of double refraction within the limits of errors of observation. The error, if any, could hardly exceed a unit in the *fourth* place of decimals of the index or reciprocal of the wave-velocity, the velocity in air being taken as unity. This result is sufficient *absolutely to disprove* the law resulting from the theory which makes double refraction depend on a difference of inertia in different directions.

I intend to present to the Royal Society a detailed account of the observations; but in the mean time the publication of this preliminary notice of the result obtained may possibly be useful to those engaged in the theory of double refraction.

XIII. "On a Voltaic Standard of Electromotive Force." By Latimer Clark, M.I.C.E. Communicated by Prof. Sir William Thomson, F.R.S. Received May 30, 1872.

(Abstract.)

In the year 1861 a Committee was appointed by the British Association for the Advancement of Science to report on standards of electrical resistance, and subsequently on other standards of electrical measurements. Reports were presented in 1862, 1863, 1864, 1865, and 1867.

They recommended the adoption of a system of electromagnetic units based on the metre and gramme, the relations of the units being such that the unit of electromotive force acting through the unit resistance should give the unit current, and that the unit current flowing for the unit time should give the unit quantity.

They issued standards of resistance (known as the B. A. unit or ohm) and standards of electrostatic capacity, or condensers of such magnitude that when charged with the unit electromotive force they contained a submultiple of the unit quantity of electricity (known as the farad).

No material standard of electromotive force has yet been issued. Much difficulty has, in fact, been found in devising such a standard. Mechanical means, such as the rotation of a conductor in a magnetic field of known intensity, are too complicated for ordinary use; thermoelectric couples are extremely variable, and voltaic elements, which would constitute the most convenient form of standard, have been hitherto found singularly inconstant, and therefore inapplicable. The Daniell's element, which has been most frequently used for this purpose, commonly varies five per cent. or more without apparent cause.

From a conviction that if similar conditions could be ensured similar combinations would always give the same electromotive force, the author was led to institute a series of experiments, extending over four years, which led to the discovery of a form of battery that is sensibly constant and uniform in its electromotive force.

The battery is composed of pure mercury as the negative element, the mercury being covered by a paste made by boiling mercurous sulphate in

a thoroughly saturated solution of zinc sulphate, the positive element consisting of pure zinc resting on the paste. The best method of forming this element is to dissolve pure zinc sulphate to saturation in boiling distilled water. When cool, the solution is poured off from the crystals and mixed to a thick paste with pure mercurous sulphate, which is again boiled to drive off any air; this paste is then poured on to the surface of the mercury previously heated in a suitable glass cell; a piece of pure zinc is then suspended in the paste, and the vessel may be advantageously sealed up with melted paraffine-wax. Contact with the mercury may be made by means of a platinum wire passing down a glass tube, cemented to the inside of the cell, and dipping below the surface of the mercury, or more conveniently by a small external glass tube blown on to the cell, and opening into it close to the bottom. The mercurous sulphate ($Hg_2 SO_4$) can be obtained commercially *; but it may be prepared by dissolving pure mercury in excess in hot sulphuric acid at a temperature below the boiling-point: the salt, which is a nearly insoluble white powder, should be well washed in distilled water, and care should be taken to obtain it free from the mercuric sulphate (persulphate), the presence of which may be known by the salt turning yellowish on the addition of water.

The electromotive force of the elements thus formed is remarkably uniform and constant, provided the elements be not connected up and allowed to become weak by working. A long series of comparisons was made between various elements, some of which had been made many months, and it was found that the greatest variation among them all did not differ from the mean value more than one thousandth part of the whole electromotive force; such a large difference was, however, very unusual, and might have been due to slight differences of temperature.

Several experiments were made to determine the variation of the electromotive force produced by temperature, from the mean of which it appears that the electromotive force decreases with increased temperature in the ratio of about ·06 per cent. for each degree Centigrade; for example, an element gave relative values of ·9993 at 0° Cent. and ·9412 at 100° C., between which limits the decrease appeared nearly proportional to the increments of temperature. These results, however, might be verified with advantage.

The element is not intended for the production of currents, for it falls immediately in force if allowed to work on short circuit. It is intended to be used only as a standard of electromotive force with which other elements can be compared by the use of the electrometer or condenser, or other means not requiring the use of a prolonged current. The author finds that the most delicate method of making these measurements is by means of his potentiometer†.

* The author has obtained it from Messrs. Hopkin and Williams, 5 New Cavendish Street.

† See 'A Treatise on Electrical Measurement,' by Latimer Clark. London, 1868, p. 106.

As it was desirable to determine the value of the force of the element in absolute measure and in terms of the British-Association units, a very careful series of measurements was made by the electrodynamometer constructed for the British-Association Committee, and referred to in their Report for 1867, and also by means of a sine galvanometer of somewhat novel form.

The following Tables give the results obtained:—

I. By the Electrodynamometer.

Date.	Value of E in volts.	Remarks.
1871.		
Dec. 8	1·4583	3 cells.
9	1·4651	3 cells.
14	1·4616	3 cells.
15	1·4561	3 cells.
15	1·4579	2 cells.
16	1·4586	3 cells.
16	1·4517	3 cells, coil turned 180°.
16	1·4552	2 cells, coil turned back 180°.
16	1·4555	3 cells.
16	1·4535	2 cells.
16	1·4564	3 cells.
18	1·4649	3 cells.
19	1·4562	3 cells, coil turned 180°.
19	1·4558	3 cells, coil turned back 180°.
20	1·4615	3 cells.
20	1·4539	3 cells.
20	1·4551	2 cells.
21	1·4549	3 cells.
Mean	1·45735	Temperature 15°·5 Cent.

