at their ends, but they are always a little distance therefrom. They are distinguished one from the other by calling one the South and the other the North pole. The poles of a battery, as before stated, are its ends. The terminating plates or electrodes in a battery composed of a number of voltaic cells are distinguished one from the other by calling one the *negative*, the other the *positive* pole.

The negative terminating plate or electrode is the positive pole, while the positive terminating plate or electrode is the negative pole of a battery. The above should be very firmly impressed on the memory, as this apparent contradiction is a common source of trouble.

Speaking generally, we may say that the *volt-meter* and the *ampere-meter* are simply galvanometers which have their coils especially wound and their dial faces carefully graduated and marked, so that the volts or amperes in a circuit of which they are a part, can be read directly as the weight on a pair of scales or as the pressure on a steam gauge.

A *volt* is the *unit of electro-motive force*, and it is symbolized by E. It is equivalent to the difference of potential between two points, or it is that force which will maintain a circuit of one ampere in a wire having a resistance of one ohm.

The volt-meter is, then, an instrument for measuring the electro-motive force or the E M F as usually written, which is expressed in *volts*.

The E M F is the force which moves electricity. It is sometimes called electric pressure, difference of potential, electric force and potential. The only difference between electromotive force and potential is that the former relates to the *conductive* while the latter relates to the *inductive* circuits. The electromotive force expresses to the electrician what steam in a boiler does to the engineer.

The *ohm* is the *unit of resistance* and is symbolized by R. One ohm is the resistance through which one ampere of current will flow when driven by a pressure of one volt of E M F.

Electrical resistance is the opposing force to electro-motive force: Resistance to electricity exists more or less in every electrical circuit, just as resistance exists in water pipes to the flow of water through them. The metals are the best conductors of electricity because they offer, compared with other metals, less resistance to the passage of the current. A good conductor renders the same sort of service to the electrician as the large water pipes do to the engineer.

The greater the E M F in proportion to the resistance of a circuit the greater will be the strength of the current, and vice versa. The greater the resistance of a circuit the less will be the current strength. Thus by doubling a given conductor, the strength of the current will be doubled.

The *ampere* is the *unit of current* per second. It is symbolized in formula by C and is that quantity of electricity which flows per second through a resistance of one ohm, at a pressure of one volt of electro-motive force. The ampere-meter is, then, an instrument employed for measuring this current strength, or the intensity of the current in amperes.

The current strength is always directly proportional to the electro-motive force. It becomes proportionately less as the resistance of the circuit becomes greater. When an electromotive force of one volt drives a current through a resistance of one ohm, that current is said to have an intensity of one ampere.

The fact that electro-motive force and resistance bear a relation one to the other was discovered by "Ohm" who propounded the law of electricity in motion, which now guides the electrician in his calculation. Knowing the current strength and the rate at which the E M F puts it in action, we can readily find the work done, as by multiplying the volts and the amperes we obtain the energy in watts.

The *watt* is the unit of energy or power and is equal to about 1 746 of a mechanical horse-power. With a constant resistance the current is proportional to the electro-motive force with the same difference of potential and it is halved by doubling the resistance In other words, if we, with a given potential, get an unit of current over a wire one mile long, we get but half this unit of current over the same conductor when it is increased in length to two miles.

Ohm's law expresses the above thus: "C," current strength, "E," electro-motive force; "R," resistance.

$$C = \frac{E}{R} \text{ or } E = C \times R$$

The current in amperes may be found by dividing the E M F in volts by the resistance in ohms.

To find the electro-motive force in volts of a circuit, it is simply necessary to multiply the current in amperes by the resistance in ohms. The resistance of a circuit may be found by dividing the electro-motive force in volts by the current in amperes.

The *colombe* is the *unit of quantity* and it is symbolized by Q. It is that quantity of electricity which is given by one ampere in one second.

The next most important effect for us to study is the action of the electric current on a bar of soft iron enclosed within a coil of insulated wire in place of the permanently magnetized steel needle we have been dealing with.

