(No Model.) 4 Sheets—Sheet 1.

E. WESTON.

STANDARD TANGENT GALVANOMETER.

No. 400,980. Patented Apr. 9, 1889.

Fig. 1.

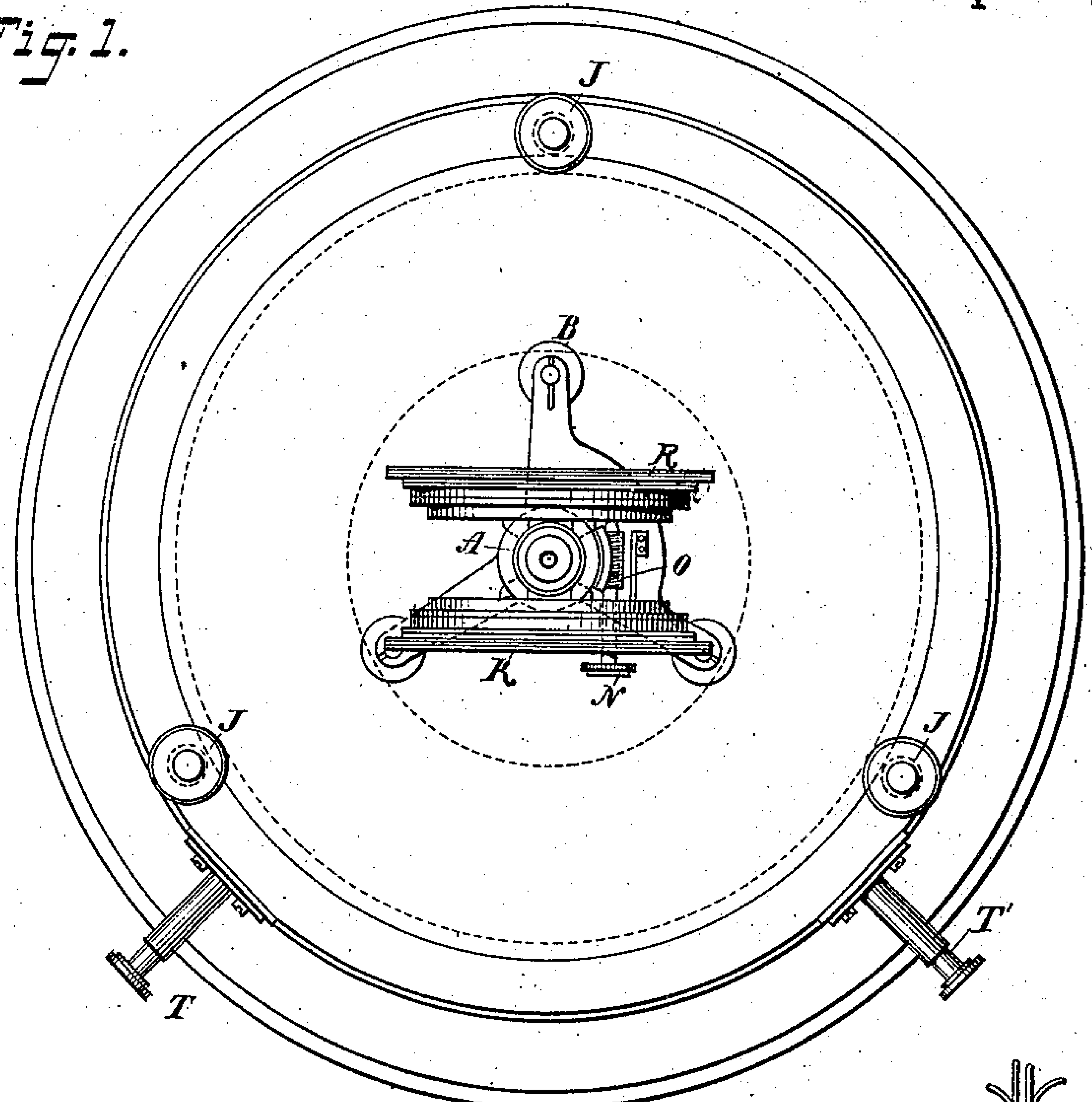


Fig. 12.

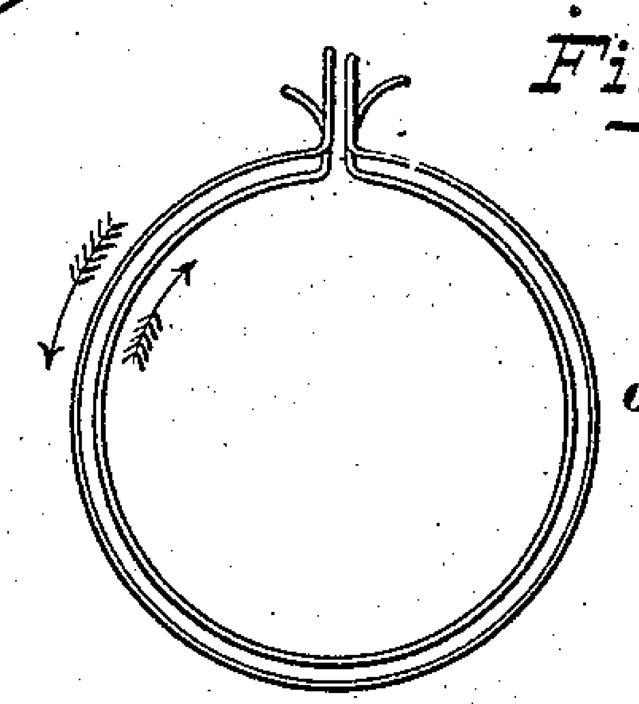
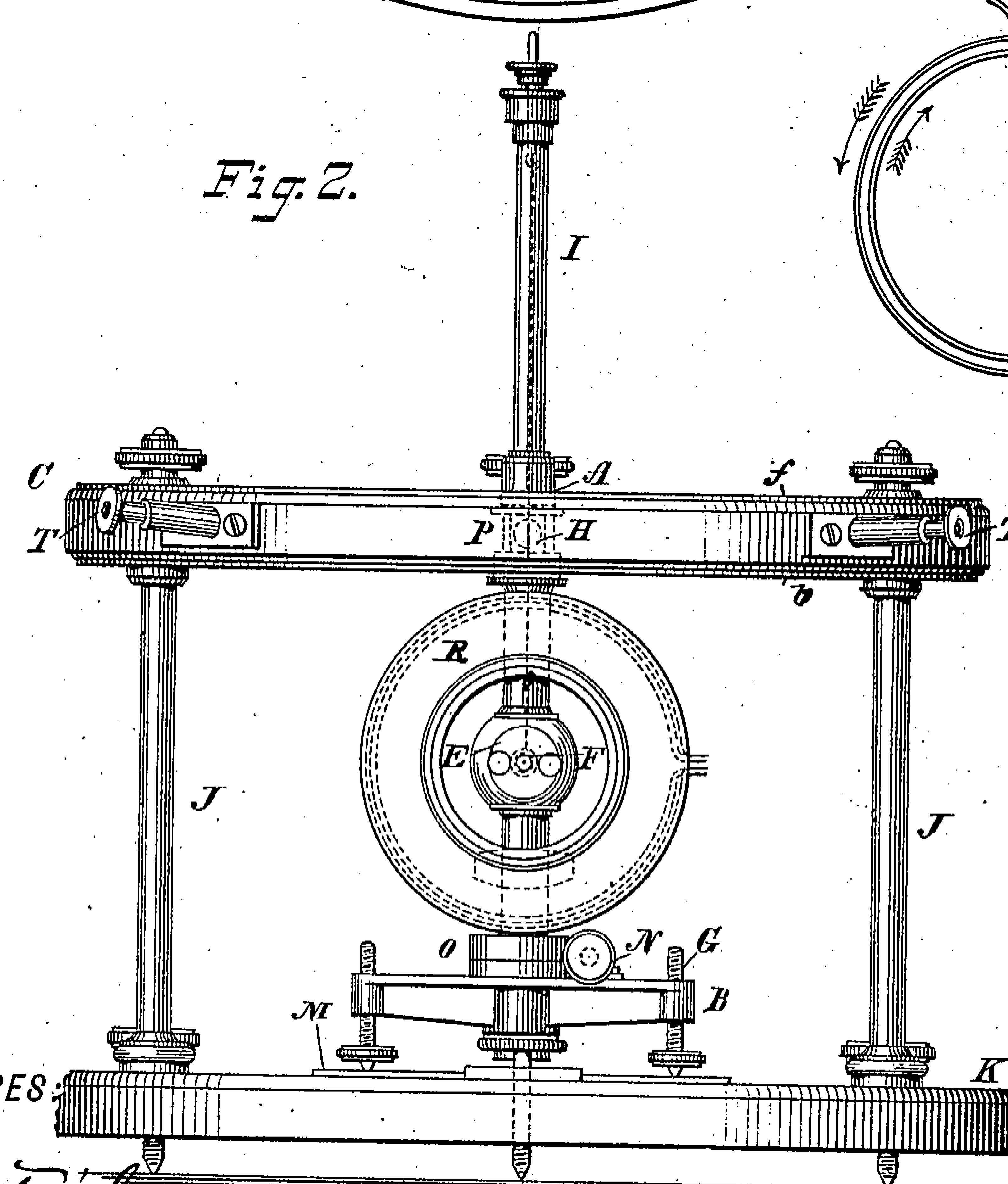


