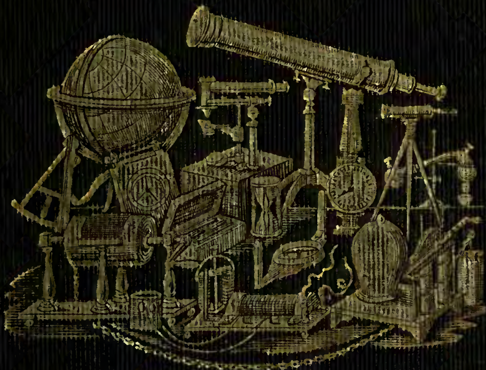
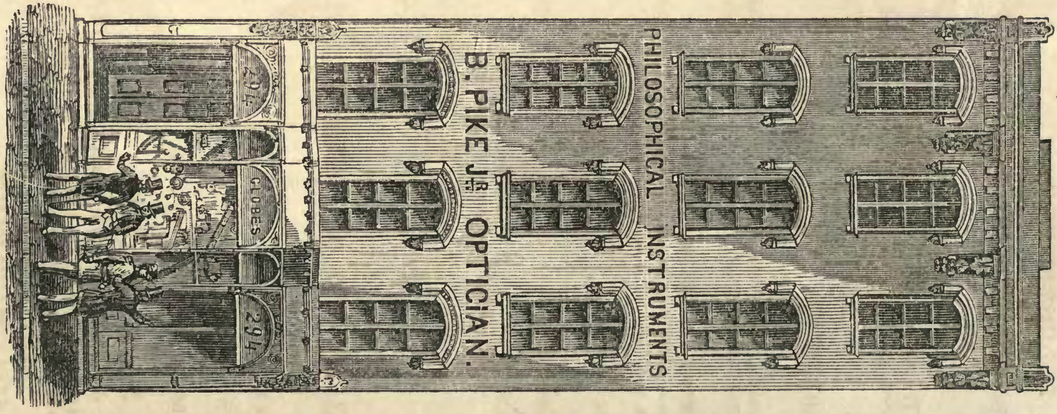




THE Establishment represented in this cut, is situated on Broadway, No. 294, the fourth building above the City-Hall and Park. It was designed and erected in 1850, by the author, for the convenient prosecution of his business. It is twenty-four feet front, one hundred and thirty deep, extending through the block to Manhattan Place, the adjoining street. The front is of brown stone, and five stories high. The interior arrangement is unique, well and conveniently arranged for the manufacture, exhibition, and sale of Philosophical Instruments.

Benjamin

PIKE'S

ILLUSTRATED

DESCRIPTIVE CATALOGUE

OF

OPTICAL, MATHEMATICAL,

AND

PHILOSOPHICAL INSTRUMENTS,

MANUFACTURED, IMPORTED, AND SOLD BY THE AUTHOR; WITH THE PRICES AFFIXED AT WHICH THEY ARE OFFERED IN 1856.

WITH UPWARDS OF 750 ENGRAVINGS,

MOSTLY ORIGINAL DESIGNS FROM THE INSTRUMENTS OF HIS ESTABLISHMENT IN THE VARIOUS DEPARTMENTS OF

ELECTRICITY,
GALVANISM,
MAGNETISM,
ELECTRO-MAGNETISM,
PNEUMATICS,
HYDROSTATICS,
MECHANICS,
OPTICS,
ASTRONOMY,
SURVEYING,
NAVIGATION,
METEOROLOGY,
CHEMISTRY, &c., &c.

Designed to aid Professors of Colleges, Teachers, and others, in the Selection and Use of Illustrative Apparatus, in every Department of Science.

BY BENJAMIN PIKE, JR., OPTICIAN.

IN TWO VOLUMES.

VOL. I.

SECOND EDITION, ENLARGED.

NEW YORK:
PUBLISHED AND SOLD BY THE AUTHOR,
AT HIS OPTICAL, MATHEMATICAL, AND PHILOSOPHICAL INSTRUMENT MANUFACTORY,
294 BROADWAY,
A FEW DOORS ABOVE THE PARK.
1856.

PREFACE.

BENJAMIN PIKE, Jr., in presenting to his friends and the public the following Catalogue of Instruments, desires to say, that he has been induced to undertake the collection of materials for such a volume, from the fact that no work corresponding to it is to be found, and the information which it is intended to impart, can only be gathered from a great variety of sources, many of which are works not published in this country. The rapid strides with which the sciences are advancing, and the fact that the arts and manufactures are calling in the aid of some of these instruments to facilitate their processes, while others may be employed in every day use, renders such a volume as this altogether appropriate and useful, if, indeed, it be not absolutely indispensable.

He wishes it borne in mind, that he is not a man of letters, but a mechanic,—a practical workman: this will account for whatever imperfections may be found in style, arrangement, &c.

The instruments illustrated in our modern works on natural philosophy are too frequently represented by old and obsolete cuts, mere copies, book after book, for many years back, furnishing but little idea of more modern articles.

In presenting this volume, the first design has been to illustrate by good drawings, and brief descriptions, articles manufactured in his establishment, or imported by him, in order that those desirous of obtaining apparatus, and not having an opportunity of personal examination, may yet be able to judge of the style, quality, and price. The usual brevity of the descriptions has in a few instances been departed from, where the instrument has demanded a more extended notice.

Particular pains have been taken, and a large expense incurred, in the illustrations (numbering over 750) of this Catalogue; they are mostly original, and drawn from the most modern and approved instruments.

These articles embrace every variety kept in an extensive Optical and Philosophical Instrument Store; and include almost every instrument used in natural and experimental philosophy.

The author having devoted himself from early youth to the manufacture of these instruments on a somewhat extensive scale, is satisfied that his collection of instruments is not surpassed, if equalled, by any in the country, for extent, style, quality, or *cheapness;* he therefore solicits with confidence a continuance of that encouragement which he has in past years received, and which he is determined to merit.

Professors of the sciences will find in his establishment a full assortment of instruments suitable for illustration and practical purposes. To his stock have been recently added many large and valuable instruments, and it will be his endeavor to continue to keep pace with the growing demand for good instruments among the scientific community.

Parents and guardians of youth, who feel desirous of promoting a taste for Chemistry and Natural Philosophy in the minds of the young, from seeing what rapid advances these sciences are making, and how necessary their acquaintance to all, will find nothing promote their wishes, nor their children's enjoyment, more than procuring for them an assortment of apparatus, whereby they may be able to follow up practically those experiments of which they have read in text books of science, or have seen in lectures. The moderate prices of some of these articles are enumerated at the end of this volume.

In the construction of apparatus, it will be the maker's aim to use the various pieces of apparatus to the best advantage, by adapting them to the performance of as great a variety of purposes and experiments as is possible.

The writer might enumerate to his patrons a number of diplomas and silver medals received for his Air-Pumps, Galvanic Batteries, Magnetic Machines, Barometers, Theodolites, Magic-Lanterns, Sliders, &c., at various Fairs of different Institutes; and also the commendatory letters of distinguished Professors in various Colleges and Universities, who are using instruments of his manufacture; but having been long established in this business, he trusts that the character of his instruments is understood, without further reference.

