

THE  
JOURNAL OF THE  
**MODEL ENGINEER**  
and **ELECTRICIAN.**

EDITED BY  
**PERCIVAL MARSHALL, A.I.Mech.E.**

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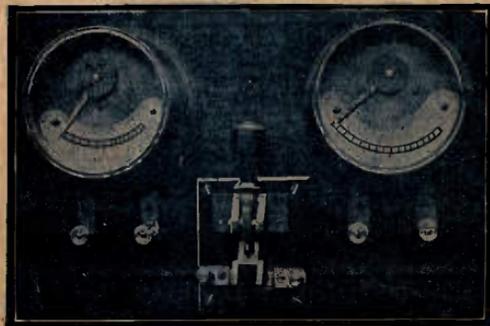
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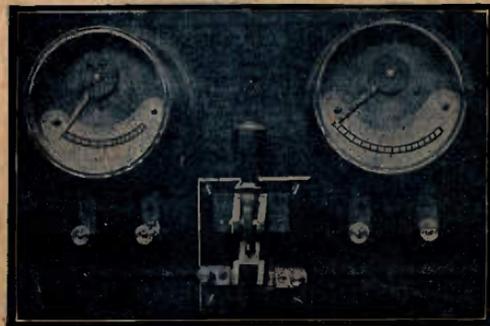
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## PREFACE

THE importance of a knowledge of the construction and use of measuring instruments to the worker in the ever-widening field of electrical engineering cannot be over-estimated. He endeavours to control and bend to his will a class of apparatus or machine which to all appearance may be of perfect construction and yet refuses to work and fulfil the function for which it was designed. A leakage of electricity does not become, like steam, visible to the eye, or hiss like compressed air; the fault must be discovered by the aid of a suitable instrument which will indicate the presence or absence of an electric current, according to the particular circumstance of the case. The information in this book is intended for those who will require to make simple tests and measurements when building and using small power dynamos, electro-motors or similar machines and fitting up installations of electric bells, telephones and indicators, or constructing and working with induction coils and batteries.

The designs and descriptions have been selected from a number which have appeared from time to

The wire used for the coils may be either No. 28 or 30 S W G silk covered. About 6 ins. of the wire is passed through one of the holes in the ends of the reel, and this piece clamped with the thumb while the reel is wound continuously in the same direction until almost filled with the wire. Now pass the finishing end of the coil through the other hole in the reel and temporarily wrap the two ends together. The reel should now be steeped for ten minutes in melted paraffin wax, after which it should be hung up to allow the wax to drip and set. The ends of the wires should now be untwisted and straightened out and then bared of their covering for a length of 1 in. at the ends. This bared portion of the wire must be made clean and bright by sand-papering or scraping with an old penknife.

The case is a piece of brass tubing, 3 ins. diameter and 2 ins. long, it is placed upon the base with its edge resting in the groove cut to receive it.

The reel is placed inside the case and secured to the base coils uppermost, by the aid of the little spring brass knees (fig 4). These are screwed to the base 1 in. apart with their longest part vertical, and the reel then forced between them. If the knees do not grasp the reel firmly, their upright pieces must be pressed slightly inwards until they do so. Fig 5 is a sectional view showing how the reel is held by the spring knees.

The ends of the coils are passed through the holes in the base and then carried along the inside of the grooves in the under side of base, and finally well

twisted round the shanks of the binding-screws. The binding-screws should have lock-nuts for clamping the wires, and these nuts must be removed to allow the wires to be twisted around the shanks of the binding screws, and then replaced and screwed up very tight. Neither these lock nuts nor any part of the shanks of the binding screws should reach to the level of the under surface of the base, and the grooves for the wires and lock-nuts should be deep enough to allow these to sink about  $\frac{1}{8}$  in. or more beneath the surface.

The next part demanding our attention is the



FIG. 4 - Spring Brass Knee



FIG. 5 - Section of Reel.

graduated circle. This is a cardboard circle 3 ins. diameter and divided into degrees in the order 0 90, 0 90, on either side of the zero line. This card is glued down upon a thin boxwood disc of the same diameter as the card  $\frac{1}{8}$  in. thick.

A needle point is fixed in the centre of the disc and card, point upwards and should protrude about  $\frac{1}{2}$  in. Two small holes should be bored in the card and disc to take a couple of very small round head brass screws for fixing the disc and its card to the reel. These screws should enter the sides of the reel at the middle of their length and thickness, and great care must be taken to avoid the screws

coming into contact with the coils or their insulating covering. It should be observed that the zero line of the graduated circle should be parallel to the length of the coils.

The magnetic needle is 2 ins. long, and should be provided at its centre with an agate or brass cup with

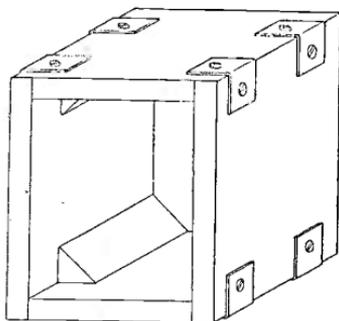


FIG. 6.—Case for Thomson's Galvanometer.

which to pivot it on the needle point. The instrument should be covered with glass to preserve it from dust etc. If possible, the reader should obtain a 3-in. lens-mounting off a disused magic lantern or telescope, and fix a piece of 21 oz. glass in the place originally occupied by the lens. The mounting will be found to have screw threads cut upon it; similar threads should be cut on the inside of the

brass case so that the glass top and its mounting can be screwed on.

The instrument will now be complete and ready for use. When using the instrument, always turn it round until the needle points to zero, the coils and the needle will then be in the magnetic meridian, and will not be affected by the earth's magnetism.

**A SIMPLE VERTICAL DEFLECTOR.**—The case is made of well-seasoned cedar,  $\frac{1}{4}$  in. thick and measures outside  $3\frac{1}{2}$  ins. by 3 ins. by 2 ins. in depth. The sides may be dovetailed together, or fixed by brass corner plates let in flush with the surface of the wood (see fig. 6). A piece of sheet brass,  $\frac{3}{32}$  in. thick, is now cut to fit inside the case. This is for the dial plate, and should be quite flat, as one side is to be polished. To fix this plate in the case we shall require a hole in each corner to take screws screwed into the four corner pieces shown in fig. 6. The face of the dial should be  $\frac{1}{8}$  in. below the level of the case.

The coils are wound on two formers made of thin sheet brass (see fig. 7) which, with all the other figures (except fig. 10, which is full size), is half size. The size of the hole through the formers is  $1\frac{1}{2}$  ins. by one  $\frac{1}{4}$  in. wide. One flange is  $\frac{1}{4}$  in. wide all round and the other is  $\frac{1}{2}$  in. deep on one side, and also turned up to form a foot  $\frac{1}{4}$  in. wide, by which the coils are secured to the dial plate. These formers are built up with the soldering iron, and must be neatly made, and all roughness in the joint edges and corners carefully smoothed off.

The formers should now be carefully insulated with thin silk, paying attention to the corners. A layer of thin brown paper, well shellac varnished, will do, if put on carefully.

The "quantity" wire should first be put on. It consists of two layers of No. 22 S W G., silk-covered, and leaving 6 ins out at each end for connections. Wind both formers exactly alike. A layer of silk ribbon or thin brown paper is put over these coils, and on top of them are wound the fine wire coils, made up of seven or eight layers of No. 38 or 40 silk covered copper wire. As this wire is very fine and easily broken, it is best to solder about 10 ins. of thicker wire, say, 22 to it, and neatly wrap the joint with silk. Leave about 6 ins. out for connections as before, and winding in the same direction, and starting in the same place as before, put on the seven or eight layers. When finishing off, solder a piece of thicker wire on, so that the last three or four turns are taken up by the thicker wire, leaving a length over for connections. A layer of silk ribbon round the coils will give a better finish to the job, and also prevent the wire from being damaged.

The needle is made from a piece of high quality steel  $1\frac{1}{2}$  ins long,  $\frac{1}{4}$  in wide, and  $\frac{1}{16}$  in thick, filed to the shape shown in fig 8. After being drilled with a  $\frac{1}{16}$  in hole in the centre, it is made a bright cherry red in the fire or blowpipe flame, and immediately quenched in cold water. This hardening is necessary, or the needle would not retain its magnetism for any length of time. The needle is

now to be magnetised (see Chap V) or should the maker know anyone who has charge of a motor or dynamo he will be able to get it done for "Thank you," and "While you wait." The pointer is now made to the shape shown in the view of the dial front (fig 9). It can be made of brass, ivory, bone, or aluminium; the lower portion must be heavier than the top, so that the pointer always hangs vertically.

