was appended to his description of this eclipse in the *Astronomical Journal*.*

In the year 1858, a system of daily photographs of the sun was instituted at the Physical Observatory of Kew, near London. This has been regularly prosecuted since that time, to the great benefit of science, and valuable inferences have been already deduced from the results, by three gentlemen in charge of this observatory.

Thus equipped with the solar eye-piece and the photographic apparatus, astronomers have assailed, with redoubled energy, the troublous problem which the sun's aspect offers to the observer, and each successive month now seems to bring us new knowledge in this regard, while the added scrutiny which the spectroscope permits, furnishes a new and most powerful ally for the exploration.

(To be continued.)

ABSOLUTE SYSTEM OF ELECTRICAL MEASUREMENTS.

BY JOSIAH P. COOKE, JR.

(Continued from page 272.)

17. *Resistance*.—Even when the electro-motive force between two points is constant, so that the total work done by the transfer of a given quantity of electricity remains unchanged, it is found by experiment that nevertheless, by modifying the material and size of the conductor, this transfer may be made to take place in very different times; or, in other words, currents of very different magnitudes are produced, and in the unit of time very different amounts of work are performed. The quality of a conductor, in virtue of which it prevents the performance of more than a certain amount of work in a given time, by a given electro-motive force, is called its electrical resistance. The resistance of a conductor is therefore inversely proportional to the amount of work done, or when a fixed electro-motive force is maintained between its two ends, to the amount of electricity passed through it in a given time. It is therefore inversely proportional to the current, which will be produced under these conditions. But since, as we have seen, the strength of current in any conductor is directly proportional to the electro-

* *Astron. Journal*, IV., No. 77.

motive force between its two ends, both relations are most simply expressed by the formula—

$$c = \frac{e}{r},$$

which is the well known equation expressing Ohm's law. Putting this in the form $r = \frac{e}{c}$, and substituting for e and c their equivalents in electro-magnetic measure, we have—

$$r = \frac{1}{v^2} \frac{E}{C}, \text{ but since } \frac{E}{C} = R,$$

$$r = \frac{1}{v^2} R, \quad \quad \quad [20.]$$

Hence to reduce resistance measured in electro-magnetic units to the electro-static equivalent, we must divide by v^2 .

The dimensions of r are—

$$\frac{T}{L} = \frac{1}{V}.$$

Thus the measure of resistance on the electro-static system is the reciprocal of a velocity.

Table of Dimensions.

$$\text{Quantity} \quad q = \frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T} = v Q.$$

$$\text{Current} \quad c = \frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T^2} = v C.$$

$$\text{Electro-motive force} \quad e = \frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T} = \frac{E}{v}.$$

$$\text{Resistance} \quad r = \frac{T}{L} = \frac{R}{v^2}.$$

$$v = 310,740,000 \text{ metres a second.}$$

18. *Electro-static Capacity.*—The electro-static capacity of a conductor is equal to the quantity of electricity, with which it can be charged by the unit of electro-motive force. Let s be the capacity, q the quantity of electricity in it, e the electro-motive force, then—

$$q = s e, \quad \quad \quad [21.]$$

Hence the dimensions of s are—

$$s = \frac{q}{e} = \frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T} \div \frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T} = L,$$

or the electro-static capacity is represented in this system by a length only. The capacity of a condenser depends, as we have seen, on a great variety of conditions, but calculation shows that the capacity of a spherical conductor in open space is equal to the radius of the sphere.

The relation of the electro-static to the electro-magnetic unit of capacity is expressed by the equation—

$$s = v^2 S, \quad \text{.} \quad [22.]$$

19. *Specific Resistance*.—On account of the difficulty of measuring with accuracy the diameters of wires it is more convenient to refer the resistance to the mass or weight in a given length than to the section. The specific resistance of a material is the resistance of the unit weight made into a conductor of the unit length. Thus the specific resistance of copper is the resistance of a wire of that metal weighing one gramme and one meter long. If the same weight of metal be drawn out into a wire of twice the length it is obvious that the section of the wire will be diminished in the same proportion. Hence the resistance will be doubled on account of the increased length, and doubled again on account of the diminished section. So in any case *the resistance of the same weight of metal varies as the square of the length of the conductor, which it forms*. Assuming now the weight to be constant, it is evident (since the section of the same length of wire must be proportional to its weight) that *the resistance of a given length of conductor is directly proportional to its weight*. Thus we deduce for the value of the resistance of any conductor in terms of its weight and length the expression—

$$R = \frac{(\text{Sp. R.}) \times l^2}{w}, \quad \text{.} \quad [23.]$$

The specific resistance of pure copper at 60° C. is 0.1523 Ohm, but it changes very rapidly with the temperature.

20. *Specific Inductive Capacity*.—Faraday discovered that the capacity of a conductor does not depend solely upon its dimensions or on its relations to other conductors, but is greatly influenced by the nature of the insulator or dielectric, separating it from them. The name inductive-capacity is given to that quality of an insulator, in virtue of which it affects the capacity of the conductor it surrounds, and this quality is measured by reference to air, which is assumed to possess the unit inductive capacity. The specific inductive capacity is therefore equal to the quotient of the capacity of any con-

ductor insulated by that material, divided by the capacity of the same conductor, in the same position separated from surrounding bodies by air alone.

Calculation of Derived Currents.

21. *Shunts*.—When an electrical current branches into two or more streams, it is said to be shunted, and any conductor which diverts a portion of the current from the main circuit is called a *shunt*, contracted from shun it.* The several subordinate streams thus formed are called *derived currents*, and it becomes of great importance in telegraphy to be able to calculate the quantity of electricity flowing in each. Moreover, several of the most valuable methods of electrical measurement are applications of the theory on which these calculations are based.

Since the several derived circuits, into which the main stream divides, may branch off at the same or at different points, and may either return on the same conductor or may flow to the earth ("make earth") through separate channels; moreover, since the original electro-motive power may be reinforced at any point, it is obvious that cases of great complexity may arise under the general theory. All such problems, however, may be solved by the application of two simple principles, the definite statement of which we owe to Kirchhoff.

22: *Kirchhoff's Laws*.—The following propositions are deductions from the general theory of electrical currents, and have been proved both mathematically and experimentally.

1. *The sum of the currents which approach any point is always equal to those which recede from it.*

Or if we distinguish the first by a plus, and the second by a negative sign we may say more generally;

The sum of all the currents which meet at a point is equal to zero.

2. *On any continuous line of conductors, the sum of the products of the resistances of the several parts by the strength of the current in each part, is equal to the sum of the electro-motive forces included in the same closed circuit.*

This last proposition holds true of every circuit which may be traced in any system of conductors and batteries, however complicated the maze; only currents flowing in opposite directions with reference to the given circuit, must be distinguished by opposite signs. Moreover, the sum is equal to zero when there is no electro-motive force on the line of conductors under consideration.

* A galvanometer, for example, is said to be shunted when only a portion of the current to be measured passes through it, the rest flowing through a wire (*the shunt*), which connects the two binding cups of the instrument.