Fig. 2.



WITNESSES:

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(No Model.) 4 Sheets—Sheet 2.

E. WESTON.

STANDARD TANGENT GALVANOMETER.

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Fig. 3.

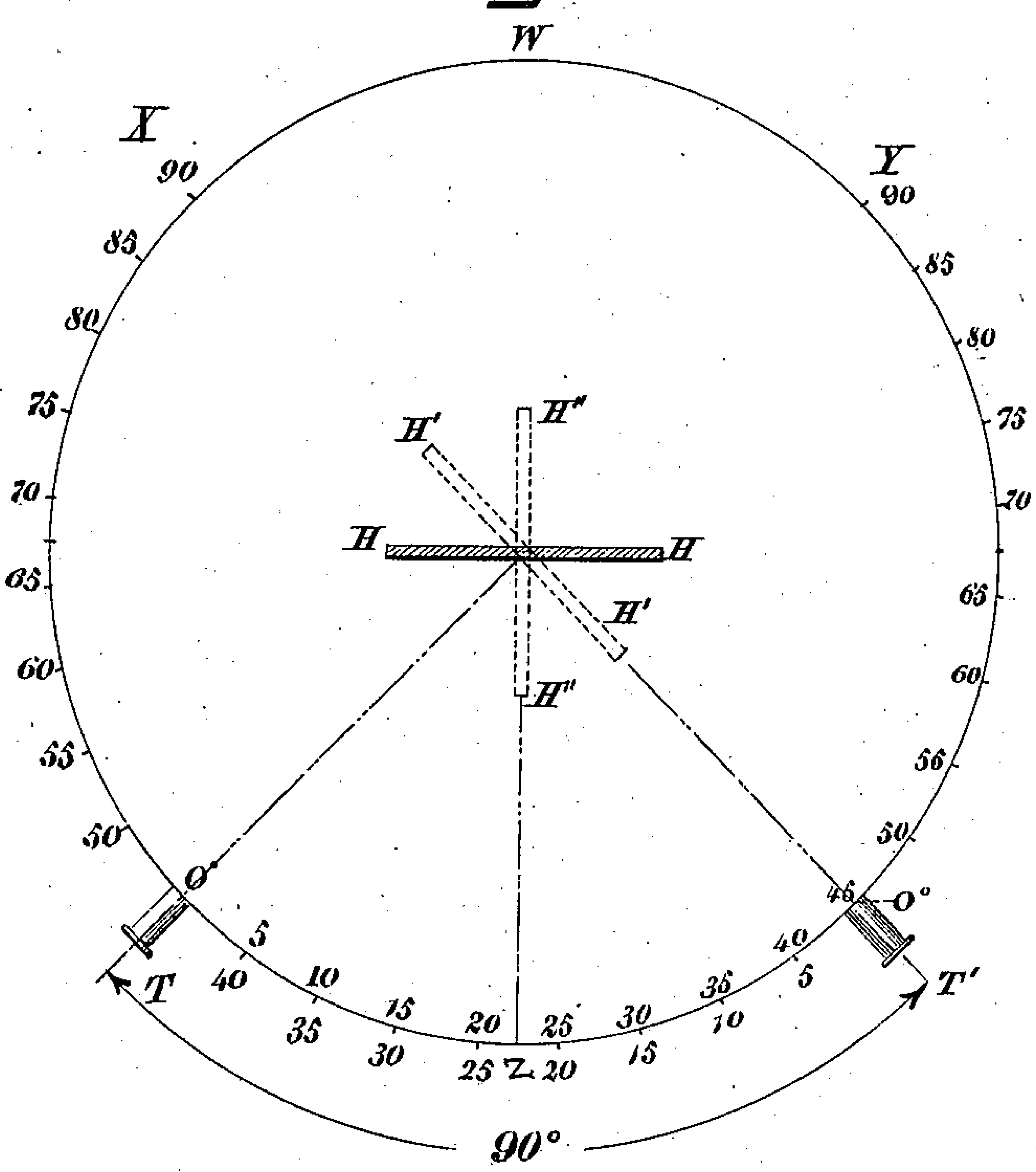


Fig. 5.

