IV.—*On the Objects, Construction, and Use of certain new Instruments for Self-registration of the Passage of Earthquake Shocks.* *By* ROBERT MALLET, ESQ., *Mem. Ins. C. E., M. R. I. A., Pres. Geol. Soc. Ireland, &c.*

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INSTRUMENTS previously designed for this purpose have not possessed the power of self-registration; they have consisted either in the trace left by the motion of a viscid fluid on the containing vessel, when the latter is shaken, or they have been upon the principle of the inverted pendulum, or watchmaker's noddy. Instruments so constructed are objectionable, because, having themselves times of vibration of their own, which may conflict with those of the earthquake shock, they are liable to fail for want of delicacy. They also possess several inconveniences of a mechanical kind, in being adapted to self-registration.

The objects to be attained in the instruments which the author has had in view are:

The self-registration—

1st. Of the time of transit, or "wave period," at a given point of the earth's surface, of an earthquake shock, or earth wave, noting same to a small decimal of a second of time.

2nd. Of the vertical element of dimension, or altitude of the earth wave, at the moment of its transit, whether the wave be a positive or a negative one.

3rd. Of the horizontal element of dimension, or amplitude of the wave, at the same moment.

4th. Of the direction, as to azimuth, of the wave transit.

The principle adopted, by means of which the wave or shock shall act in giving motion to the instrument, consists in availing ourselves of the oscillation of a column of mercury, in two vertical and four horizontal glass tubes, of peculiar construction. One end of the column of mercury, in each tube, is so adjusted *just* in contact with one pole of a constant galvanic battery, that the oscillation produced in the mercurial column by the wave, in passing, breaks contact. The time during which the contact remains broken is proportionate to the amount of the vertical and horizontal elements of the wave. The breach of contact releases one or more of six pencils at the instant of its occurrence, and, until contact is restored, either of these continues to describe a trace upon a ruled sheet, placed upon a cylindrical barrel, which is carried round by the astronomical clock. The length of this trace is, therefore, a graphic representation of the amount of the respective element of the wave, and the pencil which marks it indicates the direction of the oscillation, whether vertically positive or negative, or horizontally from any point of the compass.

The velocity of wave transit is constant for each instrument, inasmuch as it is constant for any given formation upon which the instrument may be established; hence the time of broken contact is not perplexed by any consideration of the velocity of the wave.

A somewhat similar arrangement marks, upon each of four dials, the hour, minute, second, and fraction of a second, at which the crest of the wave has passed the point of the observatory, or locus of the instrument. This is of peculiar importance, in order to ascertain the rate of progress of the wave between two distant observatories.

The instrument will continue to register by itself for twelve hours at a time, and at such an interval its registrations require to be read off and noted.

It is capable of registering waves of vertical or highly inclined transit, as well as those whose motion of translation is horizontal; but in places where waves of both orders may be expected to occur simultaneously, certain additions will be necessary, in order subsequently to distinguish the recorded elements of each system of waves.

Fig. 4.

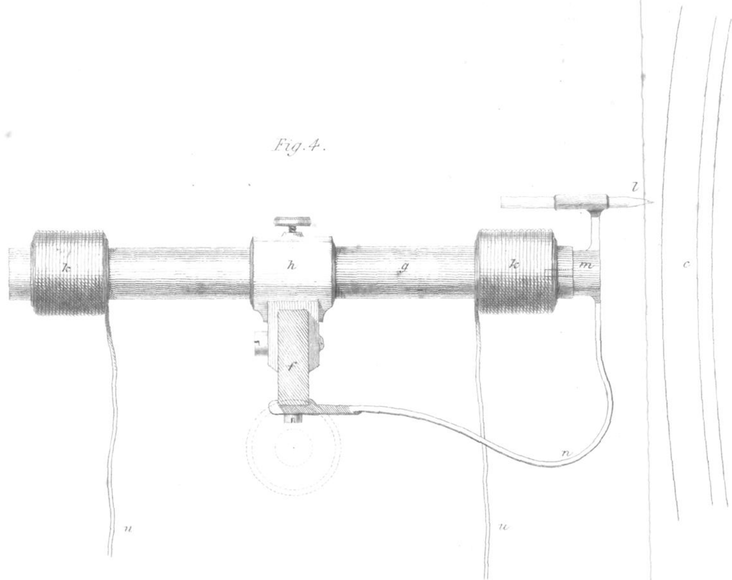


Fig. 5.

