfoil when the handle is turned. Turn the handle with as great regularity as possible, at the rate of about one turn per second, or a little slower. Speak loudly and distinctly into the mouthpiece, putting the mouth as near as possible to it, without actually touching it. When you have finished, withdraw the point by loosening the nut, turn the handle backwards until the cylinder is in its original position, and screw up the second nut until the second point presses lightly but steadily upon the bottom of the furrow. Then put on the paper resonator, and turn the handle at the same speed as before. If the adjustments are perfect, the result will be astonishing. I will conclude with a few general remarks and hints. It will be observed that this instrument has two diaphragms, whereas Edison's latest have only one, which does both the receiving and the speaking. I have made many experiments with the object of dispensing with one of the diaphragms, but I have never, under any circumstances, obtained so good results with one as with two. Mr. Preece told the Physical Society that the employment of only one was a 'retrograde step.' Reason and experience led me to concur in his opinion. I do not believe that iron and parchment paper are the best possible materials for the diaphragms, though they are better than any others which I have hitherto tried. The great fault in the iron appears to be in its tendency to resound forcibly to certain overtones, in certain vowel sounds. I have tried to overcome this with coating the diaphragm with indiarubber, but with no great success. I think, however, that a ring of indiarubber between the diaphragm and the flange has an undoubted effect in diminishing the nuisance. The steel spring is subject to independent vibrations of a similar nature. These may be damped by causing a piece of soft indiarubber to press lightly upon it at a point about ½ in. below the lower strip of brass. I have also found it an advantage to wrap indiarubber round the top of the spring before screwing it on.

"I believe that the mouthpiece of a telephone would give better results than that of a speaking-tube. A long resonating mouthpiece like that which Edison first used is worse than useless. The point on the steel spring should be made to turn very slightly upwards, instead of being perpendicular. In the latter case, it is liable to produce a squeak something like that of a pencil when drawn up a slate. If the points are too sharp, they will cut and scrape the tinfoil; if too blunt, the articulation will be muffled. After the points have traversed the cylinder 200 or 300 times, they will require sharpening. This can be done with a small oil-stone, without removing them."

§ 104. The Microphone.

A simple and yet sensitive form of this instrument may be made as follows:—

Procure a piece of good graphite from the gasworks, and cut from it with an old saw three rods about $\frac{5}{8}$ in. square by 2 in. long. If these are roughly cut out with the saw, they can be finished up beautifully by rubbing on a flat stone, with a little fine sand and water. When this has been done, they should be put in an oven to dry. A piece of planed deal 8 in. by $3\frac{1}{4}$ in. should now be procured, and a length of 3 in. cut off one end, and glued and screwed to the longer piece so as to form a letter L. A line is now drawn down the centre of the longer piece; along this line, at equal distances from the two ends of the piece, and about $1\frac{7}{8}$ in. from each other, two square holes are cut into the board, of such a size as to admit the square ends of two out of the three graphite rods just prepared. Previous to inserting the carbon-rods in these holes permanently, these holes must be bushed with thin sheet copper (the same as is used for dynamo brushes). This bushing serves to make a good connection between the carbon-rods, and two binding screws inserted into the shorter board which forms the base of the instrument. This is effected by soldering a piece of No. 20 copper wire to each bushing, and bring a wire from each to its respective binding-screw. For the sake of neatness, the wires may be taken out at the back of the L, and brought round underneath to the two binding screws, a channel being cut with a penknife to allow the wires to lie in. The third piece of graphite-rod, which has not hitherto been brought into use, is now sharpened at both extremities (by rubbing on a flat stone with sand), so as to produce conical pyramids, with sharp points at both ends of the rod. By means of a ⅛ in. bit, put in the Archimedean drill, a slight depression is made at about ¼ in. from the edge of each of the carbons which have been fitted to the holes in the upright backboard of the L. These depressions must be in the *inside* (on the *upper* surface of the *lower* carbon, and on the *lower* surface of the upper *carbon*), and serve to support the pyramidical graphite by its two opposite points. To adjust this properly, the upper carbon is removed bodily; the lower carbon pushed into the lower bushed hole until it is flush with the back of the board. If it is not quite firm in this position, small pieces of copper may be wedged in, until it is quite firm. The double-pointed carbon-rod is now placed with its lower point resting in the depression in the lower rod, and is held thus while the upper carbon is being inserted into the upper bushed hole, care being taken that the upper pointed end of the loose carbon-rod is resting in the depression, on the under surface of the upper carbon-rod. The upper carbon is now pushed into the upper hole until flush with the back of board. Care must be taken that there must be sufficient space between the upper and lower depressions to allow the central carbon-rod to turn quite freely on its axis, but not so much as to let it fall out. This microphone, if glued by its shortest base to the bottom of an empty cigar-box (turned upside down), from which the lid has been removed, will be found extremely sensitive. For use, connect one binding-screw to one pole of a small Leclanché. Connect the other binding screw, by means of a long wire, to a telephone, and bring a return wire from the telephone to the other pole of battery. The tick of a watch, the sound made by the walking of a fly can be distinctly heard at the telephone end, if the fly or the watch is placed on the cigar-box forming the *sounding-board* of the instrument.

