



## II. On a modification of Wheatstone's rheostat

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It is submitted that, considering the nature of the subject, these results are fairly confirmatory of the theory, and also of the assumed values of the densities, and to a less extent of that of the mean thickness of the crust at the sea-coast.

Geological changes of level are closely connected with the theory of hydrostatic equilibrium, as I have pointed out in my 'Physics of the Earth's Crust,' chap. xvii. When the effects of contour have been allowed for, we ought to find a general negative variation of gravity in such regions as are now disposed to rise, because that would indicate that the root is too deep for equilibrium. And for the opposite reason, a positive variable ought to be met with where depression is in progress. Whether this relation holds has, I suppose, not been noticed. Again, if the hypothesis is true, beneath plains the increment of underground temperature ought to be more rapid where the variation of gravity is positive, and more slow where it is negative.

*Postscript.*—Since the foregoing was sent to press, I have read M. Faye's article, "Sur la Constitution de la Croute Terrestre," in *Comptes Rendus* for March 22, 1886. He there discusses pendulum-observations at island and continental stations, the latter with especial reference to the Indian observations. Respecting the excess of gravity found at island stations, he comes to a conclusion similar to that arrived at by Pratt in reference to Minicoy (art. 74). With regard to continents, his views likewise agree generally with those advanced by Pratt; see in particular Pratt's art. 192. It would occupy too much space to examine here the cause to which M. Faye attributes the greater density of the suboceanic crust.—O. F.

## II. On a Modification of Wheatstone's Rheostat.

By SHELFORD BIDWELL, M.A.\*

IT is frequently desirable that the resistance of a circuit through which a current of electricity is flowing should be made to vary *continuously* and not by steps, as is necessarily the case when resistance-coils are used alone. An instrument for effecting this object was devised by Sir Charles Wheatstone in 1843, and was called by him the Rheostat. Two forms of the apparatus, both of which are well known, are described in his paper on the "Constants of the Voltaic Circuit," originally published in the Phil. Trans. and contained in the Physical Society's Reprint of Wheatstone's Scientific Memoirs.

\* Communicated by the Physical Society: read May 8, 1886.

In the first form two equal cylinders, one of wood and the other of brass, are mounted on parallel axes, and so arranged that a fine wire can be wound off the one and on to the other by turning a handle. On the wood cylinder a spiral groove is cut in which the wire lies, so that its successive convolutions are insulated from each other; but when any portion of the wire is wound upon the brass cylinder, the current passes immediately from the wire to the cylinder, and thence to one of the terminals of the instrument. The effective part of the length of the wire is therefore the variable portion which is on the wood cylinder.

In the other form there is only one cylinder, which is of wood, and has a quantity of stout wire permanently wound upon it in a spiral groove cut upon its surface. Near the cylinder and parallel to its axis is a brass rod, upon which a notched "rider," or in more modern instruments a grooved brass wheel, is capable of sliding. The notch in the rider, or the groove in the wheel, fits and presses upon the spiral wire, and when the cylinder is turned the rider or wheel moves longitudinally along the brass rod. The terminals of the instrument are connected respectively with the brass rod and with one end of the wire upon the cylinder; and the resistance introduced into the circuit depends upon the position of the point of contact of the rider or wheel with the wire.

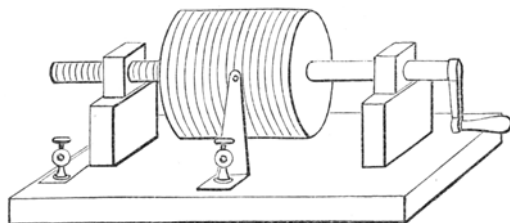
The apparatus in either form is open to serious practical objections. In that first described it is difficult to maintain good electrical contact between the wire and the brass cylinder, both of which must be kept perfectly clean and free from dust and damp. Moreover the wire is liable to become slack and to leave its groove, and not unfrequently it breaks. In the second form there is also a difficulty in securing uniformly good contact; and if the slider fits the rod sufficiently tight, the lateral pressure upon the wire is so great that it becomes permanently stretched, and is sometimes forced completely out of its groove. The wire, too, is necessarily thick; and the whole apparatus must consequently be large and cumbersome if it is to work through any considerable range of resistance.