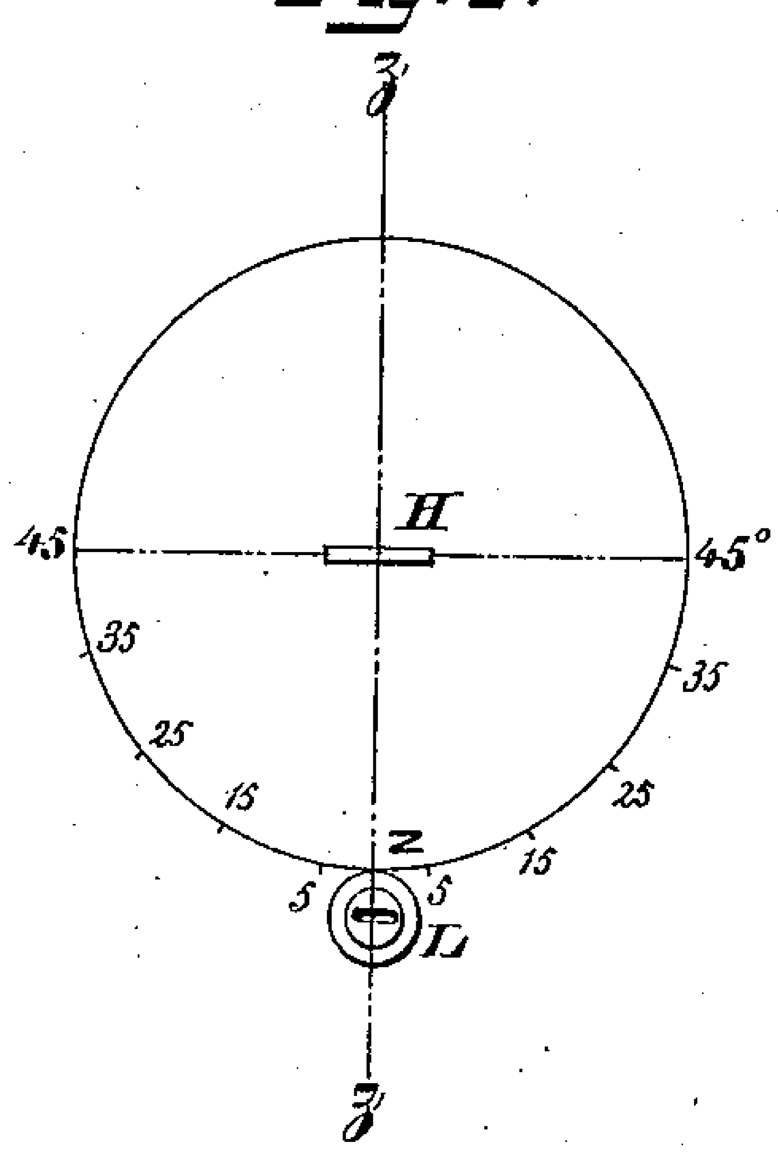


Fig. 4.

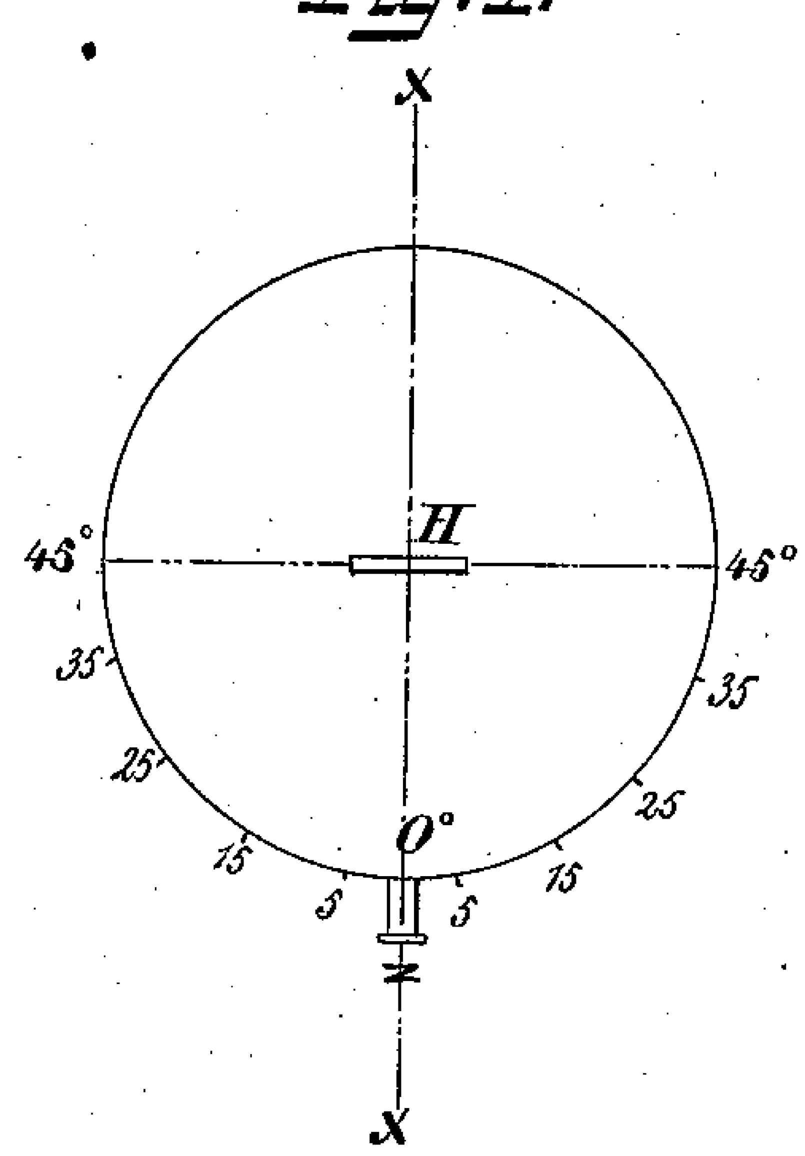
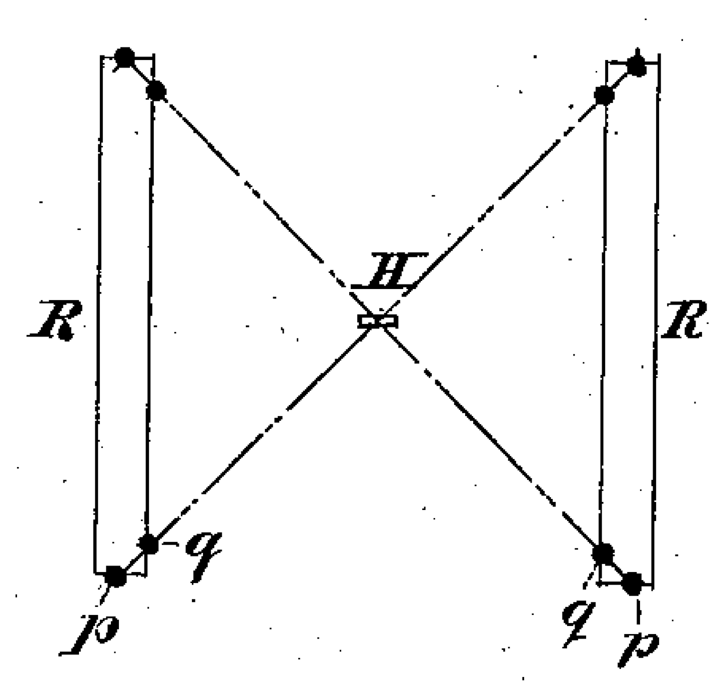


Fig. 18.



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4 Sheets—Sheet 3.

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STANDARD TANGENT GALVANOMETER.

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Fig. 6.

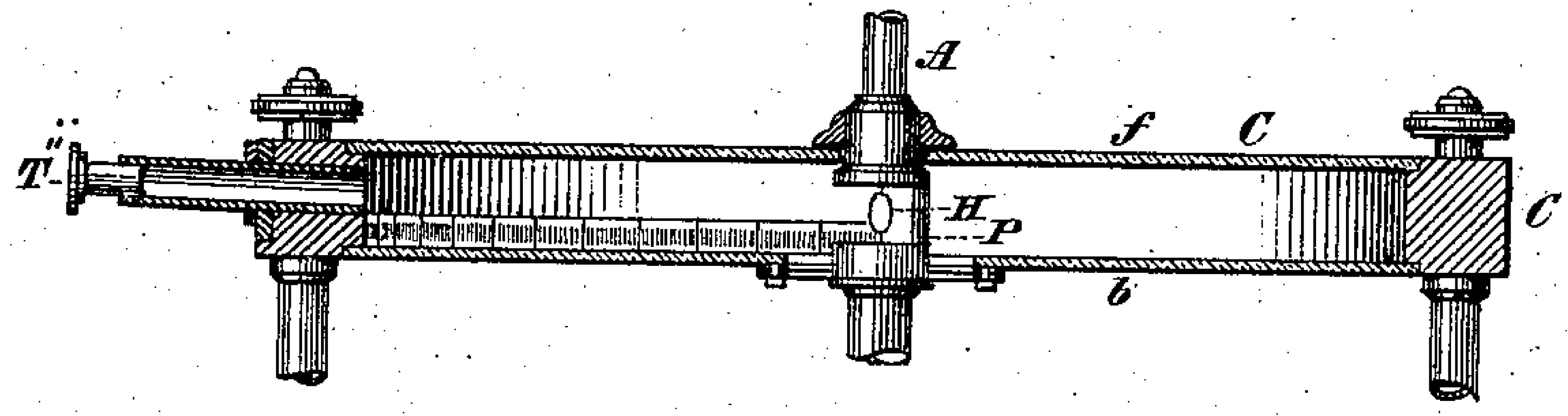


Fig. 7.

