ELEMENTARY ELECTRICAL ENGINEERING.

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This series of articles will be continued for some months. They will be of particular interest to the student of electrical work and the civil engineer anxious to secure some knowledge of the simpler electrical problems.

Ohm's Law.—Let the two bodies shown in Fig. 4 be replaced by two long conductors or wires connected together at the ends by a smaller conductor, as shown in Fig. 7. When the generator is running, its e.m.f. will tend to maintain a certain difference of potential between these conductors. Because of this difference of potential

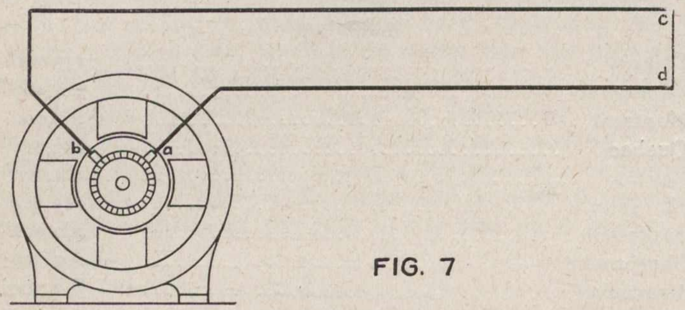

FIG. 7

there will be a flow of electricity from one conductor to the other through the end connection, and this will tend to equalize the potential. If the e.m.f. of the generator is steady, as much electricity will pass per second from one conductor to the other through the generator as will flow back through the end connection. There will thus be a continuous flow of electricity around the closed circuit formed by the generator and conductors. Experiment has shown that when the current is steady its magnitude varies directly as the e.m.f. of the generator and inversely as the resistance of the circuit. If E represents the e.m.f. of the generator in volts, I the current in amperes, and R the resistance in ohms (see definition previously given), then

$$I = \frac{E}{R} \quad \dots\dots\dots\dots \quad (4)$$

This simple equation, known as "Ohm's Law" (being named after the distinguished physicist who first established it), forms one of the corner-stones of electrical engineering. It is necessary, however, to exercise care in applying this law to any particular case. When applying it to a given circuit it must be remembered that the symbol E represents the **total e.m.f. acting in one direction around the circuit.** If, for example, the e.m.f. of the generator in Fig. 7 is 50 volts, tending to force electricity from **a** to **b**, and the resistance of the whole circuit is 5 ohms, the current will be 50/5 = 10 amperes. Suppose, now, that a second generator with an e.m.f. of 40 volts is placed in the circuit between **c** and **d**, and that this e.m.f. tends to drive electricity from **d** to **c**. The total e.m.f. acting around the circuit is now 50-40 = 10 volts, and the current will be 10/10 = 1 ampere. If, on the other hand, the e.m.f. of the second generator acts in the opposite direction, the total e.m.f. will be 50 + 40 = 90 volts, and the current will be 90/10 = 9 amperes. It must also be remembered when applying equation (4) to any circuit that the symbol R represents the **total resistance, including the resistance of the generators.**

It has been noted that electric pressure or potential is created by an e.m.f., and that the latter is measured by the former. The unit is thus the same for each, and when an e.m.f. of one volt is balanced by a potential (or difference of potential) of one volt, it is obvious that the tendency of the e.m.f. to drive electricity in one direction is exactly equal to the tendency of the latter to flow in the opposite direction because of its potential. The flow of electricity on account of potential will, therefore, be the same as the flow due to e.m.f., just as the flow of water through a pipe connected to the bottom of a tank will be the same as when the pipe is connected to a pump giving the same pressure as that due to the head of water in the tank. It thus follows that if U represents the potential between any two points of a circuit, the current flowing between these points will be