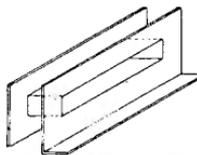


FIG. 7.—Two views of thin brass brackets for coils.



FIG. 8.—Needle.

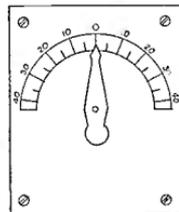


FIG. 9.—Dial.

The spindle is made of  $\frac{1}{16}$  in diameter silver steel long enough to fit between the brackets, next to be described. One end of the spindle is fitted with a pair of nuts, both ends are pointed and hardened.

We now require two brackets of  $\frac{1}{4}$  in sheet brass, or they may be cast, one made to the sizes and shape shown in fig 10, which is full size, and another exactly similar, except that it is only  $\frac{5}{16}$  in high. A

$\frac{1}{8}$ -in diameter steel screw is fitted in the centre of each bracket the ends of the screws being countersunk by a drill, the cutting edges of which are at an angle of 60 degs to each other. The screws should also have a lock-nut, and be carefully hardened.

The coils can now be fitted to the back of the dial plate  $\frac{1}{4}$  in apart and the brackets afterwards, the smaller one on the front and the deeper one over the coils on the back (see fig. 11). The needle, pointer, and spindle are now put into place. The magnetised

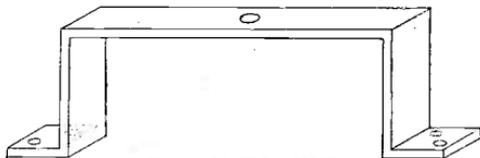


FIG. 10.—Brackets (Full Size).

needle is adjusted to swing in the centre of the coils, and the pointer just clear of the dial plate by means of nuts which are placed one on each side of the pointer. The spindle is regulated by the screws in the brackets to swing freely, but without shake, and fixed by the lock-nuts. The dial plate may either be engraved, or a scale may be fixed to it by screws.

We now take the case again and fix three terminals in the top and then fix the dial plate with the coils etc in position. The starting ends of one fine wire coil and one thick wire coil of the same bobbin are to be connected to the outside terminals, one to

each, and their finishing ends are to be joined respectively to the starting ends of the coils on the other bobbin, the remaining ends are to be both connected to the middle terminal. If you have any difficulty with these connections, or may have wound a coil in the wrong direction, they may be worked out experimentally with the aid of a battery, trying one coil at a time (see Chap. VI fig. 35). A glass

front and plain back are fixed to the case by countersunk screws let in flush with the face of the wood, and the case varnished or polished to suit the maker's taste or abilities. For a small outlay we have now a galvanometer which would cost up to a guinea in the shops. To use the instrument, the quantity coils are used when measuring heavy currents as battery cells, and the fine coils are used for detecting leakages or line wires etc. The instrument must not be used on large dynamos or batteries of accumulators, or the coils will be burnt out.

A SENSITIVE GALVANOMETER OF SIMPLE CONSTRUCTION.—This is a useful galvanometer for use with a Wheatstone or metre bridge, or as a leak detector or tester; it is sensitive enough to show a large deflection

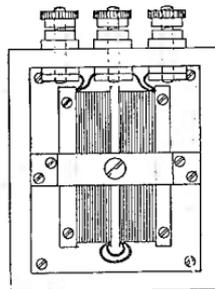


FIG. 11.—Connections between Coils and Terminals.

if a carbon and zinc plate are held in either hand—the hands being damp, and the plates, of course, joined to the terminals of the instrument by two wires, or a considerable movement will be observed if a silver coin is laid on the table, a drop of moisture is placed on it, and the head of a steel screw made to touch the moisture. It will show any of the usual experiments, such as induced currents, thermo effects, etc.

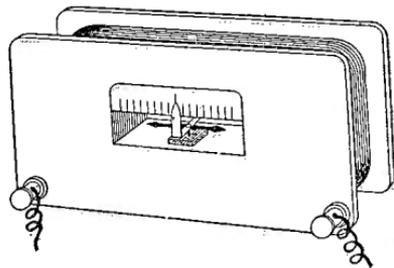


FIG. 12.—The Complete Instrument

The finished instrument is shown (fig 12), it essentially consists of a wooden frame with aluminium sides carrying 1000 turns of fine copper wire, in the centre of this frame is pivoted an agate centred magnetic needle, this needle carries a light pointer at right angles to it, which in turn carries a white paper arm at one end. This arm appears through one end of the central aperture, and shows the slightest movement of the magnetic needle upon a

scale. The scale may be green or red paper, and then the pointer's movement can be distinctly seen at a considerable distance off.

To construct, take a piece of  $\frac{1}{16}$ -in sheet aluminium (brass will do if lacquered after), cut two plates from it 4 by  $1\frac{3}{8}$  and square the edges and round off the corners; from the centre cut two slots  $1\frac{1}{2}$  by  $\frac{3}{8}$  (A, fig

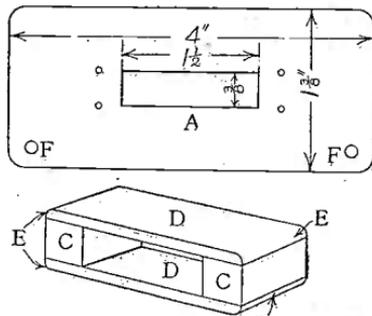


FIG. 13.—Hardwood Frame

13); these may be cut out with an ordinary fret-saw and finished up with a smooth file. A hardwood frame is now made, the end pieces C being  $1\frac{1}{2}$  by  $\frac{3}{8}$  by  $\frac{5}{8}$ , they must be dead true and square. This is best done with file and square as if metal was being worked thus avoiding the use of inaccurate planes and chisels. The side pieces D may be cut from thin

evenly. Cut a light white paper pointer  $\frac{3}{8}$  in long by  $\frac{1}{4}$  in wide and stick it to the bent end of the aluminium pointer.

A piece of cork is now cut  $\frac{1}{2}$  in by  $\frac{1}{2}$  in by  $\frac{1}{4}$  in, and a fine needle point broken off  $\frac{1}{2}$  in long is pushed into the centre of the cork, see that it stands (fig. 16) central and upright, glue the cork in the centre of the wood frame, taking care to keep all glue and dirt off the needle point. Cut a piece of green or red paper  $1\frac{1}{2}$  ins by  $\frac{1}{2}$  in wide rule a central line, and mark off similar lines every  $\frac{1}{4}$  in apart as at N, fig. 15. This is the scale, and is stuck on the plate which carries the terminals (as fig. 12).

The needle may now be carefully mounted on its centre, and should move very freely. To use the instrument it is advisable to keep it permanently on a shelf or bracket made for it and under a dust-tight glass shade. Run two light wires from the terminals along the walls to our work bench or experimental bench. The pointer can be brought to zero (the centre line) by placing a weak horseshoe or bar magnet on the shelf; it is advisable to set the galvanometer up about two yards from the table, and then there is no fear of any direct action of electromagnets, etc., upon the needle if we are experimenting with these.

## CHAPTER II

### INSTRUMENTS TO MEASURE THE PRESSURE OR QUANTITY OF AN ELECTRIC CURRENT: VOLTMETERS AND AMPEREMETERS

THE instrument here described may be made either as a voltmeter or as an amperemeter, the only difference being in the winding of the coil.

The voltmeter is intended to read to 20 volts and the amperemeter to 4 amperes.

The first part to be made is the base, which may be cut from a piece of mahogany board 1 in. thick, and turned in the lathe to the shape shown in the drawings. This could, however, be very easily made by using two thin pieces of wood, and cutting out one of them with a fret-saw, then screwing it to the other and finishing off nicely with a file and glass paper.

The containing case C C (shown in figs. 17 and 18) is a piece of large brass tube, 4 ins in diameter and 2 ins long. Holes should be drilled around the circumference of this for the purpose of ventilation, and small countersunk holes for wood screws at one end to fasten the tube to the turned part of baseboard.

The cover or outside rim R R (fig. 17), which keeps the glass in position, is made from a length of  $\frac{1}{2}$  in. brass tube, bent in a circle by hand, the two ends being soldered together. A strip of sheet brass is next procured  $\frac{1}{16}$  in. wide, and soldered around the edge of this tube, so as to be a snug fit on the outside of containing case (see S S, fig. 17). The glass front can be taken from an old alarm clock.