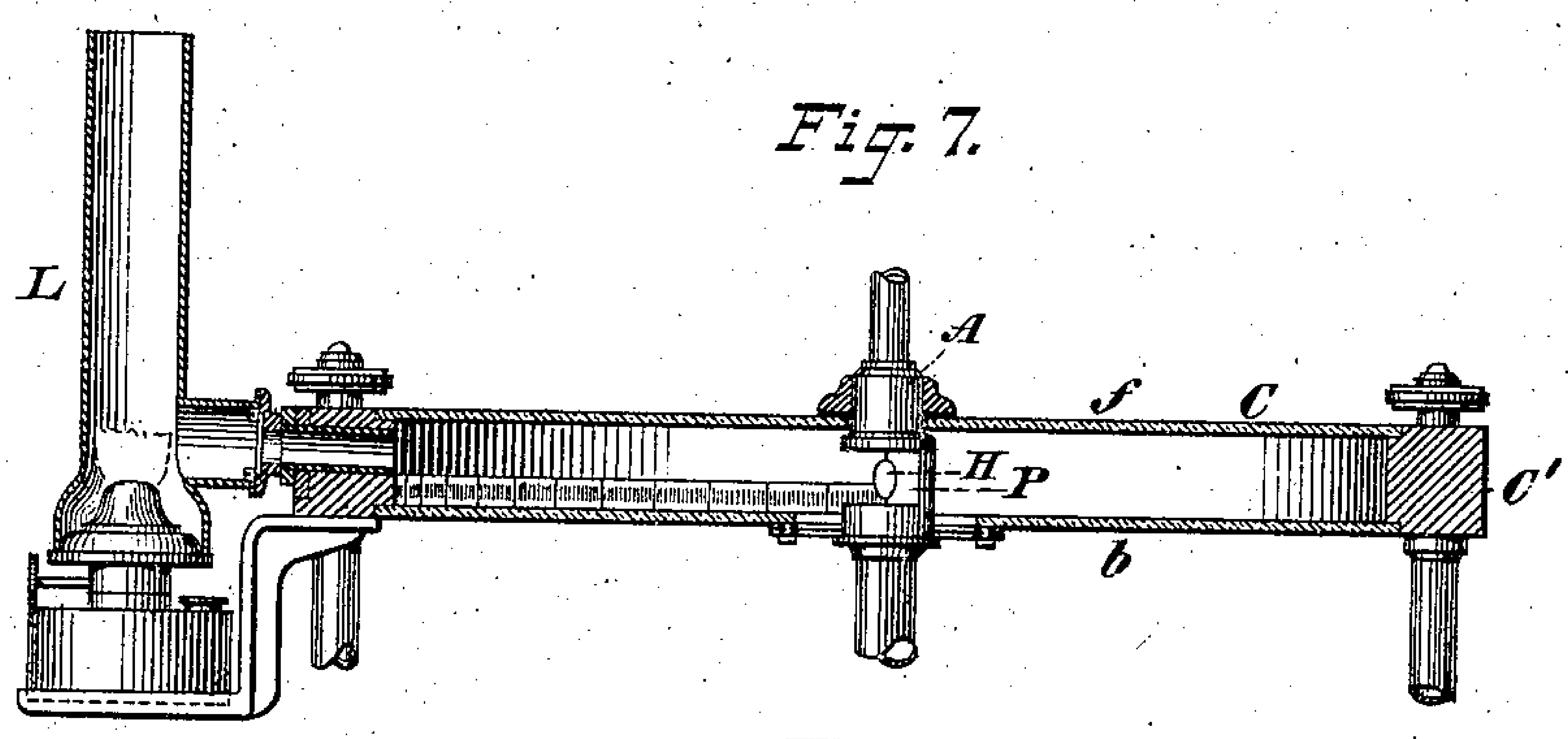


Fig. 8.

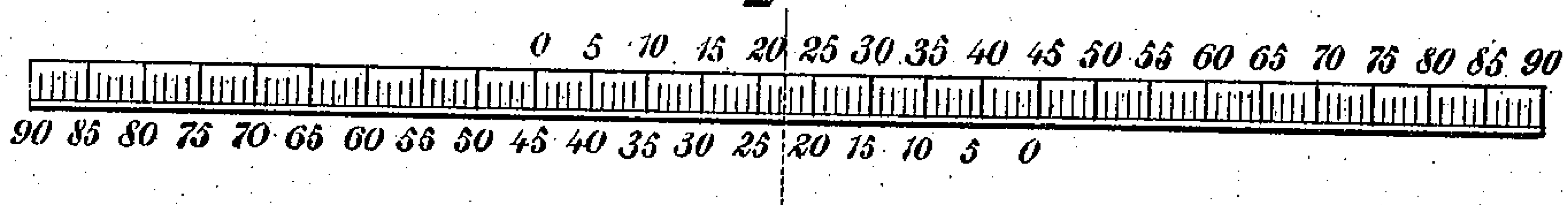


Fig. 11.

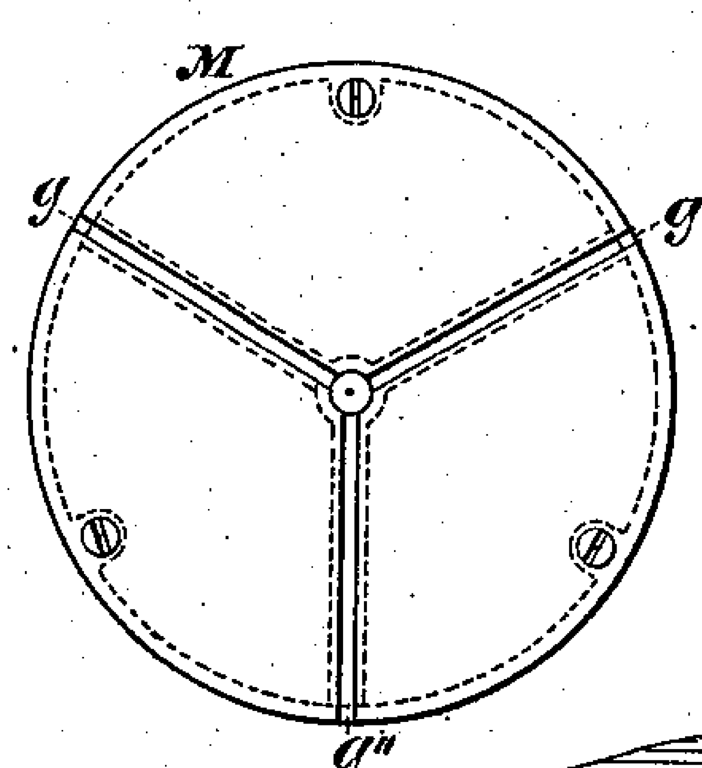


Fig. 9.

