A DESCRIPTION

OF THE

PRINCIPAL MATHEMATICAL INSTRUMENTS

EMPLOYED BY THE

ARCHITECT, ENGINEER, SURVEYOR, AND NAVIGATOR;

CONTAINING

THE PARTICULARS

OF A CASE OF

MATHEMATICAL DRAWING INSTRUMENTS, SCALES, ETC.

ILLUSTRATED BY OVER 100 ENGRAVINGS.

BY BENJAMIN PIKE, JR., OPTICIAN.

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JOHN WESTALL, Stereotyper. PUDNEY AND RUSSEL, Printers.

CATALOGUE, &c.

A CASE OF MATHEMATICAL INSTRUMENTS.

A Pocket Case of Mathematical Instruments (see Fig. 1, next page) usually contains the following, viz.:

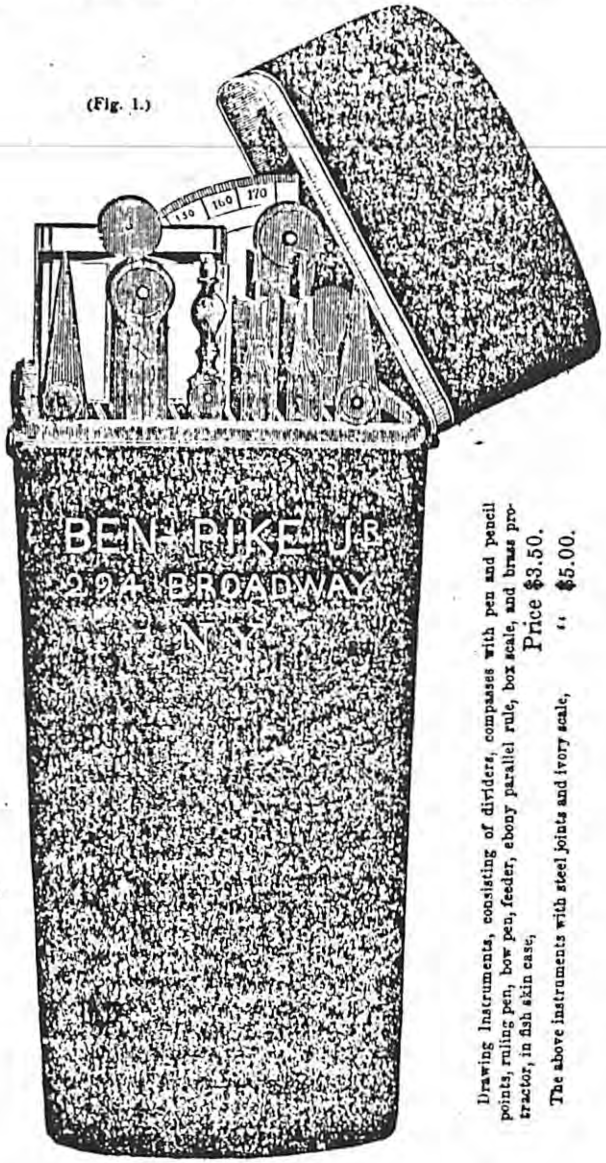
1 Pair of 5-inch plain compasses,
2 Pair of 6-inch drawing compasses, with one leg or point movable,
3 Pencil point,
4 Ink point,
5 One for dotting,
6 Drawing pen, with a protracting pin in the handle,
7 Protractor in the form of a semicircle,
8 Plain scale,
9 Parallel rule,
10 Sometimes a sector,
11 Also sometimes a bow pen,
12 Pencil.

Price $3.50; $5.00; $8.50.

A Magazine Case of Instruments (see Fig. 2, page 14), of fine quality, contains—

1 Pair of 6-inch drawing compasses, with a movable leg,
2 Ink point,
3 Pencil point,
3 Lengthening piece,
4 Pair of 5-inch hair compasses,
5 Drawing pen, with ivory handle,
6 Bow pen,
7 Bow pencil,
8 Knife, file, key, and screw-driver, for the compasses, in one piece,

(Fig. 1.)



Drawing Instruments, consisting of dividers, compasses with pen and pencil points, ruling pen, bow pen, feeder, ebony parallel rule, box scale, and brass protractor, in fish skin case; Price $3.50.

The above instruments with steel joints and ivory scale, " $5.00.

9 Drawing pencil,
10 Ivory sector,
11 Ivory parallel rule,
12 Ivory protractor and plane scale combined.

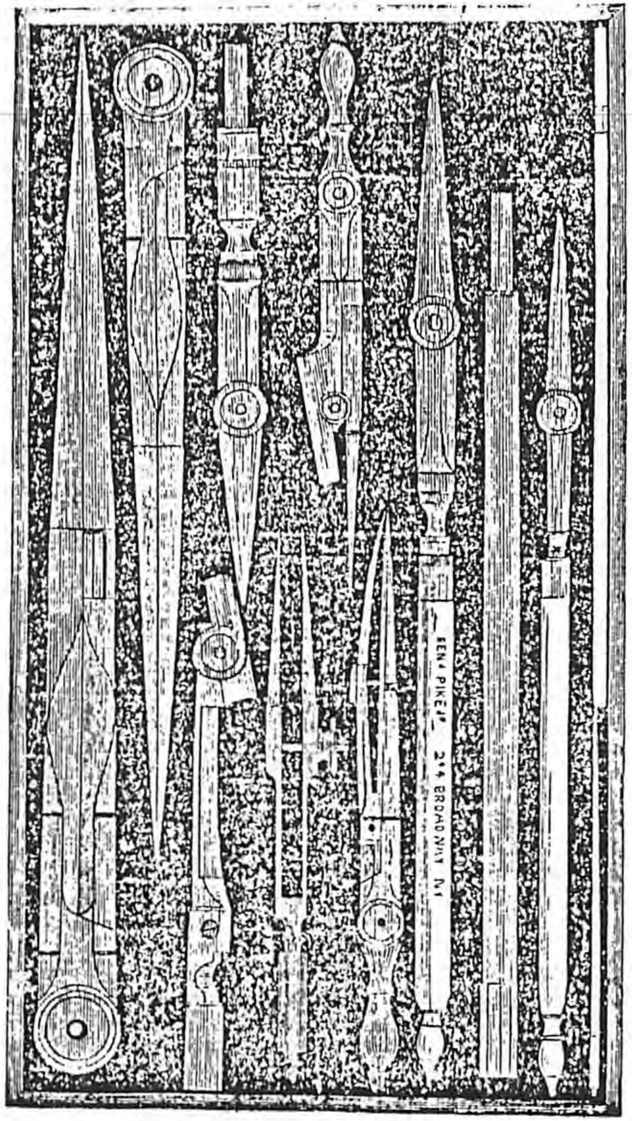
The most extensive sets contain, in addition—

13 Pair of proportional compasses,
14 Pair of triangular compasses,
15 Pair of bisecting compasses,
16 Pair of fine steel bow dividers,
17 Fine steel bow pen,
18 Fine steel bow pencil,
19 Small fine drawing pen,
20 Double drawing pen,
21 Fine dotting instrument with set of movable rollers,
22 Needle holder.

Price, mounted in German silver, $20.00.
" larger sets, $35.00 to $80.00.
" plain brass sets, $3.25;
" " " $3.75;
" " " $4.50;
" " " $5.00;
" " " $9.00.

2

(Fig. 2.)



COMPASSES.

COMPASSES are made of brass, or fine German silver, and with steel points. In good instruments the joints should be framed of different substances; one side or part should be of German silver or brass, and the other of steel, as the difference in the metals diminishes the wear and promotes uniformity in their motion; all shake and irregularity at the joint is a sign of imperfection. The points should be of steel, so tempered as neither to be easily bent nor broken; fine and tapering, and meeting closely when shut.

Plain compasses are used to measure small distances, and for subdividing them; drawing circles, arches, or for constructing any proposed figure; in plotting, or making plans. The use of the compasses occurs in every branch of practical mathematics.

The Drawing Compass.—(Fig. 3, page 17.)—These compasses are chiefly designed for drawing circles and circular arches; and it is often necessary they should be drawn with different materials, and therefore this pair of compasses has, in one of its legs, a triangular socket and screw, to receive and fasten the following parts or points for that purpose, viz.:

1. A steel point, which, being fixed in the socket, makes the compasses then but a plain pair for drawing blank circles, setting off lines, &c.

2. A pencil point (Fig. 4, page 17), for receiving a pencil or crayon, in using which the lines can be easily rubbed out if not right.

3. *The dotting points* (Fig. 5, page 17), or dotting pen, with a small indented wheel at the end, moving very freely, and receiving ink from the pen over it, communicates the same in equal and regular dots upon the paper, where dotted lines are chosen. In the most costly instruments one of the blades of this instrument is jointed, and by loosening the screw, may be separated from the other, and wheels marking different figures used; as a dot, a short line, a long line, a dot and a line, two dots and a line, &c. Also, by taking off the wheel it may be used as a pen for drawing very wide

ink lines, the pen causing the ink to flow freely in a very wide line.

4. *The ink point, or pen,* (Fig. 6, page 17), for drawing and describing lines in ink; for this purpose the two blades or sides of the pen are opened or closed with an adjusting screw, that the line drawn may be as fine or as coarse as you please; in fine instruments, one of the blades is framed with a joint, that the points may be separated, and thus cleaned more conveniently. In the pencil point, dotter, and pen point, there is a joint by which you can set the lower part always perpendicular to the paper, which is necessary for drawing a line well in every opening of the compasses.

5. *Lengthener.*—(Fig. 7, page 17.)—One or two additional pieces are often applied to the best compasses; these by lengthening the leg enable them to strike larger circles, or measure greater extents than they would otherwise perform, and that without the inconvenience that would attend using long compasses.

Compasses of the best kind are frequently framed at the end of the shank, so as to form a strong spring, and the points and lengthener slide into this socket, and are firmly held. The best description are furnished with joints in one or both legs, that they may be placed perpendicular to the paper. Price, in German silver, $12 to $18.

Hair Compasses.—(Fig. 8, page 19.)—They are so named, on account of a contrivance in the shank to set them with greater accuracy than can be effected by the motion of the joint alone. One of the steel points is fastened near the top of the compasses, and may be moved very gradually by turning the screw either backwards or forwards. To use these compasses, 1st, place the leg to which the screw is annexed, outermost; 2d, set the fixed leg on that point from whence the extent is to be taken; 3d, open the compasses as nearly as possible to the required distance, and then make the points accurately coincide therewith, by turning the screw. Price, in brass, $2.00 to $3.00.
" in German silver, $2.00 to $4.00.

The Drawing Pen.—(Fig. 9, page 19.)—This pen is used to draw straight lines; it consists of two blades with steel points fixed to a handle. The blades are so bent that the ends of the steel points meet, and yet leave a sufficient cavity

Fig. 3.

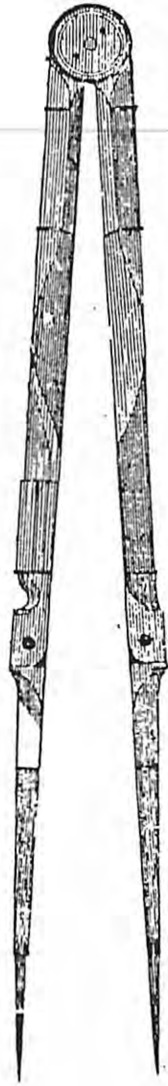


Fig. 7.

Fig. 5.

Fig. 6.

Fig. 4.

for the ink; the blades may be opened more or less by a screw, and being properly set, will draw an equal and regular line of any desirable thickness. One of the blades is formed with a joint, but the points may be separated and thus cleaned more conveniently. A small spring is sometimes inserted between the blades, to act against the movable blade, and serves to steady it in drawing wide lines; in pens with metal handles there is usually inserted in the middle part a fine point, which, when unscrewed, can be used for making a nice dot, or mark, on paper; or to set off divisions from the protractor. Price, $1,25.

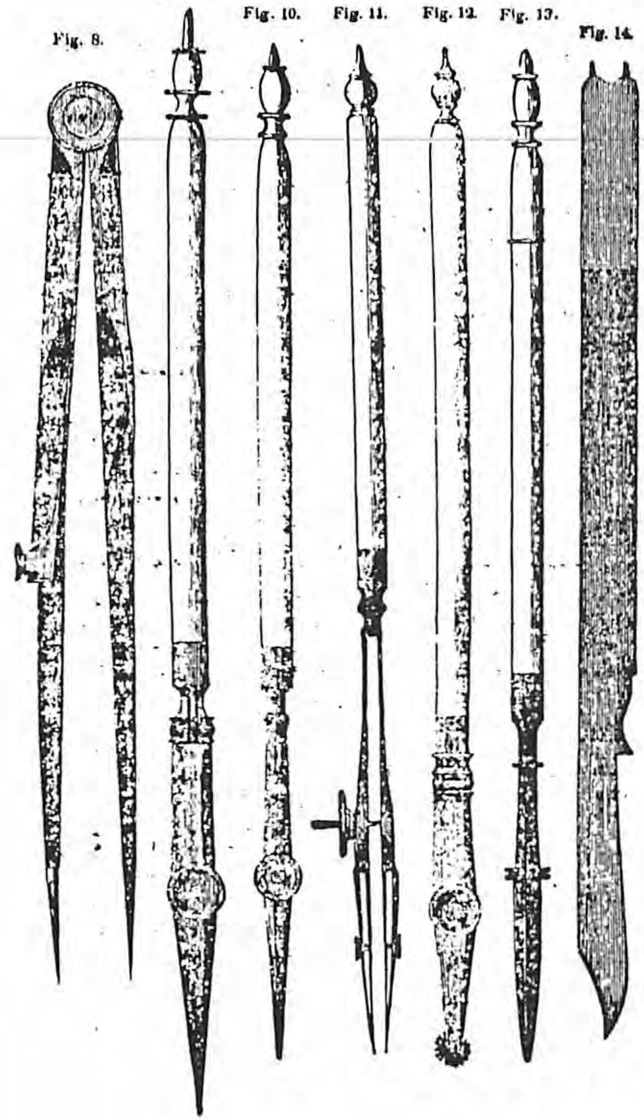
The Steel Drawing Pen.—(Fig. 10, page 19.)—Is formed of two blades of steel joined at the top, both immovable except from the spring of the steel, and terminated with very fine points. The screw in the middle of the blades will draw the points close together, or allow them to separate sufficiently to clean. This pen is mostly used for very fine lines, and is mounted with an ivory handle.

Price, $1.25.

The Road Pen (Fig. 11, page 19), or double drawing pen, is formed of two steel pens joined together with a handle, and having a screw whereby they can be set nearer or wider, at the pleasure of the drawer, and will draw two parallel lines in any direction; is much used in laying down roads and canals, in drawings where they are required.

Price, $3.00 and $3.50.

The Dotting Pen.—(Fig. 12, page 19.)—This instrument consists of two blades of metal, formed as the drawing pen, one of which is jointed, and by loosening the screw may be separated from the other at its point; near the point of the fixed blade is fastened a short pin, on which small indented steel wheels of different figures can be placed, and allowed to revolve freely when passed over paper; it is fed with ink from the blades over it, and communicates the same in equal and regular dots, lines, or a combination of dots and lines, according to the figure of the wheels or rollers used. This instrument is particularly useful where a number of courses are to be laid down on one map or plan, and it is required to distinguish each readily. It may also be used without the rollers as a drawing pen for drawing very wide ink lines;



the width of the point and the pin causing the ink to flow freely, in a much wider line than the usual drawing pen. This is a very beautiful instrument, and when well made its use may be of great advantage in many drawings.

Price, $2.25 to $6.00.

Needle Holder.—(Fig. 13, page 19.)—Is used for holding a needle, or other fine point, in pricking off spaces from the protractor, scales, etc. It consists of an ivory handle, terminated with a small round metallic shaft and point, perforated with a small hole and slit, on this moves a slide; when the needle is introduced, the slide is drawn down, and the needle held firmly for use; the top of the handle is made to screw off, having a cavity for holding the needles.

Price, in German silver, $1.25.

(Fig. 14, page 19.)—The knife, file, key, and screw-driver for the compasses in one piece. Price $1.25.

Bow Compasses.—The common compasses are not so well adapted for small drawings as this small kind, called Bows; they are used to describe small circles and arches, which may be nicely drawn with them, as, from the shape of the head, which is a short stem or shaft, the instrument may be made to roll with great ease between the fingers.

Bow Pen.—(Fig. 15, page 21.)—The same as the last with the ink point or pen, instead of the plain point.

Price, in brass, $1.00.
" in German silver, $1.38.

Bow Pencil.—(Fig. 16, page 21.)—The same, with the pencil point in place of the plain point.

Price, in brass, $1.00.
" in German silver, $1.38.

Bow Pen, jointed in the legs.—(Fig. 17, page 21.)

Price, in brass, $3.00.
" in German silver, $3.75.

Bow Pencil, jointed in the legs.—(Fig. 18, page 21.)

Price, in brass, $3.00.
" in German silver, $3.75.


Fig. 15.

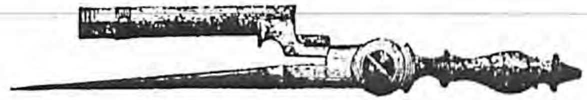


Fig. 16.


Fig. 17.

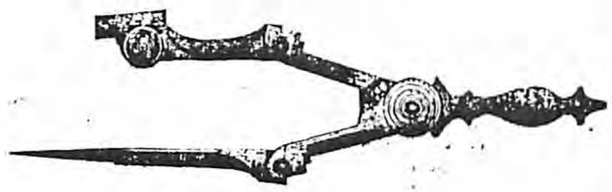


Fig. 18.


Fig. 19.


Fig. 20.


Fig. 21.

Fine French Bow Pen.—(Fig. 19, page 21.)
Price $1.75 to 3.00.

Bow Compass, with shifting leg and points.—(Fig. 20, page 21.)—The general construction is the same as the ordinary compass, with a socket in the leg to insert the ink or pencil point at pleasure, as in the large drawing compasses. Price, $2.50 to 3.50.

Steel Bow Dividers.—(Fig. 21, page 21.)—These are a still finer description of instrument, much used by good draughtsmen in forming small centres, repeating divisions of a small but equal extent, etc. Price, $2.00.

Steel Bow Pen.—(Fig. 22, page 23.)—The same as the steel bow, with the ink point in place of the plain point.
Price, $2.25.

Steel Bow Pencil.—(Fig. 23, page 23.)—The same as the steel bow, with the pencil point in place of the plain point. Price, $2.25.

The Universal Bow is formed as a bow pencil, and has a shaft with one end finely pointed, and on the other a pen for ink, either end of this can be inserted in the pencil holder, and secured by its spring or screw; thus combining the three in one instrument. Price, $3.00 to 4.00.

Needle Point Instruments.—(Fig. 24, page 23.)—Compasses and bow instruments are sometimes formed with arrangements for using needles for their points, and are called needle point instruments, and serve very well for delicate purposes. We give here a representation of a bow instrument with needle point, and the ink and pencil points to turn on a swivel, either of which can be in a moment brought into use; the bow is also jointed in the legs. It is a very desirable and useful instrument.
Price, $3.50 to 7.00.

Proportional Compasses (Fig. 25, page 25), consists of two parts or sides of brass, which lie upon each other so nicely as to appear but one when they are shut. These sides easily open, and move about a centre which is itself

movable in a hollow canal cut through the greater part of their length. To this centre, on each side, is affixed a sliding piece of a small length, with a fine line drawn on it, serving as an index, to be set against other lines or divisions placed upon the compasses. Thus, by placing the index against 1, and screwing it fast, if you open the compasses then the distance between the points at each end will be equal. If you place the index against 2, and open the compasses, the distance between the points of the longer legs will be twice the distance between the shorter ones; and thus a line is bisected, or divided, into two equal parts. If the index be placed against 3, and the compasses opened, the distance between the points will be as 3 to 1, and so a line

Fig. 22.