He would beg leave to notice his improved Magnetic Machines for medical purposes; and though, unlike many that have followed in his wake, he has not trumpeted abroad the various cures the instrument has accomplished, yet the remarkable cures it has and still is effecting, are beyond question, although he has declined to publish cases, from the fact that the most remarkable are among some of the very first families of this city, and elsewhere, to whom it would not be agreeable to have an account of their infirmities seen in print. Let it suffice to say, that this instrument arose to its high reputation, by no efforts of his own to give it publicity, but solely by the cures it accomplished, and which are now very generally known.

As every maker of these instruments claims to make the best, and the last usually makes the loudest claim, he would simply state that his instrument has been, without solicitation, purchased and used by every Hospital and Medical Institution in this city and vicinity, and by almost every Physician, as well as by over one thousand of our own citizens, and also by distinguished persons in various parts of this country and in foreign lands.

His stock of Telescopes and Microscopes will be found very extensive, and together with Optical Lenses and Sliders for the Magic Lantern, form the principal articles that are imported; and for obtaining these from London and Paris direct, and at low rates, he is possessed of unusual facilities.

As the Microscope is capable of affording a vast field for amusement and instruction, opening a new world and displaying the most extensive scenes of creative power, wisdom, and design; and it being difficult to find in print any information concerning it, a minute description of one of the kinds is given, which will be found applicable to all the others; also particular directions for procuring and applying some of the most interesting subjects for examination.

In regard to Spectacles, Eye-Glasses, and Lenses for optical purposes of every description, his assortment is most extensive and complete. To this branch of his business he devotes special attention, furnishing Glasses or Pebbles that are truly ground, and properly adapted to the sight; feeling that so important a matter as vision should receive more attention than is usually given.

He also begs leave to inform his patrons and the public, that he has recently much enlarged his establishment, increased his stock of instruments, and added to his machinery, tools, and fixtures; and as these instruments are mostly manufactured on his own premises, he is enabled to improve and simplify their construction, and personally attend to the finishing, proving, and packing of the same. With very few exceptions, they are kept ready made, and orders will be executed without delay.

Extracts from Notices of the First Edition by the Press.

"A new and useful work, in two neatly-printed and profusely illustrated volumes, and can not but be exceedingly useful as giving publicity to one of the best assorted and beautifully finished collections of Philosophical, Mechanical, and Chemical Apparatus, in the country. Each instrument is described, and its price appended, together with much other valuable information, not easily obtained elsewhere."—*Farmer and Mechanic.*

"In these volumes the latest and most improved Chemical, Mathematical, and Philosophical instruments of all kinds, are fully described and arranged under appropriate heads. An engraving of each accompanies the description, which embraces the particulars of the construction, and uses of each article, and also the price at which it can be procured."—*Day-Book.*

"This book will be found a convenient manual of reference for instruction in the necessary manipulations of philosophical apparatus: the requisite information upon which has hitherto been scattered through many volumes. . . . . An instance of private enterprise to which no parallel exists in this country; nor indeed are we aware of anything, covering so large a field, being put forth in the unpretending shape of a list of manufactured articles, even from European presses. . . . . Such a catalogue must be a valuable boon to all who are engaged in scientific pursuits; and professors of colleges, teachers, and others, will find it of infinite service 'in the selection and use of illustrative apparatus in every department of science.'"—*Lit'y World.*

"The information embodied in this work must prove valuable, if not indispensable, to men of science and skill, to the manufacturer and mechanic, and indeed to all who have taken an interest in the experimental operations of natural philosophy, and the progressive advancement of science. It will interest the curious in such matters, while it becomes a *vademecum* to the man of science."—*Merchant's Mag.*

"No similar catalogue can be found elsewhere. The work is not a mere catalogue; it is a museum to which the lovers of science may resort, and where they may examine the various apparatus which have been contrived to illustrate and explain the phenomena of nature, or to explore 'the heavens above and the earth beneath, and the waters that are upon the earth.' The work is embellished with over seven hundred and fifty good engravings of all manner of instruments, which are here thoroughly delineated and described, in the various departments of the arts—Electricity, Galvanism, Magnetism, Pneumatics, Hydrostatics, Mechanics, Optics, Astronomy, Meteorology, Navigation, Surveying, Chemistry, &c. The prices of the article are plainly designated. The work is neatly bound and finished—altogether, being a curious and interesting publication."—*Tribune.*

"These two volumes contain cuts and descriptions illustrative of the construction and uses of the great variety of instruments, &c., manufactured by the author. 'Pike's' has long been a resort for everything in the way of instruments in use by the different learned professions."—*N. Y. Observer.*

CATALOGUE, &c.

A CASE OF MATHEMATICAL INSTRUMENTS.

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

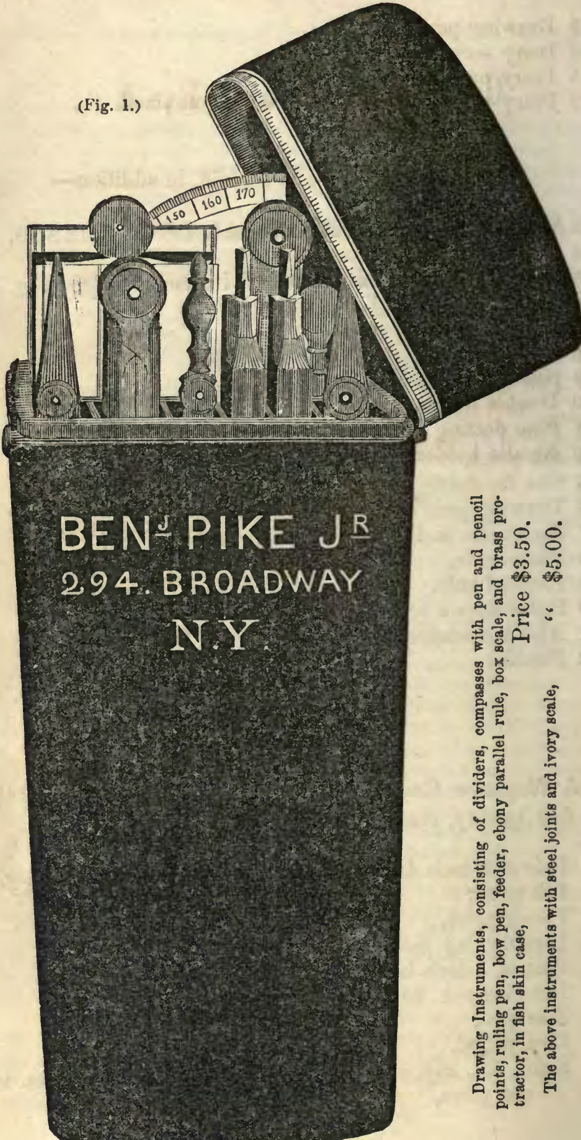
1 Pair of 5-inch plain compasses,
2 Pair of 6-inch drawing compasses, with one leg or point movable,
3 Pencil point,
4 Ink point,
5 One for dotting,
6 Drawing pen, with a protracting pin in the handle,
7 Protractor in the form of a semicircle,
8 Plain scale,
9 Parallel rule,
10 Sometimes a sector,
11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