WATER REGULATOR FOR INDUCTION COILS.—Instead of the sliding tube arrangement described at § 49, it is sometimes convenient to have a separate regulator of the strength of shocks, etc. The following will be found very easy to make. Procure a stout glass tube 1 in. bore, 12 in. long. Fit it with a sound

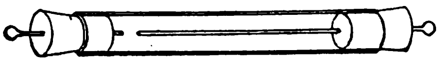


FIG. 66.

cork at each end, run a short length of No. 16 copper-wire through the centre of one cork, and a long length (about 11 in.) through the other. Make a ring of the wire at each outer extremity. Put one cork in, fill the tube with water, then insert the other cork. Wipe dry, then sealing-wax the outsides of corks. The more the long wire is drawn out, the weaker will be the shock from the coil, when this regulator forms part of the circuit.

APPENDIX TO TABLE OF WIRE RESISTANCES, ETC., § 73.

It is frequently necessary to know what diameter of wire must be used to carry a current safely; *id est*, without injurious heating. The following table gives approximately the ratio between the gauge of the wire, and the safe current in amperes, which the wire can carry.

B W G	Safe Current in Amperes.
6	60
7	48
8	43
9	36
10	28
11	21
12	18
13	13
14	10
15	8·5
16	6
17	5
18	3
19	2·5
20	2
22	1·5

The above table refers to ordinary commercial copper wire only; it is NOT applicable to any wire of different material, such as brass, lead, tin, platinum, German silver, &c. Even *pure* copper differs considerably from the ordinary commercial article, in carrying power; some samples tried by me having a "safe carrying capacity" of nearly double that given in the table.

APPENDIX TO GALVANOMETERS, § 86.

PREVIOUS to publication in a complete form, the foregoing chapters on "Electrical Instrument-making for Amateurs" have elicited a considerable amount of correspondence from the readers thereof and many kind suggestions from friends of the author. Foremost among these, and replete with valuable hints as to the desirability of encouraging pupils and teachers to make their own instruments, is one by Mr. Wm. Robertson, of Castle Douglas, N.B. Himself a teacher, he has had practical experience of the thoroughness of the knowledge acquired by students who learn to make as well as to use their own instruments. In these remarks the author fully concurs. During the ten years in which he was engaged in teaching the science of electricity at the Carshalton House School, he invariably adopted the plan of causing the pupils to construct the apparatus which formed the substance of each lesson; and the result has been that, although the apparatus turned out may have been of the roughest description, yet the insight obtained by the students has been so thorough as to enable them to pass examinations, etc., much more creditably than in cases where book knowledge alone was imparted.

Feeling that the subject may interest others, he ventures to reproduce here a portion of Mr. Robertson's letter, referring more especially to the construction of two novel forms of galvanoscope, eminently adapted to show the laws which regulate the action of currents on magnets, etc.

"Permit me," says Mr. Robertson, "to make a suggestion. I have found that in teaching no apparatus is half so valuable as that which is home-made. I have constructed several simple galvanometers (or rather galvanoscopes) which have proved very useful. Even if the teacher himself has learned to make a 'fine job' he will find it of advantage to use very plain and simple apparatus in his class work. In this way the students are encouraged to try their own hands at apparatus making. Occasionally my pupils have made fairly good 'galvanoscopes' at home, even in spite of their mammas, and their dislike to a mess at the fireside.