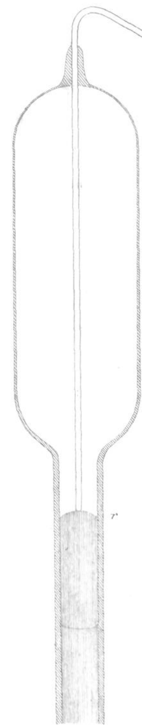
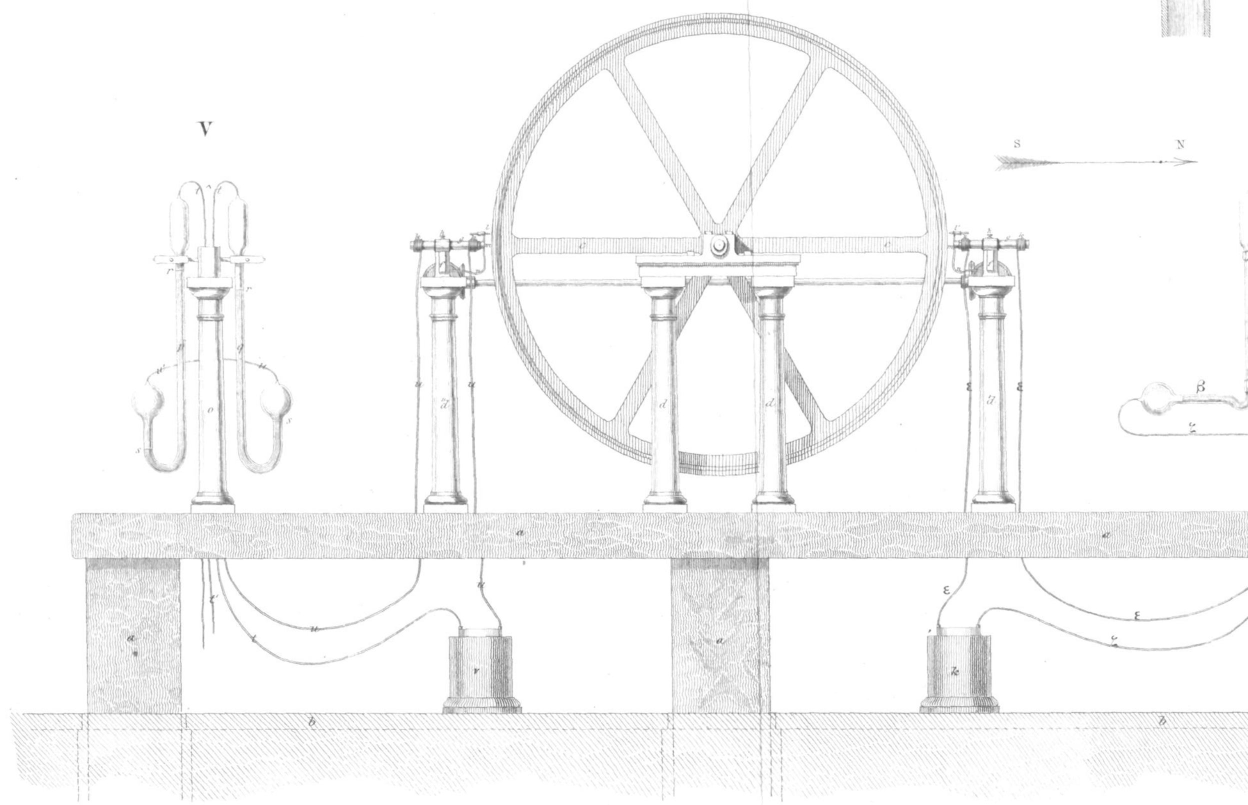
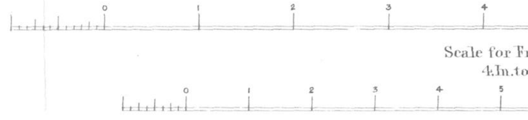


Fig. 1.