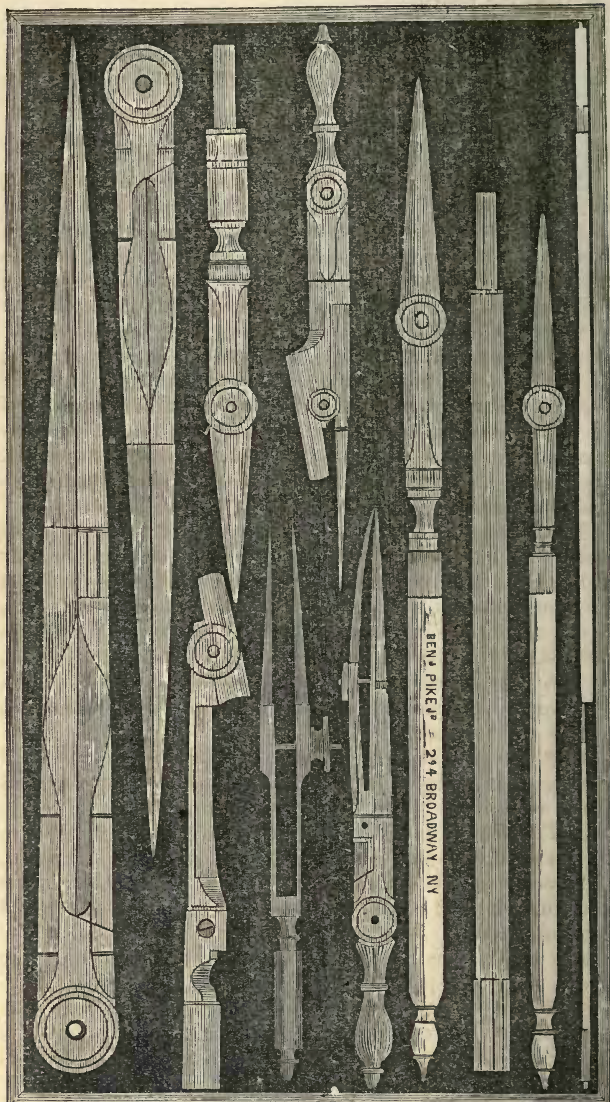
9 Drawing pencil,
10 Ivory sector,
11 Ivory parallel rule,
12 Ivory protractor and plane scale combined.

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.

(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.

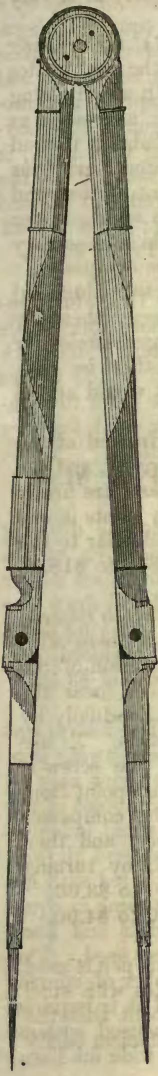


Fig. 4.

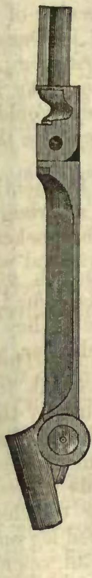


Fig. 5.

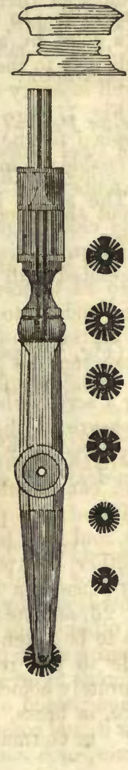
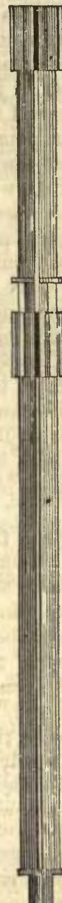


Fig. 6.

Fig. 7.



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;

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13

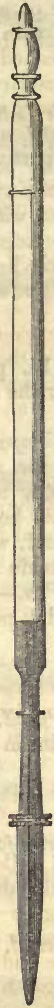


Fig. 14.

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.

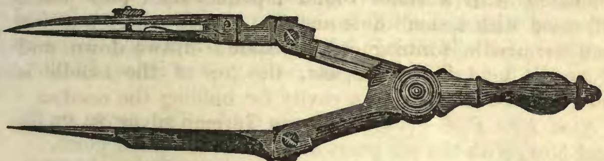


Fig. 17.

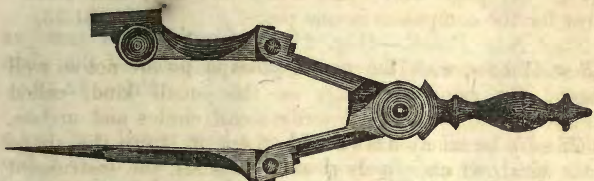


Fig. 18.

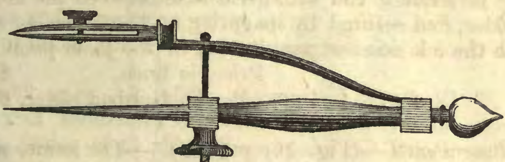


Fig. 19.

Fig. 20.

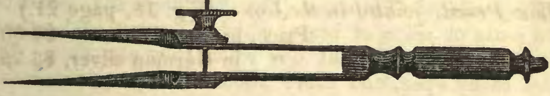


Fig. 21.

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.

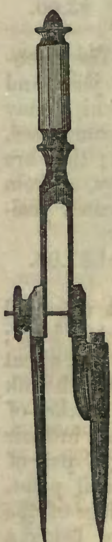


Fig. 23.

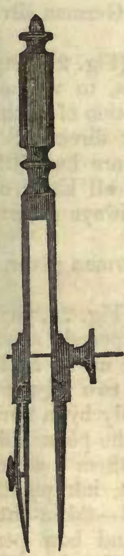


Fig. 24.

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.

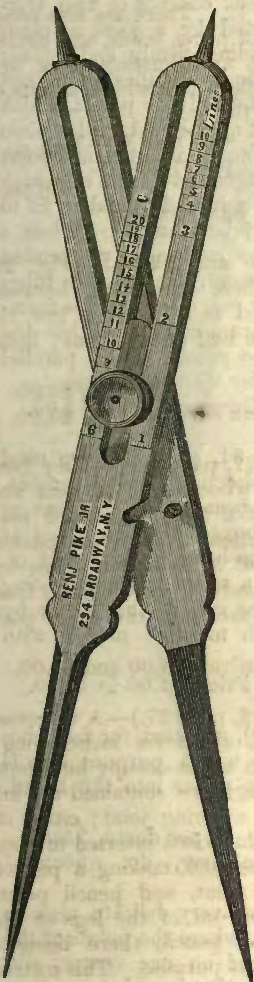


Fig. 26.

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.