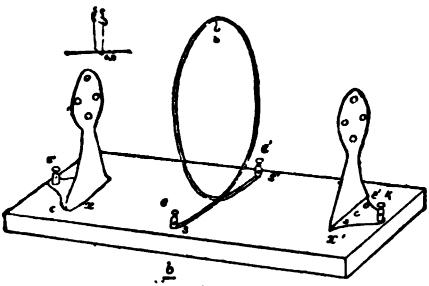


FIG. 58.

"Inclosed you will find sketches of two novel forms of 'galvanoscopes,' by means of which action of currents on magnets can be easily and accurately studied."

The first instrument is figured at Fig. 58. It consists of a base board, about 8 in. by 5 in. by ½ in., shown at *b*. In the middle of this is placed a stout brass wire, bent into the form of a ring, with the ends prolonged at *e*, *e′*, where they are held down to the base board by the two binding screws, *s*, *s'*. At the point where the wire crosses itself to form the hoop (which should be about 4 in. in diameter), the wire is wrapped round, on both portions, with a layer or two of silk ribbon, which serves at once to separate them from electrical contact with each other, and to retain the wire in the shape of a ring. At the upper portion of the ring is fastened a little hook, *h*, which is held in position by being neatly bound round with a little silk twist.

At each extremity of the stand is a wide strip of sheet brass, bent at right angles *x x'*, of the shape figured. Each strip is secured to the base-board by two small screws, *c c'*, and furnished with a binding-screw, K K', to make connection with a battery if required. Each of these strips (the centre of which should coincide with the central plane of the ring) is perforated with four equidistant holes, one on each side of the centre and one above and below. These holes are to permit the introduction of a straight wire or wires, above, below, or on either side of the centre of the ring. These wires serve to conduct the current from one strip to the other. Two magnetic needles may be used with this instrument—namely, one free to move vertically only, as figured at M; and another so suspended as to swing horizontally. The former is furnished with two hooks, by which it may be temporarily held by the ring; the latter is provided with a fine silk suspension, which can be slung on to the hook *h* in the ring. This instrument, which Mr. Robertson calls the "Deflector," may be used in the following mode:

1. Having placed the "deflector" with the brass strips pointing north and south, hang the "vertical" needle M from the top of the ring. Now insert a brass or copper wire

through the upper holes in the strips, and couple up the binding-screws on the strips with a battery. *No Deflection ensues.*

2. Place the wire in the lower pair of holes, and again couple up. *Still no deflection.*

3. Now place the connecting wire in the right-hand pair of holes. *Deflection takes place.*

4. Place the connecting-wire in the left-hand pair of holes. *Deflection ensues in the opposite sense.*

5. Remove the "vertical" needle, and substitute the "horizontal." Now place the wire connector in the pair of holes *over* the needle; couple to battery. *Deflection ensues in one direction.*

6. Place the wire connector in the pair of holes *under* the needle. *Deflection is obtained in the opposite direction.*

7. Place two exactly similar wires, one in the pair of holes *above* and the other in the pair of holes *below* the "horizontal" needle. On coupling up to battery *no deflection occurs*, if the two wires are equidistant from needle, and if both be of equal conductivity. This is, however, seldom the case; and then the nearer, or better conducting wire, rules the deflection.

8. Wires of different gauge, but of same material.

9. Wires of same gauge, but of different material. In these two latter cases the needle obeys the better conductor, provided the distances be equal.

10. Change the position of the instrument, place the plane of the ring in the magnetic meridian, remove all the wires out of the hole in the strips, suspend the horizontal needle in the ring, and when it is at rest in the plane of the ring, pass current through the binding screws connected with the ring *s s'*. *Deflection ensues.*

11. Reverse the direction of the current. *Deflection in opposite direction.*

The other instrument, or "differential galvanoscope," consists simply in a base board, as shown at Fig. 59. B, to which is fastened by four binding screws, A A and *c c′*, a ring R made of two insulated wires lying side by side, the extremities of which are connected to the four binding screws. At right angles to the plane of this ring rises a light rectangular frame of stout brass wire F, on the top of which slides with friction a small spiral of wire, terminating in a hook Q. (This serves to suspend the magnetic needle.)

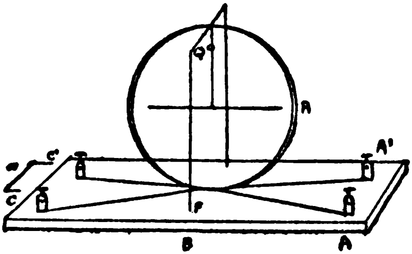


FIG. 59.