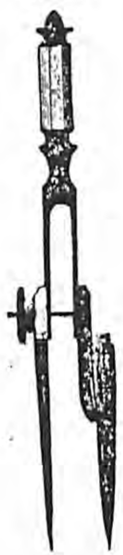


Fig. 23.

Fig. 24.

is divided into three equal parts; and thus you proceed for any number of parts under 10 or 12. There are also sometimes placed on the face, a scale of plans, solids, and circles.

They are sometimes made with an adjusting screw, or a tooth and pinion to move the slide, and which admits of great nicety in the adjustment of the index.

Price, in brass, $4.50; with rack and pinion motion, $6.50.
" German silver, $7.00; " " $8.50.
" with adjusting points, $2.00 extra.

Bisecting Compasses, or whole and halves.—(Fig. 26, page 25.)—A name given to these compasses, because, when the longer legs are opened to any given line, the shorter ones will be opened to the half of that line; being always a bisection.

Price, in brass, $2.00 to $3.00.
" in German silver, $3.00.

Triangular Compasses.—(Fig. 27, page 25.)—They consist of a pair of compasses, to whose head a joint and socket is fitted for the reception of a third leg, which may be moved in almost every direction. These compasses, though exceedingly useful, are but little known; they are very serviceable in copying all kinds of drawings, as from two fixed points they will always ascertain the exact position of a third point.

Price, in German silver, $5.00 and $7.00.

The Pillar Compasses.—(Fig. 28, page 27.)—A universal instrument, and is, when opened, about six inches long; the points are made to turn up so as to occupy but about half that space; within the two legs are contained the ink and pencil points, held firmly by a spring joint; either of these can be taken out and the plain points inserted in their places. Thus, by shifting them around, making a pair of compasses with plain point, ink point, and pencil point. Also, the points can be used—taken out of the legs of the instrument—as bow pen, and bow pencil, there being a small head attached to each for that purpose. This instrument forms in itself a pocket case of instruments.

Price, in brass, $4.00 to $6.50.
" in German silver, $5.00 to $10.00.

Fig 25.

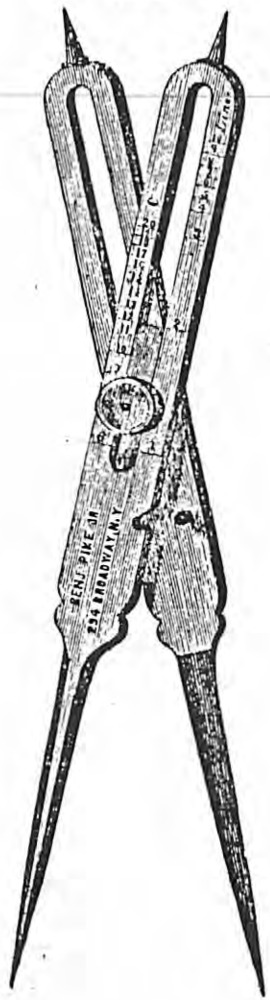


Fig. 26.

Fig. 27.

The Universal Tube Compass, with points to turn.—(Fig. 29, page 29.)—This instrument consists of two German silver or brass tubes, connected by a joint as other compasses, having other tubes sliding firmly and evenly within them; at the outer ends of the inner tubes are affixed a joint and pieces, to which are attached the points, which are fixed in pairs; the pencil point at one end, and a plain point at the other, in one arrangement, and the ink point and a plain point in the other arrangement; each of which is movable in a swivel, and can be turned round so as to bring either point into use as may be required. When a longer space is wanted than can be conveniently extended in the ordinary state of the instrument, the movable tubes can be drawn out, and thus a larger pair of compasses formed. They also can be used as a beam compass within the limits of the slides, having both the points turned parallel to each other, and also perpendicular with the paper.

Price, in German silver, $12.00.

Beam Compasses (Figs. 30 and 31, page 27) are used for describing large arches, and bisecting lines or arches. These compasses consist of a long beam, made of brass or wood, furnished with two brass boxes, the one fixed at the end, the other sliding along the beam, to any part of which it may be firmly fixed by a screw. An adjusting screw is adapted to the box at the end of the beam; by this the point connected therewith may be moved with extreme regularity and exactness.

Price, $4.00 to 10.00.

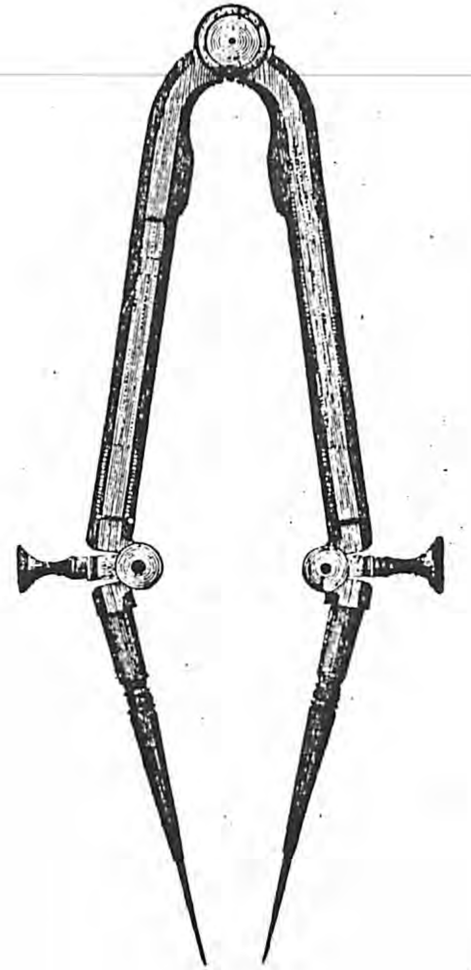
Drawing Pins (Fig. 32, page 29), are used for fastening to the drawing board paper, for which purpose one is pressed through each corner of the paper into the board, firmly securing the paper thereby.

Price, in brass, per dozen, 75cts.
" in German silver, do. 88cts.

Metal Centres, having two or more very delicate pins, to fasten to the paper used in drawing, where the points of the dividers are frequently to be placed on one centre, and preventing the injury to the paper that would arise from placing the points thereon many times.

Price, 25 to 50cts.

Fig 28.



The Protractor (Fig. 33, page 30) is an instrument used to protract, or lay down an angle containing any number of degrees, or to find how many degrees are contained in any given angle.

The Semicircular Protractor is divided into one hundred and eighty equal parts or degrees, which are numbered at every tenth degree each way, for the convenience of eckoning either from the right hand towards the left, or rom the left towards the right; or the more easily to lay down an angle from either end of the line, beginning at each end with 10, 20, etc., and proceeding to 180 degrees. The straight side is the diameter of the semicircle, and the mark or small notch in the middle points out the centre.

Price, in brass, 4 inch 50cts.
" " 5 " 75cts.
6 inch, divided to one-half degrees, $1.25.
7 inch, $1.50.

Ivory Protractors (Fig. 34, page 31), in the form of a parallelogram, or long square, are usually contained in the best cases of mathematical instruments, and are more exact than the common semicircular ones for angles to forty or fifty degrees; because at and about each end the divisions being further from the centre are larger; the side of these protractors to be applied to the paper is flat, on which is marked the lines of the plane scale, and that whereon the degrees are marked is sloped away to the edge, that an angle may be more easily measured, and the divisions set off with greater exactness. Price, $1.50 to $4.00.

Protractors of Horn, are, from their transparency, very convenient in measuring angles, and raising perpendiculars. When they are out of use they should be kept in a book to prevent their warping. Price, 4 inch, 25cts.
" 5 " 50cts.
6 inch, divided to half degrees, 88cts.
7 " " " " $1.25.

The Plane Scale.—(Fig. 35, page 33.)—The divisions used for measuring straight lines are called scales of equal parts, and are of various lengths, for the convenience of delineating any figure of a larger or smaller size, according to the fancy or purposes of the draughtsman. They are a measure in miniature for laying down upon paper, &c.,

Fig. 29.

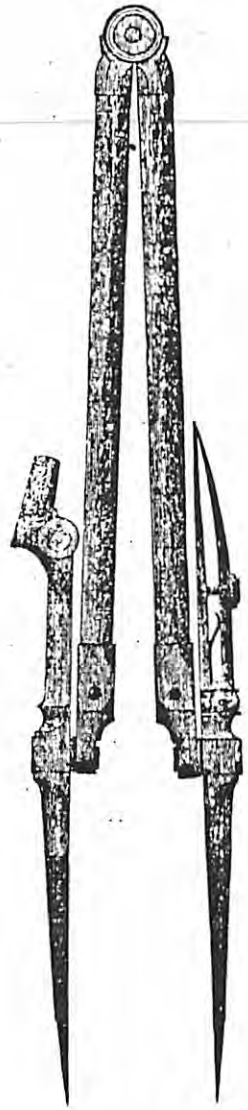


Fig. 30.

Fig. 31.

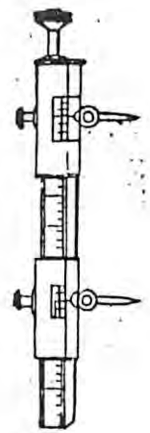
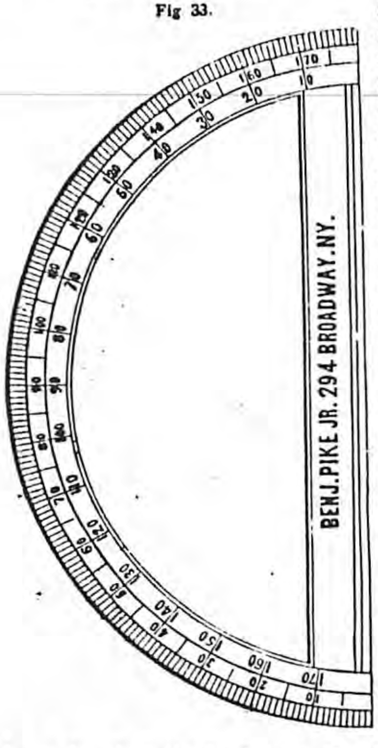


Fig. 32.

Fig 33.

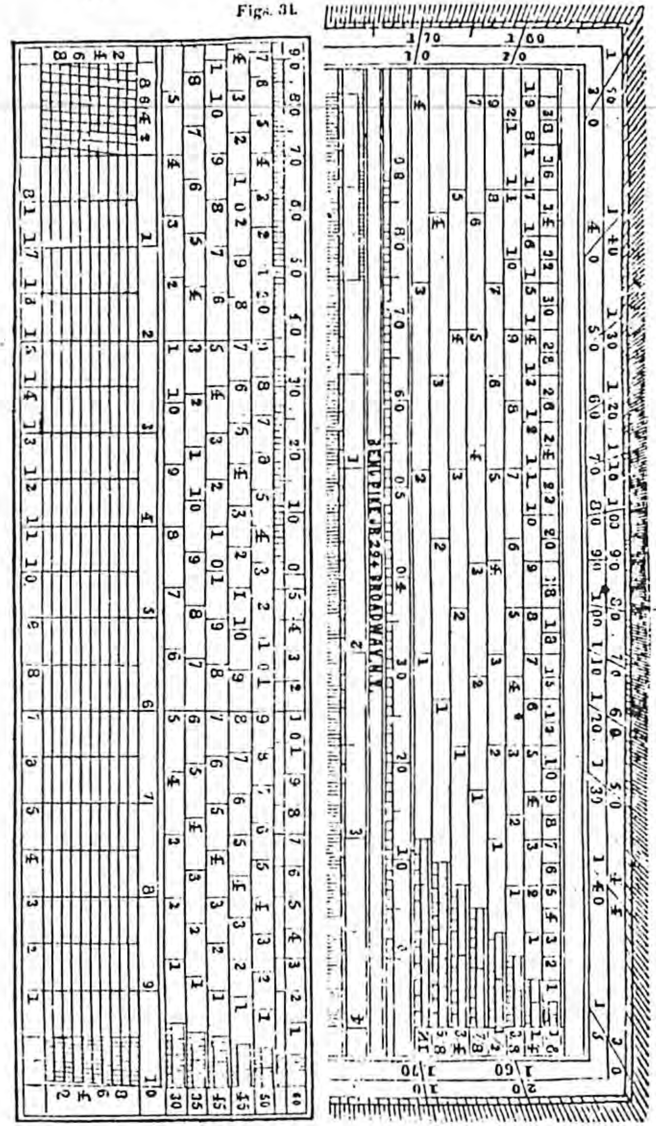


any known measure, as chains, yards, feet, &c.; and the plan will be larger or smaller as the scale contains a smaller or greater number of parts in the inch. Hence a variety of scales are useful to lay down lines of any required length, and of a convenient proportion with respect to the size of the drawing. If none of the scales happen to suit the purpose, recourse should be had to the sector.

The plane scale (Fig. 35), in the common cases of instruments, has the following lines of scales upon it, viz. 1. A line of 6 inches. 2. A line of 50 equal parts. 3. A diagonal scale. 4. A line of chords marked C. 5. Seven particular scales of equal parts, or decimal scales of different sizes. The numbers placed at the beginning of each denote how many of the small divisions at the beginning are contained in one inch, viz. 20, 25, 30, 35, 40, 45, 55. On the lines over the spaces containing the decimal divisions, is marked a line of twelve parts to the same space, answering for measures reduced from feet and inches.

The line of chords.—This line is used to set off an angle from a given point in any right line, or to measure the quantity of an angle already laid down. Thus, to draw an angle of a given number of degrees, say 35, open your compasses to the extent of 60 degrees upon the line of chords, and with that opening of the compasses describe an arch; then, taking the extent of 35 degrees from the chord

Figs. 34.



line, set it in the arch described, and the angle formed by lines drawn through these points is 35 degrees. The degrees contained in an angle to be measured, are found in nearly the same manner.

Price, in ivory, 6 inch, 88cts.; 12 inch, $3.00 to $8.00.
" in brass, " " $1.50 " " $3.00.

The Sector.—(Fig. 36, page 35.)—Of all mathematical instruments that have been contrived to facilitate the art of drawing, there is none so extensive in its use as the sector. It is a universal scale. It not only contains the most useful lines, but by its nature renders them of general application; uniting, as it were, angles and parallel lines, the rule and the compass. The sector is usually six inches long when closed, and forms a rule of twelve inches long when open. The sector consisting of two pairs, or legs, movable upon a central joint, it is requisite that the lines should be laid on the sector by pairs, viz. one of a sort on each leg, and all of them issuing from the centre; all of the same length, and every two containing the same angle. The scales or lines graduated upon the faces of the instrument, and which are used as sectoral lines, are, 1, two scales of equal parts called the line of lines, and marked L; 2, two scales of chords, marked C; 3, two scales of secants, marked S; 4, a line of polygons, marked POL. Upon the other face; 5, two lines of sines, marked S; 6, two lines of tangents, marked T; 7, another line of tangents extending from 45 to 75 degrees; the first only extending to 50. Besides these, when the sector is quite opened, there is on one side, 1, Gunter's line of artificial numbers, marked N; 2, line of artificial sines, marked S: 3, line of artificial tangents, marked T; and on the other side a line of twelve inches divided in tenths, and on the edge, the foot divided into 100 parts. To explain the proper use of all these sectoral lines would require more space than can be given in this work. A few examples will be given.

1. *In the line of equal parts.*—Having three numbers given to find a fourth proportional. To do this, take in your compasses the lateral extent of sixteen divisions in the line of lines, and apply it by a proper opening of the sector from 4 to 4 in these lines; then take the parallel distance from 7 to 7 in your compasses, with the same opening of the sector, and apply one foot of the compasses to the com-

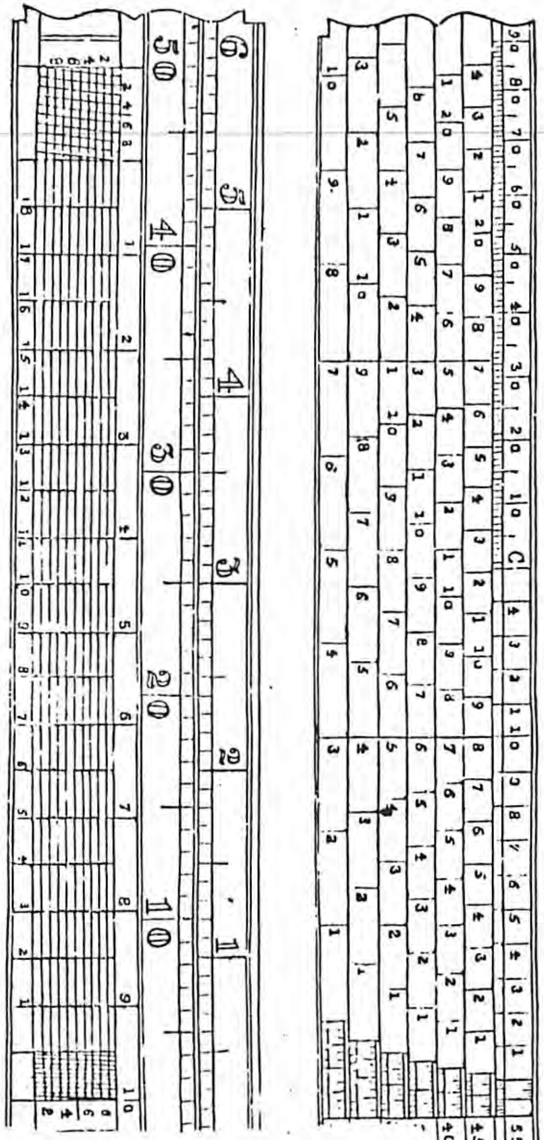


Fig. 36.

mencement of these lines, and the other will fall on 28, the number required. For as 4 is to 7 so is 16 to 28.

2. *In the Lines of Chords.*—Suppose it required to lay off an angle equal to 25 degrees, with any convenient opening of the sector, take the extent in the lines marked c, from 60 to 60, and with it describe an arch indefinitely; then, with the same opening of the sector, take the parallel distance from 25 to 25, and set it in the arch described, lines drawn from these points in the arch to its centre, will give the angle required.

3. *In the Lines of Sines.*—The lines of sines, tangents, and secants, are used in conjunction with the line of lines in the solution of all the cases of plain trigonometry; thus, suppose we are 230 feet from a spire, or elevation, the height of which we wish to measure, we ascertain the angle formed at that distance by the base and point of the spire by means of a quadrant, and find it to be 36 degrees and 30 minutes; consequently, the other angle being its complement must be $53\frac{1}{2}$ degrees; we now take the lateral distance, 230, from the line of lines, and make it a parallel from $53\frac{1}{2}$ degrees to $53\frac{1}{2}$ degrees in the line of lines; then the parallel distance between $36\frac{1}{2}$ in the same lines, will reach laterally from the centre to 170 in the line of lines, for the height of the spire 170 feet.