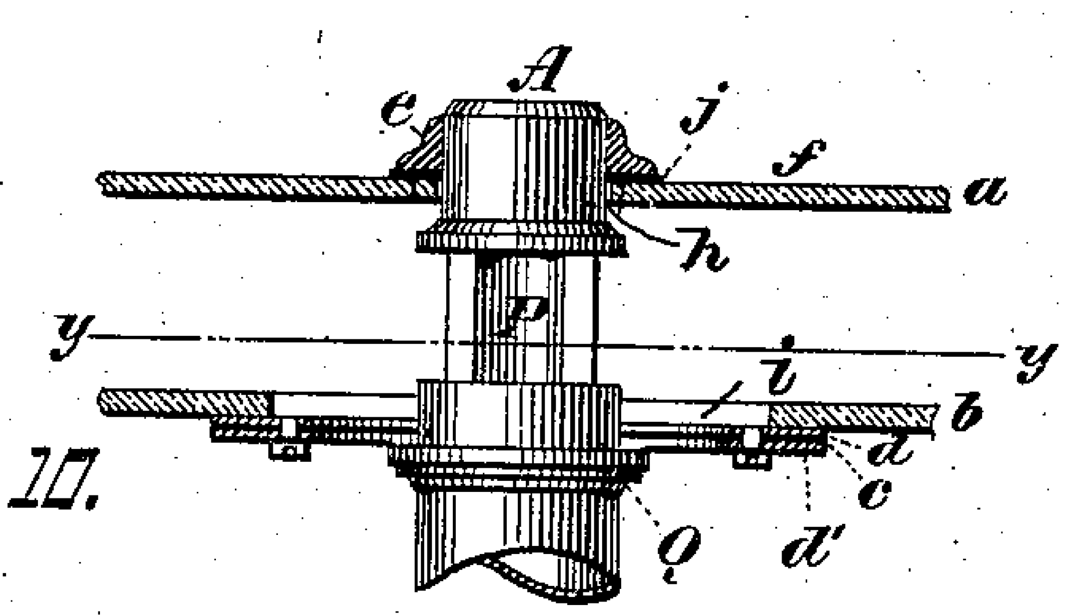
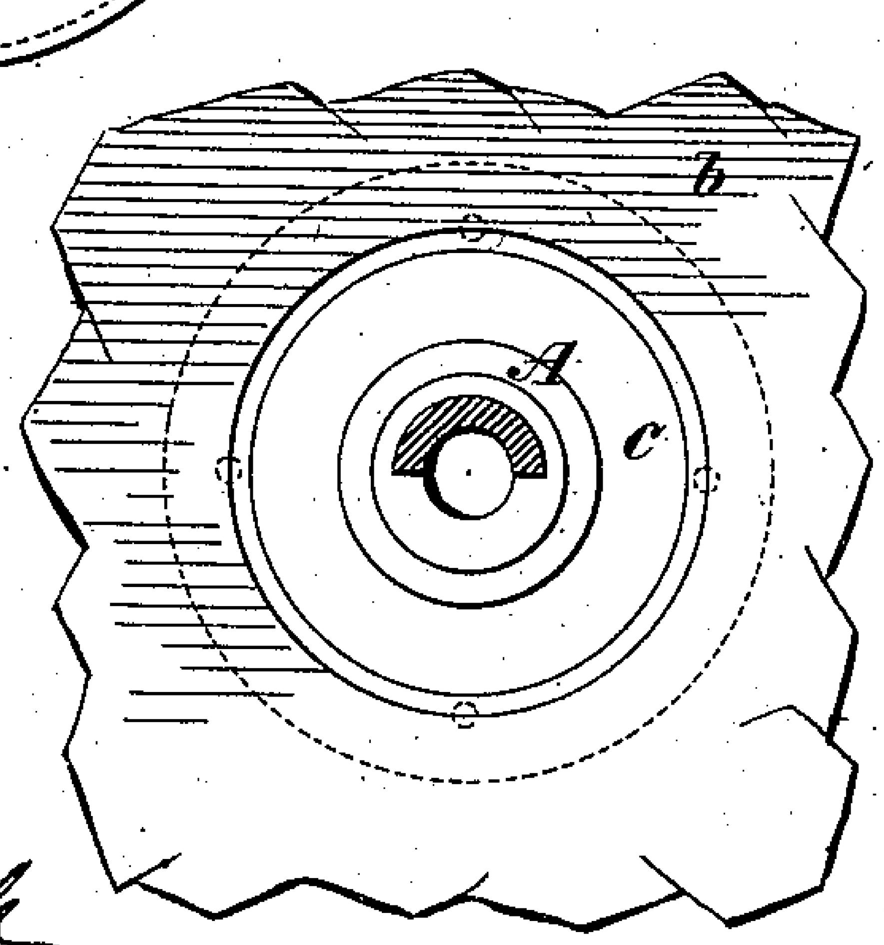


Fig. 10.



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STANDARD TANGENT GALVANOMETER.

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Fig. 13.