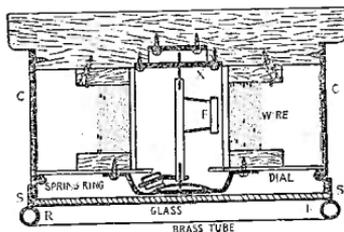


FIG. 17.—A simple radial voltmeter  
(Sectional Plan.)

The bobbin is constructed in the following manner: Two pieces of fretwood being obtained  $2\frac{1}{2}$  ins. square with the corners cut off as in fig. 18, for the ends, a hole is next cut out of the middle of each and a paper tube  $\frac{1}{16}$  in. thick,  $1\frac{1}{16}$  ins. diameter,  $1\frac{1}{2}$  ins. long made and glued in these holes so as to form a bobbin, and when dry this is wound for use as a voltmeter with No. 36 cotton covered copper wire till nearly full. Pieces of wood are then cut to

fit, and glued in each corner of the bobbin as supports (see dotted lines in fig. 18), the bobbin screwed on the base and an ordinary wire nail (minus the head) driven into the base at right hand side of paper tube (inside) as shown at W, fig. 18.

The action is made from a piece of brass wire

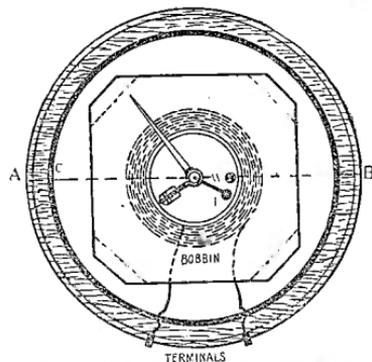


FIG. 18.—Section Elevation of Simple Voltmeter.

about  $\frac{1}{8}$  in. thick and  $1\frac{1}{2}$  ins. long in each end of which is drilled a small hole with a needle drill about  $\frac{1}{16}$  in. deep. An ordinary fine pin (without the head) is soldered in each end to act as straight pivots (fig. 17). It is very necessary to have a good working fit in the bearings, and yet no binding as, should the holes in bearings be a shade too large or too small,

## CHAPTER III

INSTRUMENTS FOR MEASURING ELECTRICAL  
RESISTANCE. THE WHEATSTONE BRIDGE

The range of the bridge to be described is from 1 to 999 ohms, but it may be used merely as a variable resistance, the Simple Sensitive Galvanometer in Chapter I would be suitable for use with it.

The wire used for the resistances which constitute the various arms of the bridge is No 26 S.W.G. manganin wire. The use of manganin reduces to a minimum any errors which may arise from changes of temperature, but the lengths of manganin given here must not be strictly adhered to, owing to slight variations in the composition of manganin. It will be necessary to get the specific resistance of the particular alloy used, when the length of wire necessary may be found from the formula  $l = \frac{RA}{\rho} 10^9$ ,

where R is the resistance, A the cross-sectional area of the wire used, and  $\rho$  the specific resistance, the result being divided by 30.48 to bring to feet. Thus the specific resistance of the manganin used here is 42000. Therefore the length of No. 26 wire necessary

to give 10 ohms resistance is  $l = \frac{10 \times .00164 \times 10^9}{42 \times 10^3 \times 30.48}$   
= 128 ft.

And the various resistances used in the box are:

1	resistance of 20 ohms	=	25.6	ft.
9	resistances „ 10 „	each =	115.2	„
9	„ „ 1 „	„ =	115.2	„
9	„ „ 1 „	„ =	115.2	„
2	„ „ 2 „	„ =	51.2	„

Therefore the total length of wire is 158.492.

The box is made from  $\frac{1}{2}$ -in. teak, and is 12 ins. by 9 ins. by 3 ins., the top is 15 ins. by 10 ins. by  $\frac{3}{8}$  in., thus overlapping and giving a better finish to the box. The other material required is as follows:—Thirty-two brass studs of the kind shown in fig 19, seven brass terminals (in this case of two different sizes, which as may be seen, adds to the appearance of the

box although for all practical purposes they could equally well have all been of the same size), a piece of sheet brass, a length of brass wire, on which

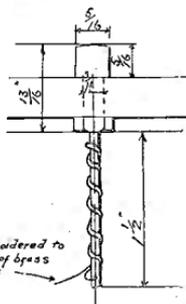


Fig. 19 — Brass Studs for Wheatstone Bridge

to wind the resistances, a piece of ebonite from which to make the knobs for the keys and levers, and brass nuts for the terminals and studs

The keys are made from  $\frac{1}{8}$ -in sheet brass, and are of the dimensions shown in fig 20. A hole is drilled and tapped through the terminal disc and key, into which a piece of brass wire is screwed, leaving about  $\frac{1}{4}$  in protruding from the under side. This protruding piece is then sunk into the wood, thus

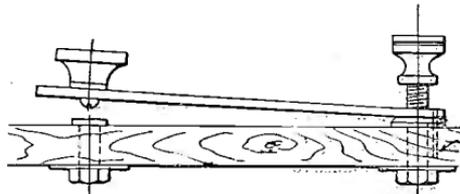


Fig 20.—Detail of Key for Wheatstone bridge.

effectually preventing the key from turning when the terminal head is screwed down. All the other terminals are pinned down in the same manner. At the end of each key is fixed an ebonite knob by means of a small round headed screw nail, the head of the screw nail also serving as a contact. The other contacts for the keys are made by turning down a brass stud until there is only about  $\frac{1}{16}$  in left to project above the top.

The pins for the levers (fig 23) are made from pieces of  $\frac{1}{4}$ -in. diam. brass wire  $1\frac{1}{2}$  ins. long, screwed

to take a nut at each end. On the end of the pin which projects above the top, and just below the

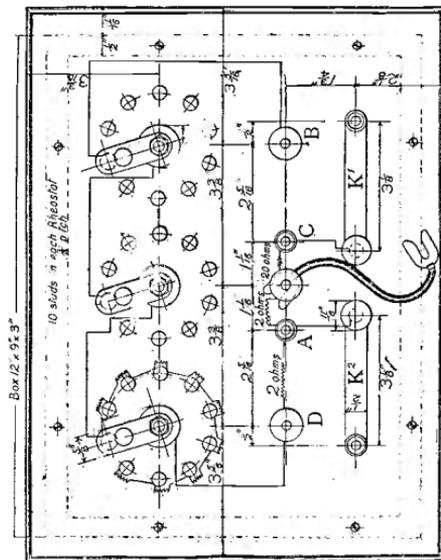


Fig 21.—A Wheatstone Bridge.

thread, a piece of brass tubing is sweated, thus providing a shoulder to bear on a brass washer, otherwise a thicker piece of wire would be necessary,

and then it would require to be turned down. The pin passes through the above-mentioned washer, which has three holes drilled in it, to enable it to be screwed at the top and then through two brass washers on the inside of the box—one a flat washer, and the other a spring washer, the former to prevent the spring washer from eating into the wood and the latter to press against the nut to prevent it from turning when the lever is moved over the studs.

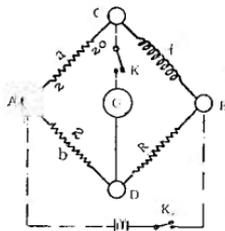


FIG. 22.—Diagram showing Use of Wheatstone Bridge.

The lever itself is made from  $\frac{1}{16}$  in sheet brass, broad enough to span two studs, and having  $\frac{1}{4}$  in hole drilled at one end, through which the pin passes. The studs are hollow and are screwed both inside and out, the inside thread to take a piece of brass wire about  $\frac{1}{16}$  in diameter on which the resistances are wound

Having found the necessary length to give the required resistance, it must be wound non-inductively—i.e. it must be wound on the double, as shown by fig. 19, one end being soldered to the wire on which it is wound and the other end connected to the next piece of brass wire. Shellac varnish or paraffin wax should be used unsparingly for the resistance coils.

For short-circuiting either the 20-ohm or the

2-ohm resistance, so as to make the ratio arms equal, or as 10 : 1, two pieces of sheet copper are made as shown in the drawing, and sweated to the ends of a short length of flexible cord.