A short piece of brass wire, bent twice at right angles, W, called the "bridge," serves to connect the nearer pair of binding-screws, *c c′*, when required. A "horizontal" magnetised needle, suspended by silk, may be hung in the middle of the ring, or to one or other side of it, by means of the hook Q.

This instrument can be used to prove the counteracting effect of currents in opposite directions; since, if the bridge W be inserted in the binding-screws *c c′*, and a current be sent round by the binding-screws A A′, it traverses the two rings in opposite directions. Hence the needle is not deflected if perfectly central; but if the needle be to one side, the nearer circle governs the needle. Having adjusted the needle to perfect centrality by sliding the spiral Q until the needle is unaffected by any current passing, the instrument may be used for comparing the current given by different cells. To this end it is only necessary to remove the bridge and couple up one cell to A *c* and the other to A′ *c*′, care being taken, of course, to send the currents in the same direction.

APPENDIX TO BATTERIES § 95.

ACCUMULATORS, OR STORAGE BATTERIES.—If a current of electricity traverse an electrolyte (any compound body capable of allowing the passage of electricity) decomposition of that body takes places. The surface of the conductor by which the current enters (the positive electrode or anode) attracts to itself the more *negative* constituents of the said body; while the conductor by which the current leaves the decomposition cell (the negative electrode or kathode) in like manner attracts to itself the more positive constituents of the compound. As this decomposition is only effected by means of the electric strain put upon the constituents of the compound, it is evident that if the strain (the original clectric current) cease, the effect will also cease, and recom-

NOTE.—For a more exhaustive work on this subject, the reader is referred to Sir D. Salomon's practical handbook, "Management of Accumulators and Private Electric Light Installations" (Whittaker and Co.), 1888.

position will be effected ; in other words, the original electrolyte will be reformed, and a current of electricity set up in the opposite direction. (See § 81). We may liken the effect of the current to a force exerted against a spring, and the electrolyte to the spring. When the force exerted is removed, the spring, in recovering itself from the strain, exerts a force in the opposite direction to that originally employed.

Based on a knowledge of these facts, and an application of Ohm's law (§ 82), we are able to construct an apparatus which shall return to us as electrical energy a considerable percentage of the current passed through it, and at will to cause the energy to manifest itself either as a large current at a low pressure, by diminishing the internal resistance ; or as a smaller current at a high pressure, by arranging the elements in series, so as to get cumulative effects.

The first accumulator ever made was, perhaps, that of Ritter, who in 1803 constructed a *secondary pile* of a number of discs of similar metal, separated by pieces of moistened cloth. On connecting for a few seconds the opposite extremities of this pile with the poles of a battery, the pile will be found to have acquired the power of producing, for a shor time, a current opposite to that of the battery.

The next to utilize the polarization current was Grove, who devised what is known as the "gas battery." This consists of two platinum plates, standing upright in a vessel of water, each plate being surrounded by a glass tube closed at the top with a platinum wire in connection with each plate sealed in the top of each tube, and projecting out of it. On passing a current through the water by means of the projecting wires, the water is decomposed, the oxygen collecting in the tube at which the current enters, and the hydrogen in that at which it leaves. On interrupting the main current, and connecting up the two platinum wires, a current is set up in the opposite direction, while the hydrogen and oxygen recombine to form water.

To Gaston Planté is, however, due the honour of having made the accumulator a practically useful instrument.

THE PLANTÉ ACCUMULATOR, which for efficiency has not yet been surpassed, may be made by taking two sheets of $\frac{1}{16}$ in. lead, each about 6 in. wide by 3 ft. long, placing one on a flat table, then placing lengthwise on this sheet three strips of india-rubber, a trifle longer than the leaden sheet, but only $\frac{1}{2}$ in. wide, at equal distances from each other. Over these is to be laid the second leaden sheet, and over this latter again, three india-rubber strips, similar to the first three. (These serve only to keep the sheets from contact with each other, and may be replaced by asbestos cloth or any insulator not acted on by acids). The two sheets are then to be rolled into a tight spiral on a wooden cylinder. A leaden strip or lug is soldered to one end of each sheet to serve as terminals, for connection.