A Wheatstone's rheostat in good working order is rarely seen, even in the shop of the instrument maker; and in point of fact it is little used except for the purpose of lecture-illustration.

In the course of some experimental work the pressing need of some means of continuously varying a resistance led me to devise the modified rheostat, which is figured in the annexed woodcut.

As in the second form of Wheatstone's instrument, a wire

is coiled in a spiral groove upon an insulating cylinder. This is mounted upon the middle of a brass axle of rather more than three times its length. Upon one of the projecting ends of the axle a screw is cut, the pitch of which is equal to



the distance between the consecutive turns of the wire. The axle revolves in two brass bearings, fixed at a distance apart equal to twice the length of the cylinder ; one of the bearings has an inside screw corresponding with that upon the axle. A flat spring is attached at one end to the base-board of the instrument midway between the bearings ; to the other end is riveted a short copper pin, which is directed perpendicularly to the axis of the cylinder and bears upon the spiral wire, being kept in position by a shallow notch cut in its end. One end of the spiral wire is electrically connected with the brass axle, and thence through the screwed bearing and a strip of copper with a terminal upon the base-board. The spring is directly connected with a second terminal. When the cylinder is turned by means of a handle, it travels backwards or forwards in the direction of its axis, the point of contact of the copper pin with the spiral wire remaining fixed in space ; thus more or less resistance is introduced between the axle and the spring, and therefore between the two terminals.

In the model exhibited at the meeting of the Physical Society, the length of the cylinder is 3 cm., its diameter is 8 cm., and the diameter of the wire, which is of German silver, is 0.5 mm. There are nine turns of wire per centimetre of length, and the greatest resistance is about 10 ohms. Since the instrument is generally used in conjunction with a set of coils, this resistance is for most purposes amply sufficient ; indeed I am inclined to think that it would be on the whole advantageous to use thicker wire and wind it in a coarser spiral, so that the total resistance might be slightly more than one ohm. The rheostat would then be used merely as a fine adjustment\*.

\* The best form of cylinder would, I think, be a hollow brass drum covered with a tightly fitting tube of ebonite, 2 or 3 mm. in thickness. Wood, even when well seasoned, is liable to shrink, and is more or less

The advantages which this apparatus appears to possess over the usual forms are obvious. It is simple, compact, easily made, and not easily put out of order. There is no lateral stress, and in consequence of the rubbing action the contact is always good. The deflections of the needle of a "dead-beat" galvanometer in circuit with it are under perfect control, responding to the rotation of the cylinder with smoothness and regularity, and there is complete freedom from jerks and retrograde movements. It is not indeed more suitable for use as a measuring instrument than the older forms; but when it is desired to adjust a resistance to a nicety, or to cause a continuous variation of a current, it is of great utility. If the interposed resistance is required to be known with accuracy, it should be measured by the bridge-method in the ordinary way.

### III. *Some Thermodynamical Relations.*—PART IV.

By WILLIAM RAMSAY, *Ph.D.*, and SYDNEY YOUNG, *D.Sc.*\*

SINCE the first portions of this research were published Professors Ayrton and Perry have criticised our work, and while we would thank them for the appreciative way in which they speak of our labours, we must differ entirely from their conclusion that "there is nothing further to be said about the four laws in question." This conclusion rests on a complete misapprehension of the whole scope of our papers, and for the obvious reason that, while we have endeavoured by a method of what may be termed approximation to arrive at a workable plan of deducing from the known vapour-pressures of a substance like water the unknown vapour-pressures of any other substance with as little expenditure of experimental work as possible, and have in our research made the statement, which is only a very rough approximation to truth, that the ratios of the absolute temperatures of any two liquids at any given pressure are equal to the ratios at any other pressure, but have materially modified this statement, and asserted next, what is a very close approximation to truth, that when the statement given does not hold (as in by far the

affected by moisture. The depth of the groove should be about half the diameter of the wire. The wire should be annealed, and should be wound on when it is warm. The notch at the end of the copper pin may be very shallow, for if the position of the spring is properly adjusted the pin has little or no tendency to slip off the wire.

\* Communicated by the Physical Society: read May 8, 1886.