proposed by Mr. T. Gray, @@1 Mr. C. A. Stevenson, @@2 and others. Prob­ably the best form would be that of a light spherical segment rolling on a level plane base and carrying a heavy bob fixed to it. To give some stability the bob should be placed so as to bring the centre of gravity a little under the centre of curvature. The centre of percussion, somewhat higher than this, would of course be the steady point, and a multiplying pointer might take the motion either from it or from any other convenient part of the rolling piece. All rolling seismometers—including rolling cylinders, which have been proposed by Mr Gray as single-freedom instruments, to register one component of horizontal motion—fail to act well, partly because of the comparatively great frictional or quasi-fric- tional resistance which is presented to the motion of the free mass, and partly because, owing to imperfections in the construc­tion and want of perfect rigidity in the materials, the ball or cylinder takes up a position in which there is an objectionably great stability as regards very small displacements. These objections make the use of rolling seismometers unadvisable, except perhaps for the rough measurement of violent earthquakes.

The seismographs which have been described draw a horizontal plan of the path pursued during an earthquake by a point on the earth’s surface. They take no note of the relation of the displace­ment to time,—an element which is required if we are to form any estimate of the violence of an earthquake from the record. With this view a different method of registration is also followed. The whole movement is resolved into rectilinear components, and these are separately recorded (by single-freedom seismometers) on a plate or drum which is kept in continuous movement, so that the record of each component takes the form of an undulating line, from which the number, succession, amplitude, velocity, and acceleration of the component movements can be deduced and the resultant motion determined. A single steady mass with two degrees of freedom may still be employed to record, separately, two components of horizontal motion ; but it is generally preferable to provide two distinct masses, each with one degree of freedom. The principal instrument of this class is the horizontal pendulum seismograph, @@3 which has been used to record Japanese earthquakes since 1880. It consists of two horizontal pendulums, set at right angles to each other, each supplying a steady point with respect to horizontal motions transverse to its own length. Each pendulum is pivoted about two points, on an axis which is nearly vertical, but in­clined slightly forwards to give a suitable degree of stability. In some forms of the instrument the pivoted frame of the pendulum is light, and the inertia is practically all furnished by a second piece or bob pivoted on the frame about a vertical axis through the centre of percussion of the frame. This construction has the advantage of compactness and of making the position of the steady point at once determinate. But a simpler construction is to at­tach the bob rigidly to the frame. This shifts the steady point a little way outwards from the position it would have if the bob were pivoted. In either construction a prolongation of the pendu­lum beyond the bob forms a convenient multiplying index. Fig.

5 shows a complete horizontal pendulum seismograph (with pivoted bobs). Two rectangular components of earthquake motion are re­corded radially on a revolving plate of smoked glass, which receives its motion through a friction roller from a clock furnished with a fluid-friction centrifugal governor. The clock may either be kept going continuously, in expectation of an earthquake at any moment,

or be started into motion by an electric seismoscope when the earliest indications of an earthquake are felt. The former plan is practicable only when the instrument can receive careful attend­ance and where earthquakes occur often. It has the drawback that the circle which is drawn by each pointer as the plate revolves below it gradually broadens, partly because of warping anil tempera­ture changes in the supports and partly because of actual tilting of the ground. As an earthquake generally begins with comparatively insignificant movements, there is not much to object to in having the plate at rest to begin with, provided a sufficiently sensitive starting seismoscope be used. A suitable arrangement for this pur­pose is one due to Palmieri : a short pendulum hangs over a cup of mercury, in the centre of which a depression is formed by an iron pin, whose top is a little lower than the surface of the mercury. The pendulum ends in a platinum point, which stands clear in the centre of this depression, but touches the edge whenever a horizontal movement of the ground takes place, thereby closing the circuit of an electro-magnet, which starts the clock. In the most recent form of the horizontal pendulum seismograph the bobs are fixed to the pivoted frames, and the pointers are arranged to trace their records side by side. Records with instruments of this class, besides giving much additional information, agree with those of the duplex pendulum in show­

ing that earthquake

motion is a tangle

of waves in all azi­

muths. This will

be seen by reference

to fig. 6, which shows

a small portion of

an earthquake re­

gistered by a pair of

horizontal pendu­

lums. Contemporary parts of the two records are shown together, the straight radial lines marking seconds of time. The phases of the two components are con­

tinually changing, and when

the two are compounded the

result is a path having the

same characteristics as those of

the diagram in fig. 3. Fig. 7

gives the result of compounding

the records of fig. 6 during three

seconds, while the range of move­

ment was a maximum.

To register the vertical com­

ponent of earthquake motions

we require to suspend a mass

with vertical freedom. Most

ways of doing this give too

much stability, as, for instance,

when a weight is hung from a spiral spring or carried by a hori­zontal bar that is fixed to a wall or table by a flexible spring joint. This last is the vertical motion seis­

mometer which was used by the British Association Commit­tee at Comrie in 1842.

Another form, me­chanically equivalent

to this, is a weighted horizontal bar, pivot- ed on a fixed hori­zontal fulcrum, and held up by a spiral spring, stretched from a point near the fulcrum to a fixed support above.

This mode of suspen­sion is still too stable, though less so than if the spring were directly loaded. To make it nearly a-

static Mr T. Gray @@4 proposed the use of a tube containing mercury, connected with the bar in such a manner that when the bar goes down the mercury, running to­wards one end of the tube, has the effect of increasing the weight, and when the bar goes up an opposite effect occurs. This plan is open to the objection that the mercury is disturbed by horizontal movements of the ground. A simpler plan is shown in fig. 8. @@5 There the pull of the spring is applied at a short distance *v* below the plane of the bar. Hence when the weight goes down the spring,

@@@1 Gray, *Phil. May.,* September 1881.

@@@2 Stevenson, *Trans. Roy. Scot. Soc. of Arts,* February 1882.

@@@3 Ewing, “ On a New Seismograph,” in *Proc. Roy. Soc.,* No. 210, 1881, or

*Trans. Seis. Soc. of Japan,* December 1880.

@@@4 Gray, *Trans. Set's. Soc. Jap.,* vol. iii. p. 137.

@@@5 Ewing, *Trans. Seis. Soc. Jap.,* vol. iii. p. 140.