Such an arrangement is called an *electro magnet*. The soft iron is called the *core* and the coil of insulated wire surrounding it the *helix*.

A current of electricity passed through the helix will act upon the soft iron core within as it did upon the permanently magnetized needle of the galvanometer. In this instance, however, the iron cores are converted into a powerful electro magnet, one free end of which is said to have North and the other free end South polarity.

The nearer the coils of wire forming the helix are to the soft iron core the greater will be the magnetic effect in the iron when the circuit is completed. A piece of Norway or Swedish iron placed with a coil of wire will, when a current is passed through the coil, become magnetized in proportion to the number of turns of wire around the iron, in proportion to the strength of the current passing through the coils, and in proportion to the distance between the coils of wire forming the helix and the core.

If we place a bar of soft iron in a helix of insulated wire, the ends of which are connected in circuit with a voltaic battery and a key for opening and closing the circuit, we may energize this core at will by simply depressing the key so as to close the circuit. This is the principle of the electric bell and the Morse and other telegraphic instruments. It will readily be understood that the closing of the circuit by depressing the key will act upon the iron core so as to make it a magnet, but only for the time during which the circuit remains closed. On arresting the flow of the current by releasing the key, the magnetic effect in the iron core is also arrested.

The softest iron and the best should alone be selected for the cores of electro magnets, for the reason that good, soft iron immediately parts with its magnetism when the influence of the current is removed by opening the circuit. Whereas hard iron or steel will retain magnetism in proportion to their hardness and consequently will respond to the action of the current proportionately slower.

The quality of the iron for the cores, armatures or field magnets of electrical machines is one of the most important points to be considered in their construction.

Of course work is done in energizing this piece of iron so as to make it an electro-magnet capable of sustaining a considerable weight.

It may be a question with some as to what the source of this energy is. When the current from a battery is emyloyed the energy to do the work is so far primarily due to the chemical energy in the cells which on being converted ints electric energy, act upon the iron so as to cause it to develop energy in the form of magnetism.

When a steam engine is used to drive a dynamo machine to generate electricity the coal burned is so far the source of energy.

It should be remembered that in every transportation of one form of energy into another there is a very considerable loss, therefore the more direct the means of producing and utilizing the current the less will be the loss. A great part of the energy expended in producing the electric-magnetic energy in the soft iron, will, if the core be removed, be expended in heating the wire. The chemical energy of the battery will likewise be expended in producing heat energy in the wire of an helix.

This heating effect will be dealt with presently as fully as space will permit. The heating effect is proportionately less as other work done by the current is proportionately greater.

We have stated that the effect of temporarily closing the electric circuit through the helix is to temporarily magnetize the soft iron core. We may say that the effect of closing a voltaic battery circuit through an electro-magnet is to convert the chemical action developed in the battery into magnetic energy developed in the soft iron core of the electro-magnet. If the core is removed from the helix the same amount of work is still done, but it shows itself in a different way. In this instance the chemical energy developed in the battery would appear in the helix and connecting wire as heat energy.

Iron is the only metal which can be practically employed for electro-magnets, although nickel is acted on in like manner by the current, but in a much slighter degree and at much greater cost. The object of insulating the wire of the helix is to compel the current to travel from one end of the wire to the other.

If the wire actually touched, *i.e.*, made metallic contact at any two points between the ends, the greater part of the current would pass at the point of contact, instead of passing around the convolution of the loop, which would be intermediate in the wire and between the points of contact.

Thus you will understand the necessity for perfect insulation in electric wires.

The current will at all times take the path of least resistance, and rather than go round the coils it will jump across if the insulation is not sufficiently good.

Fig. 1 represents a straight electro-magnet. This, if bent at its centre so that its poles approached each other, would then be called a horse-shoe. The horse-shoe form of electro magnet is considered the best, and in this form it is used in the principal electrical devices.

Iron, then, is employed because in a remarkable degree it has the property of acquiring and losing magnetism very rapidly.

We have learned that an electro-magnet immediately acquires magnetism when a current of electricity is passed through the