Kirchhoff in 1849) was of the kind just alluded to; that is to say, it involved the comparison of a resistance with a coefficient of mutual induction, the time measurement being that of the period of oscillation of a galvanometer.

Weber used two methods,—(1) the method of transient currents, in which he measured the throw of a galvanometer caused by the current from an earth inductor of known area when it was turned about a vertical axis, so that the number of the earth's lines of force through it increased from zero to a maximum; and (2) the method of logarithmic decrements, in which he observed the time of oscillation and the logarithmic decrement of a magnet in a galvanometer of known constant. In the last of these two methods the horizontal component of the earth's horizontal force comes in directly, and the magnetic moment of the galvanometer magnet must be determined, which is a matter of great difficulty.

The determination of the British Association committee was carried out by Messrs Maxwell, Balfour Stewart, and Fleeming Jenkin, and the result of it was the construction of a standard called the ohm, which professes to represent a velocity of an earth quadrant per second $(10^9 \frac{\text{cm.}}{\text{sec.}})$.—The method they used is due to Sir Wm. Thomson. It consists essentially in causing a coil of wire of known dimensions to rotate about a vertical axis, and observing the deflection of a magnet of very small moment suspended at its centre.

Kohlrausch.

In a recent determination, F. Kohlrausch[1] has combined the two methods of Weber, and thereby avoided some of the difficulties which arise in either method used by itself. His value for the resistance of Siemens's mercury unit is $0{\cdot}9717 \frac{\text{Earth quadrant}}{\text{Second}}$.

According to Dehms and Hermann Siemens, the resistance of the coil called the ohm is equal to 1·0493 mercury units. According to Kohlrausch, therefore, the actual British Association standard is $1{\cdot}0196 \frac{\text{Earth quadrant}}{\text{Second}}$ in absolute measure; or, in other words, the determination of the British Association Committee is out by nearly 2 per cent.

Lorenz.

Lorenz[2] has, still more recently, made a determination of the value of the mercury unit in absolute measure. He causes a copper disc to rotate inside a coil of known dimensions. The two ends of a circuit C are kept in contact with the axis and circumference respectively of this disc. At two points A and B of C, the resistance between which is R, are attached the two terminals of the coil of wire, in circuit with which is also a battery. A sensitive galvanometer is placed in the circuit C, and the angular velocity of the disc is adjusted till this galvanometer indicates no current. If n be the number of revolutions per second, and E the electromotive force of induction per unit of inducing current, calculated from the dimensions of the coil, then the resistance R is equal to nE in electromagnetic measure.

The result obtained by Lorenz for the value of the mercury unit in $\cdot 9337 \frac{\text{Earth quadrant}}{\text{Second}}$; this would make the value of the B. A. standard $\cdot 9797 \frac{\text{Earth quadrant}}{\text{Second}}$

There is thus considerable discordance between the different results. It is a curious fact that the mean of the result of Kohlrausch and Lorenz gives for the value of the B. A. standard $\cdot 9996 \frac{\text{Earth quadrant}}{\text{Second}}$. Fresh determinations are, however, in progress, and it is to be hoped that the doubt which hangs over the matter will be dispelled.[3]

Calorimetric method.

Besides these methods, there is yet another of a totally different character, originally suggested by Thomson in 1851, in his paper on the "Mechanical Theory of Electrolysis." This method consists in measuring the amount of heat developed in a wire by a current the square of whose strength is known in electromagnetic measure. If we know the mechanical equivalent of heat with sufficient accuracy, we can calculate from these results the resistance of the wire in absolute measure by means of Joule's law. Measurements of this nature have been made by Von Quintus Icilius,[4] Joule,[5] and H. Weber.[6]

We can, by means of a tangent galvanometer, find the value of any current in electromagnetic measure (see art. GALVANOMETER). If the resistance of the circuit be found, by comparison with the ohm or other absolute standard, we can determine the value of the electromotive force in the circuit by Ohm's law. Measurements of this kind have been made by Bosscha,[7] by Von Waltenhofen, F. Kohlrausch, and Latimer Clark. The results of Kohlrausch[8] for the cells of Daniell and Grove, when no current is passing, are 1138×10^5 and 1942×10^5 C.G.S. units respectively. Latimer Clark[9] gives 1110×10^5 and 1970×10^5 for the same constants. The results, of course, depend on the constitution of the cells.

Taking the number of electromagnetic units in an electrostatic unit to be 3×10^{10}, we get from Thomson's electrostatic measurements for the electromotive force of Daniell's element 1120×10^5 in C.G.S. units.[10] The agreement among the different results is so far good.