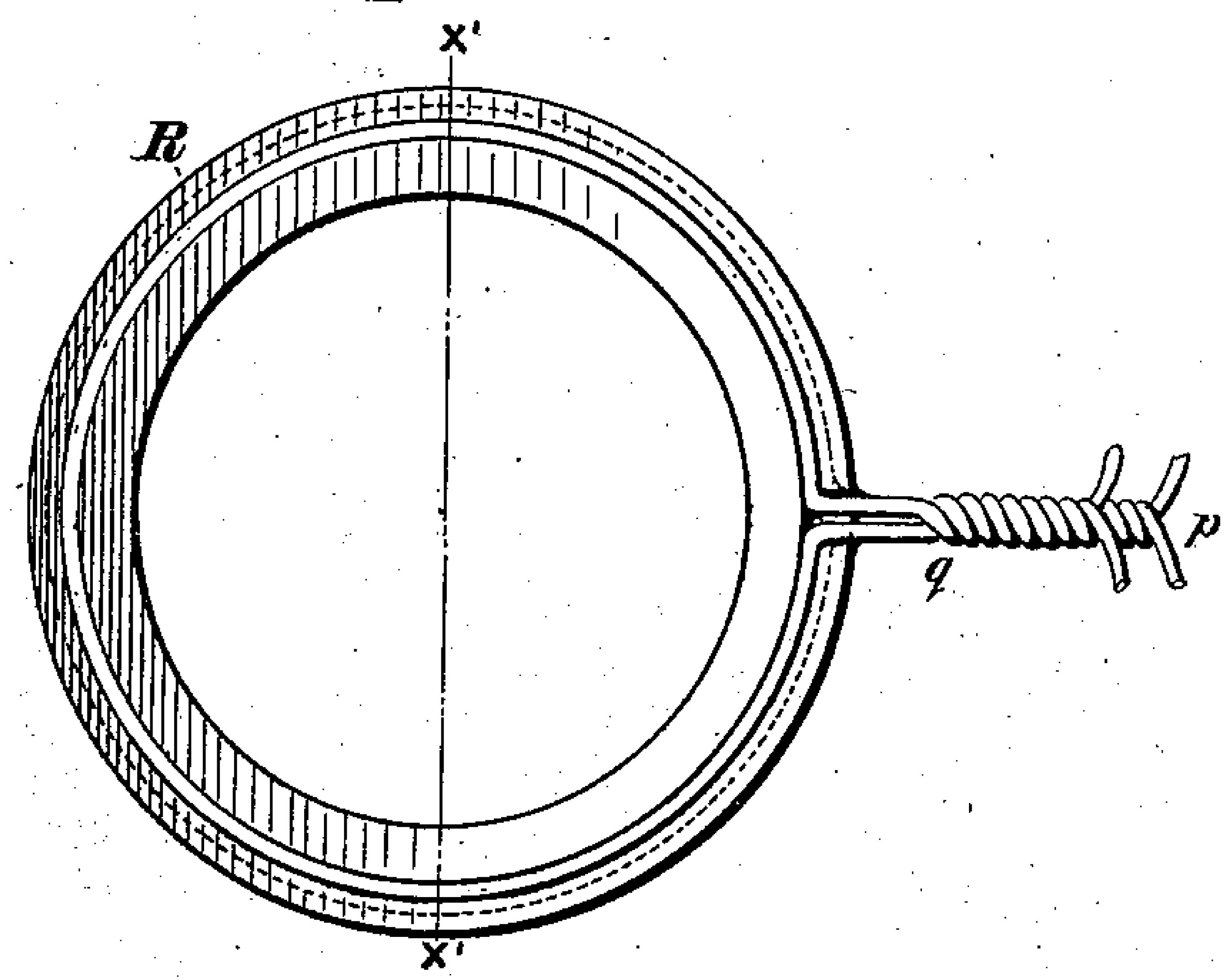


Fig. 14.

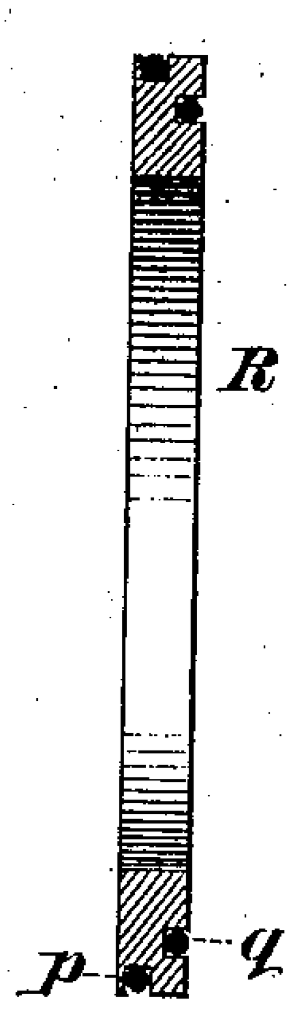
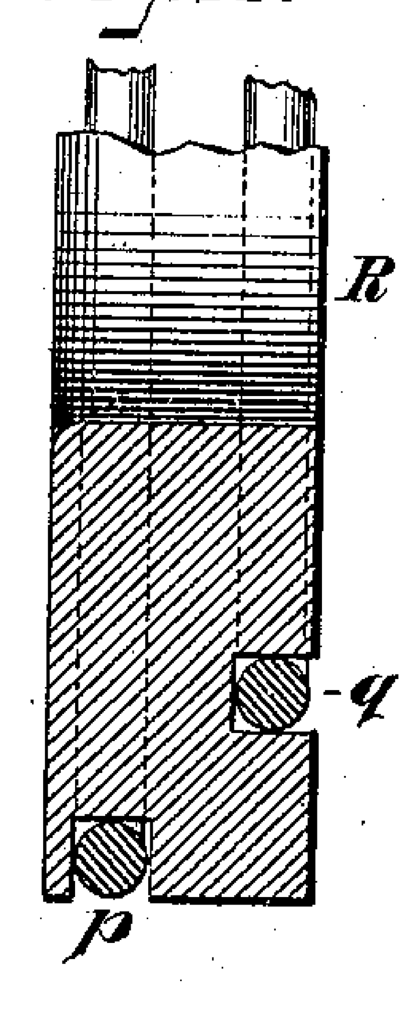


Fig. 15.



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UNITED STATES PATENT OFFICE.

EDWARD WESTON, OF NEWARK, NEW JERSEY.

STANDARD TANGENT-GALVANOMETER.

SPECIFICATION forming part of Letters Patent No. 400,980, dated April 9, 1889.

Application filed May 3, 1888. Serial No. 272,634. (No model.)

To all whom it may concern:

Be it known that I, EDWARD WESTON, of Newark, Essex county, New Jersey, have invented a new and useful Improvement in Standard Tangent-Galvanometers, of which the following is a specification.

My invention relates to that class of galvanometers in which the tangent of the angle of deflection of the magnetic needle is proportional to the strength of current traversing the coil or coils of the instrument.

The particular form of tangent-galvanometer herein illustrating my invention includes a central hollow standard on opposite sides of which are secured the coils. The magnet-needle is suspended within the standard in such position that the needle-center will be in line with the coil-centers and equidistant therefrom. The needle is suspended from a mirror, which in turn is supported by a fiber, the rod joining mirror and needle being rigid, so that the vibrations of the needle are transmitted to the mirror. The standard is supported upon a tripod-base, which is provided with the usual leveling-screws.

The base of the central standard in my present apparatus rests upon a larger base or platform, which is also provided with suitable leveling-screws. Supported from said last-mentioned base is a circular chamber, through the center of which the standard column passes. The index-mirror is arranged in that part of the column which is wholly inclosed by said chamber. Upon the inner periphery of the chamber is a scale for showing the deflections of the mirror, and in the wall of the chamber may be disposed sight-openings or telescopes directed toward the mirror, so that by looking into said telescopes the scale on the inner periphery of the chamber may be seen reflected in the mirror. At the point where the standard column passes through the scale-chamber a universal joint is provided, which allows of a suitable amount of play between the standard and the top and bottom walls of the chamber.

My invention consists in the combination of the index-mirror and the circular scale extending around the same, in the marking of said scale, in the combination of the mirror with a scale marked as described and with sight-openings arranged as set forth, in the construction and arrangement of the scale-chamber and its combination with the galvanometer-standard, and in the novel construction of the coils of the instrument, together with various other novel instrumentalities and combinations, all as hereinafter more particularly set forth.

The object of my invention is to provide a standard tangent-galvanometer provided with a suitable scale for showing the mirror deflections, the said scale being arranged so that a very wide range of measurement can be had and the instrument and scale forming one apparatus.

In the accompanying drawings, Figure 1 is a plan view of my galvanometer. Fig. 2 is an elevation thereof. Fig. 3 is a diagram showing the arrangement of scale, two telescopes, and mirror. Fig. 4 is a diagram showing the arrangement of scale and mirror with one telescope in lieu of two. Fig. 5 is a diagram showing the arrangement of scale and mirror with a lamp in place of the single telescope shown in Fig. 4. Fig. 6 is a section of the scale-chamber and telescope on the line $x\ x$ of Fig. 4. Fig. 7 is a section of the scale-chamber and lamp on the line $z\ z$ of Fig. 5. Fig. 8 is a face view of the scale as represented in Fig. 3. Fig. 9 shows in detail the device for permitting some play of the central supporting-column at the points where it passes through the covering-plates of the scale-chamber. Fig. 10 is a section on the line $y\ y$ of Fig. 9. Fig. 11 is a plan view of the centering device for the tripod. Fig. 12 is a diagram illustrating the arrangement of differential conductors upon a coil. Fig. 13 is a side view of a coil, and Fig. 14 a section thereof on the line $x'\ x'$ of Fig. 13. Fig. 15 is an enlarged partial section of the coil, showing the arrangement of conductors in the side and periphery of the spool. Fig. 16 is a diagram showing the arrangement of the differential conductors with reference to the center of the magnet.

Similar letters of reference indicate like parts.