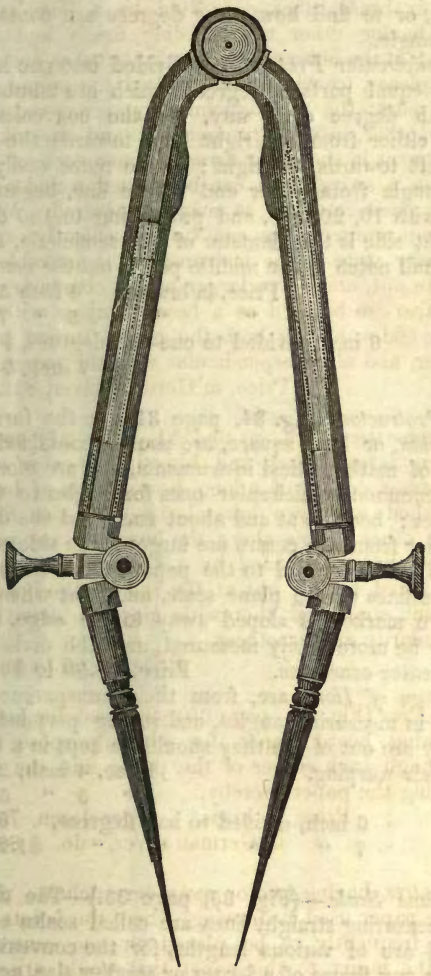
Drawing Pins (Fig. 32, page 29), are used for fastening to the drawing board paper, for which purpose one is pressed through each corner of the paper into the board, firmly securing the paper thereby.

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 reckoning either from the right hand towards the left, or from 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.

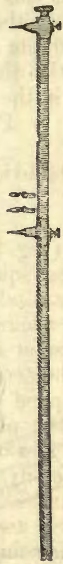


Fig. 31.

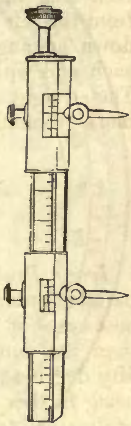
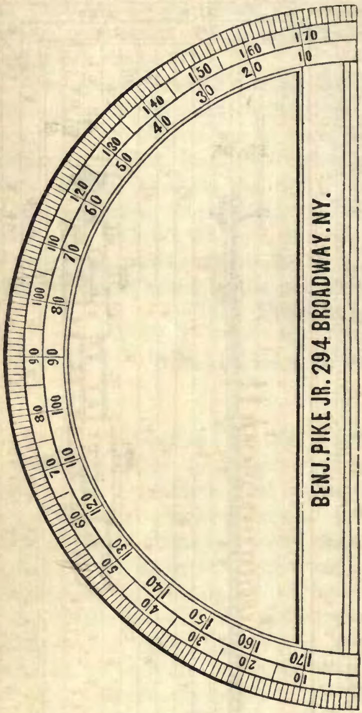


Fig. 32.

Fig. 33.

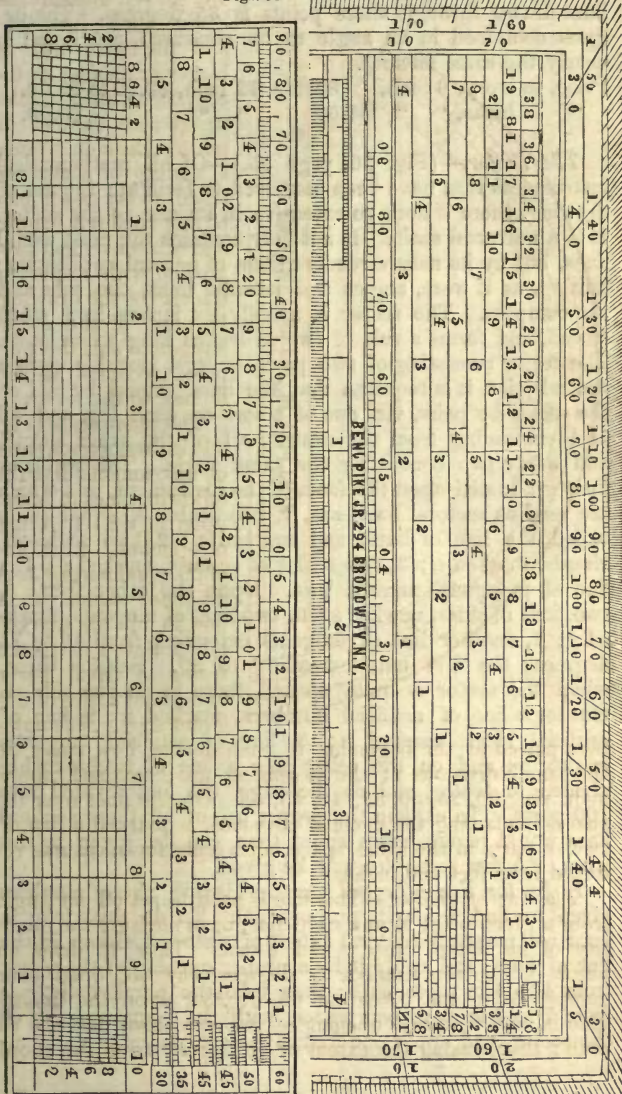


any known measure, as chains, yards, feet, &c.; and the plan will be larger or smaller as the scale contains a smaller or greater number of parts in the inch. Hence a variety of scales are useful to lay down lines of any required length, and of a convenient proportion with respect to the size of the 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.

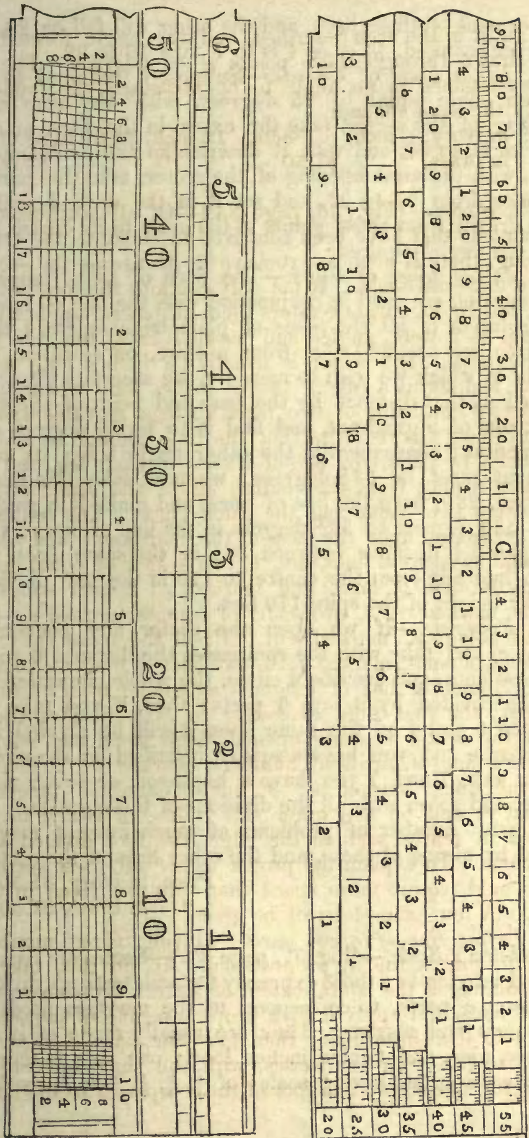


line, set it in the arch described, and the angle formed by lines drawn through these points is 35 degrees. The degrees contained in an angle to be measured, are found in nearly the same manner.

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-



Figs. 35.

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.

