A Duplex Horizontal Pendulum Apparatus.[1]

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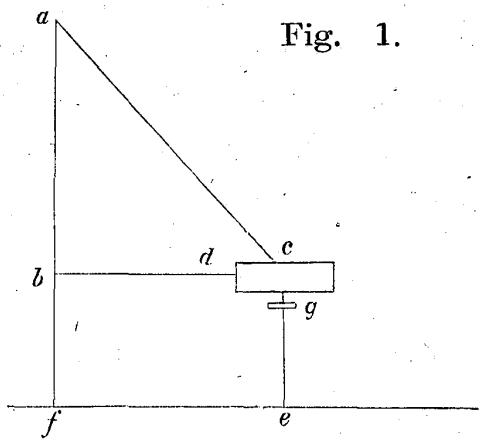
With Plates I and II.

The duplex horizontal pendulum apparatus, which is shown in fig. 2, Pl. I, is an improved form of the mechanically registering seismograph, which I have used for some years[2]; the modification consisting in the introduction of the principle of the duplex pendulum of Professors Gray, Ewing and Milne. The essential part of the instrument, which is shown in the accompanying figure, is made up of a heavy flat cylinder *c* (fig. 1) of brass filled with lead, about 16 kg in weight, suspended from the top, *a*, of a strong cast iron stand *af*, which is bolted at *f* to the foundation stone, *fe*; the strut *db* being pivoted at *b*. The pendulum *c*, which is first brought very nearly to a state of neutral equilibrium, is to be further adjusted by means of an inverted pendulum *ge*. The mechanical details of the latter as well as the recording arrangement are shown in Pl. II.

Fig. 1.



Pl. II. The auxiliary inverted pendulum consists of a light alu-

1) A short preliminary description of this instrument has been given in Tokyo Sugaku-Butsuri Gakkwai Kiji Gaiyō, Vol. II, No. 8, Jan., 1904.

2) See the *Publications*, No. 5.

minium tube eg, about 30 cm in length, carrying a small metallic disc g, about 0·017 kg in weight, put very closely to the heavy bob c. The upper end of the tube eg is furnished with a brass fork, between whose two limbs fits exactly a highly polished steel axis h, about 2 mm in diameter and 3 cm in length, pivoted between two small supports, ii, attached to the lower face of the heavy cylinder c; the axis h being parallel to the strut. The lower end of the tube eg is furnished with two foot-screws, jj, which fit respectively in a conical socket and in a V-groove, mounted on a base plate k. The line formed by joining the apex of the socket and the vertex of the V-groove is to be brought exactly below and parallel to the axis h, by means of the screws l, l, m, which move the plate k in two rectangular horizontal directions.

It will thus be seen that the inverted pendulum eg can rotate only about a line parallel to the equilibrium position of the strut, its upper part being joined to the heavy weight in such a way that the friction at the point of contact is reduced to a minimum. Now, the equilibrium of a horizontal pendulum has always a certain degree of stability, which depends on the angle φ, formed by the vertical and the line joining the point of suspension, a, with the point of support, b; this angle being determined by the well known relation

$$\varphi = \frac{T_0^2}{T^2},$$

in which T is the period of oscillation of the horizontal pendulum (when not joined to the inverted pendulum), and T_0 the period when the system formed by the strut bd and the heavy bob c is made to swing as an ordinary vertical pendulum. If W and w denote respectively the weights of the heavy bob c and the small disc g, we have, for making neutral the equilibrium of the horizontal pendulum, the following relation :—

$$w = W \times \frac{H.\varphi}{L},$$

in which L is the length between the centre of the heavy bob c and the point of support b, and H is the height of the inverted pendulum

eg. To take an example, let $W=15$ kg, $L=100$ cm, $H=30$ cm, and $\varphi=\frac{2\times 2}{30\times 30}$; we then find $w=0{\cdot}02$ kg.

The mechanism at the top, *a*, of the cast iron stand, the multiplying pointer, and the record-receiver whose details will be seen from figs. 3 and 4, Pl. I, and from Pl. II, are exactly similar to those in the older instruments. With a portable instrument of this description, in which the length *bc* and the height *ab* is each equal to 1 metre, the complete period of free oscillation of the steady mass can be raised without much difficulty to 1 minute, the multiplication of the recording pointer being 20 to 30.

