electrode is positive, then the small velocity of the positive ions is not favourable to their being dragged away from the electrode before they can recombine, so that the current is very small unless a very great E.M.F. is applied.

"On a Quartz-thread Gravity Balance." By RICHARD THRELFALL, lately Professor of Physics in the University of Sydney, and JAMES ARTHUR POLLOCK, lately Demonstrator of Physics in the University of Sydney. Communicated by Professor J. J. THOMSON, F.R.S. Received April 11—Read April 27, 1899.

(Abstract.)

The first part of the paper contains an account of the instrument in its present form, an account of the investigations leading up to the form adopted being relegated to an appendix.

The principle of construction is as follows:—A quartz thread (which requires to be prepared with much care) is stretched horizontally between two supports, to which it is soldered. At one end the point of attachment is the centre of a spring of peculiar construction, designed so as to be capable of displacement in the direction of the thread, but incapable of any transverse motion or vibration.

At the other end the thread is attached to the axle of a vernier arm moving over a sextant arc; by turning the axle the thread may be more or less twisted, the amount of twist being ascertained in terms of the divisions of the sextant arc.

Midway between the two supports the thread is soldered to a short length of fine brass wire, which is adjusted so that the centre of gravity of the wire does not lie immediately above or below the thread, but at some distance from it. The wire forming the "lever" is then rotated about the thread as axis in such a manner that the two halves of the thread are twisted through about three whole turns, and the torsion of the thread is then of such a value that the lever assumes a horizontal position. This adjustment is made by weighting the lever with a small speck of fusible metal. The "balance," which determines the position of the lever with respect to the horizontal plane through the thread, is composed of the earth's gravitational force on the one hand, and the forces of resilience of the twisted thread on the other. Were gravitational force to increase, the centre of gravity of the lever would fall, the end of the lever would move out of its sighted position, and the thread would have to be slightly twisted by the vernier axle in order to bring the lever back to its sighted position.

Differences in the gravitational intensity at different stations are expressed in terms of the amount by which one end of the thread

has to be twisted or untwisted to bring the lever to its sighted position.

In carrying out the construction of the instrument on the principle thus explained the following conditions have to be fulfilled:—

The instrument must be portable, and must be able to withstand the rough usage inseparable from travelling, without being put out of adjustment. It must have a sensitiveness of at least one part in 100,000 of the value of "g," *i.e.*, a change in the value of "g" amounting to one part in 100,000 must be shown by the balance.

These conditions have been satisfied in the following manner:—The thread supports form part of a girder mechanism which is itself contained in a thermally insulated tube. During transport the lever is arrested by a mechanism which clamps it with a definite pressure in a definite position. The end of the lever is observed by a microscope which is always brought into the same relative position with respect to the horizontal plane through the thread by means of sensitive striding levels. It is shown as a consequence of the mechanical conditions that the lever will be in unstable equilibrium when its centre of gravity rises above the horizontal plane through the thread by about 3°. Consequently the accuracy with which the lever can be brought to its sighted position is very great, for the position selected as the sighted position is within a small fraction of a degree of the position of instability.

As it is necessary either to keep the balance in an atmosphere of constant density or to correct the observations for changes in the barometrical pressure, the former course was decided upon, and consequently the instrument is contained in an air-tight space. This involves working the vernier axle through a stuffing box which must be practically frictionless, a condition satisfied by a sort of mercury sealing.

The difficulty in making the apparatus arises from the fact that quartz fibres, though infinitely better than any other material, are not really sufficiently perfect in their elastic properties for the present purpose, and it is only by a judicious balancing of advantages that it is possible to arrive at the necessary sensitiveness. Even after two years' twisting the thread of the instrument still undergoes a continual, though small, viscous deformation; this, however, becomes sensibly constant, and can be allowed for.

A further complication arises from the fact that as the temperature rises the quartz becomes stiffer, so that at a given station the circle readings are a function of the temperature. We have found that the relation between the circle reading and the platinum temperature is a linear one at ordinary temperatures.

An essential feature of the apparatus, therefore, is a platinum wire thermometer placed alongside the thread.