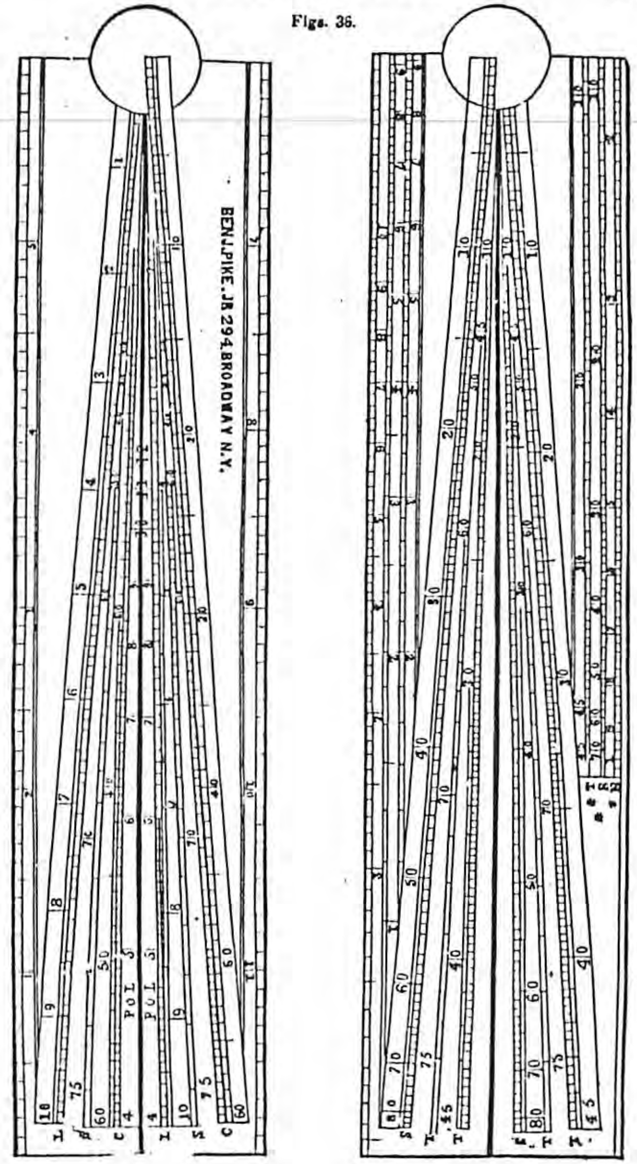
4. *Polygons.*—If we open the sector any convenient distance, and take with the compasses the distance 6 and 6 on these lines, and inscribe a circle, the whole circumference will be divided by it into 6 parts; then, if you take the distance 4 and 4 on the same lines, it will be divided into four parts, and you have a square inscribed in the circle; if you take 7 and 7 you have a heptagon, or seven sided figure, and so on with all the divisions of these scales.

A great number of problems of much interest may be solved by means of these, and the other lines of the sector.

Price, in ivory, $1.50.
" in brass, $1.50.

Architect's Scale.—(Fig. 37, page 37.)—Scales are usually divided into tenths; those expressly for architects are divided into twelve parts, to correspond to the measure used by carpenters and masons. They are usually made of ivory, and six, nine, and twelve inches long; one side is slanted off at each edge, having scales of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 1 inch, marked

Figs. 36.



thereon; these are very convenient, as any proportion may be marked off, from the edge, directly on the drawing, without the use of a pair of dividers; the scales on the other part are usually $\frac{3}{8}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, and on the other side of the scale $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, 3 inch.

Price, 6 in. in ivory, $2.50.; 9 in. $3.00.; 12 in. $4.00.
" in brass, from - - $1.00. to $3.00.

The Parallel Rule (Fig. 38, page 37) is used for drawing one or more lines parallel to, or equally distant from, any line proposed. It consists of two straight rules, which are connected together, and always maintained in a parallel position by the two equal and parallel bars, which move very freely on the centre, or rivets, by which they are fastened to the straight rules.

Price, in black ebony, 6 in., 62c.; 9 in., 88c.; 12 in., $1;
15 in., $1.25; 18 in., $1.50;
24 in., $2.50; 36 in., $5.00.
" in ivory, 6 in., $1.50; 12 in., $3.00.

Double Parallel Rule.—(Fig. 39, page 38.)—This instrument consists of two equal flat rules, and a middle piece they are connected together by four brass bars. The end of two bars are riveted on the middle line of one of the straight rules; the ends of the other two bars are riveted on the middle line of the other straight rule; the other ends of the brass bars are taken two and two, and riveted on the middle piece, as is evident from the figure; the brass bars move freely on their rivets, as so many centres. The advantage of this rule is, that in using it the movable rule may always be so placed, that its ends may be exactly over, or even with, the ends of the fixed rule; whereas, in the former kind, they are always shifting away from the ends of the fixed rule.

Price, 6 inch, ivory, $3.50.
" 12 " " $7.00.

Eckhardt's, or Rolling Parallel Rule.—(Fig. 40, page 38.)—This is a rule of black ebony, with slips of ivory laid on the edges of the rule, and divided into inches and tenths. The rule is supported by two small wheels, which are connected together by a long axis, the wheels being exactly of the same size, and their rolling surfaces being parallel to the axis; when they are rolled backwards or forwards, the axis

Figs. 37.

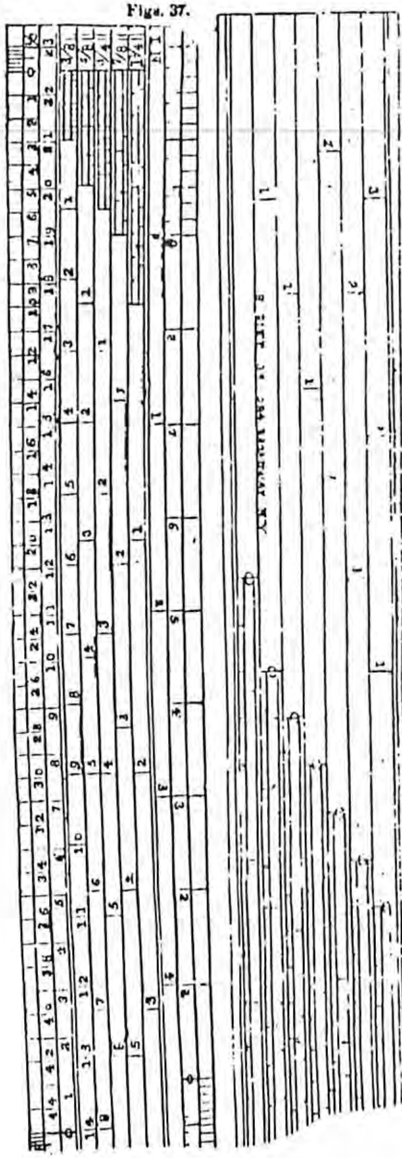


Fig. 38.

Fig. 39.

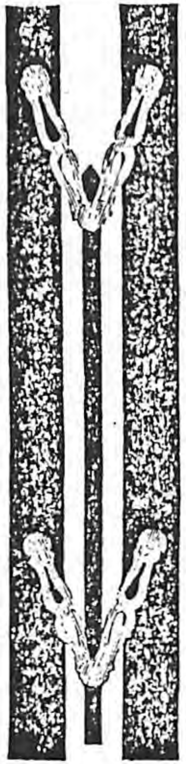
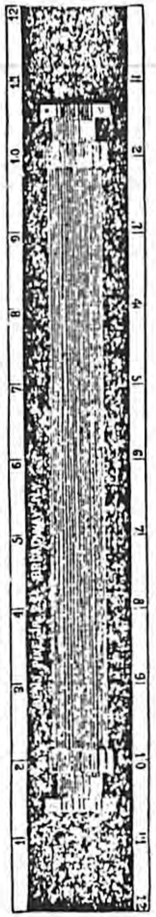


Fig. 40.



and rule will move in a direction parallel to themselves. The wheels are somewhat indented, to prevent their sliding on the paper; small ivory cylinders are sometimes affixed to the rollers, as in the figure. The circumferences of these are so adjusted, that they indicate with exactness the parts of an inch moved through by the rule.

In rolling these rules, one hand only must be used, and the fingers should be placed nearly in the middle of the rule, that one end may not have a tendency to move faster than the other; the wheels only should touch the paper when the rule is moving, and the surface of the paper smooth and flat.

Price, 12 in., $5.50.

The T Square.—(Figs. 41 and 42, page 39.)—This is a very useful article in drawing. A ruler, about two to three feet in length, made of hard wood, or steel, is fixed, as a square, to the middle of a piece of hard wood, about one foot long and two inches wide, and on one side a loose piece is fastened by a thumb screw, which passes through both pieces, allowing both to be clamped together at any angle, thus forming a bevel.

The head of the square, applied close to the edge of a true drawing board, will admit of true lines being drawn as

Fig. 41.

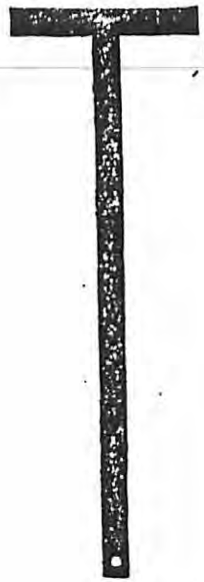


Fig. 42.

Fig. 43.

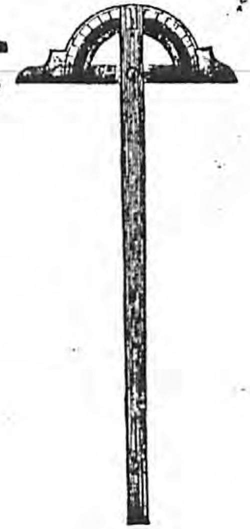


Fig. 44.

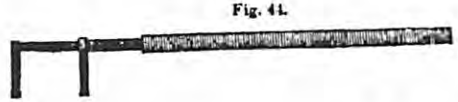
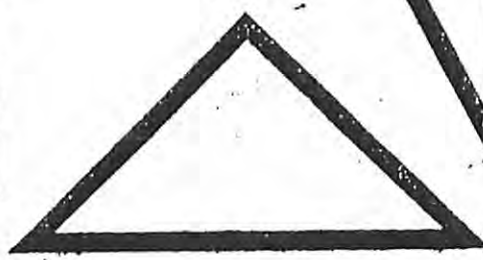


Fig. 46.

Fig. 45.

Fig. 48.



well as oblique ones, with more ease and expedition than by the common parallel rule.

Price, 75 cts. to $2.50.
" with steel blade, $3.00 to $5.00.

The T Square and Protractor.—(Fig. 43, page 39.)—This instrument is formed of a divided arc of brass, usually about ten inches in diameter, whose graduation commences at the middle, and is continued each way to 90 degrees; at the centre of the arc is attached a movable arm, about 30 inches long; at the shorter end is a vernier, running on the graduated arc, and subdividing the degrees of the arc into minutes, and having a spring bent over to the under side of the arc, with a screw to clamp it fast in any position. Used on a true drawing board, this instrument is simple and convenient, answering all the purposes of plotting and protracting of a square and bevel, and for drawing parallel lines in different directions. Price, $7.00 to $12.00.

Gauge for measuring Diameters, Interiors, etc.—(Fig. 44, page 39), with steel blades and brass sliding bars, the bars sliding within each other, and graduated to inches and tenths, with one, two, or three slides.

Price, $1.50 to $7.50.

Draughtsman's Squares.—(Figs. 45 and 46, page 39.)—These squares are best made of hard wood, and are used with a common flat ruler, one of the edges of the square being placed against the rule, and by holding the rule fast, and moving the square, parallel lines may be drawn with ease and accuracy. One of the squares represented is a solid one, having a hole for the finger to move it by. The other is open in the centre, and is used where they are required of a large size.

Price 25 cents to 75 cents.

Curves.—(see pages 41, 42, 43.)—These are various in shape and size, and from 6 to 24 inches long. Their use is to present a variety of forms for drawing curves, and they are extensively used in naval architecture and other drawings. Price, 38 cents to 50 cents each.
The set of 25, $7.

Fig. 47. Fig. 48. Fig. 49. Fig. 50.

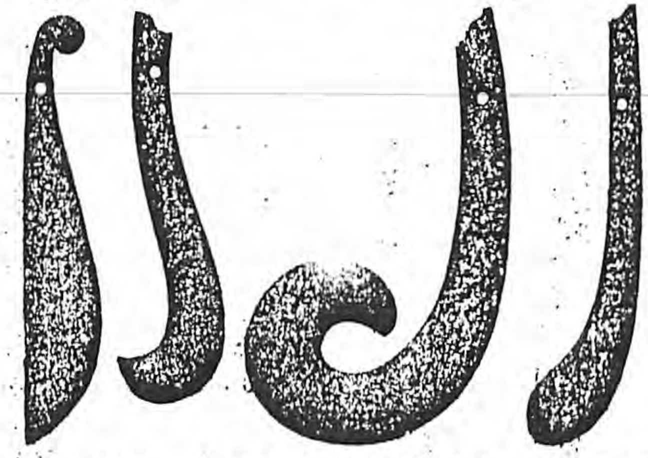


Fig. 51. Fig. 52. Fig. 53. Fig. 54. Fig. 55.

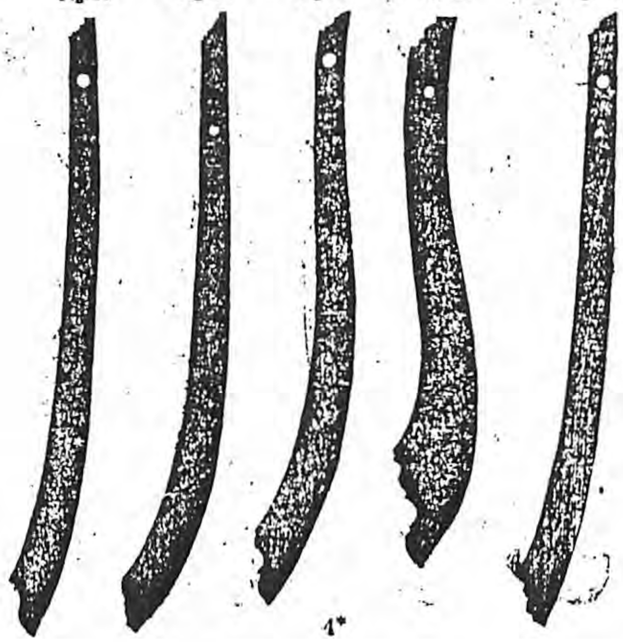


Fig. 56.

Fig. 57.

Fig. 58.

Fig. 59.

Fig. 62.

Fig. 61.

Fig. 60

Fig. 63.

Fig. 64.

Fig. 65.

Fig. 66.

Fig. 67.

Fig. 68.

Fig. 69.

Fig. 70.

Fig. 71.

Fig. 72.

Fig. 73.

Centrolinead.—(Fig. 74, page 45.)—The Centrolinead is an instrument used in perspective drawing, for drawing lines towards a distant centre, as towards a distant vanishing point. They are made in pairs right and left. In the cut, the blades are represented as broken off. Price, with blades, each $10.

Improved Circular Protractor.—(Fig. 75, page 45.)—This instrument consists of an entire circle, A A, connected with its centre by four radial bars, *a a*. &c. The centre of the metal is removed, and a circular disk of glass fixed in its place, on which are drawn two lines crossing each other at right angles, and dividing the small circle into four quadrants, the intersection of the lines denoting the centre of the protractor. When the instrument is used for laying down an angle, the protractor must be so placed on the paper that its centre exactly coincides with, or covers the angular point; which may easily be done, as the paper can be seen through the glass centre-piece.

Round the centre, and concentric with the circle, is fitted a collar, *b*, carrying two arms, *c c*, one of which has a vernier at its extremity adapted to the divided circle, and the other a milled-head, *d*, which turns a pinion, working in a toothed rack round the exterior circle of the instrument; sometimes a third arm is applied at right angles to the other two, to which the pinion is attached, and a vernier can then, if required, be applied to each of the other two, and it also prevents the observer disturbing that part of the instrument with his hand when moving the pinion. The rack and pinion give motion to the arms, which can thus be turned quite round the circle for setting the vernier to any angle that may be required. Upon a joint near the extremity of the two arms (which form a diameter to the circle) turns a branch, *e e*, which for packing may be folded over the face of the instrument, but when in use must be placed in the position shown in the figure: these branches carry, near each of their extremities, a fine steel pricker, the two points of which, and the centre of the protractor, must, for the instrument to be correct, be in the same straight line. The points are prevented from scratching the paper as the arms are moved round, by steel springs, which lift the branches a small quantity, so that, after setting the centre of the protractor over the angular point, and the vernier in its required position, a slight downward pressure must be given to the branches, and each of the points will make a fine puncture in the paper; a line drawn through one of these punctures and the angular point will be the line required to form the angle.

Any inaccuracy in placing the centre of the protractor over the angular point may easily be discovered, for, if incorrectly done, a straight line drawn through the two punctures in the paper will not pass through the angular point, which it will do, if all be correct.

The face of the glass centre-piece, on which the lines are drawn, is placed as nearly even with the under surface of the instrument as possible, that no parallax may be occasioned by a space between the lines and the surface of the paper.

By help of the vernier, the protractor is graduated to single minutes, which, taking into consideration the numerous sources of inaccuracy in this kind of proceeding, is the smallest angular quantity that we can *pretend* to lay down with certainty. Price, $18.00 to $40.00.

Fig. 74.

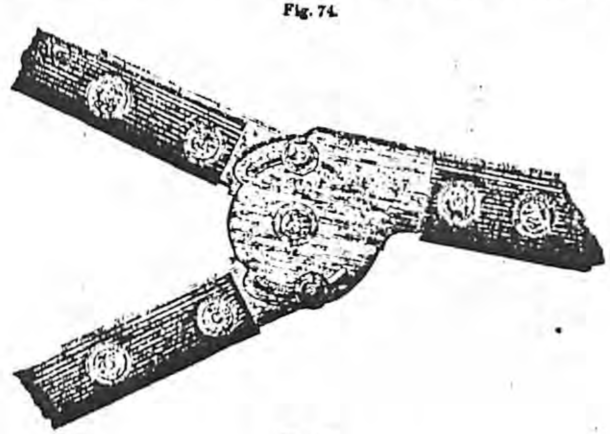


Fig. 75.

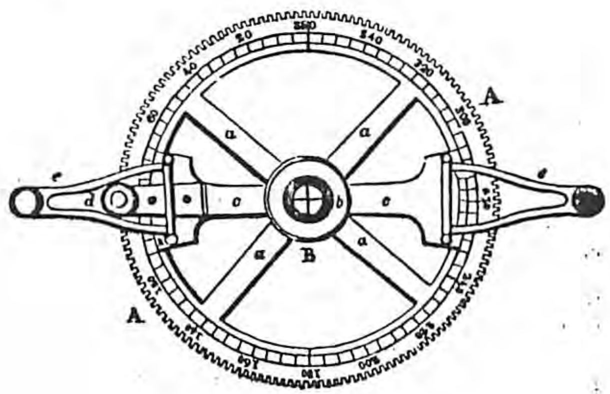
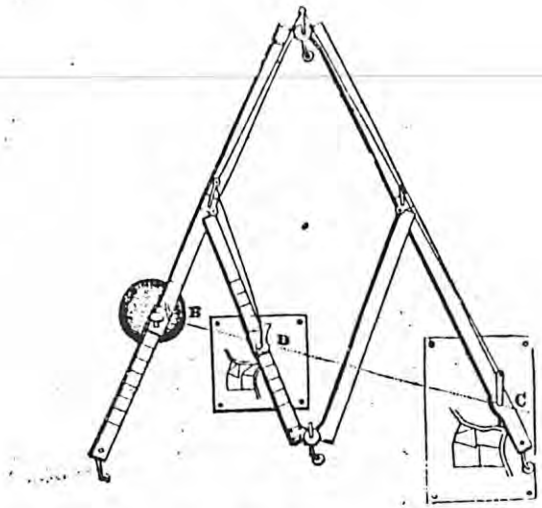


Fig. 76.