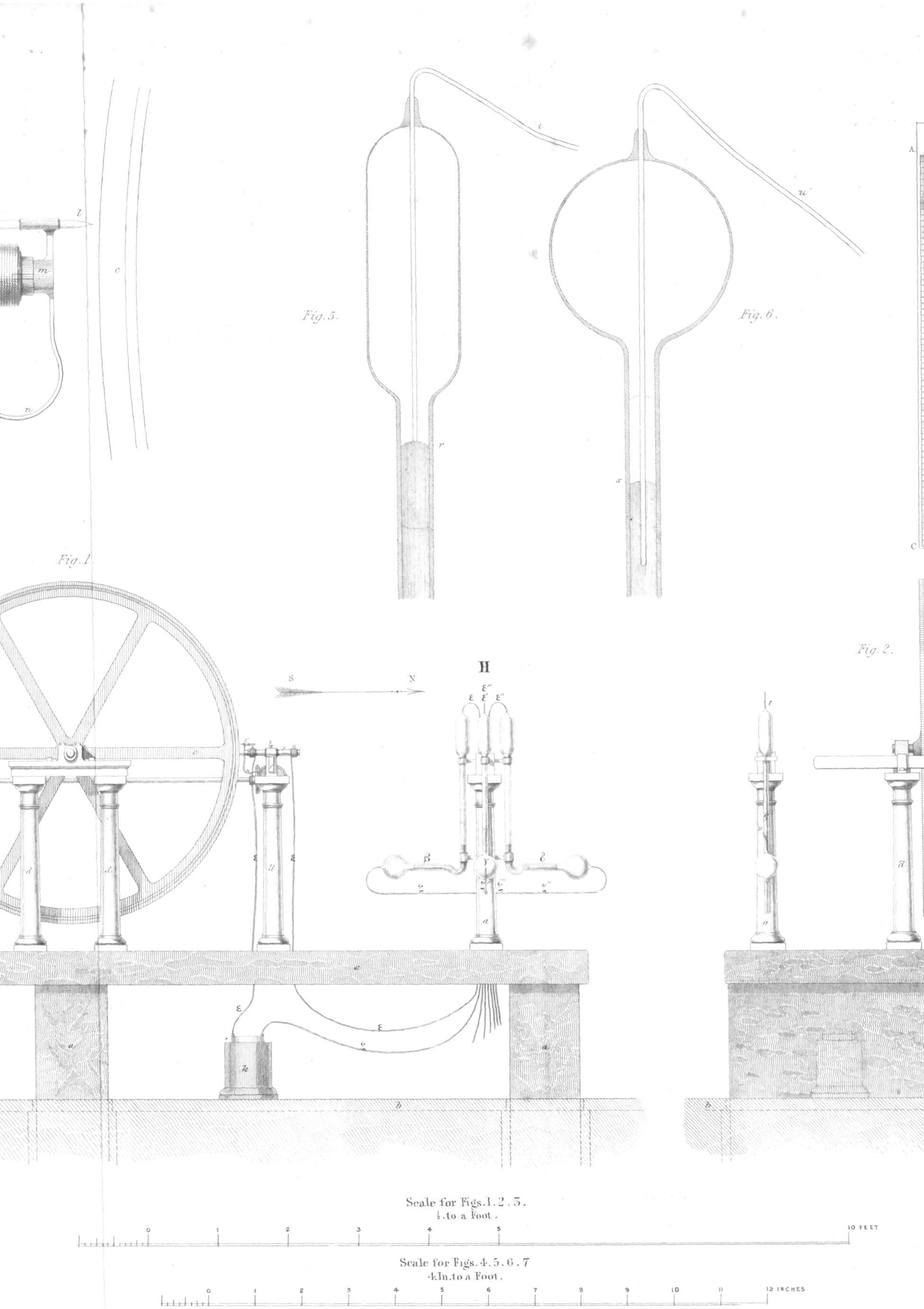
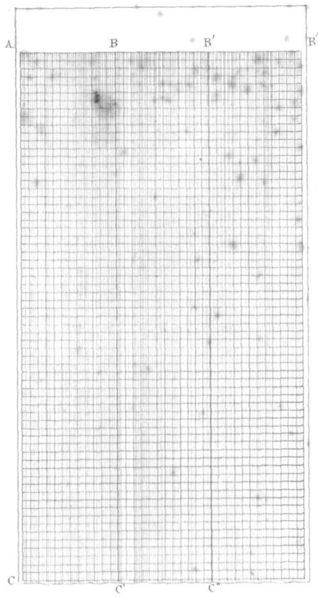