A cylindrical glass or earthenware vessel (glazed), of sufficient size to contain the spiral, but leaving the lugs projecting above the upper extremity, is now fitted with a paraffined wood, or ebonite cover, having two apertures to admit of the passage of the lugs. The spiral having been tied together on the outside with a gutta-percha or india-rubber band, may now be inserted in the containing vessel, into which must have previously been poured the following mixture, to reach nearly to the top of the spiral, when this latter is inserted into the jar, viz.:

Water ...	10 parts	by measure.
Sulphuric Acid	1 part	

N.B.—In mixing sulphuric acid with water, it must be borne in mind that the *acid* must be added in a fine stream to the water, stirring with a glass rod in the meantime, and *not* the water to the acid; otherwise the violent reaction may cause a dangerous accident. The Planté cell thus constructed has to be "formed," that is to say a current of electricity has to be passed into it until small bubbles of oxygen gas show themselves at the anode, then discharged, then again charged in the opposite direction, and again discharged, and so on for a fortnight or more, until the surfaces of the leaden sheets, by continual oxidation and deoxidation have become sufficiently spongy to retain a considerable charge. It is this "forming" that constitutes the great, and, indeed, the only objection to the Planté accumulator. The time necessary to effect the "formation" may be greatly shortened, as shown by Planté in 1883, by immersing the leaden sheets in a 20 per cent. solution of nitric acid, previous to subjecting them to the action of the charging current. Faure, later on, showed that the long and tedious process of "forming" the plates by the influence of the current, might be still farther abbreviated, by mechanically dressing the surfaces of the plates with lead in an oxidised condition. This is effected by making a paste of red lead and sulphuric acid, and smearing the surfaces with this paste, previous to rolling up the sheets. This enables the accumulator to be used, after it has been charged two or three times only. Innumerable "patents" and improvements have been made on this device, such as punching, honeycombing, or gridding the leaden plates, to enable them to retain the paste, which is very apt to fall away from the surface during action.

The following data as to the E.M.F. and capacity of accumulators may be of interest :—

1st. Each cell, irrespective of size and number of plates it may contain, provided these are connected to form virtually but TWO plates, will have an E.M.F. of about 2·25 volts when first charged, quickly falling to about 2 volts, at which it remains steady until nearly exhausted. When the E.M.F. falls to 1·9 volt, it is a sign that the discharge should be stopped, as it is not advisable to completely discharge the cell.

2nd. Every square foot of surface of the positive plate in a well-made accumulator (say the E.P.S. type) is capable of discharging at the rate of six ampères per hour, or one ampère for six hours (six ampère hours). This is only true if the plates are arranged in *parallel*, if they are arranged in series, so as to obtain a higher E.M.F., then the quantity to be discharged is equal to the surface of the one element only at the same rate.

3rd. The charging current, in ampères should be somewhat less (say $\frac{1}{4}$ less) than that of discharge.

As a practical illustration of the application of the two first rules: suppose we desire to light a 5 c.p. lamp, of 8 hours' resistance, for one hour. Such a lamp will require about 1 ampère of current to flow through it to light it properly.

Hence to drive 1 ampère through 8 ohms we shall need an E.M.F. of 8 volts, since $\frac{E}{R} = C$. Therefore 4 cells will be needed, coupled in series. As 1 square foot of positive surface can furnish 6 ampères per hour, $\frac{1}{6}$ of a square foot will be sufficient to furnish the 1 ampère needed for 1 hour. Hence *each* cell (as these are coupled in series) must present at least this amount of positive surface. Therefore 6 cells, coupled in series, each cell containing a pair of plates 1 foot long by 2 inches wide, would just do the work desired.