The Pantagraph.—(Fig. 76, as above.)—The pantagraph is usually made of ebony or brass, from 12 to 24 inches long, and consists of four flat rules, two of them long and two of them short. The two longer are joined at the end by a double pivot, which is fixed to one of the rules, and works in two small holes placed at the end of the other. Under the joint is an ivory castor, to support this end of the instrument. The two smaller rules are fixed by pivots near the middle of the larger rules, and are also joined together at their other end; by the construction of this instrument, the four rules always form a parallelogram. There is a sliding box on the longer arm, and another on the shorter arm. These boxes may be fixed at any part of the rules, by means of their milled head screws; each of these boxes is furnished with a cylindrical tube, to carry either the tracing point, crayon, or fulcrum. The fulcrum or support, B, Fig. 76, is a leaden weight; on this the whole instrument moves when in use, there being movable rollers under different parts of the instrument to facilitate the movement thereof. The graduations are placed on two of the rules, B and D, with the proportions of $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c., to $\frac{1}{12}$, marked on them. The pencil

holder, tracer, and fulcrum, must in all cases be in a right line, so that when they are set to any number, if a string be stretched over them, and they do not coincide with it, there is an error either in the setting or the graduations. The long tube that carries the pencil, or crayon, moves easily up or down in another tube, passing afterwards through the holes in the three small knobs to the tracing point, where it may, if necessary, be fastened. By pulling this string, the pencil is lifted up occasionally, and thus prevented from making false or improper marks upon the copy.

To Reduce in any proportions, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, etc., as marked on the bars.—Suppose, for example, $\frac{1}{2}$ is required: place the two sockets at $\frac{1}{2}$ on the bars B and D, place the fulcrum or lead weight at B, the pencil socket with pencil at D, and the tracing point at C. Fasten down upon a smooth board, or table, a sheet of white paper under the pencil D, and the original map, &c., under the tracing point C; allowing yourself room enough for the various openings of the instrument. Then, with a steady hand, carefully move the tracing point C over the outlines of the map, and the pencil D will describe exactly the same figure as the original, but half the size. In the same manner for any other proportion, by only setting the two sockets to the number of the required proportion. The pencil holder moves easily in the socket to give way to any irregularity in the paper. There is a cup at the top for receiving an additional weight, either to keep down the pencil to the paper, or to increase the strength of its mark.

If the original should be so large, that the instrument will not extend over it at any one operation, two or three points must be marked on the original, and the same to correspond on the copy. The fulcrum and copy may then be removed into such situations as to admit the copying of the remaining part of the original; first observing, that when the tracing point is applied to the three points marked on the original, the pencil falls on the three corresponding points upon the copy. In this manner, by repeated shiftings, a pantagraph may be made to copy an original of ever so large dimensions.

To enlarge in any of the proportions, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c.—Suppose $\frac{1}{2}$. You set the two sockets at $\frac{1}{2}$, as before, and have only to change places between the pencil and tracing point, viz. to place the tracing point at D, and the pencil at C.

To copy off the same size, but reversed, place the two sockets at $\frac{1}{2}$, the fulcrum at D, and the pencil at B.

Price, ebony bars and brass mounting, \$7.50 to \$14.00.
" all brass, - - - \$15.00 to \$30,00.

SURVEYING INSTRUMENTS.

SURVEYOR'S LAND CHAIN.

GUNTER'S Chain (Fig. 77, page 51) is the one now commonly used in taking the dimensions of land; it is sixty-six feet, or four poles, in length, and is divided into 100 links, each of which is joined to the next by three rings; the length of each link, including the connecting rings, is 7.92 inches, and at the end of every tenth link is attached a piece of brass (each of a different shape) for more readily counting the odd links.

Short distances, or offsets from the chain line, are usually measured with a rod, called an off-set staff, the most convenient length for which is 6 feet 7.2 inches, being equal to 10 links of the chain, and it should be divided accordingly.

With the chain should be provided ten arrows, which may be made of strong iron wire, about 12 or 15 inches long, pointed at one end for piercing the ground, and turned up at the other, in the form of a ring, to serve as a handle: their use is to fix in the ground at each extremity of the chain whilst measuring, and to point out the number of chains measured. Price, 2 pole, \$1.00 and \$1.25.
" 4 " \$2.25 to \$2.75.

Perambulator, or Measuring Wheel.—(Fig. 78, page 51.)—An instrument which being run along a road or other level surface indicates and registers the exact distance it passes over. The general form of the instrument, and its system of wheel-work, are as follows:—

The wheel is $8\frac{1}{4}$ feet in circumference, and consequently measures exactly a pole in every two revolutions. The number of revolutions made, and consequently the distance passed over, is seen on the dial-plate, where there are two hands, one moving round a circle, upon which are inscribed yards, poles and furlongs; the other, that is the shorter hand, indicates the number of miles travelled.

Price, $50.00.

Tape Measure.—(Fig. 79, page 51.)—This instrument consists of a tape prepared and painted, or varnished, on which is divided feet and inches, one end of which is attached to a brass axis having a handle, by turning which the tape is wound up in a small compass, and inclosed usually in a leather box; to the other end of the tape a ring is attached, by which the tape may be drawn out, the measurement commencing at the ring; on one side there are frequently divided links, 100 of which make a chain, or 66 feet.

Price, 25 feet long, $1.25; 30 feet long, $1.37.
" 40 " " $1.50; 50 " " $1.75.
" 60 " " $2.00; 100 " " $3.00.

Pocket Tape Measure.—(Fig. 80, page 51.)—These are from three to twelve feet long, and mounted in a variety of styles, some having springs by which the tape is drawn in when required, and are mounted in brass or German silver.

Price, 3 feet, brass case, - - $0.63.
" 6 " " " - - $0.88.
" 12 " " " - - $1.25.
" 3 " " " with spring, $1.25.
" 6 " " " " " $1.50.
" 3 " German silver, " " $2.00.

Plumb Bob.—(Fig. 81, page 51.)—This consists of a cone of metal with steel point and rounded top, suspended by a cord, for which a small perforated piece of brass is screwed into the top, within which the knot fastening the cord is tied.

Price, 2 inch, $1.25; 3 inch, $2.00.
" 4 " - - - $2.50.

Pocket Compass.—(Fig. 82, page 53.)—The pocket compass is a very valuable instrument to travellers, and persons visiting pathless forests, or unfrequented places, as by the help of this little instrument they may direct their course with certainty in any direction; they are usually made in small brass boxes, from one inch to two inches in diameter, and half an inch thick; the points of the compass are repre-

Fig. 77.

Fig. 78.

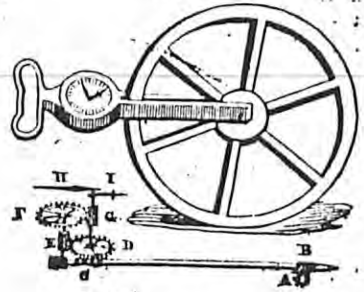


Fig. 79.

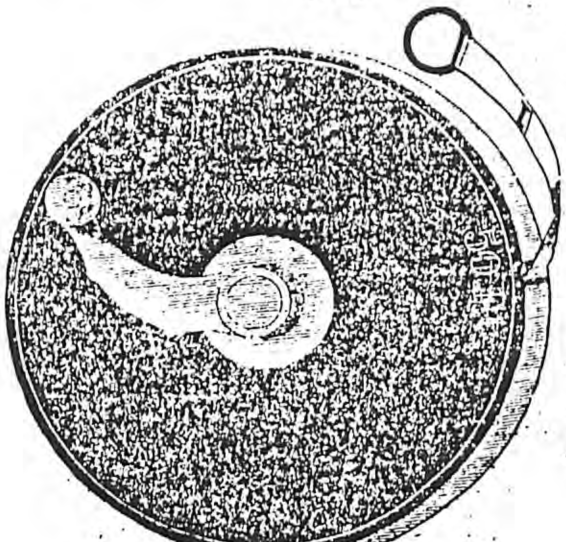


Fig. 80.

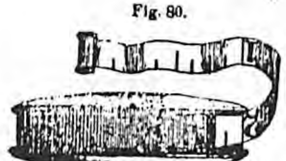
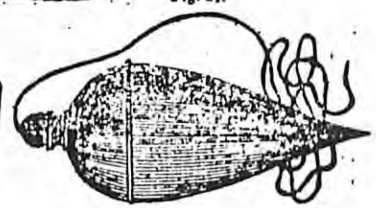


Fig. 81.



sented on a card at the bottom of the box, and over it the magnetic needle is suspended on a fine point, a glass covering the needle, and a brass cap covering the whole.

Price, - - - - - - 38cts.

" two sizes larger 50cts., and 63cts.

(Fig. 83, page 53) represents a pocket compass in a watch form, with a pendant, the case usually gilt and neatly and lightly made. Price, $1.00.

(Fig. 84, page 53) represents a pocket compass of the best make, having an enamelled dial with all the 360 degrees and all the points of the compass marked thereon, having a fine edge bar needle with agate centre, a stop to lift the needle from the fine point on which it turns, to prevent unnecessary wear when not in use; the case is either of silver or well gilt, and is enclosed in a morocco case.

Price, strong gilt case, $9.00.

" silver case, $12.00.

Pocket Compasses (Fig. 85, page 53) in square wood cases, with lever to stop the magnetic needle when the lid is closed, but on opening the lid, is left free to assume its directive tendency.

Price, 2 inch, $1.25; 2½ inch, $1.50; 3 inch, $2.00.

The Mariner's Compass (Fig. 86, page 53) consists of a magnetic needle, formed of a thin plate of steel, about six inches long, and half an inch wide, having at its centre a cap fitted to it, usually having an agate centre, which is supported on a sharp pointed pivot fixed in the base of the instrument; beneath the needle is fixed a circular card, on the circumference of which are divided 360 degrees, while an inner circle, described on it, is marked with the thirty-two points, of which the four, viz. North, South, East, and West, are called cardinal points, while intermediate between these are N.E. or north-east, S.E. or south-east, S.W. or south-west, N.W. or north-west, N.b.E. is north by east, N.N.E. is north of north-east, etc.; the pivot of support rises from the bottom of a circular box, which contains the needle and its card, and is covered with a glass; the compass box is suspended within a larger square box, by means of two concentric brass circles, or gimbals, as they are called, the

Fig. 82.

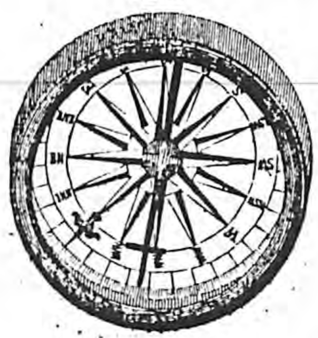


Fig. 83.

Fig. 84.

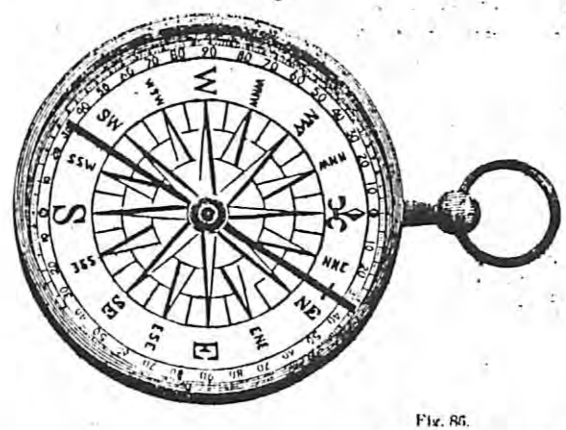


Fig. 86.

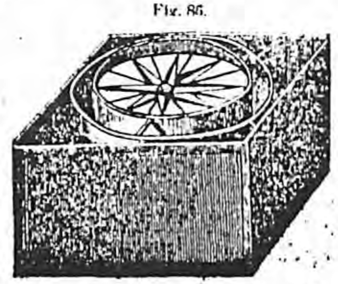
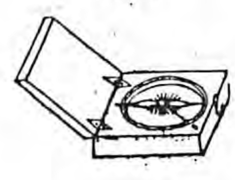


Fig. 85.



outer one being fixed by horizontal points, both to the inner circle which carries the compass box, and also to the outer box; and the two sets of axes being in directions at right angles to one another, by the combinations of movements determined by these axes, the inner circle, with the compass box and its contents, always retains a horizontal position during the rolling of the ship; and the pilot, by looking at the position of the needle, can steer his course in any required direction. Although the north pole of the magnet, in every part of the world, when freely suspended, points to the northern parts, and the south pole to the southern parts, yet its ends seldom point exactly towards the poles of the earth. The angle in which it deviates from due north and south is called the angle of declination, or the variation of the compass; and this declination is said to be east or west, according as the north pole of the needle is eastward or westward of the astronomical meridian of the place. This deviation from the meridian is not the same in all parts of the world, but is different in different places, and it is even continually varying in the same place; the present declination of the needle is ——

Price, with wood bowl, $2.50.
" " brass " $4.50.

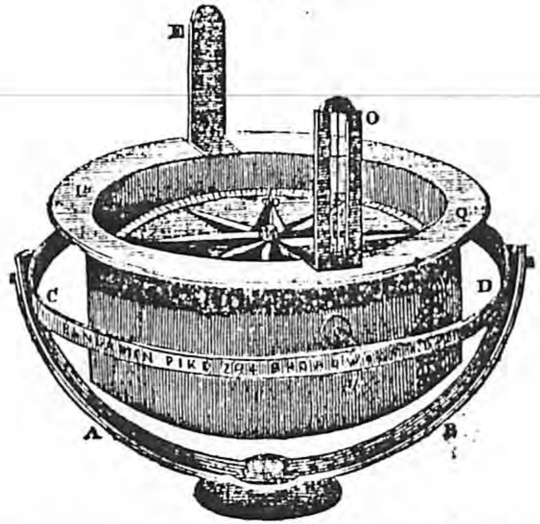
Fig. 87

Brass Boat Compass.—(Fig. 87.)—The brass boat compass with nautical floating card.

Price, $2\frac{1}{2}$ inch diameter, $2.25.
" 3 " " $2.75.

The Azimuth Compass.—(Fig. 88, page 55.)—The azimuth compass differs from the ordinary mariner's compass, only in the circumference of its inner box being provided with sights, through which any object, either in the horizon or above it, may be seen, and its bearings from the magnetic points of the compass determined, by reference to the position of the card, with respect to the sights. For this purpose the whole box is hung in detached gimbals, which turn on a strong vertical pin fixed below the box, which is thus capable of being moved around horizontally, and of the sights being directed to whatever object is to be viewed through them. On one side of the box there is usually inserted a nut, or stop, which, when pushed in, presses against the card and stops it; this is done to enable the

Fig. 88.



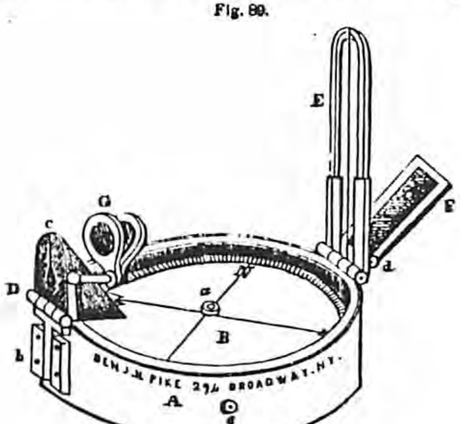
observer to read off the number of degrees from the card, which correspond with an index, or perpendicular line, drawn on the inside of the box.

Description.—The semicircle A B is fixed by a screw at its middle, or lowest point, to a stand at the bottom of the outer box containing the whole apparatus, in such a manner as to admit of its being turned round horizontally, and placed in all azimuths. To the upper extremities of this semicircle a brass circle C D is fixed by two pivots, constituting a horizontal axis of motion; while the inner cylindrical brass box P Q, containing the compass, is attached to the brass circle O D by similar pivots, of which one is seen at *g*, forming a horizontal axis at right angles to the former, and both together acting as gimbals. The compass with its card is balanced in the usual manner on a pointed pivot rising from the centre of the bottom of the inner box, the upper side of which is covered with a circular glass. The two sights E and O are fixed vertically on the upper side of the cylinder of this box, diametrically opposite to each other; the one, E, to which the eye is intended to be applied, consists of a brass slip, having a narrow vertical slit; the other, o, which is turned to the object, is a similar slip, having an oblong aperture containing a fine thread, passing along the middle of the open space in a vertical direction. Two vertical lines are also marked on the inside of the box, which are prolongations of the slit in the sight for the eye, and of the thread in that for the object. These lines are intended as indexes for the measurement of the angular distance in azimuth of an object viewed through the two sights, from the place of the magnetic meridian, as shown by that portion of the graduated edge of the card which coincides with the line with which it is compared.

Price, $8.00 to $20.00.

The Prismatic Compass.—(Fig. 89, as below.)—The use of this little instrument is to measure horizontal angles only, and from its portability it is particularly adapted for military surveying, or where but little more than a *sketch map* of the country is required. It is also very useful in filling in the detail of a map, where all the principal points have been correctly fixed by means of the theodolite. It may likewise be used for determining approximately the direction of the true meridian, the variation being determined by comparing the observed azimuth of a celestial object, with its true azimuth deduced from an observation made for the purpose.

Fig. 89.



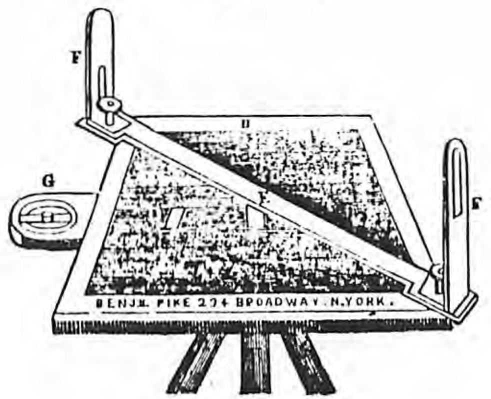
In the preceding figure, A represents the compass box, and B the card, which, being attached to the magnetic needle, moves as it moves, round the agate centre, *a*, on which it is suspended. The circumference of the card is usually divided to 30′ of a degree; *c* is a prism, which the observer looks through in observing with the instrument. The perpendicular thread of the sight-vane, E, and the divisions on the card appear *together* on looking through the prism, and the division with which the thread coincides when the needle is at rest, is the magnetic azimuth of whatever object the thread may bisect. The prism is mounted with a hinge joint, D, by which it can be turned over to the side of the compass box, that being its position when put into the case. The sight-vane has a fine thread stretched along its opening, in the direction of its length, which is brought to bisect any object, by turning the box round horizontally; the vane also turns upon a hinge joint, and can be laid flat upon the box, for the convenienceof carriage. F is a mirror, made to slide on or off the sight-vane, E; and it may be reversed at pleasure, that is, turned face downwards; it can also be inclined at any angle, by means of its joint, *d;* and it will remain stationary on any part of the vane, by the friction of its slides. Its use is to reflect the image of an object to the eye of the observer when the object is much above or below the horizontal plane. When the instrument is employed in observing the azimuth of the sun, a dark glass must be interposed; and the colored glasses represented at G, are intended for that purpose; the joint upon which they act allowing them to be turned down over the sloping side of the prism box.

At *e* is shown a spring, which, being pressed by the finger at the time of observation, and then released, checks the vibrations of the card, and brings it more speedily to rest. A stop is likewise fixed at the other side of the box, by which the needle may be thrown off its centre; which should always be done when the instrument is not in use, as the constant playing of the needle would wear the point upon which it is balanced, and upon the fineness of the point much of the accuracy of the instrument depends. A cover is adapted to the box, and the whole is packed in a case, which may be carried in the pocket without inconvenience.