Fig. 1.
Fig. 2.
Fig. 5.
Fig. 6.
H
S
N
Scale for Figs. 1. 2. 3.
¼. to a Foot.
10 FEET
Scale for Figs. 4. 5. 6. 7
4. In. to a Foot.
12 INCHES

Fig. 7.



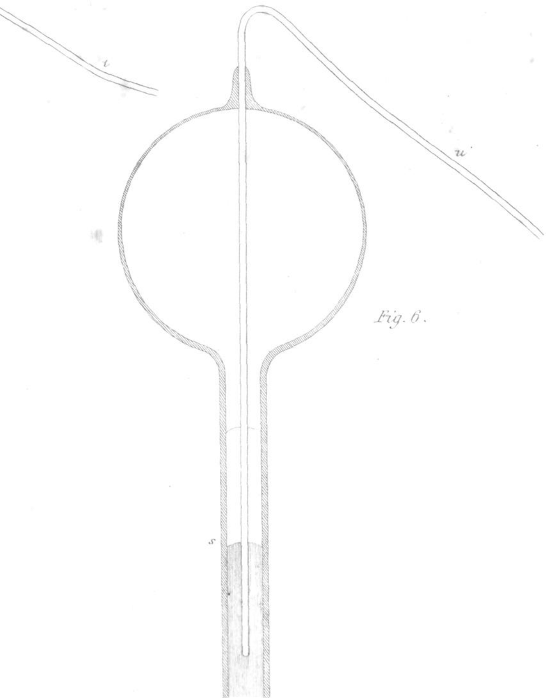


Fig. 6.

Fig. 3.