Tokyo. June, 1904.

Duplex Horizontal Pendulum Apparatus.

Fig. 2.

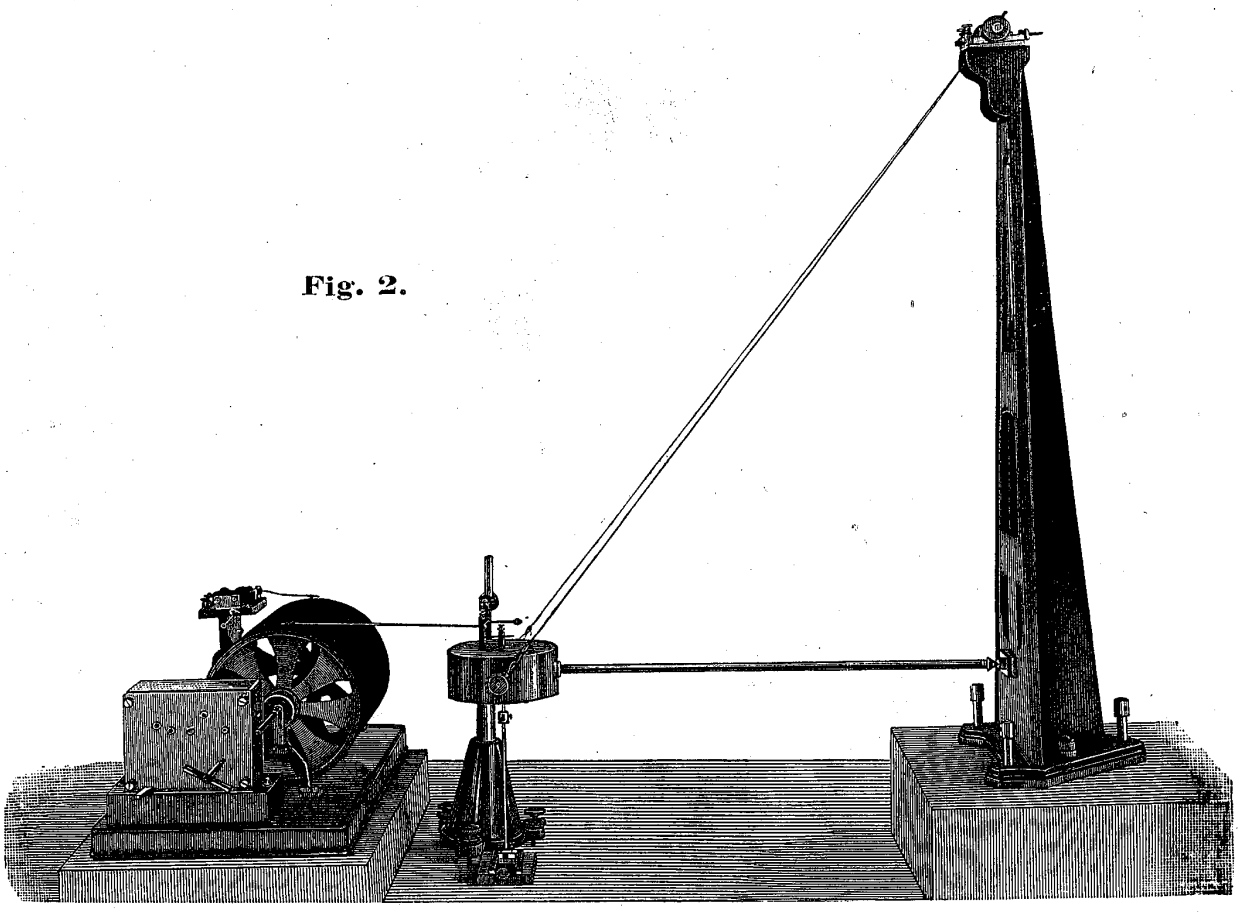


Fig. 3.

