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Two Fundamental Equations of Current Electricity

L. Begeman
Iowa State Teachers College

And so the family of inert, atmospheric gases was complete.

Conceived in pure science, their value to humanity has already been demonstrated. Argon, by virtue of its inertness, is used in electric light bulbs. Because of its low solubility in the blood, helium is supplanting nitrogen in caissons, to reduce the danger of "bends" among workmen. And the great dirigible Akron with its seven and one-half million cubic feet of helium is a reminder that this gas is superior to hydrogen in its diffusion rate and incombustibility, and has 92% of its lifting power.

R. W. Getchell.

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TWO FUNDAMENTAL EQUATIONS OF CURRENT ELECTRICITY

Formulas in physics are mathematical expressions of natural laws or principals well established. The two most important for the ordinary citizen are first the one that gives expression to Ohm's law and second, the one that shows how to calculate the power of a current.

The mathematical expression for Ohm's law is $C = E \div R$. In this equation C stands for the current in amperes, E for the electromotive force in volts and R for the resistance of the electric circuit in ohms. Since this equation is the most basic in current electricity, it should be given special emphasis by the instructor of high school physics. The units ampere, volt and ohm should be made concrete to the student. The best way to do this is, of course, the one that is generally employed in the best texts when discussing current electricity, viz.: by bringing out the analogy that exists between an electric current and a water current.

A water current running down a river channel has three clearly defined characteristics which are easily observed. First, the stream of water in a river possesses magnitude which can be expressed arithmetically by stating that a certain number of cubic feet of water pass a given line drawn at right angles to its flow in a minute or in an hour. In other words the magnitude of a river stream is the quantity of water discharged past a given line across its bed in a given unit of time.

The second property readily observed with reference to a stream of water is manifested by its rapidity of flow. This property is clearly due to the intensity of the force operating upon the water to make it flow. As we know, this force is gravity and its intensity is directly proportional to the slope of the channel or the difference in level between two points located above and below the point of observation. If in a distance of 100 feet along the bed of the river there is a difference of 10 feet in level with reference to some plane of observation, the force of flow will be just twice as intense as that which exists when the fall in level is only 5 feet under the same conditions.

The third characteristic of water current is determined by the character of its bed or channel. If the bed of the stream is rough and rocky there is more resistance to its flow that when the bed is smooth and wide. The magnitude of the flow in a water stream is clearly dependent upon the resistance of its bed. In fact the magnitude of a flowing current of water varies roughly directly as the force operating upon it and inversely as the roughness or resistance of its bed. This, of course, does not consider the internal resistance of the water itself due to its viscosity.

The basic characteristics, current magnitude, electromotive force and resistance of an electric current are quite analogous to those of a water current. In the first place the magnitude of an electric current is the quanity of electricity discharged past a given point in its circuit in one second. This quantity is measured in terms of a unit called the coulomb. A coulomb is the quantity of electricity discharged by a current of one ampere in one second past a given point of its circuit. Since the magnitude of a current of electricity cannot be observed directly, as is the case with the water current, it must be apprehended from its effects. An ampere of current is one that can free .001118 grams of pure silver from a silver plating solution in one second. The value of an ampere can be determined from the electrolysis of any metallic salt, although it is customary to use solutions of copper or silver. An ampere of current will free .0003287 grams of copper from a copper plating solution in one second.

The force operating in an electric circuit to maintain the current flow is denoted as electromotive force. The magnitude of the electromotive force of a current is properly determined by measuring the work a unit current can do while flowing between two fixed points of its circuit. If the work accomplished per second by the unit current between two such fixed points equals 10,000,000 ergs, then we know that the force of flow, or difference of potential, between these two points is one volt. The total electromotive force, or difference of potential, between two points of an electric circuit carrying a current is measured by the total amount of work necessary to carry a coulomb of electricity from one point to the other. In the same way the operating force, or head of a water current can be measured by the amount of work necessary to lift a cubic foot of water from the lower point of level to the higher point of level in the stream.

Finally, the resistance that a current of electricity encounters by virtue of the length, cross-sectional area and the nature of the material of its circuit is measured in ohms. An ohm is a unit arbitrarily taken as the resistance of a column of mercury 106.3 cm. long with a cross-sectional area of one square millimeter at zero degrees Centigrade. This is approximately the resistance of 1000 feet of copper wire one-tenth of an inch in diameter. As indicated above, the resistance of a conductor is conditioned in three ways, viz: by the length of the conductor; by the area of cross-section of the conductor and by the kind of material or substance of which it is made. A conductor two feet long offers twice the resistance to the flow of current that a conductor one foot long of the same material and diameter would offer. A conductor two millimeters in diameter offers only one-fourth the resistance of a conductor one millimeter in diameter of the same material and length would offer. Finally a silver conductor offers less resistance to a current of electricity than a copper conductor of the same length and cross-section. The laws of electrical resistance are stated in a formulary way by saying that resistance of a conductor is equal to the product of its specific resistance times its length divided by the area of its cross-section. The equation of this statement is as follows: $R = K(1 \div A)$. In this equation R is the resistance in ohms, K is the specific resistance, 1 is the length of the conductor and A is the area of cross section. The specific resistance is the resistance in ohms of a conductor one centimeter long and one square centimeter in cross section for any given substance at zero degrees Centigrade. A table of specific resistances can be found in any good laboratory manual.

The second fundamental principle essential to a practical understanding of current electricity might be called the power law. It enables one to calculate readily the work or power of an electric current. Just as the work done by a column of water flowing from a dam is calculated by multiplying the quantity of water in the column by the average height of its fall, so also the work of an electric current is calculated from the product of the amount of electricity discharged times the difference of potential between the two points of its flow. If an electric iron takes five amperes of current and the difference of potential between its two terminals is 110 volts, then the work performed by the current will equal 5×110 or 550 joules of work per second. A joule per second is called a watt. A thousand watts makes a kilowatt.

In practice the energy of an electric current is sold in kilowatt hours. Every commercial electric device has its current rate and electromotive force stamped upon it. To determine the kilowatt hours used when the device is in operation we proceed as follows: kilowatt hours equals the product of the amperes times the volts times the time in hours divided by one thousand. To get the cost of operation the kilowatt-hours are multiplied by the price per kilowatt-hour which varies from a few cents to fifteen cents in Iowa. It would be well in this age of electricity if every citizen possessed at least a practical understanding of these two fundamental laws of current electricity.

L. Begeman.