A is a central hollow standard pivoted at its lower extremity upon the tripod B. Upon opposite sides of standard are fixed supports or brackets, to which are secured the spools R, upon which are wound the coils. These coils may either consist of a single conductor wound in the usual way continuously around the periphery of the spool or two conductors, *p* and *q*, wound separately, as set forth farther on in this specification. Upon the tripod B is a horizontal worm-screw, N, which engages with a toothed segment upon the enlargement O on the lower part of the standard A. By turning the screw N the standard A may be rotated upon its vertical axis, and the coils thus adjusted in the magnetic meridian. In an enlargement at about the middle of the standard A is arranged a cylinder, E, of diamagnetic metal, having a central chamber in which is suspended a ring-magnet, F.

The cylinder-block E is made of diamagnetic metal, so as to dampen or check the oscillations of the magnet inclosed in the central chamber. Said block is divided transversely into halves, and the parts are inserted into the bore of the enlargement of the standard A from opposite sides, and are connected together by screws.

Seated in a socket in the upper end of standard A is a glass tube, I, having at its upper extremity a vertically-adjustable hook or other support, to which is attached a fiber of silk or other suitable material. This fiber carries the mirror H, which is situated in the chamber P in standard A. The side of this chamber is open, so that the face of the mirror is exposed. Depending from the mirror is a light aluminium rod, which at its lower end carries the magnet F. At the extremities of the arms of the tripod B are leveling-screws of usual construction.

The construction and relation of standard A and coils are such that a line joining the centers of the coils intersects the longitudinal axis of the standard at right angles thereto, and the magnet F is disposed so that its center coincides with this point of intersection.

The aforesaid instrument is placed upon a base, K, upon which is disposed a circular plate, M, upon the upper side of which are formed three grooves, *g* *g′* *g″*, radiating at angles of one hundred and twenty degrees. The lower ends of the supporting-screws of the tripod B rest in the said grooves, and as said ends are accurately equidistant from one another and from the center of the tripod it follows that when they are so placed the centers of the plate M and tripod B must coincide, and the tripod is thus self-centered upon the base K. From the base K rise three pillars, J, which support the scale-chamber C. This chamber consists of a peripherical ring, C′, which rests upon the pillars J, and is covered above and below by glass plates *f* and *b*, Figs. 6, 7, and 9.

The standard A passes through the scale-chamber C, the upper and lower plates of which come above and below the chamber in said standard, wherein the mirror H is suspended. In order to allow of movement of the standard A in the opening of said plates through which it passes, as is necessary when the instrument is raised or lowered or leveled by means of the screws in the arms of the tripod B, the hole *h*, Fig. 9, cut through the upper plate, *f*, is made larger than said column, and the annular opening thus left is covered by a loosely-fitting collar, *e*, provided on its lower side with a soft-rubber washer, *j*. In the lower plate, *b*, is made an aperture, *i*, considerably larger in diameter than standard A. This opening is closed by a rubber washer, *c*, which is held between two metal rings, *d* and *d′*. The washer *c* rests upon a flange, Q, (said washer is shown in Fig. 9 as slightly above and separated by an interval from flange Q for the sake of clearness,) on the standard A, and the upper ring, *d*, bears against the lower side of plate *b*. This device permits the requisite movement of the central standard and effectually prevents the access of dust or air-currents to the chamber C.

Around the inner periphery of the inclosing-ring C′ of chamber C is marked a scale, and passing through said ring are two telescopes, T and T′. The disposition of this scale and its relation to the telescopes and the mirror H, I will now describe, reference being had more particularly to the diagram, Fig. 3.

Let H represent the position of the mirror at rest—that is, when no current traverses the coils. The circle W represents the inner periphery of the ring C′, on which the scale is marked. From the point Z (a radial line from which point meets the face of the mirror at right angles) is set off on each side an arc of forty-five degrees, and at the ends of these arcs the telescopes T T′ are located. Therefore these telescopes are ninety degrees apart, and lines drawn from each telescope to the mirror will make equal angles of forty-five degrees with the line drawn from Z to mirror-face. Consequently an observer looking at the mirror through telescope T will see reflected therein the image of a zero-point of the scale marked at the telescope T′, while on looking at the mirror through the telescope T′ he will see another zero-point which is marked at the telescope T. Now from the telescope T′ around to the point X is one hundred and eighty degrees, and equally from the telescope T around to the point Y is one hundred and eighty degrees. Suppose next that the mirror H be deflected over an angle of forty-five degrees to the position H′, dotted lines. This is obviously at right angles to the line of sight of telescope T, and the forty-five-degree mark at that telescope will be directly reflected back into it. If the mirror moves still further in the same direction, as to the position H″, then the end of the scale at X will be seen in telescope T. Now the total movement of the mirror has been but ninety degrees, but the image of the scale has been reflected over an arc of one hundred and eighty degrees. This because of the well-known optical law that the angular movement of the reflected ray is equal to twice that of the reflecting surface. In lieu of marking the scale, however, in divisions of one degree from 0° to 180° and then halving the reading to get the angular deviation of the mirror, I mark two degrees of the scale as one degree—that is, I mark one hundred and eighty degrees of the scale as ninety degrees, Fig. 3, and hence the reflected image of the scale-reading shows the actual angle of deviation of the mirror. Consequently by observing the mirror through telescope T, when the direction of the current in the coils is such as to move the needle into the positions indicated by the dotted lines H' H'', I can measure its angular deviation of ninety degrees upon an arc of one hundred and eighty degrees from the zero-point at telescope T' to the point X, and equally when the current is in the other direction, and by observing the mirror through the telescope T', I can measure its angular deviation over the corresponding scale-distance from the zero-point at telescope T to the point Y.

It will be apparent that by this construction I am enabled to augment the useful scale range of instruments of this class, and as one degree deflection of the mirror is represented by two degrees of the scale I am also enabled to note slight variations in deflection with accuracy. This device also affords a very certain and easy mode of proving the correct adjustment of the needle. If the mirror, when observed through telescope T, reflects the zero at telescope T', and vice versa, then obviously its center point must be in the axial line joining the centers of two coils. Then, in order to prove that the coils are in the magnetic meridian, in which case the deviation of the needle will be the same on either side of the zero-point, it is requisite to simply establish the current and note the deflection through one telescope and then reverse the current and note the deflection through the other telescope. If the readings are the same in both telescopes, the deflections are equal and the coils are in the magnetic meridian.

In Fig. 8 is shown a face view of the scale-marking.

While I greatly prefer the arrangement of the scale above described and of two telescopes, I may employ a single telescope located at the point Z, with its line of sight at right angles to the mirror H when at rest; but in such case the scale is to be marked each way from a zero-point located at said point Z, as shown in Fig 4, (two degrees, as before, being marked as one degree.) Instead of the telescope, I may here substitute a lamp, as shown in section in Fig. 5, and observe the position of the reflected beam on the scale in the usual manner.

The coils, as already stated, may comprise each a single conductor, or they may be made differential and each include two conductors, as p and q, wound upon the same ring, R. As shown in Figs. 13, 14, and 15, a groove or channel is made in the periphery of the ring R to receive one conductor, and a second groove in the face or side of the ring to receive the other conductor. These grooves are so disposed that when the ring is in place a cone passing through the center of both wires will have its apex at the center of the magnetized needle, as indicated in the diagram, Fig. 16, the object being to preserve the ratio between the diameter of the turns of the respective wires to their distances from the center of the magnet. This result has hitherto been attempted by winding the coils upon a bobbin having a conical periphery, which is a difficult operation to accomplish so as to secure the desired result with accuracy.