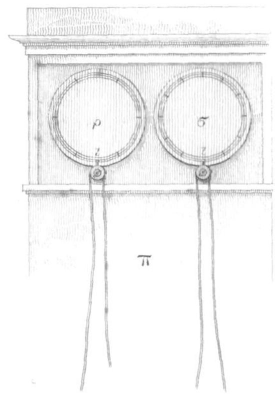
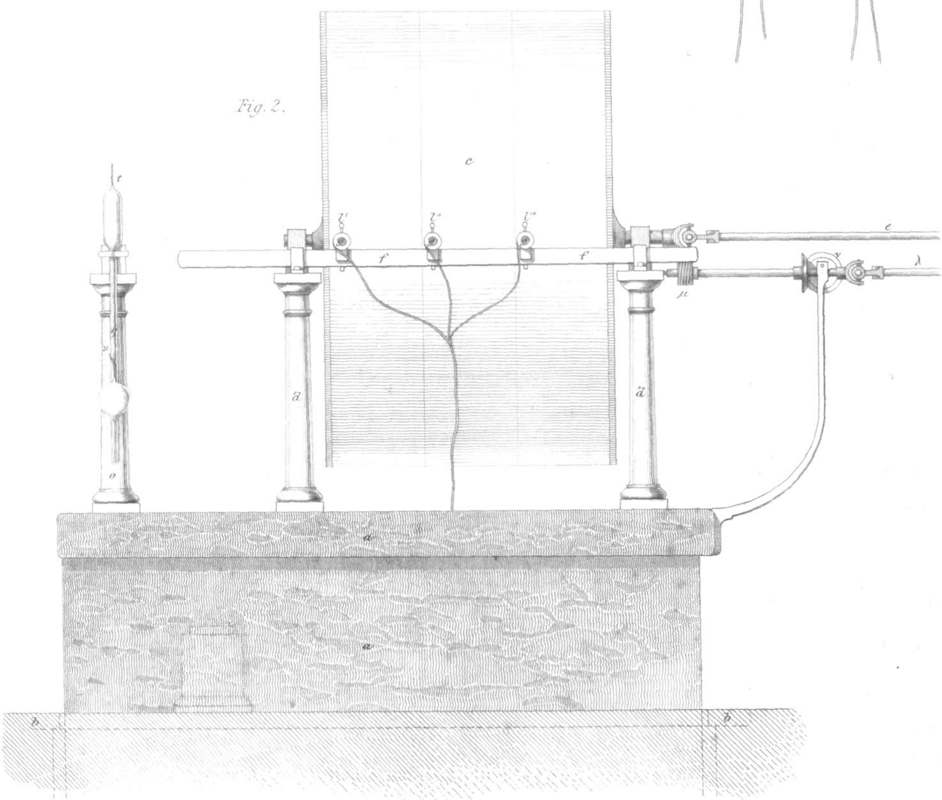
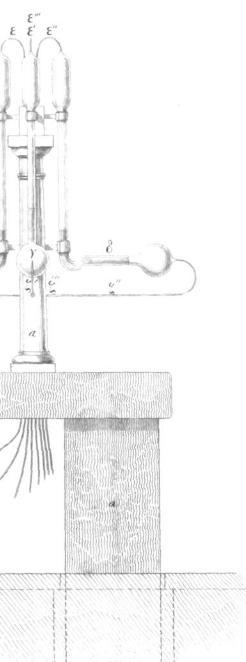


Fig. 2.



H



Figs. 1. 2. 3.
a Foot.
5 10 FEET

gs. 4. 5. 6. 7
a Foot.
6 7 8 9 10 11 12 INCHES

EXPLANATION OF THE PLATE.

Fig. 1 is a side elevation of the whole instrument.

Fig. 2 is an end elevation of the same, omitting the horizontal element tubes, to avoid confusion.

Fig. 3 is an elevation of one face of the transit dials.

Fig. 4 is an enlarged view of the electro-magnetic apparatus, for the movement of the registering pencils.

Figs. 5 and 6 are enlarged views of the upper and lower bulbs of the oscillation tubes.

Fig. 7 shews the mode in which the paper is ruled for the registration cylinder.

The same letters refer to all the figures, as far as is possible.

The instrument is firmly secured to the surface of a large, heavy slab of marble, tenoned into three vertical blocks, *a*, *a*, *a*, which are built into masonry, forming the floor of the observatory, *b*, *b*. *c*, a cylinder, formed of staves of red cedar, screwed to the circumference of two or more sets of brass arms, and prepared to receive the sheet of ruled paper, A B C, Fig. 7. The circumference of this cylinder is 180 inches, and it is caused to revolve once in a minute, being connected with the astronomical clock by the shaft *e* ; any point in the circumference, therefore, passes over three inches in a second of time. The horizontal axis of the cylinder is supported upon the columns *d*, *d*.

