II. "On a Determination of the Mean Density of the Earth and the Gravitation Constant by means of the Common Balance." By J. H. Poynting, D.Sc., F.R.S., Professor of Physics, Mason College, Birmingham. Received May 13, 1891.

(Abstract.)

In a paper printed in the 'Proceedings of the Royal Society,' No. 190, 1878, an account was given of some experiments undertaken in order to test the possibility of using the common balance in place of the torsion balance in the Cavendish experiment. The success obtained seemed to justify the continuation of the work, and this paper contains an account of an experiment carried out with a large bullion balance, in place of the chemical balance used in the preliminary trials. The work has been carried out at the Mason College, Birmingham.

The Principle of the Experiment.—The immediate object of the experiment may be regarded as the determination of the attraction of one known mass on another. If two spheres, of masses M and M′, have their centres a distance d apart, the attraction is, according to the law of gravitation, GMM'/d^2, where G is the gravitation constant. Astronomy justifies the law in certain cases as regards M'/d^2, but does not give the value of G or M, except in the product GM. To find G we must measure GMM'/d^2 in some case in which both M and M′ are known. Having found G, we may determine the mean density of the earth, for, assuming that it is a sphere of radius R, the weight of any mass M′ at its surface is

$$G \times \tfrac{4}{3}\pi R^3 \Delta M'/R^2$$
$$= \tfrac{4}{3} G\pi R \Delta M'.$$

But if g is the acceleration of gravity the weight of M′ may be expressed as $M'g$. Equating these values, we get

$$\Delta = \tfrac{3}{4}\frac{g}{G\pi R}.$$

Method of Using the Common Balance.—With the length of beam used (about 123 cm.) a differential method was applicable, in which the attraction on the beam was eliminated. Two spherical masses of lead and antimony, about 21 kilos. each, were hung from the two arms of the balance, so that their centres in the first position were about 30 cm. above the centre of a large attracting mass, a sphere of lead and antimony about 153 kilos., placed on a turntable,

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so that it could be brought in turn immediately under either of the suspended attracted masses. A balancing mass of half the weight, and at double the distance from the centre of the turntable on the other side, was found necessary, so that the centre of gravity should be in the axis of rotation. Before this was used, the ground level was seriously altered by the rotation of the turntable. The attraction of the balancing mass was calculated and allowed for.

The alteration in the weights of the attracted masses, due to the motion of the attracting masses from one side to the other, was the quantity to be measured. When this was determined in the lower position of the attracted masses they were raised to about double the distance, and the attraction again determined. The difference eliminated the pull on the beam, suspending wires, &c. To lessen the effect of want of homogeneity or sphericity in the masses, or of want of symmetry in the turntable, the masses were all inverted and changed over each to the other side, and the weighings repeated.

The position of the beam was determined by the reflection of a scale in a mirror used with "double suspension." The mirror was suspended by two silk threads, one attached to the end of the ordinary pointer about 60 cm. below the central knife edge, the other parallel to it, being attached to a fixed support. The mirror turned through an angle about 150 times as great as that through which the beam turned, and one scale division corresponded to an angle of tilt in the beam of about 2/15ths of a second.

The value of a scale division was determined by the use of two equal centigram riders which could be placed on or taken off wire frames representing the scale pans of a small subsidiary beam, 2·5 cm. long, fixed parallel to and at the centre of the large beam. When one rider was placed on one supporting frame the other was at the same instant lifted off the other frame.

The balance was left free throughout a series of weighings, and no moving parts of the apparatus were connected with the case.

The values obtained are as follows:—

$$\text{The gravitation constant } G = \frac{6{\cdot}6984}{10^8}.$$

$$\text{Mean density of the earth } \Delta = 5{\cdot}4934.$$

In the paper a description is given of a new form of cathetometer used to measure the diameters of the masses.