The method of using this instrument is very simple. First raise the prism in its socket, *b*, until you obtain distinct vision of the divisions on the card, and standing at the place where the angles are to be taken, hold the instrument to the eye, and looking through the slit, *c*, turn round till the thread in the sight-vane, bisects one of the objects whose azimuth or angular distance from any other object is required; then, by touching the spring, *e*, bring the needle to rest, and the division on the card which coincides with the thread on the vane, will be the azimuth or bearing of the object from the north or south points of the magnetic meridian. Then turn to any other object, and repeat the operation; the difference between the bearing of this object and that of the former, will be the angular distance of the objects in question. Suppose the former bearing to be 40° 30′, and the latter 10° 15′, both east, or both west, from the north or south, the angle will be 30° 15.′ The divisions are generally numbered 5°, 10°, 15°, etc., round the circle to 360°. A stand can be had with the instrument, if required, on which to place it when observing, instead of holding it in the hand. Price, $16.00 and $20.00.

The Plane-Table.—(Fig. 90, as below.)—Before the theodolite came into general use, the plane-table was extensively employed in the practice of surveying; it is still sometimes, though seldom, used in surveying small plots of ground, or

Fig. 90.



(where great accuracy is not required) in forming a sketch map, or laying down the details of a country where the relative situation of the principal conspicuous objects have been previously fixed by triangulation. The expedition with which such work may be performed, by a person who is expert in the use of this instrument, is its chief recommendation.

The construction and size of the plane-table have been varied at different times, to suit both the convenience and intentions of the surveyor; but the annexed figure is a representation of that which is now in most general use. It is a board, as A, about sixteen inches square, having its upper edge rabbeted, to receive a boxwood frame, B, which being accurately fitted, can be placed on the board in any position, with either face upwards. This frame is intended both to stretch and retain the drawing paper upon the board, which it does by being simply pressed down into its place upon the paper, which for this purpose must be cut a little larger than the board.

One face of the frame is divided to 360 degrees, from a centre, C, fixed in the middle of the board, and these are subdivided as minutely as the size of the table will admit. The divisions are frequently numbered each way, to show at sight both an angle and its complement to 360°. There is sometimes a second centre piece, D, fixed on the table, at about a quarter of its width from one of the sides, and at *exactly* half its length in the other direction. From this centre, and on the other side of the frame, there are graduated 180°; each of these degrees is subdivided to 30 minutes, and numbered 10, 20, 30, &c., both ways, to 180. The object of these graduations is, to make the plane-table supply the place of the theodolite, and an instrument formerly in use called a semicircle. The reverse face of the frame is usually divided into equal parts, as inches and tenths, for the purpose of ruling parallel lines or squares, and for shifting the paper, when the work requires more than one sheet. G is a compass-box, let into one side of the table, with a dove-tail joint, and fastened with a milled-headed screw, that it may be applied or removed at pleasure. The compass, besides rendering the plane-table capable of answering the purpose of a circumferentor, is principally useful in setting the instrument up at a new station parallel to any position that it may have had at a former station, as well as a check upon the progress of the work.

The ruler or index, E, is made of brass, as long as the diagonal of the table, and about two inches broad; it has a sloping edge, like that of a Gunter's scale, which is called the fiducial edge. A perpendicular sight vane, F F, is fixed to each extremity of the index, and the eye looking through one of them, the vertical thread in the other is made to bisect any required distant object. Upon the flat surface of the index, there are frequently engraved scales of various kinds, such as lines of equal parts, with diagonal scales, a line of chords, &c.

To the under side of the table, a centre is attached with a ball and socket, or parallel plate-screws like those of the theodolite, by which it can be placed upon a staff-head; and the table may be set horizontal, by means of a circular spirit-level placed upon it for that purpose.

Price, $20.00 to $35.00.

Fig. 91.

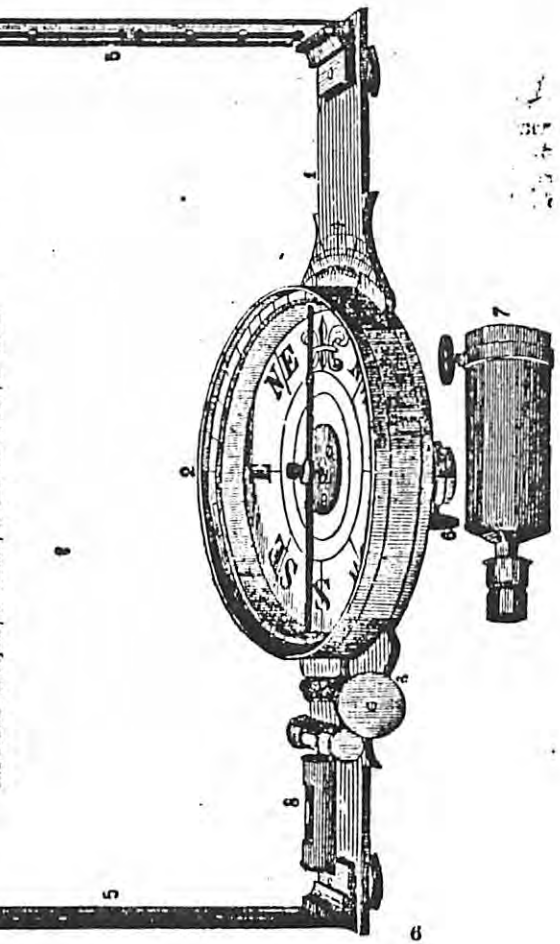
Surveyor's Cross.—The surveyor's cross (Fig. 91) consists of two pair of sights, placed at right angles to each other. These sights are sometimes pierced out in the circumference of a thick tube of brass, or sides of a square box, about three inches in diameter. It has a socket, which, when in use, is screwed on a staff, having a sharp point at the bottom to stick in the ground. The more improved instruments are made octangular, having the intermediate angle of 45 degrees also pierced.

Price $3.00 to $6.00.

Circumferentor, or Surveyor's Compass.—(Fig. 92, next page.)—This instrument consists of a brass plate, usually about fourteen or fifteen inches long, with sights at each end, and in the middle thereof a circular box with a glass cover, usually from five to seven inches diameter; within the box is a brass graduated circle, the upper surface divided into 360 degrees, and frequently subdivided into half degrees, and numbered from the north and south points each way from 0 to 90. On the face of the plate are engraved the principal points of the compass, a fleur de lis answering for the north. In the middle of the box is placed a steel pin finely pointed, called the centre pin, on which is

poised a magnetic needle, which, if freely mounted, will rest in the position called the magnetic meridian; and however the instrument may be moved about, the bearing or angle which any line makes with the magnetic meridian is at once shown. The sights at the ends of the plate are fastened in

Fig. 92.



No. 1. Plate of compass; 2. Box of compass; 3. Tangent screw; 4 Divided arc and nonius; 5. sights; 6. Socket; 7. Ball and socket; 8. Levels.

their position, perpendicular to the plate, by milled-head screws, and may be detached for convenient transportation; in each sight there is a large and small aperture, or slit, the one over the other; these are alternate, that is, the large aperture being above the smaller in one of the sights, and below it in the other; a fine piece of sewing silk is fastened vertically through the middle line of the large slit, through small holes for the purpose. Under the compass box is a socket to fit in the pin of the staff; the instrument may be turned around on this pin, or fixed in any situation by the milled-head screw; it may also be readily fixed in a horizontal direction by the ball and socket of the staff, moving for this purpose the box, till the ends of the needle are equidistant from the bottom, and traverse or play with freedom.

There are usually one or two levels on the plate of the instrument, for more accurately finding a horizontal position. A spring is also placed within the box, having a milled-head screw acting against it, by which the magnetic needle can be lifted off the centre pin and the cap pressed against the glass, to preserve the point of the centre pin from being blunted by the continual friction of the cap of the needle. The most improved instruments have a loose plate, to which is attached the compass box, having a vernier over a graduated arc on the face of the brass plate; by this contrivance the compass box may be moved about its centre without moving the plate to which the sights are attached; a long screw with a milled head being on the opposite side of the compass box, for the purpose of giving a slow motion when required. Suppose the needle to rest between two of the divisions on the graduated circle; by this vernier the number of minutes contained between the needle and either of the divisions is indicated. The sights also are improved, having small slits in both the upper and lower part, in which holes are placed alternately, for taking sight through.

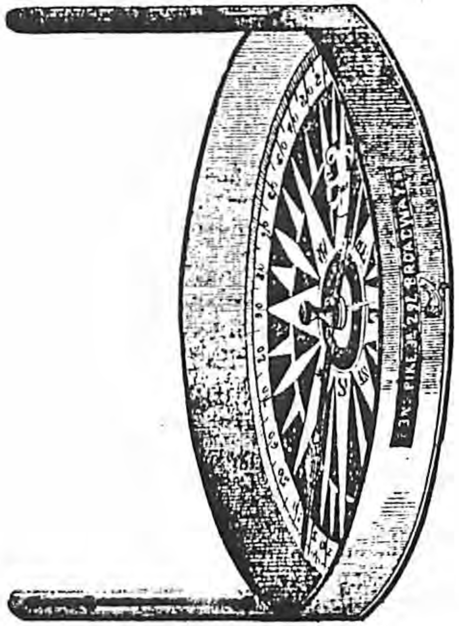
To use the Circumferentor, or Surveyor's Compass.—Suppose a given angle to be measured; the instrument being fixed on the staff, place its centre over one of the points of the angle, set it horizontal by moving the ball in its socket till the needle is parallel to the bottom of the compass box, or the levels indicate a horizontal position; turn the end of the compass box on which the N or fleur de lis is engraved next the eye, look through the sights to one of the objects

forming the angle to be measured, and observe at what degree the needle stands, suppose 40, turn the instrument around on the pin of the ball and socket till you can see the object forming the other angle, and suppose the needle now to stand at 85, take the former from the latter, and the remainder, 45, is the required angle.

Packed in a mahogany case, with lock,

Price, with 4 in. needle,	$14.00.	
" with 5 in. needle,	$20.00	and $22.50.
" with 6 in. needle,	$28.00	and $32.00.
" with nonius, 5 in.	$30.00.	
" with nonius, 6 in.	$35.00	to $42.

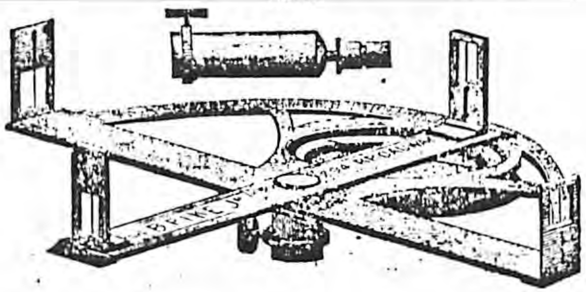
Fig. 93.



Plane Surveyor's Compass.—The above engraving (Fig. 93) represents a low-priced surveyor's compass, that is very useful to farmers and others, in running lines and laying out their fields, as well as in surveying them. It is used by setting it on the top of a post, fence, &c. Its diameter is 4 inches.

Packed in a mahogany case, Price $5.00.

Fig. 94.



The Graphometer, and Four Sighted Theodolite.—(Fig. 94, as above.)—The error arising from the use of an instrument, where the whole dependence is placed on the needle, being frequently influenced by local attractions, has rendered it necessary for some other method to be employed to measure angles with accuracy; among these the common theodolite with four sights has taken the lead.

It is simple in its construction, and easy in its use.

The annexed figure represents the graphometer, a brass plate or part of a circle about twelve inches in diameter, graduated on its edge from 0 to 180 degrees; in the opening between the moving centre and the graduated arc, is a compass about four inches in diameter; two sights are fixed on the graduated arc, one at 0 and the other at 180°. Perpendicular to the plane of the instrument, there is a movable limb attached to the limb of the arc, but a little shorter, and having the extremities slanted off, one of which forms a nonius, subdividing the degrees on the limb to minutes, and having two sights, one at each end; in each sight there is a large and a small aperture, placed alternately, the large aperture in one sight being always opposed to the narrow aperture in the other; underneath the plate is a spring to fit on the pin of a ball and socket, which fixes it the single or three legged staff, as may be required. In the figure the ball and socket are represented detached from the instrument.

The Four Sighted Theodolite is the same instrument, except that the circle is entire, and the compass is placed in the centre of the circle.

Cautions in using the instrument.—1. Spread the legs that support the theodolite rather wide, and thrust them firmly into the ground, that they may neither yield nor give unequally during the observation. 2. Set the instrument horizontal. 3. Screw the ball firmly in its socket, that in turning the index the theodolite may not vary from the objects to which it is directed. 4. Where accuracy is required, the angles should always be taken twice over, oftener where great accuracy is material, and the mean of the observation, must be taken for the true angle.

To measure an angle with the Theodolite.—Let A B C represent the angle to be measured; place the theodolite over the angular point A, and direct the fixed sights along one of the lines, till you see through the sights the point B; at this screw the instrument fast; then turn the movable index till through its sights you see the other point, C; then the degrees cut by the index upon the graduated limb or ring of the instrument show the quantity of the angle.

The fixed sights are always to be directed to the last station, and those of the index to the next.

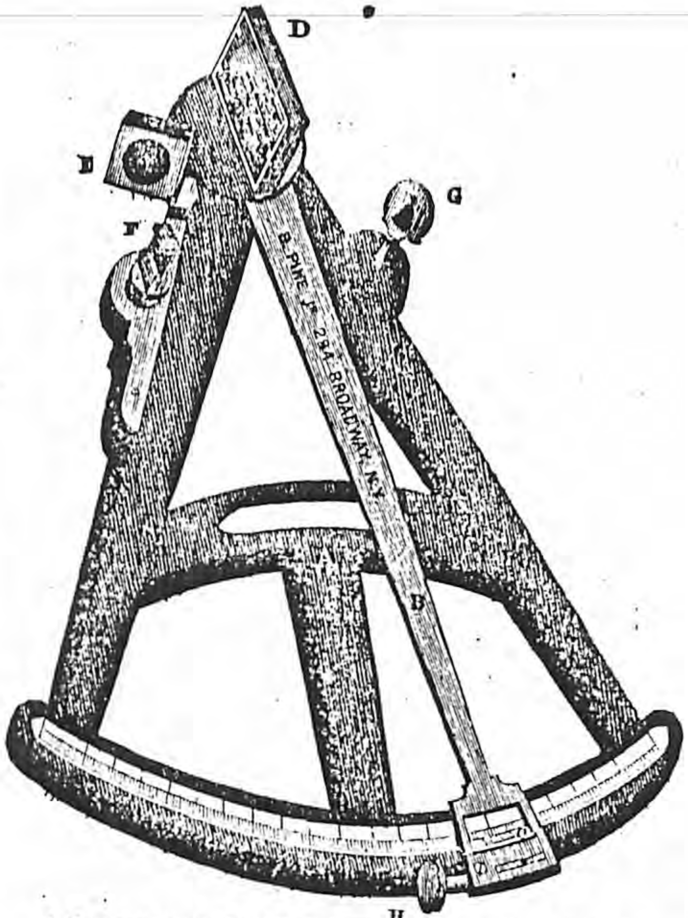
Price, 8 inch, in case, $15.00.
" 12 " " $30.00.

The Quadrant.—(Fig. 95, next page.)—The Quadrant consists of an arc firmly attached to two radii, or bars, which are strengthened and bound together by two braces.

Of the Index.—The Index is a flat bar of brass attached to the centre of motion. At the lower end of the index there is an oblong opening; to one side of this opening a nonius scale is fixed to subdivide the divisions of the arc. At the bottom, or end of the index, there is a piece of brass, which bends under the arc, carrying a spring to make the nonius scale lie close to the divisions; it is also furnished with a screw to fix the index in any desired position. The best instruments have an adjusting screw fitted to the index, that it may be moved more slowly, and with greater regularity and accuracy than by the hand. The circular arcs on the arc of the quadrant are drawn from the centre on which the index turns. The position of the index on the arc, after an observation, points out the number of degrees and minutes contained in the observed angle.

Of the Index Glass.—Upon the index, and near its
is fixed a plain speculum, or mirror of glass, quicksilv
It is set in a brass frame, and is placed so that the fa

Fig. 95.



A. Frame and arc; B. Index: C. Nonius scale; D Index glass; E. Dark glasses or screens; F. Horizon glass; G. Vane or sight

it is perpendicular to the plane of the instrument; this mirror being fixed to the index, moves along with it, and has its direction changed by the motion thereof; this glass is designed to receive the image of the sun, or any other object, and reflect it on the horizon glass. The brass frame with the glass is fixed to the index by screws which serve to adjust it in a perpendicular position.

Of the Horizon Glass.—On the radius of the frame is a small speculum, the surface of which is parallel to the index glass, when the counting division of the index is at O on the arc, and receives the reflected rays from the object, and transmits them to the observer. The horizon glass is not entirely quicksilvered, but only on its lower half, or that next to the frame of the quadrant, the other half being transparent; and the back part of the frame is cut away, that nothing may impede the sight through the unsilvered part of the glass. The edge of the foil of this glass is about parallel to the plane of the instrument, and ought to be very sharp, and without a flaw; the glass is set in a brass frame, to which there is an axis which passes through the wood-work, and is fitted to a lever on the under side of the quadrant; by this lever the glass may be turned a few degrees on its axis, in order to set it parallel to the index glass; the lever has a contrivance to turn it slowly. To set this glass perpendicular to the plane of the quadrant there are two sunk screws, one before and one behind the glass; these screws pass through the plate on which the frame is fixed, into another plate, so that by loosening one, and tightening the other of these screws, the direction of the frame, with its mirror, may be altered, and thus set perpendicular to the plane of the instrument.

Of the Shades.—These are two red, or dark, and one green glass; they are used to prevent the rays of the sun from hurting the eye at the time of observation; they are each of them set in a brass frame, which turns on a centre, so that they may be used separately, or together, as the brightness of the sun may require. These glasses are fixed on the frame, between the index and the horizon glasses.

Of the Sight Vane.—This is a piece of brass fixed on the frame opposite the horizon glass, perforated with two small holes, one exactly at the height of the quicksilvered edge of the horizon glass; the other somewhat higher, to direct the sight to the middle of the transparent part of the mirror for those objects that are bright enough to be reflected from the unsilvered part of the mirror.

The Arc and Nonius.—The Arc is divided into 90 degrees from the right to the left, and each degree is subdivided into three parts, or 20 minutes, which are again subdivided by the Nonius into every minute. The Nonius is numbered at every fifth of three divisions, from the right to the left, with 5, 10, 15 and 20. The first division to the right hand being to be considered the index division.

Directions to hold the Quadrant.—It is recommended to support the weight of the instrument by the right hand, and reserve the left to govern the index; place the thumb of the right hand against the edge of the quadrant, under the swelling part on which the sight stands, extending the fingers across the back of the quadrant, so as to lay hold on the opposite edge, placing the forefinger above, and the other fingers below the swelling part, or near the horizon glass; thus the instrument may be supported conveniently in a vertical position, by the right hand only. By resting the thumb of the left hand against the side, or the fingers against the middle bar, you may move the index gradually either way.

To adjust the Quadrant.—It is a peculiar excellence of the Quadrant that the errors to which it is liable are easily detected and soon rectified; the observer may, therefore, if he will be attentive, always put his instrument in a fit state for accurate observation.

1. *To adjust the Index Glass, or make it perpendicular to the Plane of the Instrument.*—Hold the Quadrant in a horizontal position, with the index glass close to the eye, look nearly in a right line down the glass, and in such a manner, that you may see the arc of the quadrant by direct view, and by reflection at the same time. If they join in one direct line, and the arc seen by reflection forms an exact plane with the arc seen by direct view, the glass is perpendicular to the plane of the quadrant; if not, the error must be rectified by altering the position of the screws behind the frame.