To use the bridge, connect the battery, galvanometer, and the resistance to be measured, as shown in the diagram. Make a rough estimate

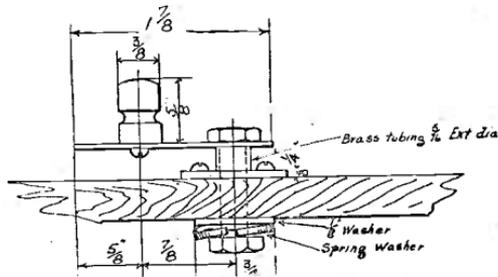


FIG. 23.—Detail of Levers for Bridge

of the unknown resistance, and place the levers accordingly, afterwards moving them about until no deflection of the galvanometer is observed when both keys are tapped. Then if the 20-ohm resistance be short-circuited so that the ratio arms are equal the unknown resistance will be equal to the sum of the resistances in the various rheostats. If the unknown resistance be estimated at over 100 ohms, short circuit the 2 ohm resistance, making the ratio

as 10 : 1 then the unknown resistance will be equal to ten times the sum of the resistances in the various rheostats. It will thus be seen that for resistances over 100 ohms the degree of accuracy which can be attained is to 1 ohm, while for resistances less than 100 ohms a degree of accuracy can be attained to 1 ohm. The reason why, by making the ratio as 10 : 1, the range of the bridge may be increased will be better understood by comparing the wiring diagram (fig 21) with the diagram (fig 22). When there is no potential difference between the pts. C and D then there will be no tendency for a current to flow along the wire connecting the galvanometer with these points, and therefore there will be no deflection of the galvanometer needle. This happens when  $a=b$  and  $x=R$ , or when  $a$  is in the same ratio to  $b$  as  $x$  is to  $R$ . The connections are shown in the general arrangement, also the manner in which the resistances are connected although the resistances are only shown in one of the rheostats still the other resistances are connected in the same way.

While making a test the galvanometer should if possible be placed on a separate table so as to be as free from vibration as possible, but before connecting it to box, the battery key should be tapped, and if any deflection is observed on the galvanometer it should be taken into account, or the wires leading to the galvanometer should be twisted together. Also the battery key should be tapped before the galvanometer key.

## CHAPTER IV

## INSTRUMENTS FOR MEASURING STATIC ELECTRICITY

**GOLD LEAF ELECTROSCOPE**—This instrument consists of the base (fig 24), into which fits the glass bell jar shown in fig 25. The top plate or table (fig 26) is struck from sheet brass  $\frac{1}{8}$  in thick. This can be cut to shape as near as possible with a hack-saw, and having been fitted with the  $\frac{1}{8}$ -in brass wire



FIG. 24.—Base of Electroscope.

seen in fig 26, turned up in the lathe. Or it may be trued up with a file and then fitted to the brass wire by soldering. Soldering is an easy matter when done in the right way. Well clean the surfaces to be soldered together by filing until quite bright, heat over the spirit lamp or Bunsen burner and use rosin as a flux, touch the centre of the brass plate with a stick of solder, and when the former is

of gum on the flat sides of the rod and hold your breath for a moment, whilst the strips are taken up on a needle point and set in place on the rod. The strips may be cut by placing the gold leaf between a sheet of clean notepaper and cutting the notepaper into  $\frac{1}{2}$ -in strips. This, of course, will cut the leaf at the same time. Place the jar in the groove in the base, and all is complete. If properly made, this electroscope will be very sensitive, and should possess an excellent appearance.

## CHAPTER V

## PRACTICAL DETAILS OF CONSTRUCTION — MAGNETISING NEEDLES, SUSPENSION, LEVELLING DEVICES, AND CALIBRATION

TO MAKE MAGNETIC NEEDLES—These are usually of lozenge shape and flat, not circular like a sewing-needle though such a needle can be used, it is advisable to keep to the recognised form. The needle must be made of steel which can be hardened; iron or tin will not do. Such material as steel watch and clock springs will do very well. If you take a piece of old spring anneal it first by making it red hot and allowing it to cool slowly, if it is buried in lime or ashes it will cool more slowly than if exposed to the air. When filed to shape make the needle red hot and plunge it into water to harden it, this hardening will make the steel very brittle, so that care must be used in handling, but it is advisable to make the needle very hard because the harder it is the better will the magnetism be retained, you can, however, re-magnetise the needle any number of times should it become weak by loss of magnetism during use.

needle upon one of the poles of a dynamo, in this instance the magnet would be, of course, fixed and the needle moved, but the method of stroking always in one direction must be adhered to.

Supporting the needle.—When supported on a point, the centre of gravity of the needle must be below the point's tip or it will not remain in position, this is managed by fitting a little brass cup into a hole in the centre of the needle as shown in fig 31, taking care that the point comes well through the needle, the cup is made with a slight shoulder, which is buried down over the needle after it has been slipped on.

Note.—It is of no use to attempt to magnetise a needle whilst it is red-hot, or to harden it after it has been magnetised, heating it destroys the magnetism.

LEVELLING SCREWS.—For the purpose of setting a galvanometer truly level, so that the needle may swing freely, attachments known as levelling screws are often fitted. These consist of brass strips screwed to the base, each strip being drilled and tapped to receive a vertical milled head screw (fig 32 shows such a levelling screw), three are always used because a body will rest firmly upon an uneven surface if supported upon three points, the brass strips should be fixed at three equally-spaced intervals as shown in the sketch (fig 33), which represents a galvanometer base fitted with three levelling screws, the screws are placed with their points downwards, by screwing any one up or down the instrument will be tilted

at that place and very accurate levelling can be quickly attained, the dimensions are approximate, and may be altered to suit any particular requirements.

WINDINGS OR INSTRUMENTS.—These are not calculated with the accuracy required for windings of dynamos and motors, except in some very special case the exact gauge of wire or quantity does not matter, the gauge is selected so as to be appropriate for the current which the instrument has to carry, but anything within several gauge numbers will do, if the instrument is to measure small currents a fine gauge of wire is selected if it will be used to measure heavy currents a coarse wire is selected, if the instrument is required for measuring both weak and heavy currents two or three windings are sometimes put on the same instrument, as in the case of the vertical detector described in Chapter I. For very heavy currents insulated flat copper strip may take the place of wire, being rolled up into a coil, this is especially useful for amperemeters. A coil of fine wire having a great number of turns and carrying a very weak current has practically the same power as a coil of similar size consisting of few turns of thick wire but carrying a strong current. If the coil does not have sufficient effect, wind on some more wire and try again. Silk covering is best for fine wires, but cotton covering will do

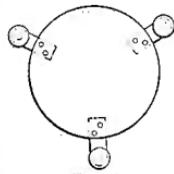


Fig. 33.

instrument might be quite accurate enough for many purposes, especially as you would know the value of the readings. Suppose you had graduated a voltmeter up to 10 volts by means of ten Daniell cells, you would know that each volt on your scale represented more than an actual volt; in fact, your 10-volt division would represent nearly eleven volts, and you would make allowance accordingly when reading the scale.

You will probably find that the needle moves a much greater distance for an addition of one volt when in the middle of the scale than when near either end; this is a peculiarity of certain types of instruments; the spaces from volt to volt can be divided up into divisions to show quarter and half volts by dividers, but the exact positions should bear some relation to the general character of the scale; in the middle of the scale the half volt will be about central between the volt divisions, but at the ends the half volt will be rather more to the right or left, according to the amount the scale generally is opening out or shutting up.

**AMPEREMETERS**—The method of connection is shown in fig. 35, and the instructions given for voltmeters apply to amperemeters also, but whereas to calibrate a voltmeter you need a very small current and a large number of cells, to calibrate an amperemeter you need only one or two cells, but they must be capable of giving a large current, as you must have the amperes required by the highest reading you are going to mark on the scale. The

resistance must be of wire thick enough to carry the current.

Having connected the instruments in circuit,

### Standard Instrument

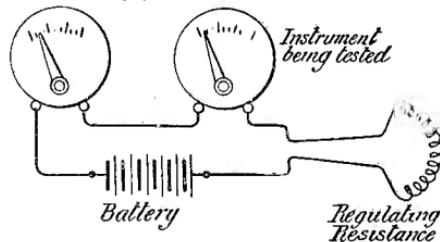


FIG. 35.

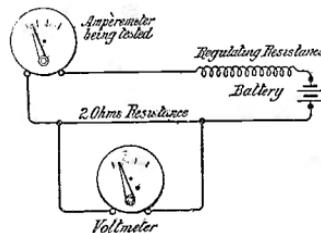


FIG. 36.

adjust the resistance until the standard instrument reads, say, 1 ampere, then mark off your division on the scale under test, readjust the resistance until

the standard reads 2 amperes, and mark off the second division, and 20 on, intermediate divisions can be marked if you can get a sufficiently fine adjustment of the resistance.