POCKET ACCUMULATOR.—Many amateurs are desirous of constructing a small pocket battery, capable of lighting the little 4 volt "fairy" lamps, used for scarf pins or head decorations. The following will be found easy to make, and effective in action:—Having procured some good sheet gutta-percha, $\frac{1}{8}$ in. in thickness, let three squares be cut from it $3\frac{1}{2}$ in. × 5 in. each, two others 5 in. × $1\frac{1}{4}$ in., and one $3\frac{3}{4}$ in. × $1\frac{1}{4}$ in. This latter having been laid on a smooth slate (previously moistened on the surface to prevent adhesion) a rather hot poker is passed quickly once or twice over its surface, so as to render it soft and sticky. The narrowest edges ($3\frac{1}{2}$ in.) of the three larger squares (those 5 in. × $3\frac{1}{2}$ in.) are then lightly rubbed over with the hot poker, and immediately pressed down upon the strip on the slate, so as to divide it into two equal spaces, or little over $\frac{1}{2}$ in. wide, by $3\frac{1}{2}$ in. long. Special care must be taken that the three upright squares which) are to form the sides and central partition of the accumulator box) adhere firmly and at all parts to the bottom strip. An assistant should hold these square upright and parallel, while the operator proceeds to heat with the poker the two remaining side strips (5 in. by $1\frac{1}{4}$ in.) which he applies while hot to the sides o the cell. The same care must be taken that perfect adherence takes place with these strips and the three squares, as in the case above with these latter and the bottom. If this be not attended to, either the whole cell will leak into the carrier's pocket or the internal divison will allow the fluid to pass from one side to the other. This latter defect would be fatal to the due action of the accumulator. To test this, when the cell is quite cold and hard, it will be well to fill one side carefully with water, and notice whether there be any leakage, either through the sides of the central partition, or to the outside. Should there be any leakage externally, the water should be emptied out, the cell dried, and the defective joint rubbed over externally with the hot poker, until the joint is made sound. Should the defect be internal, a piece of stout wire bent into the shape of L should be heated at one limb, and this rubbed over the defective portion, so as to secure a perfect water-tight compartment.

Four plates, $4\frac{3}{4}$ in. × 3 in., with an ear or lug about one in. long by one in. wide, must now be cut out of some $\frac{1}{16}$ in. sheet lead. With a small punch or bradawl, these plates must be perforated all over, as thickly as possible to within about $\frac{3}{4}$ in. of the top, or lug end. A thick paste must now be made by mixing some good red lead with equal parts of oil of vitriol and water. The holes which have been punched in the four plates, must now be filled in with this thick paste, by means of a flat wooden stick or spatula. The surface also of the plates must be liberally smeared over with the paste, the lugs only excepted. The plates should now beset aside for a short time, to allow the paste to harden. While this is taking place, a piece of cigar box should be cut of the exact size to fit the top of the gutta-percha box previously made, viz., $3\frac{3}{4}$ in. × $1\frac{1}{4}$ in. A central line having been drawn lengthwise down this, two slots $\frac{1}{16}$ in. wide by 1 in. long are cut on each side of the said line. The use of these slots is to admit the passage of the lugs or ears of the leaden plates. They should be all parallel, and stand about $\frac{1}{4}$ in. apart. Two circular holes, nearly $\frac{1}{4}$ in. in diameter must also be drilled through this cover, one on each side of the central line, and equidistant from the slots. These holes serve to take short lengths of glass tube, similar to that used in feeding bottles. The wooden cover must now be soaked in hot melted paraffin until thoroughly permeated with it. The lugs of the leaden plates are now passed through the slots (which they ought to fit tightly), the two central ones bent towards each other till they meet, cut off at the point thy meet, and soldered together. To each of the two outer lugs is soldered a small binding screw, to serve as terminals. Any excess of lead on the lugs may now be cut off. The gutta-percha cells should now be nearly three parts filled with dilute sulphuric acid (1 part acid to 4 parts water) and the plates immersed therein. The acid should not reach the top of the cells when the plates are in, the lid or cover should rest on the top of the cells all round. Should this not be the case, the leaden plates must be cut a trifle shorter. Two short lengths of tube are now inserted into the holes left for that purpose, and cemented into position with a cement made of one part melted pitch and two of gutta-percha, applied hot. With the same cement, the top or cover must be cemented down to the outer cell; if the cover be cemented all over (except the mouth of the tubes), it will prevent any chance leakage. A little soft india-rubber stopper should now be made to fit the orifice of each tube, removable at will.

To charge this accumulator it should be connected to a small dynamo, or to a four-cell bichromate or chromic acid battery (§ 98) for three hours, then the terminals connected, so as to allow it to discharge itself, then charged in the reverse direction, and so on for several days in succession, or until it is found that the accumulator will ring an electric bell for fifteen minutes, after being charged only ten minutes.

When this occurs, the cell must be charged in one direction only, the terminals being marked in order to know where to connect for the next time of charging. When complete, this accumulator will light a 3 or 4 volt lamp well for about two consecutive hours.