At either side of the cylinder, and parallel to its axis, is a straight bar of brass, *f*, *f′*; each of these carries three separate sets of marking apparatus, at equidistant intervals along the bar, the interval being equal to the spaces AB, BB′, B′B″, upon the ruled sheet, viz. twelve inches; and, by means of the endless screw, μ, working into a screw rack on the lower edge of each of the bars, and rotation given to the screw and shaft, λ, by the clock, a slow motion, in the direction of its own length, is given to each bar, so that it moves over twelve inches in twelve hours; and then, by a simple coupling, attached to the moving gear of the clock, the motion is reversed, and the bars move in the opposite direction over twelve inches, at the same rate as before, and so on.

These bars, together with their moving gear, the mitre wheels, *ν*, &c., are supported by the columns *d′*, *d″*, all of which are of brass.

The portion of the instrument at V receives the oscillation from the vertical element of positive or negative waves, and that at H receives the oscillation from the horizontal elements of the same, in whatever azimuth.

p is a glass tube of about $\frac{6}{10}$ of an inch in diameter, having at top and bottom bulbs blown of the form shewn, and more at large, in Figs. 5 and 6. These bulbs are of equal capacity. The tube is so filled with boiled mercury that, when closed, the tube being vertical, the lower surface of the mercury shall stand at *s*, in one leg of the syphon, and the upper surface at *r*, in the other leg, the air being compressed in the lower, and rarified in the upper, bulb, by the insistent column. A stout platina wire is sealed into each bulb, and so adjusted as to position that the extremity of that in the upper bulb shall *just* be in metallic contact with the surface of the mercurial column, as shewn more at large in Fig. 5. The platina wire in the lower bulb is *immersed* in the other end of the mercurial column, as in Fig. 6. The wire *t*, from the upper bulb, passes down through the brass column *o*, and is connected with one pole of the small, constant, galvanic battery, *v*, from the opposite pole of which a wire is carried, which, being properly insulated, is wound round the bar of soft iron *g*, first at one end, then at the other, and passing down at *u*, is finally connected with the platina wire *u*; sealed into the lower bulb of the syphon tube *p*.

Thus the bar *g* becomes an electro-magnet, the current passing round it, through the wires, and through the mercurial column in the syphon tube.

Referring now to Fig. 4, *f* is the end of the traversing bar before described as carrying all the magnets and marking apparatus, of one of which, *g* is the soft iron bar, passing through the screw socket *h*, and surrounded by the helices K, K; *c* is part of the circumference of the large cylinder holding the ruled paper; *l* is a pencil (all the pencils are black at the V side of the cylinder, and red at the H side), held in an iron socket, formed in one piece with the armature *m* and with the spring *n*, the position and form of which are so adjusted that while ever a current continues to pass round the bar *g*, the armature *m* is held fast in contact with the magnetic pole, and the pencil point kept out of contact with the ruled paper on the cylinder; but the instant the current ceases, the action of the spring *n* presses the pencil point against the paper, and continues it there until the restoration of the current enables the magnet again instantly to lift it off; and in the interval, as the cylinder has continued to revolve, the pencil has marked a line, the length of which is in proportion to the interval of time during which the current was suspended.

When an earthquake positive wave passes the instrument, a sudden jerk upwards is given to the whole instrument; the column of mercury *rs* is therefore momentarily depressed by its inertia, and the upper surface *r*, receding from the extremity of the wire *t*, contact is broken, and the current ceasing to pass round the bar *g*, it ceases to be magnetic, and the pencil instantly commences to mark upon the ruled paper on the cylinder, until, by the restoration of equilibrium in the mercurial column, after the transit of the wave, the current is again restored.

Now, as the depression of the surface of the mercury *r* is proportionate to the altitude of the positive wave, and as the length of the mark made by the pencil is proportionate to the same, the pencil registers the altitude of the wave.