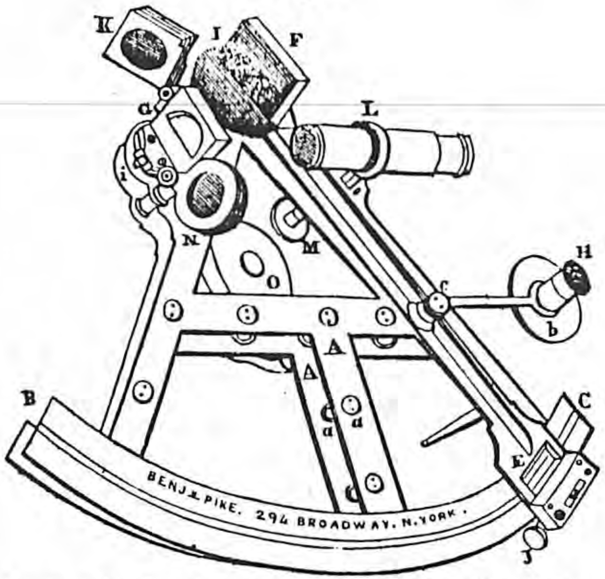
2. *To adjust the Horizon Glass, and set it parallel to the Index Glass.*—Set the index line of the nonius exactly at *o* on the limb, and fix it there by the screw at the under side. Now look through the sight at some distant small object; the object will be seen directly through the unsilvered part of the glass, but by reflection in the silvered part; if the object in the silvered part exactly meets, and forms one continued line with that seen through the unsilvered part, then is the instrument said to be adjusted, and the horizon glass to be parallel to the index glass; but if the objects do not coincide, then loosen the screw on the under side of the quadrant, and turn the horizon glass on its axis, by means of its adjusting lever, till you have made them perfectly coincide. This adjustment ought to be examined before every important observation.

3. *To adjust the Horizon Glass perpendicular to the Plane of the Quadrant.*—Incline the quadrant on one side as much as possible, provided the distant object continues to be seen in both parts of the glass at the same time. If, when the instrument is thus inclined, the object continues to form an unbroken line, the quadrant is perfectly adjusted; but if the reflected object be separated from that seen by direct vision, the glass is not perpendicular to the plane of the quadrant; and if the observer is inclined to the right, with the face of the quadrant upward, and the reflected object appears higher than the real object, you must slacken the screw before the horizon glass, and tighten that which is behind it; but if the reflected object appears lower, the contrary must be performed. Care must be taken in these adjustments to loosen one screw before the other is screwed up, and to leave the adjusting screws tight, or so as to draw with a moderate force against each other.

Price $14.00 to $18.00.

Sextant.—(Fig. 96, page 70.)—The annexed figure represents a sextant of Troughton's construction, having a double frame, A A, connected by pillars, *a a*, &c., thus uniting strength with lightness. The arc, B C, is generally graduated to 10′ of a degree, commencing near the end, C, and it is numbered towards B. The divisions are also continued on the other side of zero, towards C, forming what is called the arc of excess, which is useful in determining the index error of the instrument, as will be explained hereafter. The limb is subdivided by the vernier, E, into 10″, the half of which (or 5″) can be easily estimated: this small quantity is easily distinguishable by the aid of microscope, H, and its reflector, *b*, which are connected by an arm with the index, I E, at the point, *c*, round which it turns as

Fig. 96.



a centre, affording the means of examining the whole vernier, the connecting arm being long enough to allow the microscope to pass over the whole length of it.

To the index is attached a clamp to fasten it to the limb, and a tangent-screw, J (in the plate, the clamp is concealed from view), by which the index may be moved any small quantity after it is clamped, to render the contact of the objects observed more perfect than can be done by moving it with the hand alone. The upper end, I, terminates in a circle, across which is fixed the silver-indexed glass, F, over the centre of motion, and perpendicular to the plane of the instrument. To the frame at G is attached a second glass, called the horizon-glass, the lower half of which only is silvered: this must likewise be perpendicular to the plane of the instrument, and in such a position that its plane shall be parallel to the plane of the index-glass, F, when the vernier is set to 0° (or zero) on the limb, B C. A deviation from this position constitutes the index error before spoken of.

The telescope is carried by a ring, L, attached to a stem, *e*, called the up-and-down piece, which can be raised or lowered by turning the milled screw, M: its use is to place the telescope so that the field of view may be bisected by the line on the horizon-glass that separates the silvered from the unsilvered part. This is important, as it renders the object seen by reflection, and that by direct vision, equally bright; two telescopes and a plain tube, all adapted to the ring, L, are packed with the sextant, one showing the objects erect, and the other inverting them; the last has a greater magnifying power, showing the contact of the images much better. The adjustment for distinct vision is obtained by sliding the tube at the eye-end of the telescope in the inside of the other; this also is the means of adapting the focus to suit different eyes. In the inverting telescope are placed two wires, parallel to each other, and in the middle of the space between them the observations are to be made, the wires being first brought parallel to the plane of the sextant, which may be judged of with sufficient exactness by the eye. When observing with this telescope, it must be borne in mind, that the instrument must be moved in a contrary direction to that which the object appears to take, in order to keep it in the field of view.

Four dark glasses, of different depths of shade and color, are placed at K, between the index and horizon glasses; also three more at N, any one or more of which can be turned down to moderate the intensity of the light, before reaching the eye, when a very luminous object (as the sun) is observed. The same purpose is effected by fixing a dark glass to the eye-end of the telescope: one or more dark glasses for this purpose generally accompany the instrument. They, however, are chiefly used when the sun's altitude is observed with an artificial horizon, or for ascertaining the index error, as employing the shades attached to the instrument for such purposes, would involve in the result any error which they might possess. The handle, which is shown at O, is fixed at the back of the instrument. The hole in the middle is for fixing it to a stand, which is useful when an observer is desirous of great steadiness.

Of the adjustments.—The requisite adjustments are the following: the index and horizon-glasses must be perpendicular to the plane of the instrument, and their planes parallel to each other when the index division of the vernier is at 0° on the arc, and the optical axis of the telescope must be parallel to the plane of the instrument. We shall speak separately of each of these adjustments.

To examine the adjustment of the Index-glass.—Move the index forward to about the middle of the limb, then, holding the instrument horizontally with the divided limb from the observer, and the index-glass to the eye, look obliquely down the glass, so as to see the circular arc, by direct view and by reflection, in the glass at the same time; and if they appear as one continued arc of a circle, the index-glass is in adjustment. If it requires correcting, the arc will appear broken where the reflected and direct parts of the limb meet. This, in a well-made instrument, is seldom the case, unless the sextant has been exposed to rough treatment. As the glass is in the first instance set right by the maker, and firmly fixed in its place, its position is not liable to alter, therefore no direct means are supplied for its adjustment.

To examine the Horizon-glass, and set it perpendicular to the Plane of the Sextant.—The position of this glass is known to be right, when by a sweep with the index, the reflected image of any object passes exactly over or covers its image, as seen directly; and any error is easily rectified by turning the small screw, *i*, at the lower end of the frame of the glass.

To examine the Parallelism of the Planes of the two Glasses, when the Index is set to Zero.—This is easily ascertained; for, after setting the zero on the index to zero on the limb, if you direct your view to some object, the sun for instance, you will see that the two images (one seen by direct vision through the unsilvered part of the horizon-glass, and the other reflected from the silvered part) coincide or appear as one, if the glasses are correctly parallel to each other; but if the two images do not coincide, the quantity of their deviation constitutes what is called the index error. The effect of this error on an angle measured by the instrument is exactly equal to the error itself; therefore, in modern instruments, there are seldom any means applied for its correction, it being considered preferable to determine its amount previous to observing, or immediately after, and apply it with its proper sign to each observation. The amount of the index error may be found in the following manner: clamp the index at about 30 minutes to the left of zero, and looking towards the sun, the two images

will appear either nearly in contact, or overlapping each other; then perfect the contact, by moving the tangent-screw, and call the minutes and seconds denoted by the vernier, the reading on the arc. Next, place the index about the same quantity to the right of zero, or on the arc of excess, and make the contact of the two images perfect as before, and call the minutes and seconds on the arc of excess the reading off the arc; and half the difference of these numbers is the index error; additive when the reading on the arc of excess is greater than that on the limb, and subtractive when the contrary is the case.

EXAMPLE.

	'	"
Reading on the arc - - -	31	56
" off the arc - -	31	22
Difference - - - - -	0	34
Index error - - — —	0	17

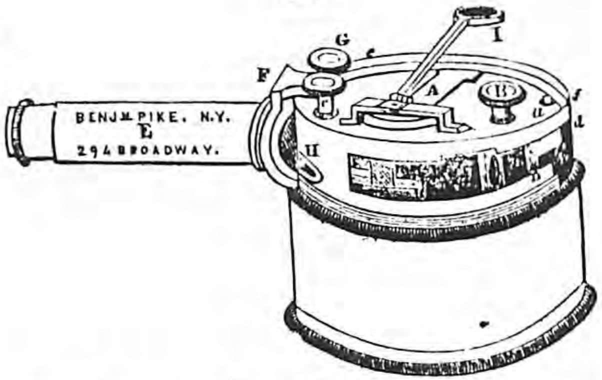
In this case, the reading on the arc being greater than that on the arc of excess, the index error, — 17 seconds, must be subtracted from all observations taken with the instrument, until it be found, by a similar process, that the index error has altered. One observation on each side of zero is seldom considered enough to give the index error with sufficient exactness for particular purposes: it is usual to take several measures each way; "and half the difference of their means will give a result more to be depended on than one deduced from a single observation only on each side of zero."

To make the Line of Collimation of the Telescope parallel to the Plane of the Sextant.—This is known to be correct, when the sun and moon, having a distance of 90 degrees or more, are brought into contact just at the wire of the telescope which is nearest the plane of the sextant, fixing the index, and altering the position of the instrument to make the objects appear on the other wire; if the contact still remains perfect, the axis of the telescope is in proper adjustment; if not, it must be altered by moving the two screws which fasten, to the up-and-down piece, the collar into which the telescope screws. This adjustment is not very liable to be deranged.

Of the sextant, it has been said, that it is in itself a portable observatory; and it is doubtless one of the most generally useful instruments that has ever been contrived, being capable of furnishing data to a considerable degree of accuracy for the solution of a numerous class of the most useful astronomical problems; affording the means of determining the time, the latitude and longitude of a place, &c., for which and many other purposes, it is invaluable to the land-surveyor as well as the navigator.

Price,		$100 to $120.
"	Single Framed,	50 to 80.
"	Ebony "	35.

Fig. 97.



Pocket Sextant.—(Fig. 97.)—This useful little instrument is represented in the above figure. The principle of its construction and adjustment is precisely the same as the sextant before described; a minute description, therefore, would be little more than a recapitulation of what has already been advanced. A is the index, which, instead of being moved along the divided limb, *e f*, by the hand, has a motion given to it by a rack and pinion, concealed within the box, and turned by the milled head, B, which acts as the tangent-screw does to the index of the large sextant. The glasses (shown at C and D) are within the box, by which they are protected from injury, and their adjustments, when

once perfected, kept secure: so much so, that it would require considerable violence to derange them. The horizon-glass, D, alone has a contrivance for adjustment at *a* and *d*, both to set it perpendicular to the plane of the instrument, and to correct or reduce the index error, which, in this instrument, had better be kept correct, as it is not so likely to get out of order as in the large sextant, which, as we have before observed, seldom admits of its index error being rectified. The key, *c*, is formed to fit both squares at *a* and *d*, to make the adjustments, and it is generally tapt into some square place in the instrument, as at *c*, that it may be always safe and at hand.

It is supplied with a telescope, E, which screws into a shoulder-piece, F, and can be attached to the box by the screw G: this can be applied or not, at the pleasure of the observer, as there is a contrivance at H to enable him to observe without the telescope, if he prefers plain sights. Two dark glasses are placed within the box, and there is also one adapted to the eye-end of the telescope.

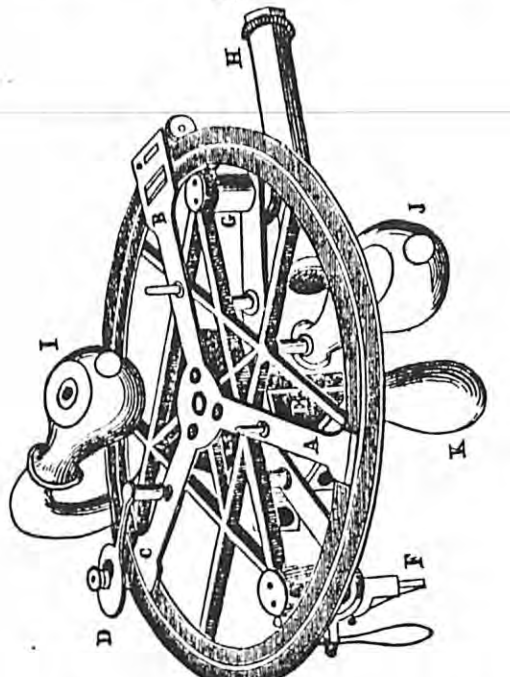
The angle is read off by the help of the glass, I, which being mounted with a joint, can be moved over the vernier on any part of the limb. The instrument is divided to 30 minutes of a degree, and by the vernier is subdivided to single minutes, one half of which, or 30 seconds, can be obtained by estimation.

The divided limb is numbered both to the right and left, commencing at 0° to 120°.

The lid of the box is contrived to screw on the bottom (as is shown in the plate), where it makes a convenient handle for holding the instrument. Price $35.00 to $40.00.

Reflecting Circle.—(Fig. 98, next page.)—This instrument, in principle and use, is the same as the sextant. It has three vernier readings, A B C, moving round the same centre as the index-glass, E, which is upon the opposite face of the instrument. One of the verniers, B, carries the clamp and tangent-screw. D represents the microscope for reading the verniers; it is similar to the one used in reading the sextant, and is adapted to each index-bar, by slipping it on a pin placed for that purpose, as shown in the figure. The horizon-glass is shown at F. The barrel, G, contains the screws for giving the up-and-down motion to the telescope; it is put in action by turning the milled head under

Fig. 98.



the barrel. H is the telescope, adapted to the instrument in a manner similar to that of the sextant. I and J are two handles fixed parallel to the plane of the circle, and a third handle, K, is screwed on at right angles to that plane, and can be transferred to the opposite face of the instrument by screwing it into the handle, I; the use of this extra handle is for convenience in reading and in holding the instrument, when observing angles that are nearly horizontal; it can be shifted, according as the face of the instrument is held upwards or downwards. The requisite dark glasses are attached to the frame-work of the circle, to be used in the same manner and for the same purposes as those of the sextant. With respect to the adjustments and application of this instrument, we cannot do better than use the words

of the inventor, Mr. Troughton, contained in a paper which he calls

Directions for observing with the Reflecting Circle.—Prepare the instrument for observation by screwing the telescope into its place, adjusting the drawer to focus, and the wires parallel to the plane, exactly as you do with a sextant; also set the index forwards to the rough distance of the sun and moon, or moon and star; and holding the circle by the short handle, direct the telescope to the fainter objects, and make the contact in the usual way. Now read off the degree, minute, and second, by that branch of the index to which the tangent-screw is attached; also, the minute and second shown by the other two branches; these give the distance taken on three different sextants; but as yet, it is only to be considered as half an observation: what remains to be done, is to complete the whole circle, by measuring that angle on the other three sextants. Therefore set the index backwards nearly to the same distance, and reverse the plane of the instrument, by holding it by the opposite handle, and make the contact as above, and read off as before what is shown on the three several branches of the index. The mean of all six is the true apparent distance, corresponding to the mean of the two times at which the observations were made.

When the objects are seen very distinctly, so that no doubt whatever remains about the contact in both sights being perfect, the above may safely be relied on as a complete set; but if, from the haziness of the air, too much motion, or any other cause, the observations have been rendered doubtful, it will be advisable to make more; and if, at such times, so many readings should be deemed troublesome, six observations and six readings may be conducted in the manner following: Take three successive sights forwards, exactly as is done with a sextant; only take care to read them off on different branches of the index: also make three observations backwards, using the same caution; a mean of these will be the distance required. When the number of sights taken forwards and backwards is unequal, a mean between the means of those taken backwards and those taken forwards will be the true angle.

It need hardly be mentioned, that the shades, or dark-glasses, apply like those of a sextant, for making the objects nearly of the same brightness; but it must be insisted on, that the telescope should, on every occasion, be raised or lowered, by its proper screw, for making them perfectly so.

The foregoing instructions for taking distances, apply equally for taking altitudes by the sea, or artificial horizon, they being no more than distances taken in a vertical plane. Meridian altitudes cannot, however, be taken both backwards and forwards the same day, because there is not time: all therefore that can be done, is, to observe the altitude one way, and use the index-error; but even here, you have a mean of that altitude, and this error, taken on three different sextants. Both at sea and land, where the observer is stationary, the meridian altitude should be observed forwards one day, and backwards the next, and so on alternately from day to day; the mean of latitudes, deduced severally from such observations, will be the true latitude; but in these there should be no application of index-error, for that being constant, the result would in some measure be vitiated thereby.

When both the reflected and direct images require to be darkened, as is the case when the sun's diameter is measured and when his altitude is taken with an artificial horizon, the attached dark glasses ought not to be used; instead of them, those which apply to the eye-end of the telescope will answer much better; the former having their errors magnified by the power of the telescope, will, in proportion to this power, and those errors, be less distinct than the latter.

In taking distances, when the position does not vary from the vertical above thirty or forty degrees, the handles which are attached to the circle are generally most conveniently used; but in those which incline more to the horizontal, that handle which screws into a cock on one side, and into the crooked handle on the other, will be found more applicable.

When the crooked handle happens to be in the way of reading one of the branches of the index, it must be removed, for the time, by taking out the finger-screw, which fastens it to the body of the circle.

If it should happen that two of the readings agree with each other very well, and the third differs from them, the discordant one must not on any account be omitted, but a fair mean must always be taken.

It should be stated, that when the angle is about thirty

degrees, neither the distance of the sun and moon, nor an altitude of the sun, with the sea horizon, can be taken backwards; because the dark glasses at that angle prevent the reflected rays of light from falling on the index-glass; whence it becomes necessary, when the angle to be taken is quite unknown, to observe forwards first, where the whole range is without interruption; whereas, in that backwards, you will lose sight of the reflected image about that angle. But in such distances, where the sun is out of the question, and when his altitude is taken with an artificial horizon (the shade being applied to the end of the telescope), that angle may be measured nearly as well as any other; for the rays incident on the index-glass will pass through the transparent half of the horizon-glass, without much diminution of their brightness.

The advantages of this instrument, when compared with the sextant, are chiefly these: the observations for finding the index-error are rendered useless, all knowledge of that being put out of the question, by observing both forwards and backwards. By the same means the errors of the dark glasses are also corrected; for, if they increase the angle one way, they must diminish it the other way by the same quantity. This also perfectly corrects the errors of the horizon-glass, and those of the index-glass very nearly. But what is of still more consequence, the error of the centre is perfectly corrected, by reading the three branches of the index; while this property, combined with that of observing both ways, probably reduces the errors of dividing to one-sixth part of their simple value. Moreover, angles may be measured as far as one hundred and fifty degrees, consequently the sun's double altitude may be observed when his distance from the zenith is not less than fifteen degrees; at which altitude, the head of the observer begins to intercept the rays of light incident on the artificial horizon; and, of course, if a greater angle could be measured, it would be of no use in this respect.