It is advisable to charge the accumulator within about an hour or so of being wanted for use, so as to incur as little loss of power as possible, due to the unavoidable short-circuiting which takes place in the inside, through the damp lid. Previous to permanently sealing up the cell, it will be necessary to place a small piece of india-rubber between each pair of plates, to prevent any accidental contact or "short circuiting."

APPENDIX TO DYNAMO, § 74.

ELECTRO-MAGNETS.—Many amateurs are puzzled how to wind the iron cores of dynamos, electric bells, &c., in order to obtain desired results.

The first point to be noted is the *amount* of wire to be got on the core. Since the magnetizing effect of the current decreases as the distance from the iron core increases, in proportion to the square of the distance, it follows that we do not gain power if we add on layers of coils beyond a certain point. In practice, it will be found that no advantage is gained in putting on more wire than will increase the section of the completed electro-magnet to *three times* that of the bare iron core. Let us suppose we had a core one inch in diameter: the diameter of the wound electro-magnet, including the wire coils, should not exceed three inches.

The second point is, What gauge of wire must be used wherewith to coil the core ?

By experiment it has been ascertained that the magnetizing effect is the same, whether 1,000 ampères are sent *once* round an iron core, or whether one ampère is sent 1,000 times round the same core ; or, in other words, "the magnetising effect is proportional to the number of ampère-turns of coil." If, therefore, we have to wind an electro-magnet to be used with a large current of low E.M.F. we must wind our electro-magnet with few coils of thick wire, both for the sake of carrying this large current, and of avoiding resistance. If, however, the current at our disposition is small, but delivered by a high E.M.F. then we select a finer wire.

The third point is the direction of winding.

To produce a magnet with normal poles (one north and the other south), the direction of winding must always be the same. Let us suppose we start winding in the direction of the motion of the hands of a clock : then, although we are at liberty to coil *over* the first layer, any number of times, yet we must always wind in that same direction, viz., from left *over* to right. This is true, whatever be the form of the magnet core. It is easily seen, that if (as in bell magnets, horseshoe magnets) the winding is not carried on right round the bend or "yoke," but the wire made to cross over to the other limb, the winding will *apparently* be in the opposite sense, that is, if viewed from the poles, will pass over one core to the other, thus : ꝏ. Lastly, it is sometimes necessary, as in the Gramme machine, § 72 Fig 43, to produce one pole in the middle of a bar, and two opposite poles at the extremities. In a Gramme machine, the upper pole-piece is to be, say north. Hence. the two extrmities of the upper bar or core must be south. To obtain this result (consecutive poles) the direction of winding must be *reversed* when we cross over from the left-hand bar or core, to the right-hand one. Suppose we start winding to the left-hand of the upper pole-piece, and begin winding in a direction *opposite* to the motion of clock-hands. When we have coiled the bar with the desired amount of wire (always in the same direction) we carry the wire over the pole-piece and commence winding the right-hand core or bar in the opposite direction, *i.e.*, the *same* as the motion of the hands of a clock.

INDEX.

WILLIAM RIDER AND SON PRINTERS LONDON.

The Specialist's Series.

A Series of Handbooks for Students and Practical Engineers, Crown 8vo. With many Illustrations.

Electric Transmission of Energy. By G. KAPP. 7s. 6d.

Arc and Glow Lamps. By J. MAIER. 7s. 6d.

The Conversion of Heat into Work. By WM. ANDERSON. 6s.

Sewage: Treatment, Purification and Utilisation. By J. W. SLATER. 6s.

Gas Engines. By W. MACGREGOR. 8s. 6d.

Ballooning. By G. MAY. 2s. 6d.

The Telephone and its Practical Applications. By W. H. PREECE, F.R.S., and J. MAIER, Ph. D. 12s. 6d.

Manures. By Dr. A. B. GRIFFITHS, F.R.S.Ed., F.C.S., Principal and Lecturer on Chemistry in the School of Science, Lincoln. 7s. 6d.

Hydraulic Motors. By GEORGE R. BODMER, Assoc. M. Inst. C.E. 14s.

Alternating Currents of Electricity. By T. H. BLAKESLEY, M.A. 4s. 6d.

The Dynamo. By C. C. HAWKINS and T. RAASCHOW. [*In preparation.*

(Others to follow.)

(Uniform.)

Construction, Working and Management of an English Railway. A Practical Handbook. By Lieu.-Col. FINDLAY, A.I.C.E., General Manager, London and North-Western Railway.