It is possible that negative earthquake waves of horizontal transit occasionally pass the earth's surface (those in which the wave crest is a hollow, instead of an elevation). To register these the syphon tube *q* is arranged similar in all respects to *p*, except that the arrangement of the wires with reference to the bulbs is reversed—the wire in the lower bulb *s* being *just* in contact, and that in the upper bulb *r*, *immersed* in the mercury, so that a sudden jerk *downwards*, may break contact, in place of one *upwards*, as in the former case.

The registrations of *p* are made with a black pencil, *l*, on one side of the cylinder, and those of *q* with a red pencil, *l'*, upon the opposite side, both being registered upon the column BAC of the ruled sheet; two out of the six marking apparatus are thus employed; the remaining four apply to the syphon tubes, α, β, γ, δ, which register the horizontal element of the wave, and its direction in azimuth. These four tubes, only three of which are visible in the figure, are placed with their horizontal limbs, β and δ, north and south; α and γ east and west.

The arrangements of the surfaces of the mercurial columns, and of the wires and magnets, are precisely similar to those described for the vertical elements, except that contact is broken in each case at the surface in the horizontal limb. Thus, when the wave passes from south to north, contact is broken in the tube β; when from north to south, in the tube δ; and so by east and west shocks. When the direction of shock is at any intermediate point, contact is broken in two tubes at once, as, for example, in N and E; and the direction of the wave motion is got by taking the resultant of the two motions, as read off from the cylinder paper. The wires from the upper bulbs, $\epsilon, \epsilon', \epsilon'', \epsilon'''$, and from the lower ones, $\zeta, \zeta', \zeta'', \zeta'''$, are connected with the battery κ, and with the four separate sets of marking magnets, of which two are seen at l'', l''', in Fig. 2, precisely in the way before described,—all the wires are for convenience twisted together, as there shewn, although individually insulated.

The horizontal elements of North and South waves are marked, the former in red, the latter in black, on the column B′BC′ of the ruled sheet, Fig. 7, and those of the East and West waves in black on the column B′ B′C″ of the same. It is obvious that the ordinate AB on the ruled paper, is that of time, and the ordinate AC, or the circumferential motion of the cylinder, that which corresponds to the dimension and direction of the wave.

The place in which a pencil mark occurs on the ruled sheet, with reference to AB, BB, or B′B″, therefore, roughly determines the time of the shock or wave transit; but it is essential to know this epoch with minute accuracy. Four brass dials are therefore connected with the astronomical clock, two of which, ρ and σ, are shewn in Fig. 3,—the other two being at the opposite side or at the ends of the case π. These are so arranged, that one dial revolves once in twelve hours; another, once in one hour; the third, once in a minute; and the fourth, once in a second. To each of these is adapted a magnetic marking apparatus, precisely similar to those already described, Fig. 4, except that the marking instrument is a fine steel point, which strikes the brass, in place of a pencil point, and makes a fine dot, capable of being readily burnished out after observation.

The wires from these magnets carry a current through a mercurial column in a single tube, much in the same way as described for the vertical element oscillation tubes, but the range of oscillation of this is extremely limited, so that the current is instantly restored, as soon as broken. Thus, at the instant of the arrival of the shock, a mark is simultaneously made on each of the four dials, by which the time of its passage is registered to a fraction of a second of time. The astronomical clock is not shewn in the drawing, to avoid complexity. The instrument, as thus designed, is self-registering for twelve hours without attention; it must then be examined, and the registrations, if any, read of; but no alteration or re-adjustment is requisite at any time, beyond winding the clock, and changing the ruled paper.

It has been suggested that a provision to guard against the effect of expansion in the mercurial columns, as affecting the points of contact, *rs*, &c., may be requisite. The inventor is not of this opinion; but if it be so, the provision is easily made. Alterations of temperature will not affect the instrument in any other way, so as to derange its action. These instruments are intended for the registration of those minute earthquake shocks which have of late been ascertained to be so frequent in almost all countries. The principle is applicable to those of greater magnitude and force; but the instrument would require certain modifications to meet the greater violence of the motions it would be then called upon to record.