This instrument, in common with the sextant, requires three adjustments. First, the index-glass perpendicular to the plane of the circle. This being done by the maker, and not liable to alter, has no direct means applied to the purpose; it is known to be right, when, by looking into the index-glass, you see that part of the limb which is next to you, reflected in contact with the opposite side of the limb, as one continued arc of a circle; on the contrary, when the arc appears broken, where the reflected and direct parts of the limb meet, it is a proof that it wants to be rectified. The second is, to make the horizon-glass perpendicular. This is performed by a capstan-screw, at the lower end of the frame of that glass; and is known to be right, when, by a sweep of the index, the reflected image of any object will pass exactly over, or cover the image of that object seen directly. The third adjustment is, for making the line of collimation parallel to the plane of the circle. This is performed by two small screws, which also fasten the collar into which the telescope screws to the upright stem on which it is mounted: this is known to be right, when the sun and moon, having a distance of one hundred and thirty degrees, or more, their limbs are brought in contact, just at the outside of that wire which is next to the circle; and then, examining if it be the same, just at the outside of the other wire: its being so is the proof of adjustment.

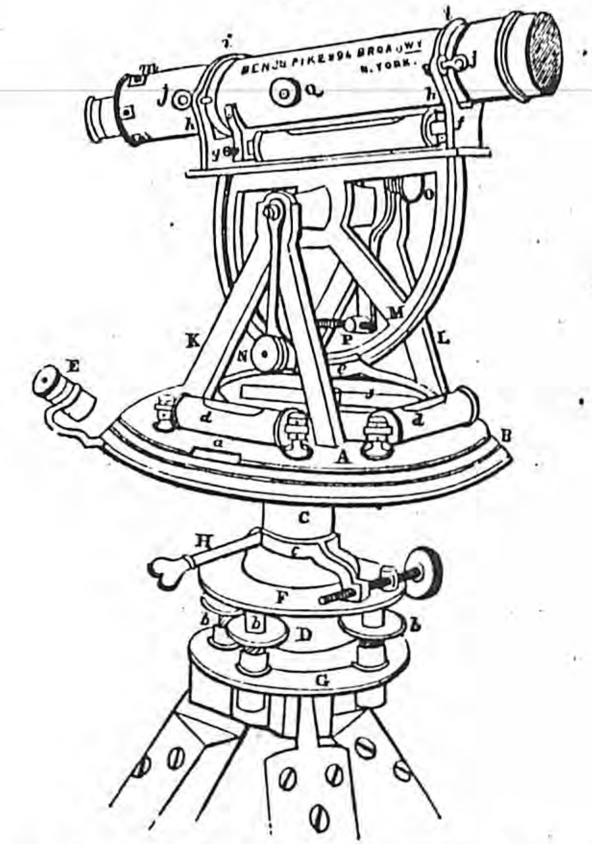
Price $150 to $200.

Theodolite.—(Fig. 99, next page.)—As an angular instrument, the theodolite has from time to time received such improvements that it may now be considered as the most valuable instrument employed in surveying. Instruments of this kind, of the best construction, may to a certain extent be used as altitude and azimuth instruments; and several astronomical operations, such as those required for determining the time, the latitude of place, &c., may be performed by them, and to a degree of accuracy sufficient for most of the purposes that occur in the ordinary practice of a surveyor.

There are various modes of constructing theodolites to suit the convenience or the views of purchasers; but we shall confine ourselves to a description of one of the most perfect, as a person acquainted with the details of its adjustments and use, will find no difficulty in comprehending those of others.

Description of the Theodolite.—This instrument consists of two circular plates, A and B, called the horizontal limb, the upper or vernier plate, A, turning freely upon the lower, and both have a horizontal motion by means of the vertical axis, C; this axis consists of two parts, external and internal, the former secured to the graduated limb, B, and the latter to

Fig. 99.



the vernier plate, A. Their form is conical, nicely fitted and ground into each other, having an easy and a very steady motion; the external centre also fits into a ball at D, and the parts are held together by a screw at the lower end of the internal axis.

The diameter of the lower plate is greater than that of the upper one, and its edge is chamfered off and covered with silver, to receive the graduations: on opposite parts of the edge of the upper plate, or 180° apart, a short space, *a*, is also chamfered, forming with the edge of the lower plate a continued inclined plane; these spaces are likewise covered with silver, and form the verniers. The lower limb is usually graduated to thirty minutes of a degree, and it is subdivided by the vernier to single minutes, which being read off by the microscope, E, half or even quarter minutes can easily be estimated.

The parallel plates, F and G, are held together by a ball and socket at D, and are set firm and parallel to each other, by four milled head-screws, three of which, *b b b*, are shown in the figure: these turn in sockets fixed to the lower plate, while their heads press against the under side of the upper plate, and being set in pairs, opposite each other, they act in contrary directions; the instrument by this means is set up level for observation.

Beneath the parallel plates is a female screw adapted to the staff head, which is connected by brass joints to three mahogany legs, so constructed that when shut up they form one round staff, secured in that form for carriage by rings put on them; and when opened out they make a very firm stand, be the ground ever so uneven.

The lower horizontal limb can be fixed in any position, by tightening the clamping screw, H, which causes the collar *c* to embrace the axis, C, and prevents its moving; but it being requisite that it should be fixed in some precise position more exactly than can be done by the hand alone, the whole instrument, when thus clamped, can be moved any small quantity by means of the slow-motion screw, I, which is attached to the upper parallel plate. In like manner the upper or vernier plate can be fixed to the lower, in any position, by a clamp (in the plate this clamp is concealed from view), which is also furnished with a slow motion, the screw of which is generally called the tangent-screw. The motion of this limb and of the vertical arc, hereafter to be described, is sometimes effected by a rack and pinion; but this is greatly inferior, where delicacy is required, to the slow motion produced by the clamp and tangent-screw.

Upon the plane of the vernier plate, two spirit-levels, *d*, *d*, are placed at right angles to each other, with their proper adjusting screws; their use is to determine when the horizontal limb is set level; a compass also is placed at J.

The frames K and L support the pivots of the horizontal axis of the vertical arc, or semicircle, M, on which the telescope is placed. The arm which bears the microscope, N, for reading the altitudes or depressions, measured by the semicircle, and denoted by the vernier, *e*, has a motion of several degrees between the bars of the frame, K, and can be moved before the face of the vernier for reading it off. Another arm clamps the opposite end of the horizontal axis by turning the screw, O, and has a tangent-screw of slow motion at P, by which the vertical arc and telescope are moved very small quantities up or down, to perfect the contact when an observation is made.

One side of the vertical arc is inlaid with silver, and divided to single minutes by the help of its vernier; and the other side shows the difference between the hypothenuse and base of a right-angled triangle, or the number of links to be deducted from each chain's length, in measuring up or down an inclined plane, to reduce it to the horizontal measure. The level, which is shown under and parallel to the telescope, is attached to it at one end by a joint, and at the other by a capstan-headed screw, *f*, which, being raised or lowered, will set the level parallel to the optical axis of the telescope, or line of collimation; the screw, *g*, at the opposite end, is to adjust it laterally, for true parallelism in this respect. The telescope has two collars, or rings, of bell metal, ground truly cylindrical, on which it rests in its supports, *h h*, called Y's, from their resemblance to that letter; and it is confined in its place by the clips, *i i*, which may be opened by removing the pins, *j j*, for the purpose of reversing the telescope, or allowing it a circular motion round its axis, during the adjustment.

In the focus of the eye-glass are placed three lines, formed of spider's web, one horizontal, and two crossing it, so as to include a small angle between them; a method of fixing the wires which is better than having one perpendicular wire, because an object at a distance can be made to bisect the said small angle with more certainty than it can be bisected by a vertical wire. The screws adjusting the cross wires are shown at *m*: there are four of these screws, two of which are placed opposite each other, and at right angles to the other two, so that by easing one and tightening the opposite one of each pair, the intersection of the cross wires may be placed in adjustment.

The object-glass is thrust outwards by turning the milled head, Q, on the side of the telescope, that being the means of adjusting it to show an object distinctly.

A brass plummet and line are packed in the box with the theodolite, to suspend from a hook under its centre, by which it can be placed exactly over the station from whence the observations are to be taken; likewise, if required, two extra eye-pieces for the telescope, to be used for astronomical observations; the one inverts the object, and has a greater magnifying power, but having fewer glasses possesses more light; the other is a diagonal eye-piece, which will be found extremely convenient when observing an object that has a considerable altitude; the observer avoiding the unpleasant and painful position he must assume in order to look through the telescope when either of the other eye-pieces is applied. A small cap, containing a dark-colored glass, is made to apply to the eye-end of the telescope; to screen the eye of the observer from the intensity of the sun's rays, when that is the object under observation. A magnifying glass, mounted in a horn frame, a screw-driver, and a pin to turn the capstan-screws for the adjustments, are also furnished with the instrument.

The Vernier.—This is a contrivance for measuring parts of the space between the equidistant divisions of a graduated scale. It is a scale whose length is equal to a certain number of parts of that to be subdivided, depending on the degree of minuteness to which the subdivision is intended to be carried; but it is divided into parts which in number are one more or one less than those of the primary scale taken for the length of the vernier: in modern practice, the parts on the vernier are generally one more than are contained in the same space on the primary scale.

If it is required to measure to hundredths of an inch, the parts of a scale which is graduated to 10ths, it may be done by means of a scale whose length is nine tenths of an inch, and divided into 10 equal parts; or by one whose length is eleven tenths of an inch, and divided into 10 equal parts; for in either case the difference between the divisions of the scale so made and those on the primary scale is the hundredth of an inch. Such a scale, made to move along the edge of that to be subdivided, is called a vernier. By its application, either to straight lines or arcs of circles, the subdivisions of graduated instruments are read off.

The adjustments.—The first adjustment is that of the line of collimation; that is, to make the intersection of the cross wires coincide with the axis of the cylindrical rings on which the telescope turns: it is known to be correct, when an eye looking through a telescope observes their intersection continue on the same point of a distant object during an entire revolution of the telescope. The usual method of making this adjustment is as follows:

First, make the centre of the horizontal wire coincide with some well-defined part of a distant object; then turn the telescope half round in its Y's till the level lies above it, and observe if the same point is again cut by the centre of the wire; if not, move the wire one half the quantity of deviation, by turning two of the screws at *m* (releasing one, before tightening the other), and correct the other half by elevating or depressing the telescope; now if the coincidence of the wire and object remains perfect in both positions of the telescope, the line of collimation in altitude or depression is correct, but if not, the operation must be repeated carefully, until the adjustment is satisfactory. A similar proceeding will also put the vertical line correct, or rather the point of intersection, when there are two oblique lines instead of a vertical one.

The second adjustment is that which puts the level attached to the telescope parallel to the rectified line of collimation. The clips, *i i*, being open, and the vertical arc clamped, bring the air-bubble of the level to the centre of its glass tube, by turning the tangent-screw, P; which done, reverse the telescope in its Y's, that is, turn it end for end, which must be done carefully, that it may not disturb the vertical arc, and if the bubble resume its former situation in the middle of the tube, all is right; but if it retires to one end, bring it back one half, by the screw *f*, which elevates or depresses that end of the level, and the other half by the tangent-screw, P; this process must be repeated until the adjustment is perfect; but to make it completely so, the level should be adjusted laterally, that it may remain in the middle of the tube when inclined a little on either side from its usual position immediately under the telescope, which is effected by giving the level such an inclination, and if necessary turning the two lateral screws at *g*; if making the latter adjustment derange the former, the whole operation must be carefully repeated.

The third adjustment is that which makes the azimuthal axis, or axis of the horizontal limb, truly vertical.

Set the instrument as nearly level as can be done by the eye, fasten the centre of the lower horizontal limb by the staff-head clamp, H, leaving the upper limb at liberty, but move it till the telescope is over two of the parallel plate-screws; then bring the bubble of the level under the telescope, to the middle of the tube, by the screw P; now turn the upper limb half round, that is 180°, from its former position; then, if the bubble returns to the middle, the limb is horizontal in that direction; but if otherwise, half the difference must be corrected by the parallel plate-screws over which the telescope lies, and half, by elevating or depressing the telescope, by turning the tangent-screw of the vertical arc; having done which, it only remains to turn the upper limb forward or backward 90°, that the telescope may lie over the other two parallel plate-screws, and by their motion set it horizontal. Having now levelled the limb-plates by means of the telescope level, which is the most sensible upon the instrument, the other air-bubbles fixed upon the vernier-plate, may be brought to the middle of their tubes, by merely giving motion to the screws which fasten them in their places.

The vernier of the vertical arc may now be attended to; it is correct, if it points to zero when all the foregoing adjustments are perfect; and any deviation in it is easily rectified, by releasing the screws by which it is held, and tightening them again after having made the adjustment; or, what is perhaps better, note the quantity of deviation as an index error, and apply it, plus or minus, to each vertical angle observed. This deviation is best determined by repeating the observation of an altitude or depression in the reversed positions, both of the telescope and the vernier plate: the two readings will have equal and opposite errors, one half of their difference being the index error. Such a method of observing angles is decidedly the best, since the mean of any equal number of observations taken with the telescope reversed in its Y's, must be free from the effects of any error that may exist in the adjustment of the vernier, or zero of altitude.

The theodolite, as constructed in the manner we have described, is not inconveniently heavy, as the diameter of the horizontal limb seldom exceeds five inches; but when the diameter is increased, the other parts must be made proportionably large and strong, and the instrument becomes too weighty and cumbersome to be easily carried from station to station. The object of increasing the dimensions, is to enable the instrument to furnish more accurate results, by applying a telescope of greater power, and by a more minute subdivision of the graduated arcs. With the increase of size, a small variation takes place in the construction, principally consisting in the addition of a second telescope, and in the manner of attaching the supports, K and L, to the horizontal limb, to afford the means of adjusting the horizontal axis, and of course, making the telescope and vertical arc move in a vertical plane. In the smaller instruments this is done by construction, but in the larger ones, the supports, K and L, are attached to a stout frame, which also carries the compass-box, instead of being fixed, as represented in our figure, to the upper horizontal-plate. The frame is attached to the limb by three capstan-headed screws forming an equilateral triangle, two of them lying parallel to the horizontal axis, and the third in the direction of the telescope; the adjustment is made by means of these screws. To prove its accuracy, set up the theodolite in such a situation that some conspicuous point of an elevated building may be seen through the telescope, both directly and by reflection, from a basin of water, or, what is better, of oil or quicksilver. Let the instrument be very correctly levelled, and if, when a vertical motion is given to the telescope, the cross-wires do not cut the object seen, both directly and by reflection, it is a proof that the axis is not horizontal; and its correction is effected by giving motion to the screws above spoken of, which are at right angles to the telescope, or in the direction of the horizontal axis. The third screw, or that which is under the telescope, serves for adjusting the zero of altitude, or vernier of the vertical arc.

A second telescope is sometimes attached to the instrument beneath the horizontal limb; it admits of being moved, both in a vertical and horizontal plane, and has a tangent-screw attached for slow motion; its use is to detect any accidental derangement that may occur to the instrument whilst observing, which may be done by it in the following manner. After levelling the instrument, bisect some very remote object with the cross-wires of this second telescope, and clamp it firm; if the instrument is steady, the bisection will remain permanent whilst any number of angles are measured, and by examining the bisection from time to time, during the operation at the place where the instrument is set up, any error arising from this cause may be detected and rectified.

Price, 5 inch,	brass arches,		$100.00 to $120.00
" 5 "	silver	"	$125.00
" 6 "	"	"	$150.00
" 7 "	"	"	$250.00 to $300.00.

Fig. 100.

The Spirit Level (Fig. 100) consists of a glass tube, nearly filled with a liquid, spirits of wine being now used, on account of its mobility, and not being liable to freeze, the bubble of which, when the tube is placed horizontally, would rest indifferently in any part, if the tube could be made mathematically straight; but that being impossible to execute, and every tube having some slight curvature, if the convex side be placed upwards, the bubble will occupy the higher part; such a tube firmly fastened on a straight bar, and marked at two points distant by the length of the bubble, if so placed that the bubble shall occupy this interval, has one definite relation to the horizon; for were it ever so little moved one way or other, the bubble would shift its place, and run towards the elevated side.

The accuracy of the indications of the level depends in a considerable degree on the regularity of the interior surface of the tube. They are commonly made of glass tubes, in the same state as they are obtained from the glass-house; but when very great accuracy is required, the inside is ground, to give them a regular spherical curvature. The larger the bubble, the more freely it moves. The spirit level is extensively used in instruments for surveying, and for astronomical and geological purposes; the glass tube being inclosed in a brass case, which is cut out on the upper side, so that the bubble may be seen.

The Pocket Spirit Level.—(Fig. 101, next page.)—This cut represents a brass pocket spirit level; they are made from three to twelve inches long, are mounted on a stout brass plate, having the bottom ground true, and supported by a small pillar at each end, on the upper part of which are two nuts, between which the level is supported by projec-

tions from the ends of the brass tube in which it is enclosed, and thus affording facilities for accurate adjustment.

They are made sometimes with sights at each end, and adapted to a staff, serving for conducting small parcels of water, draining a field, &c.

The adjustment of these levels is very easily proved, or made, by bringing the bubble in the middle, upon any table, or base; if upon reversion in the same place precisely, the bubble keeps to the middle, it is adjusted; if not, turn one of the screws at the end, till it be so raised or depressed as to cause the bubble to stand the reversing, at the same time altering the inclination of the plane on which the level is tried. Price, $2 to $6.

Fig. 103.

The Masons' or Carpenters' Level.—(Fig. 102.)—This spirit level is mounted in a mahogany stock, or frame, usually from one to two feet long, but sometimes as small as three inches; the glass tube is sunk in the wood, and cemented fast; a stout brass plate covering the wood around, leaving a long aperture through which to view the bubble; occasionally the ends of the wood are capped with stout brass, to prevent wear.

Fig. 101.

Fig. 102.

They are made sometimes with sights, for the purpose of sighting through for levelling long distances.

Price, 88cts. to $1.50.

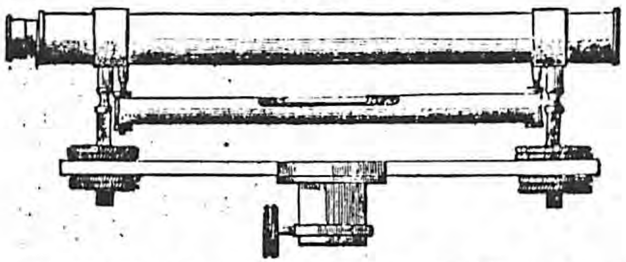
The Level and Plumb.—(Fig. 103.)—This is made similar to the last, with the addition of a cross level, for which the stock is made a little wider; the cross level is enclosed in a tube and accurately fixed in the stock, having a large circular or semicircular hole for viewing the bubble; when placed against a wall, post, or the like, will indicate if it is plumb, or not. This is a valuable instrument for masons, carpenters, mill-wrights, &c., for setting their work perpendicular, with more expedition than the plumb-bob and string.

Price, $2.00.

Common Surveying Level.—The annexed cut (Fig. 104) is a representation of a spirit level of a plainer construction than those that we shall describe, and though not having the accuracy of the Y levels that are used by engineers, yet will answer an ordinary purpose in the construction of ditches, mill-seats, &c. The telescope is from twelve to fourteen inches long, having adjusting tubes, and cross hairs within, and is attached to a strong brass bar by screws that have adjusting nuts; the level is attached to the telescope with the usual adjustments, and beneath the bar a socket with a milled-head screw, for the purpose of firmly mounting on the staff.

Price, $12.00.