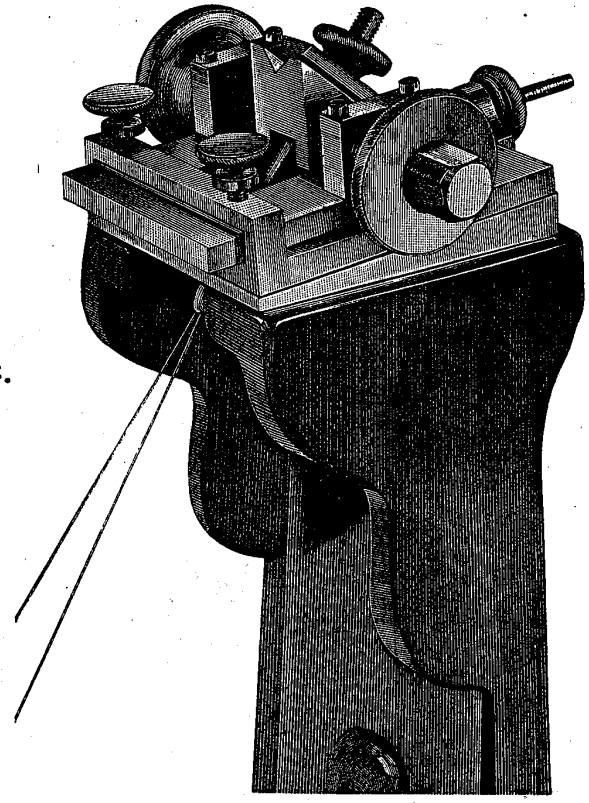
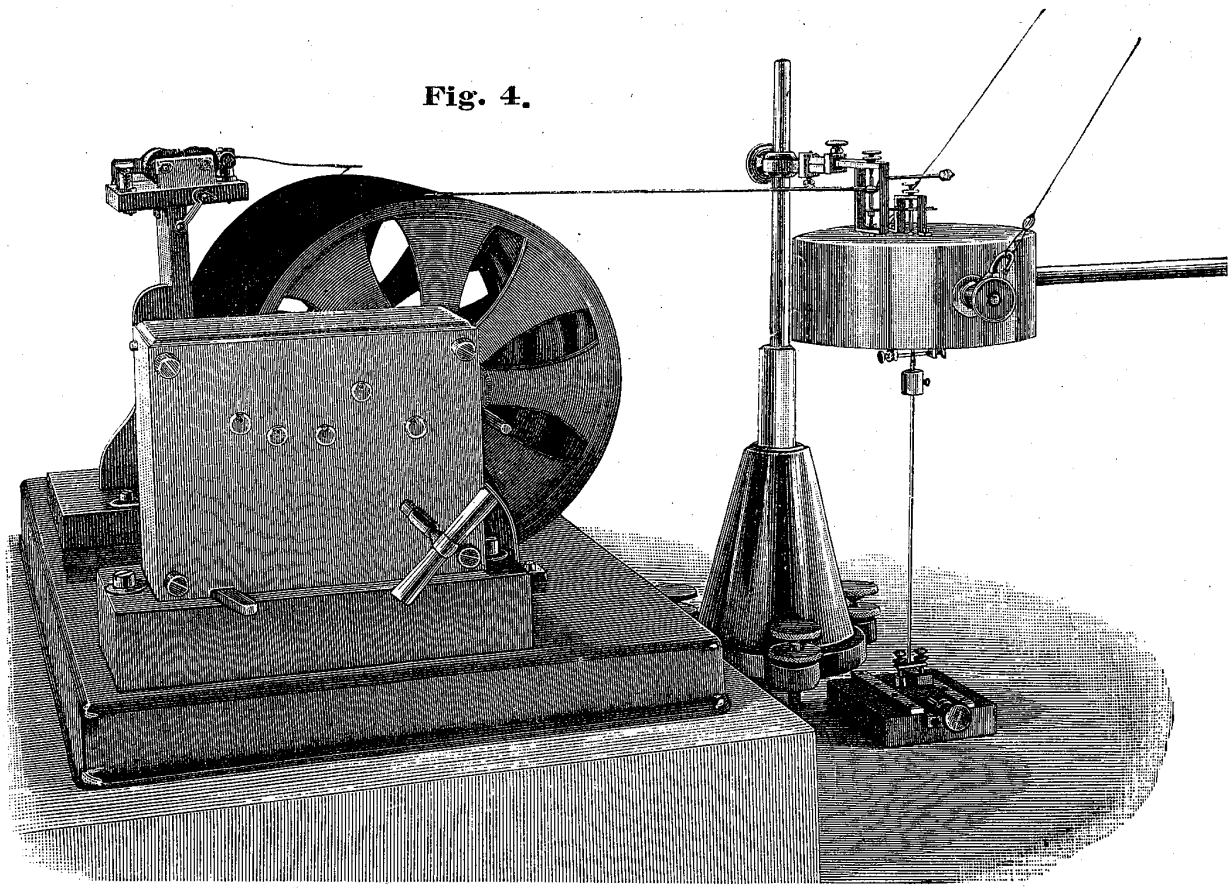