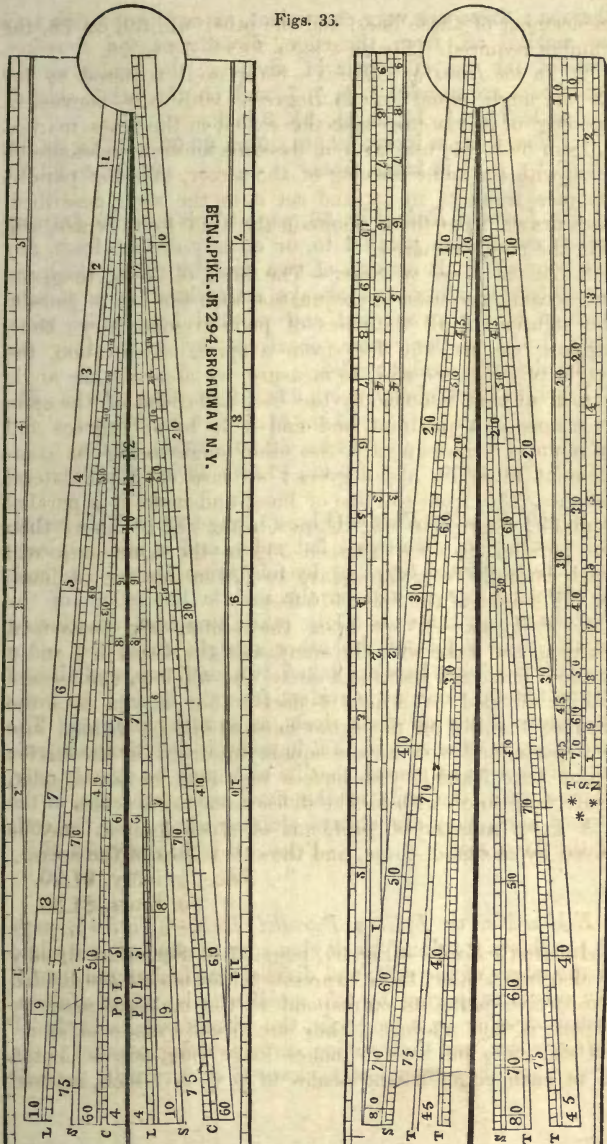
4. *Polygons.*—If we open the sector any convenient distance, and take with the compasses the distance 6 and 6 on these lines, and inscribe a circle, the whole circumference will be divided by it into 6 parts; then, if you take the distance 4 and 4 on the same lines, it will be divided into four parts, 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 ends 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.

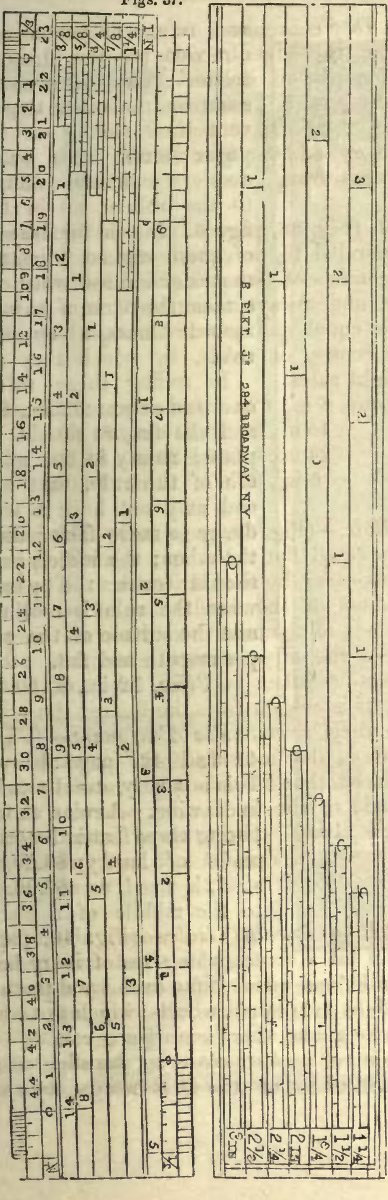


Fig. 38.

Fig. 39.

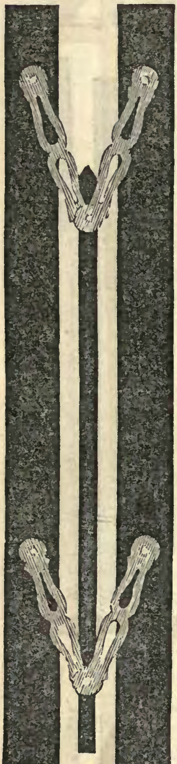
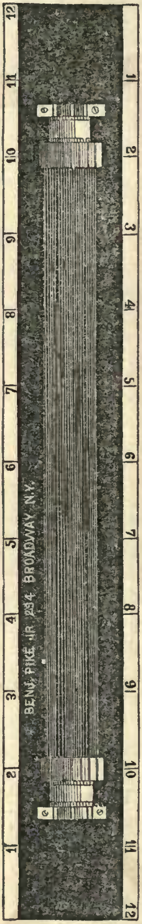


Fig. 40.



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.

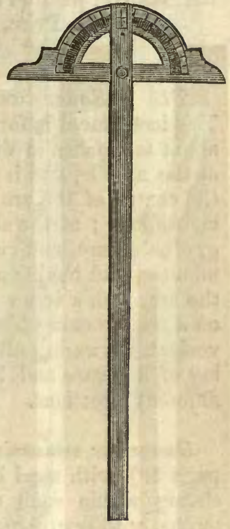


Fig. 44.

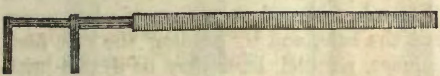


Fig. 46.

Fig. 45.

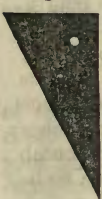
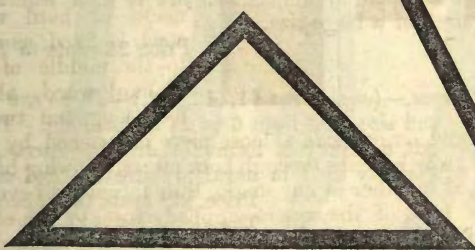


Fig. 46.



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.

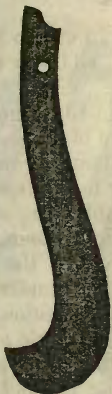


Fig. 48.


Fig. 49.

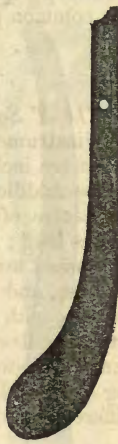


Fig. 50.

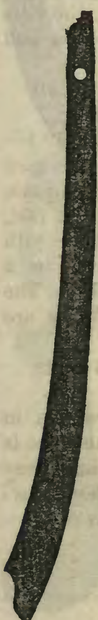


Fig. 51.

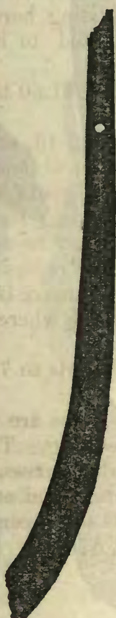


Fig. 52.

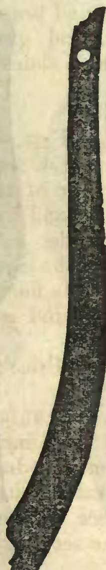


Fig. 53.

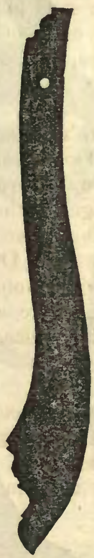


Fig. 54.