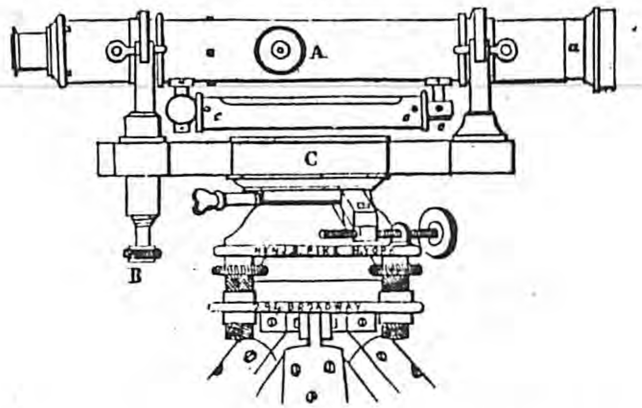
Fig. 104.



The Y Spirit Level.—(Fig. 105,) on the following page, represents this instrument; it has an achromatic telescope mounted in Y's like those of the theodolite, and is furnished with a similar system of cross wires for determining the axis of the tube, or line of collimation. By turning the milled-headed screw, A, on the side of the telescope, the internal tube, *a*, will be thrust outwards, which carrying the object-glass, it is by this means adjusted to its focal distance, so as to show a distant object distinctly.

The tube, *c c*, carrying the spirit-bubble, is fixed to the under side of the telescope by a joint at one end, and a

Fig. 105.



capstan-headed screw at the other, which sets it parallel to the optical axis of the telescope; at the opposite end is another screw, *e*, to make it parallel in the direction sideways. One of the Y's is supported in a socket, and can be raised or lowered by the screw B, to make the telescope perpendicular to the vertical axis. Between the two supports is a compass-box, C, having a contrivance to throw the magnetic needle off its centre when not in use; it is convenient for taking bearings, and is not necessarily connected with the operations of levelling, but extends the use of the instrument, making it a circumferentor. The whole is mounted on parallel plates and three legs, the same as the theodolite.

It is evident, from the nature of this instrument, that three adjustments are necessary. First, to place the intersection of the wires in the telescope, so that it shall coincide with the axis of the cylindrical rings on which the telescope turns; secondly, to render the level parallel to this axis; and lastly, to set the telescope perpendicular to the vertical axis, that the level may preserve its position while the instrument is turned quite round upon the staves.

To adjust the Line of Collimation.—The eye-piece being drawn out to see the wires distinctly, direct the telescope to any distant object, and by the screw, A, adjust to distinct vision;* bring the intersection of the cross wires to coincide with some well-defined part of the object, then turn the telescope round on its axis as it lies in the Y's, and observe whether the coincidence remains perfect during its revolution; if it does, the adjustment is correct; if not, the wires must be moved one-half the quantity of error, by turning the little screws near the eye-end of the telescope, one of which must be loosened before the opposite one is tightened, which, if correctly done, will perfect this adjustment.

To set the Level parallel to the Line of Collimation.—Move the telescope till it lies in the direction of two of the parallel plate-screws, the clips which confine the telescope in the Y's being laid open, and by giving motion to the screws, bring the air-bubble to the middle of the tube, shown by the two scratches on the glass. Now reverse the telescope carefully in its Y's, that is, turn it end for end; and should the bubble not return to the centre of the level as before, it shows that it is not parallel to the optical axis, and requires correcting. The end to which the bubble retires must be noticed, and the bubble made to return one-half the distance by the parallel plate-screws, and the other half by the capstan-headed screw at the end of the level, when, if the halves have been correctly estimated, the air bubble will settle in the middle in both positions of the telescope. This and the adjustment for the collimation generally require repeated trials before they are completed, on account of the difficulty in estimating exactly half the quantity of deviation.

To set the Telescope perpendicular to the Vertical Axis.—Place the telescope over two of the parallel plate-screws, and move them, unscrewing one while screwing up the other, until the air-bubble of the level settles in the middle of its tube; then turn the instrument half round upon the vertical axis, so that the contrary ends of the telescope may be over the same two screws, and if the bubble again settles in the middle, all is right in that position; if not, half the

* The eye-piece must first be drawn out until the cross wires are perfectly well defined, then the object-glass moved till distinct vision is obtained without parallax, which will be the case, if, on looking through the telescope at some distant object, and moving the eye sideways before the eye-glass, the object and the wires remain steadily in contact; but if the wires have any parallax, the object will appear flitting to and from them.

error must be corrected by turning the screw, B, and the other half by the two parallel plate-screws over which the telescope is placed. Next turn the telescope a quarter round, that it may lie over the other two screws, and make it level by moving them, and the adjustment will be complete.

Before making observations with this instrument, the adjustments should be carefully examined and rectified, after which the screw, B, should never be touched; the parallel plate-screws alone must be used for setting the instrument level at each station, and this is done by placing the telescope over each pair alternately, and moving them until the air-bubble settles in the middle. This must be repeated till the telescope can be moved quite round upon the staff-head, without any material change taking place in the bubble.

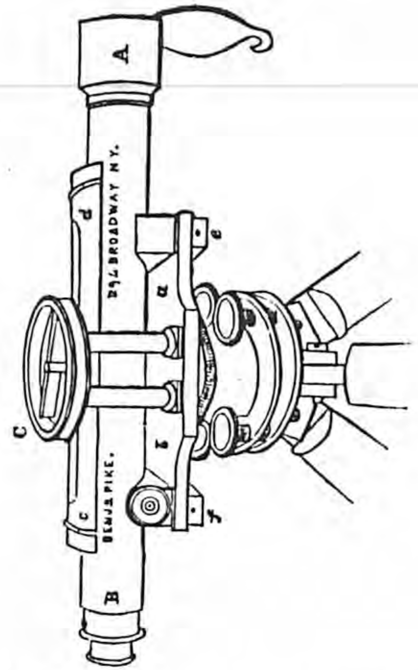
A short tube, adapted to the object-end of the telescope, will occasionally be found useful in protecting the glass from the intensity of the sun's rays, and from damp in wet weather. Price, $80 and $100.

Troughton's Level.—(Fig. 106.)—The telescope, A B, rests upon the horizontal bar, *a b*, which turns upon the staff-head (similar to the one employed in the Y level and the theodolite). On the top of the telescope, and partly imbedded within its tube, is the spirit-level, *c d*, over which is supported the compass-box, C, by four small pillars; thus admitting the telescope to be placed so close to the horizontal bar, *a b*, that it is much more firm than in the former instrument. The bubble of the level is sufficiently long for its ends to appear on both sides of the compass-box; and it is shown to be in the middle by its coinciding with scratches made on the glass tube as usual.

The wire plate (or diaphragm) is generally furnished with three threads, two of them vertical, between which the station-staff may be seen; and the third, by which the observation is made, is placed horizontally.

The telescope is generally constructed to show objects inverted; and as such a telescope requires fewer glasses than one which shows objects erect, it has the advantage in point of brilliancy; and when an observer is accustomed to it, the apparent inversion will make no difference to him. A diagonal eye-piece, however, generally accompanies the instru-

Fig. 106.



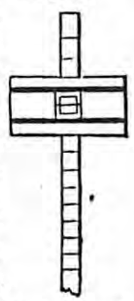
ment, and by it objects can be seen in their natural position. A cap is adapted to the object-end of the telescope, to screen the glass from the rays of the sun, or from the rain: when the cap is used, it should be drawn forwards as much as possible.

The requisite adjustments for this instrument are the same as those of the Y level; viz. that the line of collimation and the level be parallel to each other, and that the telescope be exactly perpendicular to the vertical axis; or in other words, that the spirit bubble preserve its position while it is turned round horizontally on the staff-head. The adjustment of the level is effected by correcting half the observed error by the capstan-screws, *e*, *f*, which attach the telescope to the horizontal bar, and the other half by the

parallel plate-screws: the capstan-screws, *e*, *f*, have brass covers to defend them from injury or accidental disturbance, but admit their adjustment when necessary.

The spirit level itself has no adjustment, being firmly fixed in its cell by the maker, and therefore the line of collimation must be adjusted to it, by means of two screws, near the eye-end of the telescope; the manner of doing this is as follows:—Set up the instrument on some tolerably level spot of ground, and, after levelling the telescope by the parallel plate-screws, direct it to a staff held by an assistant at some distance (from ten to twenty chains); direct him by signals to raise or depress the vane, until its wire coincides with the horizontal wire of the telescope (or central division of the micrometer scale): now measure the height of the centre of the telescope above the ground, and also note the height of the vane on the staff; let, for example, the former be four feet and the latter six, their difference shows that the ground over which the instrument stood is two feet higher than where the staff is placed. Next make the instrument and staff change places, and observe in the same manner as before, and if it gives the same difference of level, the instrument is correct; if otherwise, take half the difference between the results, and elevate or depress the vane that quantity, according as the last observation gives a greater or less difference than the first. Again, direct the telescope to the staff, and make the coincidence of the horizontal wire and that on the vane perfect, by turning the collimation screws. Price, $100.

Fig. 107.



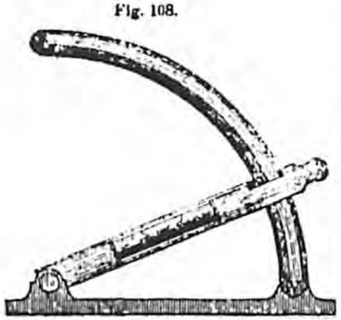
Levelling Staves.—(Fig. 107.)—A mahogany rod, about 12 feet long, and two inches wide, is divided into feet and hundredths. A target of brass, about 8 inches square, or round, slides on the rod, by means of a brass box, on the back, having a spring to give ease and regularity to the movement; on the face of the target is an aperture, over the divisions of the rod, having a vernier, which reads to thousands of a foot. The face is varnished in sectors of different colors, as white and black, affording a very distinct dividing line to the observer. A stout cord is fastened to the upper part of this box, on one side, and is carried around the whole length of the rod, passing through pulleys in the ends, and is attached to the lower part of the box. By means of this cord the target may be moved up or down, when out of the reach of the vane man. Price, $5.00 to $8.00 each.

Portable Levelling Staves.—Two mahogany station-staves generally accompany the spirit-level; they consist of two parts, capable of being drawn out when considerable length is required. They are divided into feet and hundredths, or feet, inches, and tenths, and have a sliding-vane, with a wire placed across a square hole in the centre, as shown in Fig. 107: this vane being raised or lowered by the assistant, until the cross-wire corresponds with the horizontal wire of the telescope, the height of the wire in the vane, noted on the staff, is the height of the apparent level above the ground at that place.

When both the staves are used, they should be set up at equal distances on each side of the spirit level: the difference of the heights of their vanes will be the absolute difference of level between the two stations. But when one staff only is employed, the difference between the height of the vane and the height of the centre of the telescope of the instrument, will be the apparent difference of level, which, if the distance between the staff and instrument is great, requires to be corrected for the curvature of the earth.

Price, $5.00 to $8.00 each.

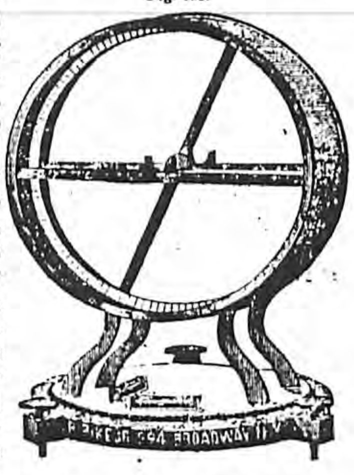
Fig. 108.



Angle Meter, or Level for Slopes.—(Fig. 108.)—This level, used for measuring the angle of strata in mines, geological formations, and any inclination or slope, consists of a stout brass plate, about 6 inches long, jointed at one end to another plate, having a level at the side, and having a graduated arc attached to the lower plate, and moving in a slide on the back of the level plate, and also jointed for portability. In use the lower plate is placed on the slope, and the jointed plate moved till the bubble of the level stands in the middle of the opening, the angle being shown on the divided arc.

Price, $6.00 and $8.00.

Fig. 109.

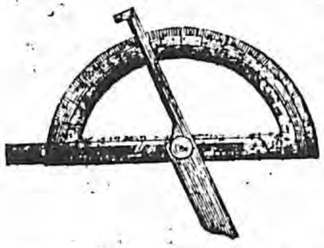


Dipping Needle.—The dipping needle (Fig. 109) is usually a flat oblong piece of steel, about 6 in. long, accurately centred, and balanced previous to being magnetized, and having a slender cylindrical axis, fixed at right angles through its centre, and moving freely on its supports. The mounting consists of a brass plate, supported by three screws. In the centre of this brass plate is another, concentric with the former, and movable round a centre-pin, like the movable plate of a theodolite. To this plate are attached two levels, the one placed at right angles to the other, and used to adjust the plate horizontally. Four pieces of brass support the circular case of the dipping needle, the two faces of which are of plate glass, within which two straight bars of brass are firmly fixed across in a horizontal direction; other two brass pieces are fixed by screws to the centre of the bars, and carry two finely polished planes of agate, on which the axis of the needle rests, and upon which it turns with very little friction. There is a contrivance inside the box, connected with a small knob outside, by which the observer can lift, by means of Y's, the needle from the agate plates, or lower it upon them at pleasure; the Y's being carefully adjusted so as always to leave the axis of the needle on the same part of the agate planes, and in the centre of the graduated circle, and from which graduated circle, the angle the needle makes with the horizon is indicated; this circle is usually divided to half or quarter degrees, and there is sometimes a vernier attached to the end of the needle, and also a reading microscope attached to the rim of the glass face, movable so as to be easily placed on any part of it, for the purpose of reading off the dip with greater accuracy.

To use the instrument, set the graduated rim in the plane of the magnetic meridian by means of a common compass, levelling it by means of the screws of the stand.

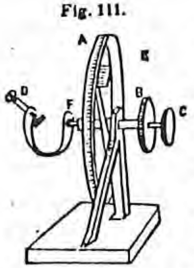
Price, $40.00 to $50.00.

Fig. 110.



The Goniometer.—(Fig. 110.)—An instrument for measuring angles, and more particularly the angles formed by the faces of crystals. The common goniometer consists of a pair of steel blades moving on a centre, as shown in the cut; the edges, *a a*, are carefully adjusted to the faces of the crystal, whose inclination to each other it is required to ascertain; and then the instrument being applied to the divided semicircle, the angle contained is at once read off. An approximate measurement, within one or two degrees, can be easily obtained by this instrument, provided the planes of the crystal be tolerably perfect, and large enough for the purpose. Price, $3.00 to $5.00.

Fig. 111.



Wollaston's Reflecting Goniometer.—(Fig. 111.)—The reflecting goniometer is a very superior instrument, its indications being correct within the fraction of a degree; it is applicable also to the measurement of the angles of crystals of very small size, the only conditions required, being, that their planes be smooth and brilliant. It consists of a brass circle, A, graduated on the edge, and furnished with a vernier, E, by which the divisions may be read accurately to minutes. The circle moves in a vertical plane, and is supported on a stand. The axis of the circle is a hollow tube, within which is a smaller axis, fitting so tightly that when turned round it carries the other axis, and consequently the wheel, along with it, unless

the latter is purposely prevented from moving. The interior axis is furnished with a milled-head, C, and the exterior with a milled-head, B, also; so that when the head, C, is held and the other turned, the circle may be moved independently of the smaller axis; and when the outer one, B, is held, and the inner one, C, turned, the smaller axis may be turned independently of the circle. Attached to the end of the smaller axis is a sort of universal joint, D, capable of being fixed in different positions. The crystal to be examined is attached to the joint at F, by a little soft wax, and placed so that its edge shall be parallel to the axis of motion; which adjustment is obtained by placing it so that the image of some horizontal object, as the bar of a window, successively reflected from the two faces of the crystal, coincides with another horizontal line seen by direct vision. When this adjustment has been made, the instrument is turned till the horizontal object is seen reflected from one of the faces. The smaller axis is then held fast, and the other turned till the index of the vernier points to the zero of the graduated limb. The circle is then turned round, along with the smaller axis, till the same object is seen in the same position, by reflection from the other face of the crystal; when the arc passed through by the circle is obviously the supplement of the angle formed by the two faces of the crystal. In order, however, to avoid calculation, the supplements of the angles are marked on the limb, so that the angle to be measured is read off immediately. Price, $20.00.

The Artificial Horizon.—When the altitude of a celestial object is to be taken at sea, the observer has the natural, or sea horizon, as a line of departure; but on shore, he is obliged to have recourse to an artificial one, to which his observations may be referred: this consists of a reflecting plane, parallel to the natural horizon, on which the rays of the sun or other objects falling, are reflected back to an eye placed in a proper position to receive them; the angle between the real object and its reflected image being then measured with the sextant, is double the altitude of the object above the horizontal plane.

Various natural, as well as artificial, reflecting surfaces have been made by mechanical arrangements, to afford the means of obtaining double angles; such as pouring water, oil, treacle, or other fluid substances into a shallow vessel;

and to prevent the wind giving a tremulous motion to its surface, a piece of thin gauze, talc, or plate-glass, whose surfaces are perfectly plane and parallel, may be placed over it, when used for observation. But the most accurate kind of artificial horizon is that in which fluid quicksilver forms the reflecting surface, the containing vessel being placed on a solid basis, and protected from the influence of the wind. The adjoining figure (No. 112) represents an instrument of this kind. The mercury is contained in an oblong wooden trough, placed under the roof A, in which are fixed two plates of glass, whose surfaces are plane and parallel to each other. This roof effectually screens the surface of the metal from being agitated by the wind, and when it has its position reversed at a second observation, any error occasioned by undue refraction at either plate of glass will be corrected. Price, $20.00 and $25.00.

Fig. 112.

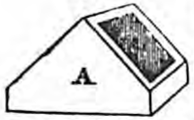


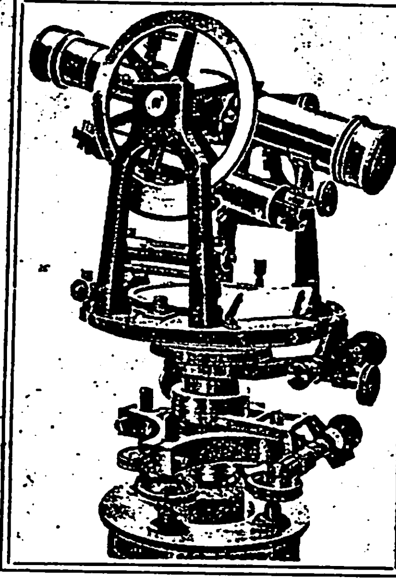
Fig. 113.

Fig. 114.

Another and more portable contrivance for an artificial horizon, is represented in the annexed figures, which consists of a circular plate of black glass, about two inches diameter, mounted on a brass stand, half an inch deep, with three foot screws, *a b c*, to set the plane horizontal; the horizontality being determined thus by the aid of a short spirit-level, *d*, having under the tube a face ground plane, on which it lies in contact with the reflecting surface; place the level on the glass, in a direction parallel to the line joining two of the three foot-screws, as *a* and *b*, then move one of these screws till the bubble remains in the middle of the tube, in both the reversed positions of the level, and the plate will be horizontal in that direction; then place the level at right angles to its former position, and turn the third foot-screw back or forwards till the bubble again settles in the middle of its tube, the former

levelling remaining undisturbed, and the plane will then be horizontal. Price, $6.00 to $10.00.

When an artificial horizon is used, the observer must place himself at such a distance that he may see the reflected object as well as the real one; then, having the sextant properly adjusted, the upper or lower limb of the sun's image supposing (that the object) reflected from the index-glass, must be brought into contact with the opposite limb of the image reflected from the artificial horizon, observing that when the inverting telescope is used, the upper limb will appear as the lower, and *vice versa;* the angle shown on the instrument, when corrected for the index-error, will be double the altitude of the sun's limb above the horizontal plane; to the half of which, if the semidiameter, refraction, and parallax be applied, the result will be the true altitude of the centre.



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