There is a method by which the standard ampere-meter can be dispensed with provided you have your voltmeter ready, and this is as follows: obtain a length of wire of known resistance, say 2 ohms, and of thick enough gauge to carry the largest current your amperemeter is to take, connect it to a battery or dynamo so that it is in series with your amperemeter (see fig 36), and join your voltmeter to its ends; a regulating resistance is required to vary the current. By Ohm's Law the current flowing through the resistance will be equal to the volts applied to its ends divided by its resistance in ohms—as you know what that resistance is, and can see what the volts are at any given instant by means of the voltmeter you can calculate the amperes flowing through the amperemeter. For instance, if the voltmeter reads 10 volts the current would be 10 volts divided by 2 ohms (if the previously mentioned wire was used) = 5 amperes; you would therefore mark the ampere scale at the place where the pointer was standing as 5 amperes. You do not need to know the volts of the battery exactly, but it is obvious that you must select your resistance to suit the current to be measured and the volts of your battery.

## CHAPTER VI

### THE PRINCIPLES UPON WHICH ELECTRICAL MEASURING INSTRUMENTS WORK

**GALVANOMETERS**—These instruments usually work by the attraction or repulsion of a magnetised needle placed near a wire carrying the electric current; sometimes a second wire, through which the current also passes, is used instead of the needle. The wire is wound into a coil to increase the effect. If you support a magnetised needle upon a pivot at its centre or suspend it by means of a fine thread so that it can freely turn round like a compass needle, and present one of the poles of a magnet to either end, that end will be attracted to or repelled from the magnet: like poles repel one another, unlike poles attract one another. When an electric current passes through a wire that wire becomes a magnet, but its poles are *at right angles* to its length instead of in the direction of its length, as in the case of the magnetised needle or steel bar magnet, and these poles remain thus no matter whether the wire is kept in a straight length or wound up into a circular or flattened coil. Unlike the steel bar magnet, how-

ever, the N. and S poles are not permanently fixed, but may be respectively on one side or the other of the wire according to which way the current is sent along it.

If such a coil of wire is fixed in position and a magnetised needle pivoted or suspended close to it so that one side of the coil can affect the needle when current is passed through the wire, such an arrangement will produce the same effect as the bar magnet referred to did upon the suspended magnetised needle, according to which end of the wire the current enters, so will the needle be attracted or repelled. If a light pointer is attached to the needle, the latter with the coil can be enclosed in a case, or the needle even placed inside the coil, as its movement would be shown by the projecting end of the pointer. It may be considered that any coil of wire carrying a current is a magnet as long as the current flows. We shall now be able to understand the working of the galvanometers described in Chapter I.

Taking firstly the simple Galvanoscope or Detector. In this instrument the magnetised needle is supported on a pivot directly over the coil of wire which carries the current, as soon as the current flows an invisible magnet is created by the lines of force set up by the current, as indicated in fig 37 by the dotted lines; the N pole of the needle is attracted by the S pole of the magnet and the S pole of the needle is attracted by the N pole of the magnet, and the needle turns in the direction of the

arrows, the movement being assisted by the repelling action between the like poles of needle and magnet respectively. If the current is sent through the coil of wire in a reverse direction, that is allowed to enter at the other end of the wire, the invisible magnet will also be created with reverse poles, the N pole being where the S pole was in the first instance, consequently the needle will then move in the opposite direction, the greater strength of the current the greater will be the movement of the needle from the zero point. In this instrument the deflection of the needle is not strictly proportional to the strength of the current; if a current of half an ampere moves the needle through ten degrees, a movement of twenty degrees will not necessarily show that the current strength has increased to one ampere, it will only mean that a larger current is flowing through the coil, but will not indicate the amount (see Chapter VIII)

In order that this instrument may work in this manner it is necessary that the needle rests in the position shown in fig 37, as it is a magnetic needle, it will like a compass needle always endeavour to point north and south, so that you must turn the case of the instrument round until the needle is in the correct position before sending current through the coil, if the needle lies across the coil you can readily see that the invisible magnet will merely hold it in that position, and no indication of the current will take place.

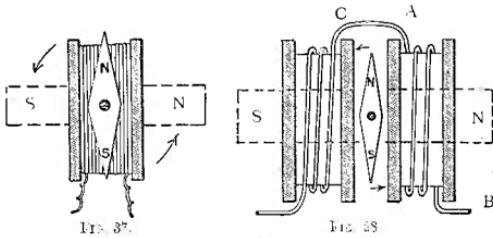
VERTICAL DETECTOR.—A galvanometer which is

52 SMALL ELECTRICAL MEASURING INSTRUMENTS.

independent of the before-mentioned necessity of setting the needle in the zero position can be made by pivoting the needle vertically instead of horizontally, and this is attained in the Vertical Detector described in Chapter I. The principle on which it works is just the same as that applying to the Horizontal Galvanometer, instead, however, of relying upon the magnetism of the earth to retain the needle at the zero position, it is kept there by means of a weight arranged that so long as the instrument is placed on a level support the needle will point to zero when no current is flowing through the coils without the necessity of placing it in a position facing north or south or any particular direction. The needle is placed inside the coils of wire for convenience and as before must lie in the same direction as the wire, when an electric current is passed through the coils an invisible bar magnet is produced as before—see dotted lines in fig 58, in which the coils are shown farther apart than actually used, to more clearly show the needle. The needle will be attracted by the poles of the magnet in the direction indicated by the arrows, when the current is sent through the coils of wire in a reverse direction the poles of the magnet will be reversed and the needle will be deflected in the reverse direction.

One coil only could be used and the action would be the same, but a better effect is produced by using a pair of coils one on each side of the needle. It will be seen from this that it is necessary to so wind the coils that they assist each other, and do not

oppose, if they opposed each other they would each try to create a magnet but having poles at opposite sides the result being that the two magnets would be trying the one to pull the needle one way and the second to pull it an opposite direction, so that no deflection would be obtained. This principle of opposing coils is used in an instrument termed the Differential Galvanometer, a separate current being sent through each coil the object being to ascertain if the two currents are equal in strength, if they



are so, the needle does not move, but if one is stronger than the other, then it will overpower the weaker coil in proportion to the difference between them, and the needle will give a deflection in one direction or the other. Such an instrument is generally only used in advanced work and for telegraph signalling, and except as an interesting example need not be considered by the elementary worker.

To return to our Vertical Detector the direction of winding is shown in fig 38, if you should happen

to have wound one coil in the reverse direction there is no need to rewind it, but simply connect end B instead of end A to end C of the first coil. It is not usual to attach a separate balance weight for the purpose of bringing the needle to the zero position: two methods are employed, either the needle is fixed so that the axle on which it turns does not pass exactly through its centre, in which case one end will be heavier than the other and always hang at the bottom, or the pointer is made with a weighted end (this is the better method), as shown in the illustration in Chapter I, which produces the same result. It is essential that both coils and needle are vertical; if the needle is horizontal and the coils vertical, no deflection will be obtained.

When two sets of coils are wound as described in Chapter I, each set is quite independent of the other, and can be regarded as if the other set did not exist, current is only sent through one set of coils at the same time.

The Simple Sensitive Galvanometer works in the same manner as the Detector shown in fig. 1; the needle is inside the coil instead of being on the top; it is again essential for the needle to be in the same direction as the coils and be preferably set N. and S. like a compass. However, as explained in the directions for making, as this is a very sensitive instrument, the needle can be brought to zero by the action of a weak magnet.

VOLTMETERS AND AMPEREMETERS—The principle of the attraction and repulsion between poles of

magnets (a magnetised needle is simply a bar magnet on a small scale) is largely used for amperemeters and voltmeters, these instruments being in reality galvanometers constructed for some definite kind of measurement, when made on this principle they are known as electromagnetic instruments. In the voltmeter and amperemeter described in Chapter II, the coil of wire attempts, as in the galvanometers previously referred to, to produce an invisible magnet passing through its centre, but as the two pieces of soft iron W and F have been placed inside it the force of the coil is concentrated in them and they become two small bar magnets whenever a current passes through the coil, the N. pole of W being at the same end as the N. pole of F and the S. pole of W being at the same end as the S. pole of F. As neither magnet can turn round, these poles repel one another, consequently the movable magnet F is thrust away from the fixed magnet W, the stronger the current flowing in the coil the more powerful will be these magnets and the greater the repelling effect. It is to be noticed that the principle of attraction between magnetic poles is not used in these instruments, and that the earth's magnetism does not affect the moving magnet, so that to bring it back to zero it is necessary to add some means of control, this is usually done by means of a spring or a weight. In the instruments described a small weight is attached to the spindle on which the moving magnet moves, so that the repelling force is compelled to lift the weight. It will be seen from

this that it is necessary to fix the instrument vertical and in one certain position only (see Chapter VII) Such an instrument is termed a gravity voltmeter or ammeter because the force of gravity is used to control the movement of the needle. When a spring is used instead of a weight, it takes the form of a watch hair spring, threaded over the spindle to which the inner end of the spring is fixed, the other end being attached to the bearing support (see fig. 39); the rotation of the spindle