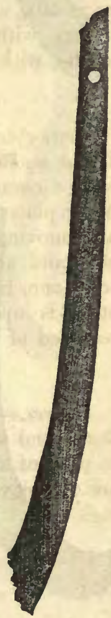


Fig. 55.

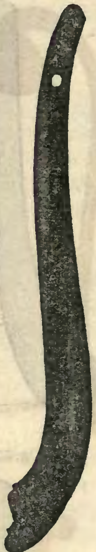


Fig. 56.

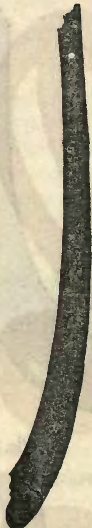
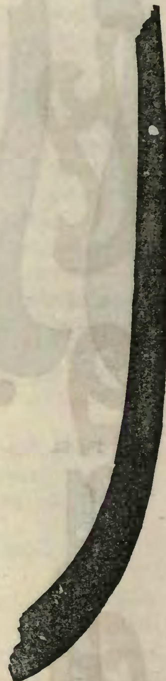


Fig. 57.

Fig. 58.



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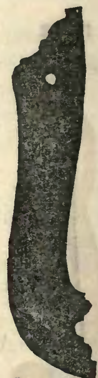

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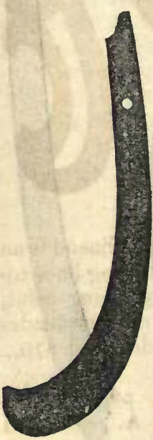


Fig. 60

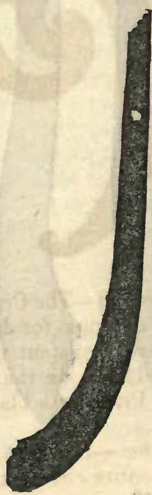


Fig. 61.

Fig. 63.

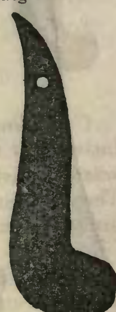


Fig. 64.

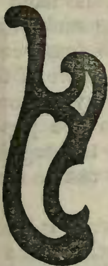
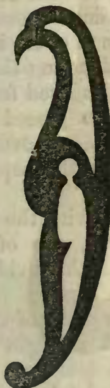


Fig. 65.



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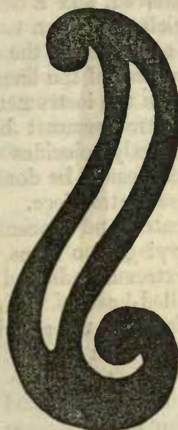


Fig. 67.

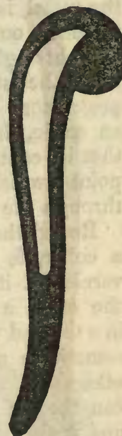


Fig. 68.

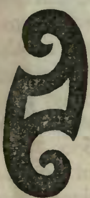


Fig. 69.

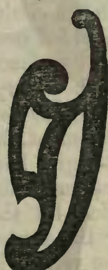


Fig. 70.

Fig. 71.

Fig. 72.

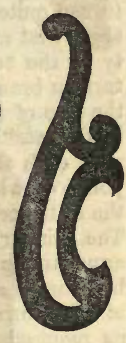


Fig. 73.

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.

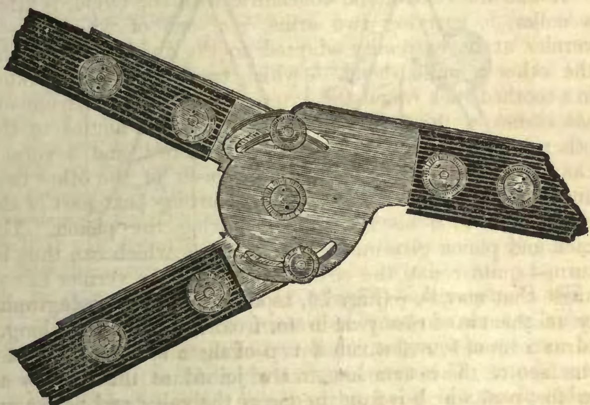


Fig. 75.

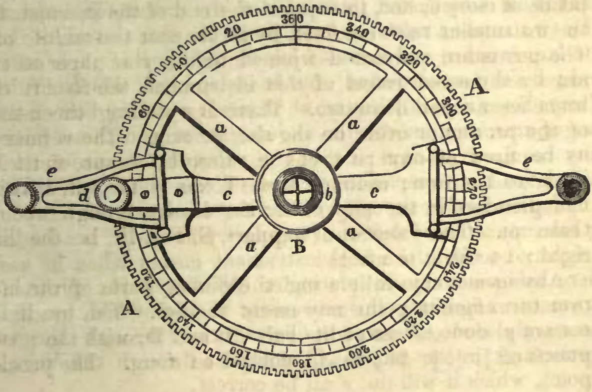
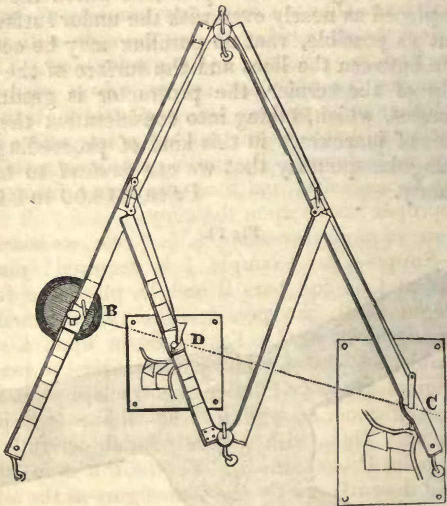


Fig. 76.



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 yonrself 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 8¼ 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.

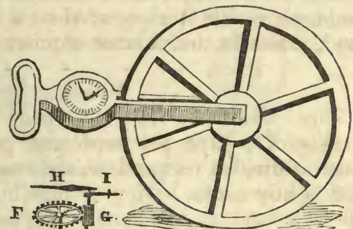


Fig. 78.

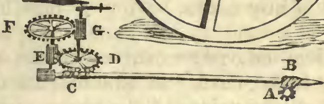


Fig. 79.

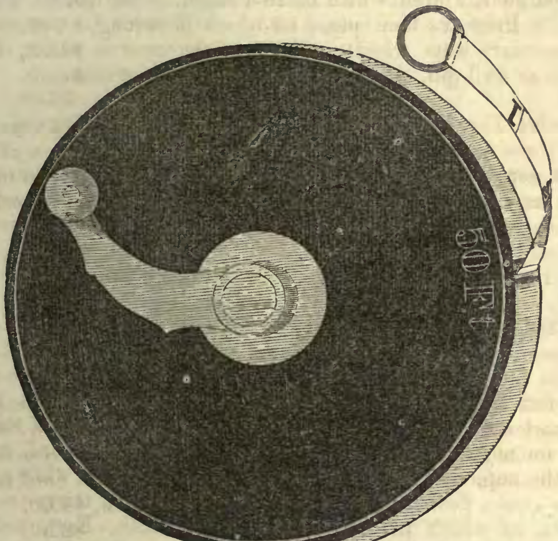
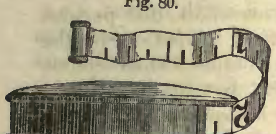
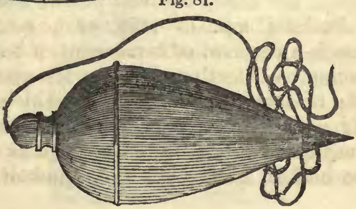


Fig. 81.

