shown that contrivances of this order are wanting in sensibility, and often remain standing during movements that are distinctly perceptible. A more satisfactory arrangement is one where the body to be overturned is placed upon a platform which exaggerates the movements of the ground. For example, the platform *h* (see fig. 1) may be on the top of a small rod r, fixed at its lower end by plaster of Paris in a watch- glass *w,* and carrying a disk or sphere of lead at *l*. When the stand on which *w* rests is shaken, a multiplied representation of this movement takes place at *h,* and any small body resting on that point, as for example a small screw *s* standing on its head, may be caused to topple oven If the loaded rod is elastic its lower end may be fixed in a stand, and the spherically curved base *w* is no longer required. In this case the motion at *h* is that of elastic switch­ing. Apparatus of this kind may be employed for several purposes beyond merely indicating that an earthquake has taken place.

For example, if the falling body *s* is attached by a thread to the pendulum of a timepiece, it may be used to stop it and indicate the approximate time at which the tremor occurred. In its most sensitive form *r* is a steel wire, the upper end of which passes freely through a small hole in a metal plate. By the movement of the wire or the movement of the plate, especially if the latter projects from the top of a second and similar piece of apparatus, an electrical contact can be established by means of which an electromagnet may ring a bell, stop a clock, or set free machinery connected with a cylinder or other surface upon which an earthquake machine may record the movement of the ground.

The next class of instruments to be considered are seismometers or earthquake measurers, and seismographs or instruments which give diagrams of earthquake motion. Although a seismograph may be designed that will not only respond to fairly rapid elastic vibrations, but will also record very slow and slight undulatory movements of the ground, experience has shown that the most satisfactory results are obtained when special instruments are employed for special purposes.

First we will consider the types of apparatus which are used to record the rapid back-and-fortn movements of earthquakes which can be distinctly felt and at times are even destructive. The essential feature in these seismographs is a fairly heavy mass of metal, so suspended that although its supports are moved, some point in the mass remains practically at rest. For small earthquakes, in which the movement is rapid, the bob of a very long and heavy pendulum will practically comply with these conditions. If a style projecting from this pendulum rests upon say the smoked surface of a glass plate fixed to the ground, the vibratory motion of the ground will be recorded on the glass plate as a set of superimposed vibra­tions. To obtain an open diagram of these movements the plate must

be moved, say by clockwork. Experience, however, has shown

that even when the movements of the ground are alarming the actual range of motion is so small that a satisfactory record can be ob­tained only by some mechanical (or optical) method of multiplication. This is usually accomplished as shown in fig. 2. *b* is the bob of a pendulum, with its style *s* passing through a slot in the short arm of a light lever, *sop,* pivoted at *o,* and with its outer end resting upon a revolving cylinder covered with smoked paper. As shown in the figure, it is evident that the motion of *o* in the line *sop* would not be recorded, and to obtain a complete record of horizontal movements it is necessary to have two levers at right angles to each other. A complete arrangement of this kind is shown in the plan of fig. 2. Here the style *s* of the pendulum rests in slots in the short arms of two writing levers pivoted at *o* and *o'.* Motion of the ground in the direction *os* actuates only the lever *so'p',* motion in the direction *o's* actuates only *sop,* whilst motion in inter­

mediate directions actuates both. The length of the short arms of the levers is usually 1/6 or 1/12 of the long arms.

This type of apparatus has been replaced in Japan by what are called duplex pendulum seismographs. The change was made because it frequently happened that in consequence of the movement of the ground agreeing with the period of the pendulum, the latter no longer acted as a steady point, but was caused to swing, and the record became little better than that given by a seismoscope. Very long pendulums (30 to 40 ft.) are less subject to this disadvantage, but on the other hand their installation is a matter of some difficulty. A duplex pendulum (fig. 3) consists of an ordinary pendulum diagrammatically repre- sented by *ab,* connected by a universal joint to an inverted pendulum *dc.* The latter, which is a rod pointed at its lower end and loaded at *c,* would be unstable if it were not connected with *b.* Now imagine this system to be suddenly displaced so that *a* moves to *a'* and *d* moves to *d'.* In the new position *b* would tend to follow the direction of its point of support, whilst *c* would tend to fall in the opposite direction, and the bob of one pendulum would exercise a restraint upon the motion of the other. If, as in practice, the moment of *b* is made slightly greater than that of *c,* the system will come *slowly* to a vertical position beneath *a'd'.* In this way, by coupling together an ordinary pendulum about 3 ft. in length with an inverted pendulum 2 ft. 6 in. long, it is easy to obtain the equivalent of a slowly-moving very long pendulum which is too sluggish to follow the back-and-forth movements of its supports.

To complete an instrument of this description (see fig. 4) a point in the steady mass *b* is used as the fulcrum for the short arm of a light-writing index. This has a ball joint at *s*, a universal joint at *o* and a writing point at *p,* resting upon a piece of smoked glass. Attention was first directed to the possibility of rendering ordinary pendulums more truly astatic by Professor Thomas Gray, who suggested methods by which this might be accomplished. The method shown in fig. 4 is that devised by Professor J. A. Ewing. Records obtained from instruments of this description give information respecting the range and principal direction of motion, and show us that in a given earthquake the ground may move in many azimuths.

For obtaining an open diagram of an earthquake the best type of apparatus consists of a pair of horizontal pendulums writing their movements upon a moving surface. A simple form of horizontal pendulum as shown in fig. 5, consists of a rod, *op,* free to swing like a gate round a vertical or nearly vertical axis, *oo',* and loaded at some point *b.* In practice the weight *b* is pivoted on the rod whilst its outer end, *bp,* which writes on a smoked surface, is made extremely

light. When the frame of this arrangement is rapidly displaced through a small

horizontal range to the right and left of

the direction in which the rod points, the

weight *b* by its inertia tends to remain at

rest, and the motion of the frame, which

is that of the earth, is magnified in the

ration *op* to *bp.* This apparatus, of which

there are many types, was first introduced into seismometry by Professor

Ewing.

To obtain a complete record of hori­zontal motion, two of these pendulums are placed at right angles; and by crank- ing one of the writing levers, *o'p',* as shown in the plan of fig. 5, two rect- angular components of the earth’s move­ments are written side by side. Since the movements of the ground are frequently accompanied by a slight tilting, which would cause *b* or *b'* to swing or wander away from its normal position, a sufficient stability is given to the weights by inclining the axis of the instrument slightly forwards. Although by com­pounding corresponding portions of the diagrams given by instruments of this type, it is possible to determine the range and direction of the movement of which they are the resolved parts, their chief value is that they enable us to measure with ease the extent of any vibration, half of which is called its amplitude, and the time taken to make any complete back-and-forth movement, or its period. Now if *a* be the amplitude expressed in millimetres, and *t* the period expressed in seconds, then the maximum velocity of an earth particle as it vibrates to and fro equals 2τr*a/t*, whilst the maximum acceleration equals 4Λ∕Z2. The former quantity determines the distance to which a body, as for example the capping