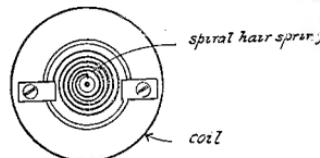


FIG. 39

tends to wind up the spring. Such an instrument can be used in any position and is termed a spring-controlled voltmeter or ammeter; the spring should be made of a material which is not affected by magnetism, such as palladium or phosphor bronze. There are other systems of movement in use for voltmeters and ammeters, one is known as the Hot Wire system, in which a thin wire is tightly stretched between a system of levers, and the current passing through the wire heats it and causes it to expand in length, permitting one of the levers to move; this movement is transferred to the

pointer by a link or gearing, the stronger the current the more the heat which is developed, resulting in greater expansion of the wire, and therefore a larger movement of the pointer. Another method is termed the Moving Coil system; instruments of this class have a rectangular coil of very fine wire attached to the spindle, and arranged so that the edges of the coil parallel to the spindle move close to the poles of a powerful horseshoe steel magnet, the spindle is controlled by a hair spring at each end. The current to be measured is sent through one spring into the coil, and leaves through the spring at the other end. The movement forms practically a magnet's electric motor with a one coil armature, which turns through a smaller or larger angle according to the strength of the current flowing through the coil. Both Hot Wire and Moving Coil instruments demand the highest class of workmanship, they may be considered as too difficult for an amateur to construct, but being largely used, are referred to as a matter of interest.

There is yet another class of voltmeters called Electrostatic instruments; these depend for their action upon the attraction effect between plates of metal which are statically charged with electricity. The moving plates are in the form of vanes which move near to the fixed plates and have the indicating pointer fixed to them; the positive and negative poles of the source of current are attached to the fixed and moving plates, one pole to each, no current flows, a static charge only being created, and in this

the insulated wire or metal, and one wire from the galvanometer to the metal which is in contact with the earth, by which is meant also in contact with any support to which the metal is fixed or on which it rests. 'earth' does not necessarily mean the ground. If the galvanometer needle does not move, there is no leak, if it moves very slightly or gives only a faint indication of moving, the leak is only

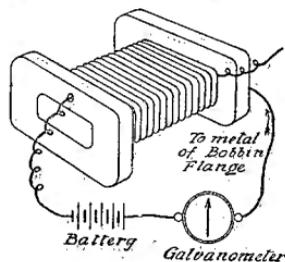


FIG. 40

partial, and is probably caused by moisture, so that, before unwinding the coil or removing any wires, an attempt should be made to dry up any moisture by warming the coil, and then the test should be made again in order to ascertain if there is any improvement. If the needle moves quickly to one side and gives a large deflection the leak is caused by metallic contact and is called a 'dead earth'; no amount of drying will remedy it, but the place must be sought for and a repair made.

TO DETECT A BREAK IN A WIRE.—Fig 41 shows the connections to be made when testing to find if a wire or coil of wire is without a break throughout its length. In the illustration a field magnet coil is being tested, one wire from the battery is joined to one end of the coil of wire, and one wire from the galvanometer is joined to the other end, if the needle moves quickly and gives a large deflection it

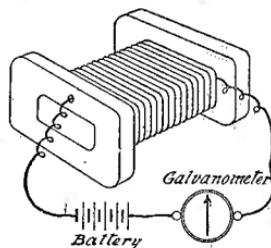


FIG. 41

is a sign that there is no break in the wire. but if there is no movement of the needle at all it shows that the wire is broken somewhere or if there is a very slight movement it shows that the break is partial, such as might be caused by a crack through the wire. This test is termed a continuity test, and may be generally used to ascertain if circuits through switchboards, instruments, arrangements of wires for lighting etc. are complete.

IDENTIFYING THE ENDS OF COILS, ETC.—The

principle of this test, which is really a continuity test, is illustrated in fig 42, which shows its application in sorting out the correct ends of a set of armature coils. Imagine an armature which has been fitted with a new commutator, and that the disconnected ends have become mixed up, so that you cannot tell by looking at them to which coil

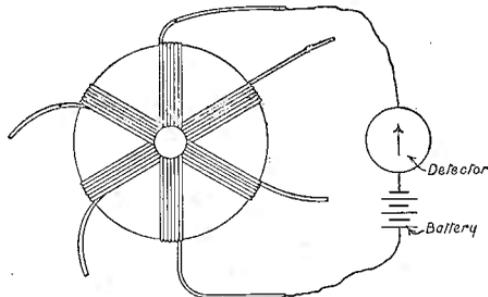


FIG. 42

they belong. Apply the continuity test by joining one wire from the battery to the end of one coil, then, taking the free wire from the detector galvanometer in your hand, touch the bare ends of all the other coils, one at a time, as soon as the needle moves you know you have found the other end of the coil to which the battery wire is joined.

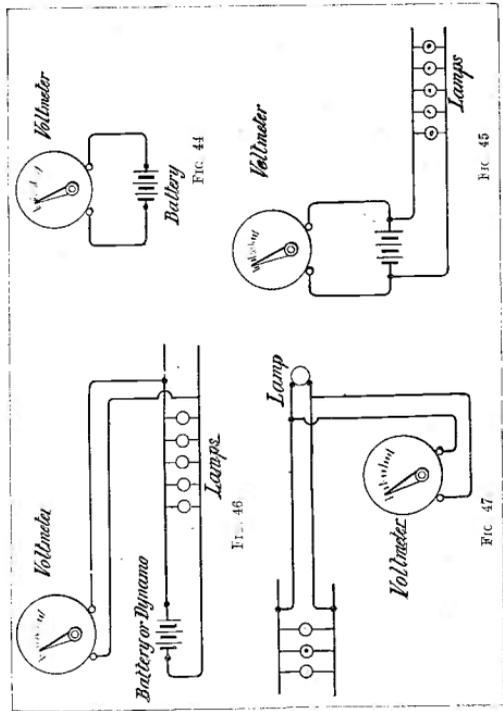
TO DETERMINE THE POLARITY OF A BATTERY OR DYNAMO.—In the foregoing tests the direction in

which the needle moved did not affect the test, it was sufficient to note the absence or presence of the deflection, we did not require to note whether it moved to the right or the left hand, but in the test which we are now dealing with, it is the direction in which the needle moves which is going to tell us what we want to know. According to which way a current is sent through the coils of a galvanometer, so will the needle move to the right or left hand. Though there is no scientific reason to say that the current leaves any particular terminal of a primary battery it is agreed, as a matter of convenience, to always consider that the current leaves the battery from the terminal which is connected to the carbon or copper plate and to call that the positive terminal the zinc connected terminal being called the negative terminal. The first thing to do, therefore, is to connect one of the terminals of the galvanometer, it does not matter which to the carbon or copper connected terminal of a battery (an accumulator will do if you know which is the positive terminal, it is generally marked with a + or a red mark), and mark it with some distinguishing sign; then touching the other terminal with the wire which is connected to the negative terminal of the battery, note in which direction the needle moves, having done this, you have an instrument which will enable you to ascertain the polarity of any source of electric current, because when you connect the galvanometer to any terminals from which electric current can flow, if the needle moves in the direction in which it did when you

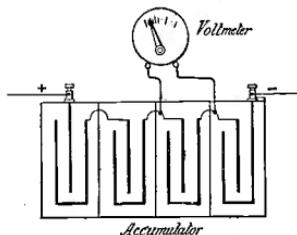
a faulty lamp or to want of volts; in this case the voltmeter becomes a shunt across the mains. It may be, however, that this last lamp is connected to the mains by very long wires in a branch circuit, and that though there is correct pressure in the mains the lamp burns dull, you therefore connect the voltmeter as shown in fig 47 to find out if you have dropped too many volts in the branch circuit; the instrument is now connected as a shunt to the terminals of the lamp, and indicates the voltage at that point.

It may be that the current is supplied by a dynamo lighting, say, 5 lamps in series, each requiring 50 volts, the voltage at the dynamo terminals will therefore be 250 volts; the last lamp is burning dull, and you desire to know if it is receiving proper pressure, the voltmeter is to be connected as shown to the terminals of the lamp, and it will indicate the volts at that particular point from one terminal of the lamp to the other. Fig 48 shows a diagram of a 4 cell accumulator, and method of applying a voltmeter to test the voltage of one of the cells, the wires from the voltmeter are pressed against the lead connecting strips at the ends of the positive and negative plates, scratching into the surface of the lead so as to get a good contact.