The determination of the electrochemical equivalent of some elementary substance in this system of units is of great importance. Determinations exist by Weber, Bunsen, Casselmann, Joule, and F. Kohlrausch. The result of the last is no doubt the best as he combined with his voltametric experiments a determination of the horizontal component of earth's magnetic force, which is the most uncertain factor in the result. According to his result, one C.G.S. unit of electricity deposits ·011363 (± ·000002) gm. of silver. From this we get for the electrochemical equivalent of water ·0009476.

Measurement of the fundamental velocity.

Ratio of Electrostatic to Electromagnetic Unit.—If we measure the same quantity of electricity first in electrostatic and then in electromagnetic measure, the fundamental units of mass, length, and time being the same in both cases, the ratio of the two measures will vary directly as the magnitude of the unit of length, and inversely as the magnitude of the unit of time adopted. This ratio may therefore be regarded as a velocity which will remain the same whatever three fundamental units we adopt.[11]

Weber and Kohlrausch.

This velocity was found by Weber and Kohlrausch by the direct process of measuring the same quantity of electricity, first in terms of the one unit and then in terms of the other. This result was $31 \times 10^9 \frac{\text{cm.}}{\text{sec.}}$.

Maxwell Thomson.

Five other methods will be found described by Maxwell, vol. ii. § 768 *sqq.* Two of these have actually been carried into execution,—one by himself, the other by Sir Wm. Thomson. The results for the fundamental velocity are $28{\cdot}8 \times 10^9 \frac{\text{cm.}}{\text{sec.}}$ and $28{\cdot}2 \times 10^9 \frac{\text{cm.}}{\text{sec.}}$ respectively.

THEORIES OF ELECTRICAL PHENOMENA.

Speculative theories &c.

Throughout this article we have limited ourselves as much as possible to an exposition of the experimental facts of electricity. Where mathematical developments have occurred, they have in most cases been simply deductions from some principle or principles well established by experience. To have made our survey of the present state of electrical science complete, we ought to have added a section on the different attempts which have been made by the doctors of the science to penetrate a little farther into the secrets of the hidden mechanism by which electrical phenomena are brought about. But any attempt at a review of this kind must be relinquished. We refer the reader to our indications of the literature (Historical Sketch, p. 10). The most important work in this department lies at hand for the English reader in Professor Clerk Maxwell's *Treatise on Electricity and Magnetism.*[12] Particularly important are his theory of electric displacement and its application to statical as well as to current electricity; his investigation of the stresses in the medium, by which the electrostatical forces on the one hand, and the electromagnetic forces on the other, may be produced; the application of the theory of displacement to the case of electrical equilibrium when the dielectric medium is not everywhere the same; the dynamical theory of the electromagnetic field; and the electromagnetic theory of light. Maxwell gives, at the end of his work, a most instructive summary of the different speculative theories. The student who desires to pursue this department farther will do well to master this summary at the outset. (G. CH.)

1 *Pogg. Ann.*, Ergbd., 1873.

2 *Pogg. Ann.*, 1873.

3 Since the above was written, an account has appeared of a new determination by H. Weber of Zurich. His results, from three distinct methods. differ by less than $\frac{1}{1000}$, and give $\cdot 9550 \times 10^9 \frac{\text{cm.}}{\text{sec.}}$ for the Siemens unit. This would make the B. A. unit $1{\cdot}0014 \times 10^9 \frac{\text{cm.}}{\text{sec.}}$

4 *Pogg. Ann.*, 1857.

5 *Brit. Assoc. Rep.*, 1867.

6 *Dissertation*, Leipsic, 1863, quoted in Wiedemann, Bd. ii. § 1109.

7 Whose result has already been quoted. It is too low, on account of polarization.

8 *Pogg. Ann.*, 1870, and Ergbd., 1874.

9 Everett, *Illustrations of C. G. S. System of Units*, § 125, of *Journ. Soc. Tel. Eng.*, 1873.

10 Everett, *l.c.*

11 Maxwell, *Elect. and Mag.*, vol. ii. § 768.

12 We have followed throughout the views expounded in this work; and we are also under great obligations to its author for his advice on many points. For aid in collecting facts we are indebted mainly to the works of Riess, Wiedemann, and Mascart. Without their aid many sections of this article could not have been written. Wiedemann's treatise, in particular, lightened our task by the extent of its information and the profusion and *accuracy* of its references to original authorities for the facts in electrical science.

INDEX.

The figures refer to the pages.