Fig. 80.





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.

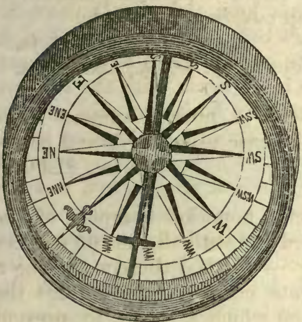


Fig. 83.

Fig 84.

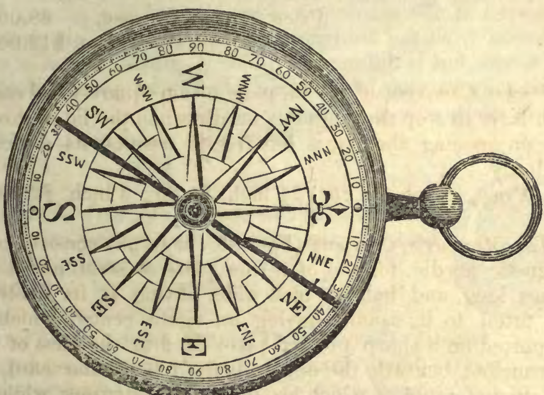


Fig. 85.

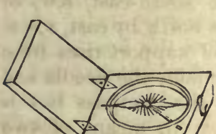
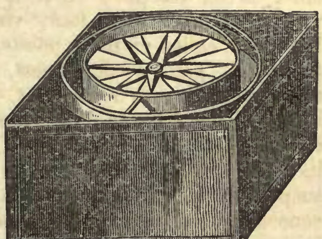


Fig. 86.



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.

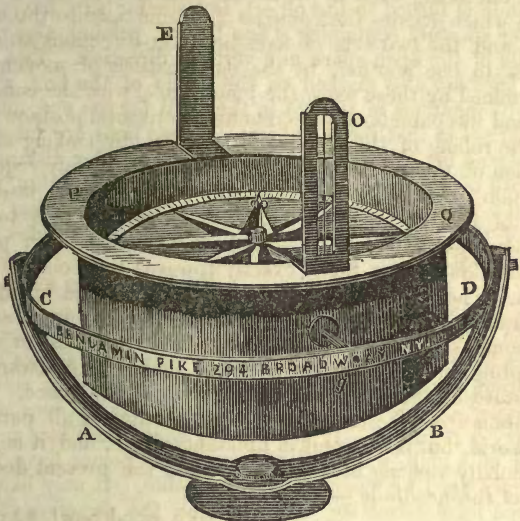
Fig. 87

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.



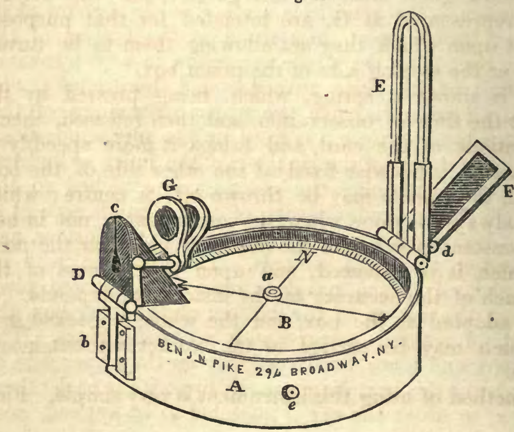
observer to read off the number of degrees from the card, which correspond with an index, or perpendicular line, drawn on the inside of the box.

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 C 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.



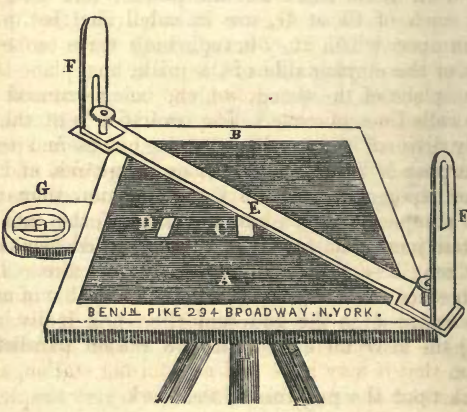
In the preceding figure, A represents the compass box, and B the card, which, being attached to the magnetic needle, moves as it moves, round the agate centre, *a*, on which it is suspended. The circumference of the card is usually divided to 30′ of a degree; *c* is a prism, which the observer looks 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.

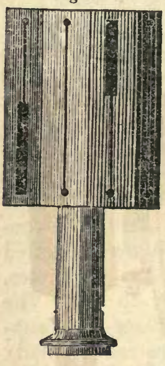
One face of the frame is divided to 360 degrees, from a centre, C, fixed in the middle of the board, and these are subdivided as minutely as the size of the table will admit. The divisions are frequently numbered each way, to show at sight both an angle and its complement to 360°. There is sometimes 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.

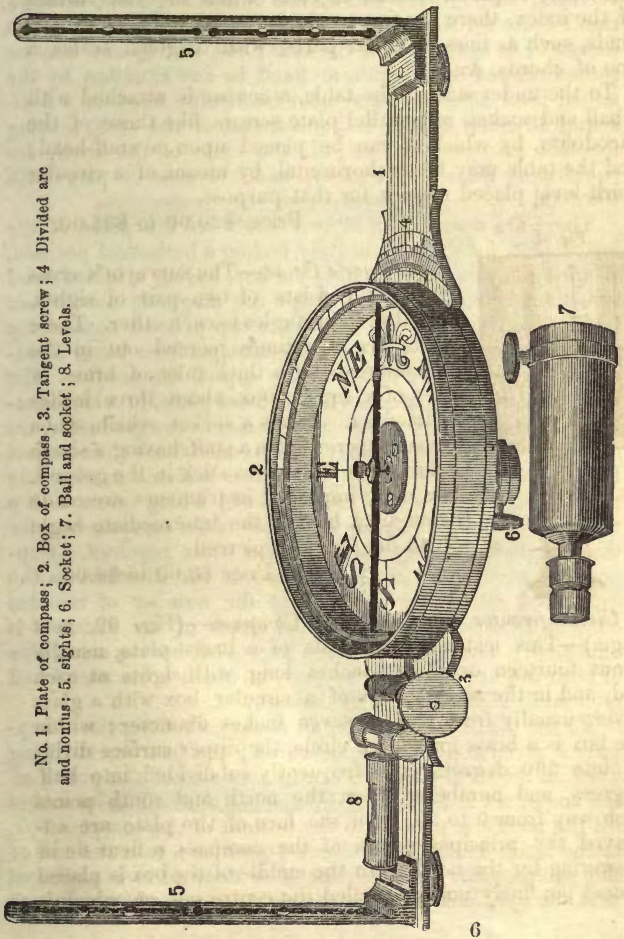


Surveyor's Cross.—The surveyor's cross (Fig. 91) consists of two pair of sights, placed at right angles to each other. These sights are sometimes pierced out in the circumference of a thick tube of brass, or sides of a square box, about three inches in diameter. It has a socket, which, when in use, is 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.