**HOW TO USE AN AMPERE-METER**—This instrument is usually called an ammeter, the word being shorter and convenient to use. Its use is to measure the current flowing through a circuit and it is always connected directly in the circuit through which the



current is flowing. When used to measure the current taken by a motor, lamp, or any piece of apparatus, the ammeter is always to be connected in series with it. As the instrument should interfere as little as possible with the existing conditions of the circuit, and should permit the current to pass freely without hindrance, its coils must have a very low resistance, on this account an ammeter should never be connected to the terminals of a



Accumulator  
FIG. 48

primary battery or accumulator to ascertain how much current such a battery will give unless you desire to find out what the battery will do when short circuited, as the ammeter, having an exceedingly low resistance, will form a short circuit. A large primary battery of low resistance, such as a bichromate or Bunsen cell, would discharge a very heavy current on short circuit and the coils of the ammeter would be probably burnt out if you made such a test and left the instrument in circuit for more than a second or two.

Some examples of the use of an ammeter are to measure the amperes flowing through (1) a main circuit, (2) a branch circuit; (3) the normal working

current given by a dynamo or battery, (4) the total current taken by a motor, (5) the volts at the ends of a known resistance, (6) the resistance of a wire or coil of wire. Fig. 49 shows an ammeter connected in the main circuit of a dynamo lighting a number of lamps, the whole of the current passing to the lamps flows through the ammeter, which thus indicates, not the current taken by one lamp or by any particular lamp, but total the current taken by them altogether.

In fig. 50 the ammeter is shown as arranged to measure the current in a branch circuit which may consist of one or more lamps, or a motor etc., the instrument does not now take any notice of the current consumed by the lamps in the main circuit, but only indicates how many amperes are passing through the branch circuit, another example of the measurement of a branch circuit is given in fig. 51, which shows the ammeter connected so as to measure the current which is flowing through the shunt field coils of a dynamo: as in the previous case, the instrument does not take any notice of the main current which is flowing to the lamps, but only indicates how many amperes are passing into the field coils of the dynamo. Example No 3 is a case in which the conditions of the circuit must be adjusted to suit the nature of the test. You do not, as a rule require to know what a battery or dynamo will do if short-circuited, but you do require very often to know what current can be continually obtained as a working rate. To ascertain this the first thing to do is to apply a working load to the

battery or dynamo to be tested either in the form of

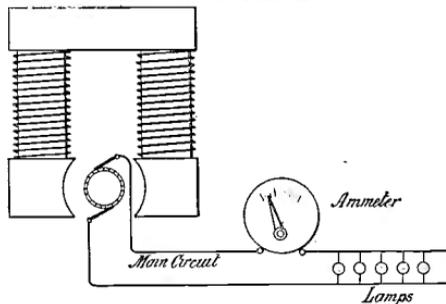


FIG. 49.

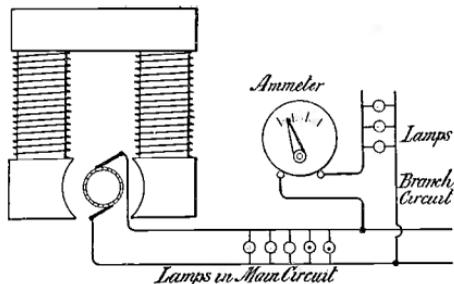


FIG. 50.

lamps or a wire resistance, though any convenient method of providing a load can be adopted; this

means that you must get some idea as to what the generator will stand in the way of current output unless you care to run the risk of damaging it through an overload. Fig. 52 shows the method of connecting the ammeter, the resistance representing the load; you adjust the load until the ampères indicated by the instrument represent the amount

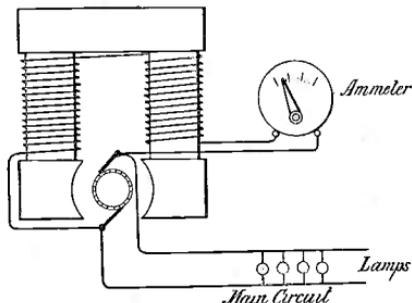


FIG. 51.

of current which the generator ought to give, and then continue the test as long as desired. When a wire resistance is used you will find that after a short time the current will fall; this may be owing to loss in the generator, but it may also be caused by increase of resistance due to the passage of the current through the wire developing heat, so that before condemning the generator you should try and bring the current up to its full value again by

cutting out some of the wire, this decrease of the excess resistance permitting more current to flow

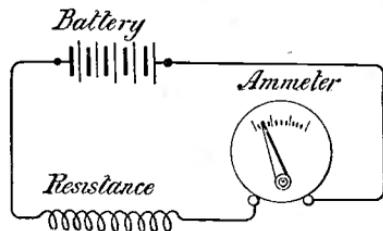


FIG. 52

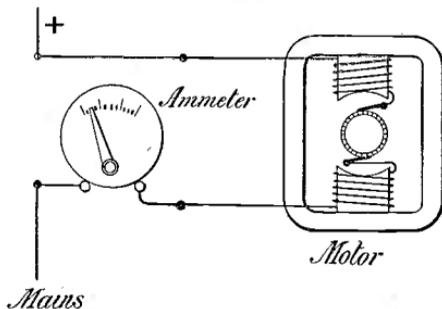


FIG. 53

Example No. 4 to measure the total current taken by a motor. Connect the ammeter in series with the motor, as shown in fig. 53; it does not matter whether

you connect the ammeter to the positive or negative main

Example No. 5 to measure the volts at the ends of a known resistance. This method depends upon the principle laid down by Ohm's law, that if you know the current in amperes which is flowing through a resistance whose value in ohms is known, then you can find out what are the volts at the ends of that resistance by the formula  $E = CR$ ; that is, the

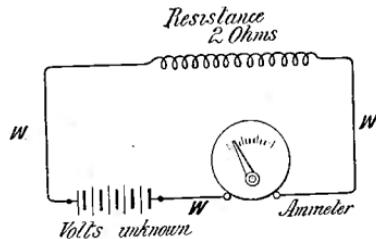


FIG. 54

unknown voltage is equal to the amperes multiplied by the resistance. For instance suppose a battery whose volts are unknown is capable of discharging a current of, say, 4 or 5 amperes; connect the terminals in series with a resistance of which you know the value in ohms (let us suppose it is 2 ohms), and with the ammeter; the ammeter indicates say 3 amperes, then  $2 \times 3 = 6$ ; therefore the battery is giving 6 volts. As a rule, you know the voltage which a battery will give by knowing the type and

number of its cells, but this method may be very useful to find out the voltage which is at the ends of a coil of wire in a circuit which may also contain a number of other coils of wire, so that though you may know the volts at the ends of the circuit, you do not know the volts at any particular part. The value of the resistance of the coil of wire is obtained either by reference to a wire-maker's table or by means of a Wheatstone bridge, such as described in Chapter III. It is important to have the connecting wires *W* of large section and as short as possible, so that they carry the current very easily, if they are small you will not get a true result, as some of the voltage will be absorbed before the current reaches the resistance. In any case there will be a loss of volts in the wires *W W* but if they are thick and short it will be so small that you can neglect it.

Example 6 to measure the resistance of a coil of wire. The principle of Ohm's law is again applied here. If you send a current of which you know the value in amperes through an unknown resistance, you can find the value of this resistance in ohms provided you know the volts at the ends of that resistance, because  $R = \frac{E}{C}$ , that is, the volts divided by the amperes will tell you the ohms of the resistance. The connections are made as in fig 55. Suppose the voltage is 100 volts and you find that a current of 2 amperes is flowing through the resistance, then 100 volts divided by 2 amperes gives 50 ohms as the resistance of the coil of wire. As in the previous example, it

is important that the wires joining up the resistance and ammeter are of ample size.

Fig 56 shows a switchboard for use with a dynamo charging accumulators, the method of connecting the voltmeter and ammeter is shown, it will be seen that the voltmeter is connected as a shunt to the dynamo mains, and indicates the voltage where the current enters the switchboard, and that the ammeter is in series with the accumulators so that it will

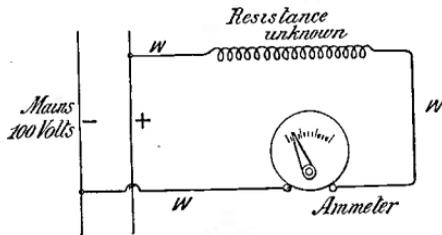


FIG. 55

measure the amperes passing into the cells. If a regulating resistance is used on the switchboard then you will probably prefer to know the voltage at the terminals of the cells, as it does not matter what voltage the dynamo is giving so long as the right voltage is at the accumulator terminals, in this case the voltmeter wires would be joined to terminals *C C* instead of to the terminals *D D*.