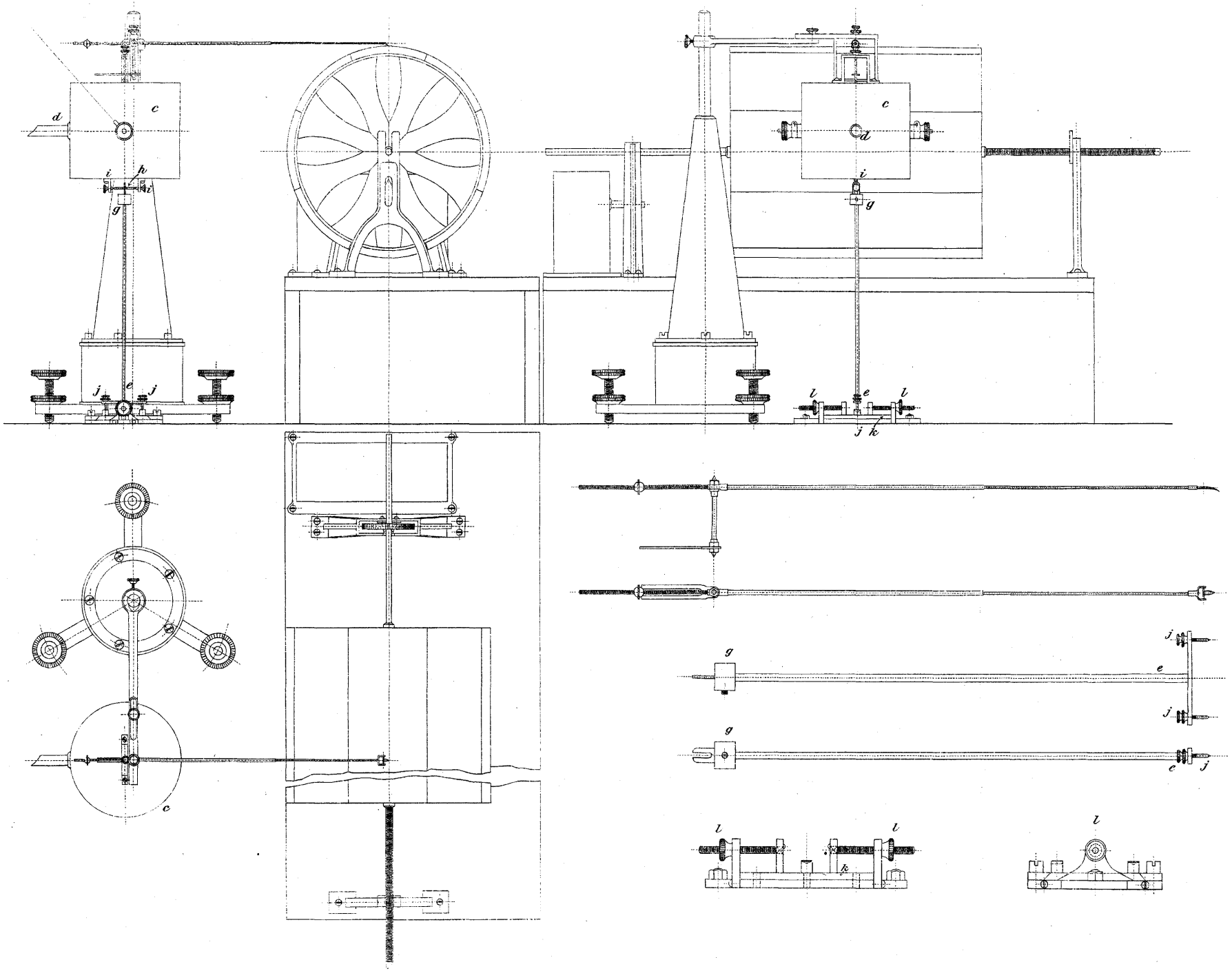


Fig. 4.

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