$$I = \frac{U}{R} \quad \dots\dots\dots\dots \quad (5)$$

A little consideration will show that this equation cannot be applied to a circuit as a whole, for the total difference of potential found by adding from point to point around the whole circuit must always be zero. This follows from the axiom that if the whole circuit is included between two points, these two points must coincide, and consequently there cannot be any difference of potential between them. For purposes of illustration the circuit shown in Fig. 7 is stretched out into a straight line in Fig. 8, the corresponding points in the two figures being indicated by corresponding letters. To make the problem as simple as possible it may be assumed that the seat of the e.m.f. is at a single point **o**, and that the point **a** is connected to earth so that its potential is zero. The direction of the e.m.f. of the generator is assumed to be from **a** to **b**, and the direction of the flow of the current, as indicated by the arrows, is taken as positive. In this case the difference of potential between the point **a** and any other point on the circuit is represented by the vertical distance between the base line **aa** and the broken line **aevxa.** From the point **a** there is a gradual decrease of potential up to the point **o**, and at this point it is increased by the e.m.f. of the generator, represented by **ev.** From **o** to **b** there is a gradual decrease, which brings the potential at **b** to the value **bw.** From **b** to **c** there is a decrease from **bw** to **cx,** and from **c** to **d** a further decrease to **dy,** and from **d** to **a** there is a final fall to zero. Starting with the potential **ov** at the point **o**, and passing from point to point around the circuit in the positive direction, the total decrease or fall of potential from **o** to **a** is **ov**, and

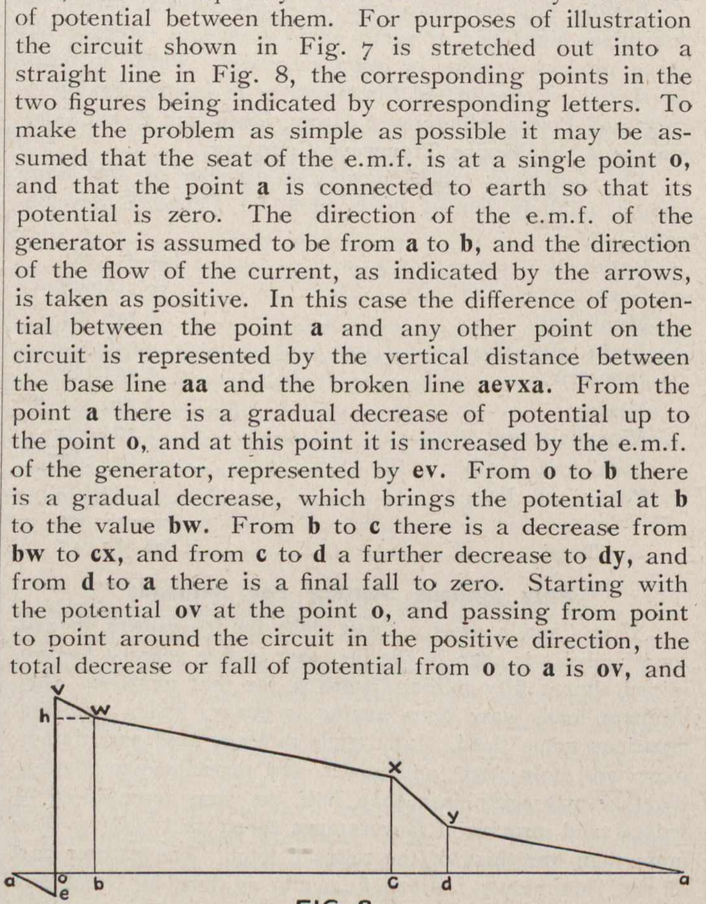

FIG. 8

the decrease from **a** to **o** is **oe.** But (**ov** + **oe**) = **ev,** and the latter represents the total increase of potential. The total change of potential around the circuit is, therefore, nil. Since, however, e.m.f. and potential have the same dimensions and are measured by the same unit—the volt—equation (5) may be combined with (4), provided the symbol E is taken to represent the resultant volts, including electromotive forces and changes of potential due to resistance. The term "voltage" may be appropriately used to express this resultant. Interpreted in this way, equation (4) may be applied to the whole or any part of a circuit. For example, in Fig. 7 the

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