II. By the Sine Galvanometer.

Date.	Value of H.	Value of E.	Remarks.
1872.			
Feb. 9	1·788	1·45605	Galvanometer wound with 8 turns of German-silver wire.
9	1·788	1·45457	
9	1·788	1·45400	
10	1·788	1·45809	
10	1·788	1·45669	
11	1·788	1·45799	
18	1·787	1·45566	Rewound with 28 turns of German-silver wire.
19	1·787	1·45671	
19	1·787	1·45680	Rewound with 27 turns of German-silver wire.
20	1·787	1·45752	
20	1·787	1·45645	
24	1·786	1·45522	
24	1·786	1·45492	
	Mean	1·45621	Temperature 15°·5 Cent.

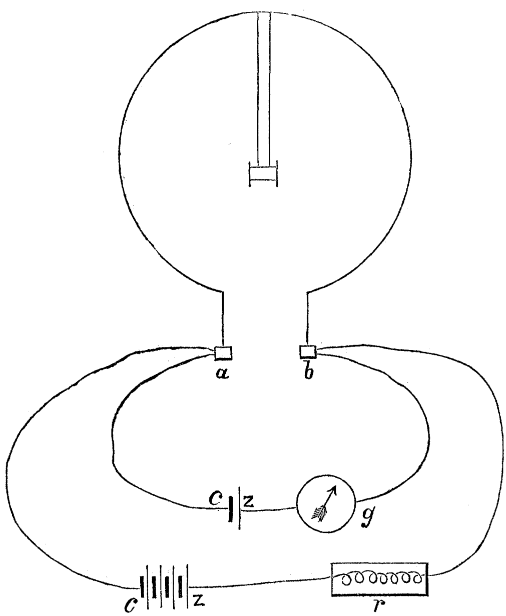
	Volt.
We have therefore the mean value of the electromotive force of the standard-cells, as determined by the electrodynamometer, 18 observations	1·45735
As determined by the sine galvanometer, 13 observations..	1·45621
Mean value........	1·45678

Or, since no importance can be attached to the figures beyond the third place of decimals, 1·457 volt or British-Association unit of electromotive force, equal to 145700 absolute electromagnetic units.

The value of H, the horizontal component of the earth's magnetic intensity, a knowledge of which is necessary for the determination by the sine galvanometer, was kindly supplied for each day by the Astronomer Royal.

A novel feature in both these series of determinations is the use of an arrangement by which the cells under comparison are not allowed to perform any work or produce any current.

The arrangement is shown in the subjoined diagram.



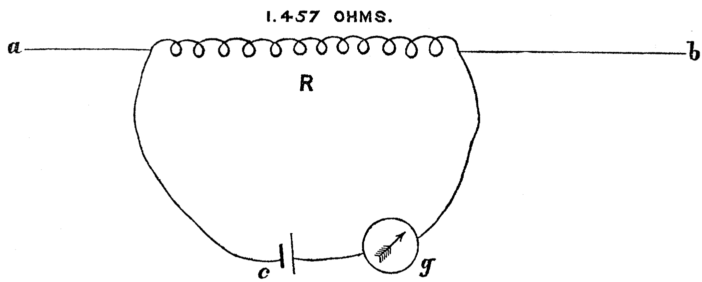
a and *b* are the terminals of the instrument; the standard cell (C Z) is connected to these terminals with an intervening galvanometer, *g*; an auxiliary battery (*c z*) is also connected with similar poles to the same terminals, so that both tend to send a current through the instrument in the same direction.

The strength of the auxiliary battery is, however, so regulated, by means of the rheostat (*r*) and by varying the number of cells, that it just balances the force of the standard cell, so that no current flows through the galvanometer (*g*), or, in other words, the terminals (*a*, *b*) are kept at a difference of potential equal to the electromotive force of the standard (C Z), the current which flows through the instrument being entirely supplied by the auxiliary battery.

This method has also the advantage of being quite independent of the resistance of the standard cell.

The uses of this standard element to practical electricians are sufficiently obvious. It may be used for determining the electromotive force of other elements by the use of an electrometer or by the discharge from a condenser. Or a condenser having a capacity of $\frac{1}{1\cdot457}$ farad charged by the standard cell would contain the British-Association unit quantity of electricity (one veber), or $\frac{1}{100}$ of the absolute unit of quantity.

It is also of great value for maintaining a current of known strength in any circuit for the purposes of experimental research.



Thus, if it be desired to produce in any circuit, *a b*, a current equal to the British-Association current ($\frac{1}{100}$ absolute unit), it is only necessary to insert in the circuit a wire (R) having a resistance of 1·457 ohm, and to connect to each end of this wire the poles of a standard cell (*c*) with a galvanometer (*g*), and to vary the strength of the current in *a b* until no deflection is produced on the galvanometer; the current through *a b* will then be equal to one British-Association unit of current, or one veber per second, whatever its length or resistance.

By varying the resistance of R, or by varying the number of elements (*c*), any given current can be steadily maintained through *a b* at pleasure; on the other hand, the value of any given current can be measured by so varying the resistance R that no deflection is produced on the galvanometer. The value of the passing current will then be

$$C = \frac{1\cdot457}{R} \text{ veber per second.}$$

It is also evident that, knowing the value of E, we may determine the horizontal intensity of the earth's magnetism (H) in any place quickly and simply by means of an ordinary sine or tangent galvanometer.

In fact, the standard of electric potential is second only in importance to that of the standard of electric resistance; and the use of such a standard, combined with an auxiliary battery in the manner above described, admits of a variety of applications which it is believed will be found of great value in electrical research.