It is sometimes desired to cut ammeters and voltmeters out of circuits without disturbing the

current flowing through the mains, this is accomplished in the following way — with an ammeter, by means of a short circuiting plug, and with a voltmeter, by means of an open-circuiting plug. There is a distinct difference between the two methods, with an ammeter the plug acts as a by pass through which the current flows instead of going into the

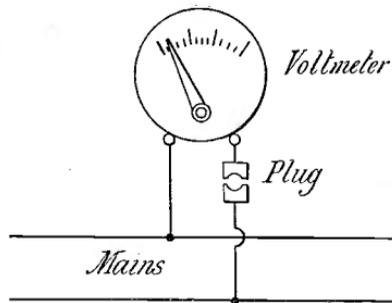


FIG. 58.

instruments; with a voltmeter the plug opens the voltmeter circuit and cuts off all current from the instrument. Figs 57 and 58 show the connections; fig 59 shows an enlarged view of the plug and block, which consists of a pair of brass blocks drilled with a taper hole into which fits a brass plug; when the plug is pushed into the hole the two blocks are connected together, when it is taken out they are disconnected from one another.

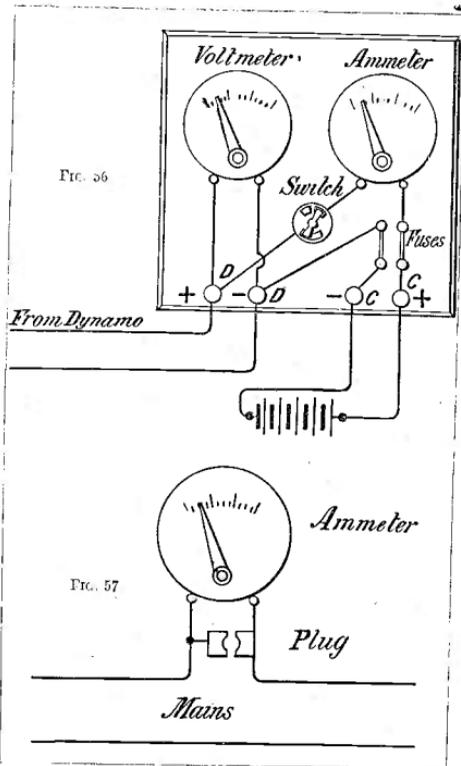


FIG. 56

FIG. 57

Ammeters and voltmeters must always be set so that their needles are pointing to zero before any current is passing through them. A gravity-controlled instrument must be set upright—it will not indicate in any other but a vertical position, a spring-controlled instrument, on the contrary, can be used in any position (see Chapter VI). Many instruments

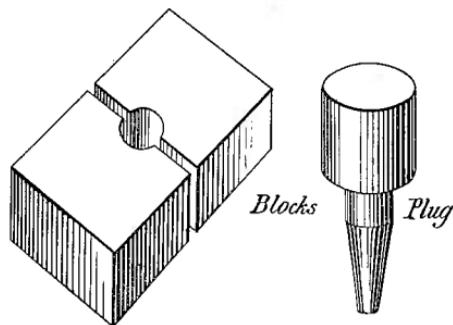


FIG. 29

are very susceptible to outside influence of magnets or wires carrying currents so that it is well, as a general rule, to keep your instruments away as far as possible from a dynamo or cable. If you have any doubt as to whether the instrument is giving a true reading, cut off all current from it, and see if the needle moves when the dynamo is at work; it is by no means unusual for an ammeter to indicate several amperes

without being connected to anything, merely because it was near the field magnet of a dynamo which was at work.

Some instruments only indicate when the positive pole of the mains is connected to a particular one of their terminals, which means that the current must always pass through the instrument in one direction; in such a case the terminal is generally marked +, but if, on trying an instrument, you find that it does not give a movement of the needle, or the needle moves the wrong way, try changing over the connections of your wires, so that the positive wire will be connected to the other terminal.

## CHAPTER VIII

HOW TO CHOOSE ELECTRICAL MEASURING  
INSTRUMENTS

In order that an instrument should be of maximum usefulness it should be selected with reference to the particular range or class of measurement in which you desire greatest accuracy. All instruments have their limitations; some are much better adapted for certain work than others, and the following hints will assist the reader to make his choice.

**GALVANOMETERS**—For rough work, such as detecting currents when making apparatus in the workshop, a simple horizontal pattern with pivoted needle and scale divided into degrees will suffice, but if the time taken up in testing is important, a vertical pattern detector galvanometer with weighted needle is better, as the needle of the horizontal pattern swings about a great deal, so that you may have to wait some little time before it comes to rest at the zero position, the vertical detector pattern is also more useful for outdoor work or testing wiring in a house, as it does not require setting to zero and is more portable. When very minute currents require to be detected, and for

delicate testing generally, the astatic pattern of galvanometer is required, in which the needle is suspended by means of a single thread of cocoon silk. There are various patterns of this instrument, that known as the Thompson Reflecting Galvanometer being a recognised type. In this instrument there is a very small mirror fastened to the needle, which reflects a beam of light from a lamp upon a horizontal scale fixed about three feet or so in front of the instrument; when the needle moves the mirror moves also and the beam of light becomes really a long pointer having no weight and moving over the scale, the image of a wire in the beam forming the indicating point.

There is also another type of galvanometer suitable for very delicate work. In this class of instrument a needle fitted with a light pointer is pivoted inside a single coil of wire. The sensitive galvanometer described in Chapter I is of this type and may be considered as a sufficiently delicate instrument for all ordinary purposes. One objection to the delicate galvanometers just described is, that their needles swing very much before coming to rest at the zero mark—they are not what is called dead beat.

Where rapid delicate testing is desired it is very desirable that the instrument should be dead beat. There is a type of instrument in which the coil carrying the current is suspended by stretched delicate wires so that its sides move near the poles of a powerful steel horseshoe magnet. This kind of galvanometer is called a D'Arsonval pattern, after

methods employed a little vane moving in oil or an air cylinder may be attached to the spindle. But there is one class of instruments termed Moving Coil ammeters and voltmeters which are automatically dead beat by virtue of the principle on which they are constructed. In these instruments a small coil of wire attached to the pointer moves near the poles of a powerful steel magnet; they are very sensitive, not much affected by outside magnetic influence, and are suitable for very accurate measurements, but they can only be used for continuous current work.

**VOLTMETERS FOR TESTING BATTERIES** — High resistance batteries such as small dry cells are not capable of giving a large current, if you desire to test such cells by measuring their volts it is necessary to use a voltmeter which has a comparatively high resistance, or else the instrument will draw more current out of the cell than it gives in regular work consequently its voltage will fall and you do not get a fair test. You should therefore be careful to see that your voltmeter is adapted for this particular class of work if you wish to get accurate results, do not accept a casual test with any voltmeter as evidence of the condition of such a cell. Batteries such as the Bichromate pattern or an accumulator may be safely tested with any ordinary voltmeter as they will give a fair amount of current.

**ALTERNATING CURRENT INSTRUMENTS** — Testing of insulation, the conductivity of wires and measurements of a similar character, are generally done with continuous current, in the case of alternating

current you require to measure amperes and volts, *i.e.* watts or electric power which in alternating current work is not always found by multiplying together the volts and amperes as in the case of continuous current, whenever the current is flowing through any apparatus having coils of wire or electromagnets in the circuit such as a motor or transformer, you would not get the watts by merely multiplying the amperes and volts together, though your result would be fairly correct in the case of alternating current lighting incandescent lamps. Whilst some types of ammeters and voltmeters are specially suitable for use with alternating current, instruments of similar principle to those described in Chapter II can be used with either alternating or continuous current. When intended for use with alternating current they are tested with that kind of current and marked accordingly, but if a continuous current instrument is used with alternating current it will probably, in the case of types as described in Chapter II, indicate about 10 per cent. less than the true reading, especially if it is a voltmeter. Unless the instrument has been made with a view to use the alternating current it will get hot after a short time, so should only be used for a few moments at a stretch. In instruments designed for alternating current, if the coil is wound on a metal bobbin the metal must be divided at one place by means of a saw, cut so that the centre and flanges do not form a complete ring.

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