The following statement shows concisely the effect on a determi-

nation of gravity of the various observational errors which are possible. The instrument of course only refers differences of gravity to a known difference. The results are expressed in round numbers, gravity being taken at its value in the latitude of Sydney.

Our temperature observations may be inconsistent by at most one-hundredth of a centigrade degree; this would correspond to an uncertainty of one part in 700,000 in the value of "g."

The accuracy with which the microscope can be set on the lever is much greater than the accuracy of reading the sextant arc. If our estimate of the latter is wrong by 5″ the resulting value of "g" is affected to the extent of one part in 1,300,000.

The errors of levelling may amount to one part in 700,000 in the value of "g." This gives a possible maximum uncertainty of one part in 300,000 in the value of "g." The daily rate of the instrument does not introduce an uncertainty of anything like the amounts mentioned above, and can in any case be eliminated by observing alternately at two stations, the difference in the value of gravity between them being the subject of observation.

Observations.—Two observers are required, one for the balance and one at the thermometer resistance box.

It is only possible to observe with sufficient accuracy when the temperature is nearly steady; we always observe therefore at a time when the temperature passes through a maximum or a minimum value. With the instrument as constructed of various metals it is also necessary to avoid observing too soon after any great and sudden variation of temperature.

Journeys.—We have travelled with the balance from Sydney to Melbourne by train, from Melbourne to Hobart by steamer, from Hobart to Launceston (in Tasmania) by train, back to Melbourne by steamer, and to Sydney by train. We have also made many less extended journeys in New South Wales, having travelled over more than 6000 miles with the instrument.

Most of these journeys led to our making improvements in the instrument, and therefore are not to be regarded as forming surveys.

If, however, a consistency of one part in 50,000 in the value of "g" be considered satisfactory, then the Tasmanian stations may be considered as surveyed, and the values assigned to gravity at these stations to be referred to the Melbourne-Sydney difference. Since this journey was undertaken the instrument has been so much improved in detail that we do not discuss its results from a gravitational point of view.

We have, however, made three test journeys between Sydney and Hornsby in New South Wales under proper conditions, and the result of these observations shows that at Hornsby the thread has to be untwisted at one end by the following amounts as referred to the reading at Sydney:—

Journey 1. Mean of Sydney—Hornsby and Hornsby—Sydney. Difference 18·5 sextant minutes.

Journey 2. Mean of Sydney—Hornsby and Hornsby—Sydney. Difference 18·1 sextant minutes.

Journey 3.—Mean of Sydney—Hornsby and Hornsby—Sydney. Difference 18·1 sextant minutes.

The maximum difference is thus 0·4 sextant minute, and corresponds to an uncertainty in the value to be assigned to the acceleration of gravity at Hornsby as compared with that at Sydney taken as known of one part in 500,000. This we believe to fairly represent the accuracy attainable by the instrument in actual field work. It is about double of the outside accuracy attainable by invariable pendulums, not connected by telegraph, and the observation takes about half an hour, but the time depends on the time required for the temperature to become steady. The observations quoted took about three hours each. Packing and unpacking takes about an hour and a half, and the actual observing about five minutes, but the temperature must be watched to the maximum or minimum before the observations begin.

The weight of the instrument and of appliances taken directly from the laboratory and packed in strong boxes is 226 lbs.; by making special appliances with a view to lightness this weight might be reduced to one-half.

The paper is illustrated by working drawings, &c.

"Data for the Problem of Evolution in Man. I. A First Study of the Variability and Correlation of the Hand." By Miss M. A. Whiteley, B.Sc., and Karl Pearson, F.R.S. Received April 6,—Read April 27, 1899.

1. In a more purely theoretical discussion of the influence of natural selection on the variability and correlation of species, which one of the present writers hopes shortly to publish, a number of theorems are proved which it is desirable to illustrate numerically. But the quantitative measures of the variability and correlation hitherto published are comparatively few in number, especially when, as in the present case, we desire to have their values for a number of local races of the same species. When we have once realised that neither variability nor correlation are constant for local races but are modified in a determinate manner by natural selection, and further that their differences are the sure key to the problem of how selection has differentiated local races, then the importance of putting on record all the quantitative measures we can possibly ascertain of variability and correlation becomes apparent. For some five years past various members of the