By varying the connections of the two conductors p and q a current may be passed through them, respectively, in opposite or in the same direction. In the former case the deflection of the magnet will be due to the differential effect thereon of the current in the wires, and thus very large currents may be measured with small deflections. Again, as the instrument is arranged with two coils, one on each side, each of which may contain differential conductors, connections between said conductors may be made so as still further to reduce the effect of strong currents on the needle. In this way I avoid the necessity of using coils of very large diameter for the measurement of strong currents in instruments of this class.

The conductors leading from the coils are twisted together, and also carried outward in a line radial to the coil-center and in the horizontal plane of vibration of the needle, as shown in Fig. 13, so as to prevent any extraneous inductive effect which they might exercise upon the magnet.

It will of course be obvious that the combination and arrangement of index-mirror, scale, and scale-chamber herein set forth may be utilized in various electrical instruments designed for testing or measuring—such, for example, as electrometers—and it should be understood, therefore, that I do not limit my invention in this respect specifically to its combination in and with a galvanometer.

I claim—

1. In combination with an electrical instrument containing a vibrating index-mirror, a curved surface extending around said mirror and concentric with the axis of vibration thereof, and a scale upon said surface for showing the angular deflections of said mirror, substantially as described.

2. In combination with an electrical instrument containing a vibrating index-mirror, a curved surface extending around said mirror and concentric with the axis of vibration thereof, and a scale upon said surface for showing the deflections of said mirror, the

zero-point of said scale being marked at a point on said surface distant forty-five degrees in arc from the point at which a radius from the mirror-center drawn perpendicular to the face meets said surface when no current traverses the instrument, substantially as described.

3. In combination with an electrical instrument containing a vibrating index-mirror, a curved surface extending around said mirror and concentric with the axis of vibration thereof, and a scale upon said surface for showing the deflections of said mirror, the said scale having two zero-points marked, respectively, at points on said surface distant forty-five degrees in arc and at each side of the point at which a radius from the mirror-center drawn perpendicular to the mirror-face meets said surface when no current traverses the instrument, substantially as described.

4. In combination with an electrical instrument containing a vibrating index-mirror, a curved surface extending around said mirror and concentric with the axis of vibration thereof, and a scale upon said surface for showing the deflections of said mirror, the said scales having two zero-points marked, respectively, at points on said surface distant forty-five degrees in arc and at each side of the point at which a radius from the mirror-center drawn perpendicular to the mirror-face meets said surface when no current traverses the instrument, and the said scale being laid off in regular successive divisions from each of said zero-points toward the other, substantially as described.

5. In combination with an electrical instrument containing a vibrating index-mirror, a wall extending around said mirror and having its inner periphery curved and concentric with the axis of vibration of said mirror, a scale on said periphery for showing the angular deflections of said mirror, and a sight-opening in said wall in line with said mirror, substantially as described.

6. In combination with an electrical instrument containing a vibrating index-mirror, a wall extending around said mirror and having its inner periphery concentric with the axis of vibration of said mirror, a scale on said periphery for showing the angular deflections of said mirror, and a sight-opening in said wall in line with said mirror, the position of said opening in said wall being such that a line of sight drawn from said opening to said mirror shall make an incident angle of forty-five degrees with the reflecting-surface when no current traverses the instrument, substantially as described.

7. In combination with an electrical instrument containing a vibrating index-mirror, a wall extending around said mirror and having its inner periphery concentric with the axis of vibration of said mirror, a scale on said periphery for showing the angular deflections of said mirror, and two sight-openings in said wall and in line with said mirror, the positions of said openings in said wall being such that lines of sight drawn from said openings to said mirror shall make equal incident angle with the reflecting-surface when no current traverses the instrument, substantially as described.

8. In an electrical instrument, a vibrating index-mirror and a scale-chamber inclosing said mirror, substantially as described.

9. The combination of an electrical instrument containing a standard, a vibrating index-mirror supported thereby, an independently-supported scale-chamber inclosing said mirror and surrounding said standard, and means—such as screws—for vertically adjusting said standard in said chamber, substantially as described.

10. In an electrical instrument, a base, a circular scale-chamber supported thereon, a central hollow standard resting on said base and passing through said scale-chamber, and an index-mirror supported in said standard and inclosed in said scale-chamber, substantially as described.

11. In an electrical instrument, a base, a circular scale-chamber supported thereon, a central hollow standard resting on said base and passing through said scale-chamber, an index-mirror supported in said standard and inclosed in said scale-chamber, universal-joint connections between said standard and the top and bottom walls of said chamber, means—such as screws—for leveling said base and chamber, and means—such as screws G—for leveling said standard upon said base, substantially as described.

12. In an electrical instrument, a central hollow standard, a vibrating index-mirror supported therein, an independently-supported scale-chamber inclosing said mirror, (through which chamber said standard passes,) and means—such as a tangent-screw and toothed segment—for rotating said standard on its axis within said chamber, substantially as described.

13. In a galvanometer, a central hollow standard, a vibrating index-mirror supported therein, an independently-supported chamber having side, top, and bottom walls inclosing said mirror, (through which chamber said standard passes,) and universal-joint connections between said standard and the top and bottom plates or walls of said chamber, substantially as described.

14. A galvanometer-coil containing an annular spool or bobbin and two encircling conductors located, respectively, upon the periphery and upon one face of said spool, substantially as described.

15. A galvanometer-coil containing an annular spool or bobbin having two encircling grooves or channels formed, respectively, in its periphery and in one face, and conductors located in said grooves, substantially as described.

16. A galvanometer-coil containing an an-

nular spool or bobbin and two conductors forming loops of different diameters, located, respectively, upon the periphery and upon one face of said spool, substantially as described.

17. In a galvanometer, a coil containing two separate conductors of unequal lengths, but each making the same number of loops or turns, substantially as described.

18. In a galvanometer, a coil containing two separate conductors forming loops, respectively, of different diameters, substantially as described.

19. In a galvanometer, a coil containing two separate conductors each making the same number of loops or turns, but relatively varying in electrical resistance, substantially as described.

20. In a galvanometer, a coil having its leading-out terminals disposed in a line radial to the coil-center and in the horizontal plane of vibration of the magnet-needle, substantially as described.

21. The combination, with a galvanometer containing a vibrating index-mirror and a central hollow standard, A, of the collars *c* and Q, scale-chamber C, having upper plate, *f*, and lower plate, *b*, and the flexible disk *c*, interposed between said collar Q and plate *b*, substantially as described.

22. The combination, in a galvanometer, of a magnet-needle and two rings supported in parallel planes on opposite sides thereof with their centers in line with and equidistant from the center of the needle, and two conducting-coils supported concentrically by each of said rings, one conductor being on the face of the ring adjacent to the needle and the other conductor being on the periphery of said ring, the diameters of said coils being relatively such that the circumferences of both coils will lie in the periphery of a cone having its apex at the needle-center, substantially as described.

23. The combination of the standard A, index-mirror H, chamber C, containing the rim C′, top plate, *f*, and bottom plate, *b*, the said plates *f* and *b* encircling said standard, respectively, above and below the position of the mirror therein, and a scale on the inner periphery of rim C′, substantially as described.

24. The combination, with a galvanometer containing the standard A and index-mirror H, of the base K and curved wall C′, having a scale on its inner periphery and supports upon said base for said wall, substantially as described.

25. The combination, with a galvanometer having the central standard, A, and tripod-base B, of the base K, scale-chamber C, supported on said base and surrounding said standard, and the centering-plate M on said base K, substantially as described.

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Witnesses:

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