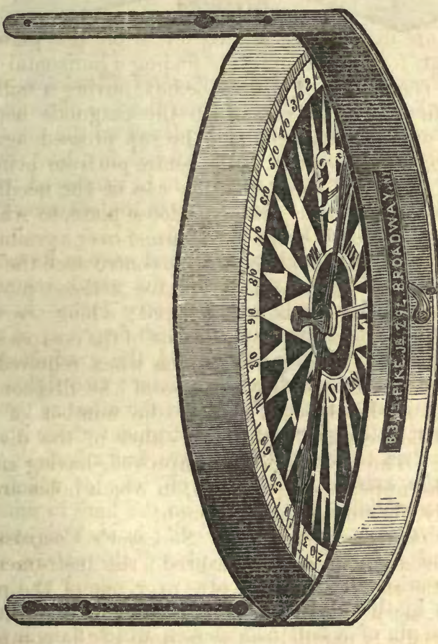
There are usually one or two levels on the plate of the instrument, for more accurately finding a horizontal position. A spring is also placed within the box, having a milled-head screw acting against it, by which the magnetic needle can be lifted off the centre pin and the cap pressed against the glass, 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.

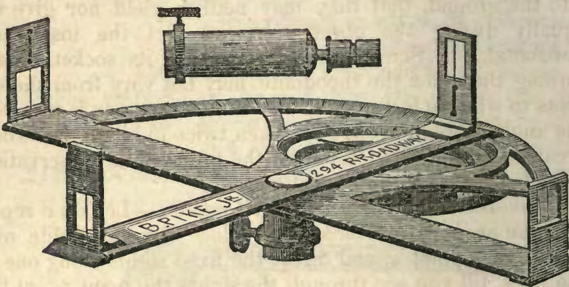
Fig. 93.



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.

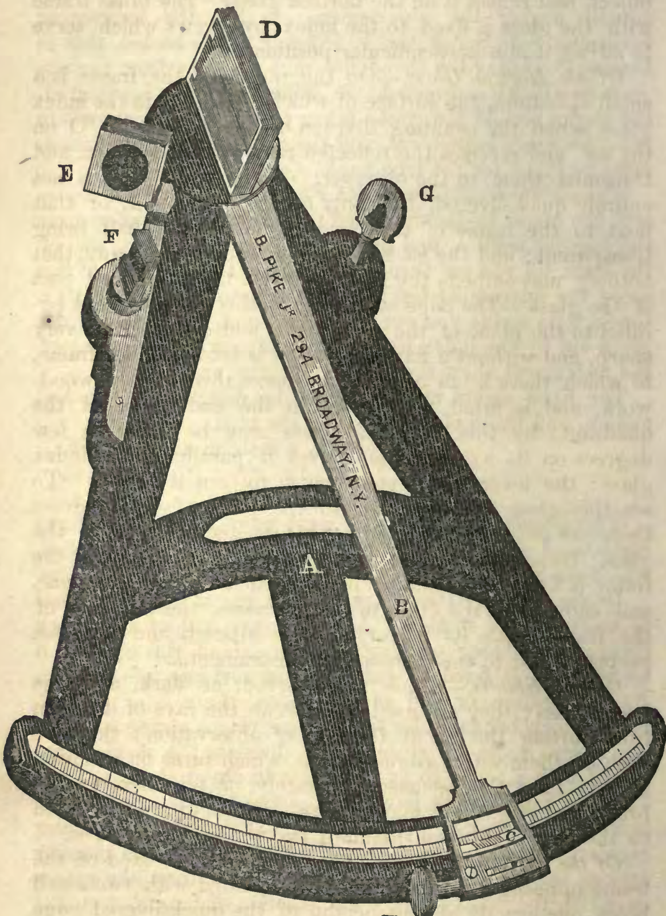
Price, 8 inch, in case, $15.00.
" 12 " " $30.00.

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 axis, is fixed a plain speculum, or mirror of glass, quicksilvered. It is set in a brass frame, and is placed so that the face of

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

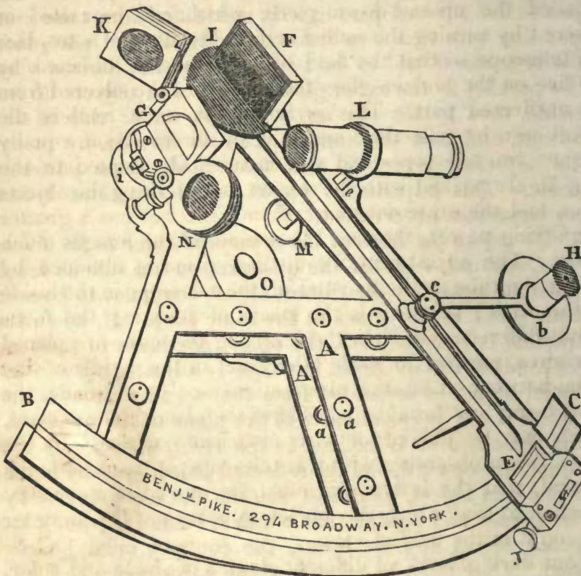
of the glass, but by reflection in the silvered part; if the object in the silvered part exactly meets, and forms one continued line with that seen through the unsilvered part, then is the instrument said to be adjusted, and the horizon glass to be parallel to the index glass; but if the objects do not 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

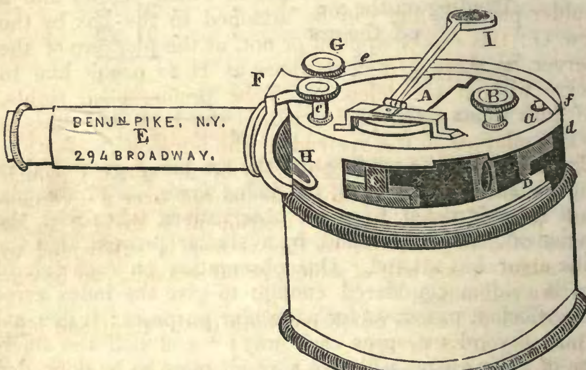
In this case, the reading on the arc being greater than that on the arc of excess, the index error, = 17 seconds, must be subtracted from all observations taken with the instrument, until it be found, by a similar process, that the index error has altered. One observation on each side of zero is seldom 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.

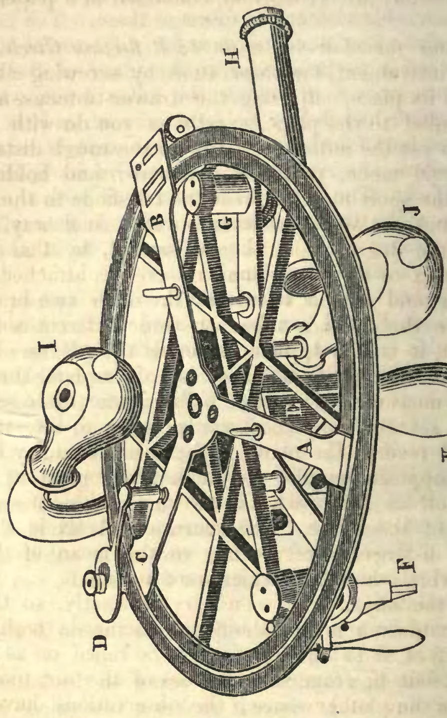
The angle is read off by the help of the glass, I, which being mounted with a joint, can be moved over the vernier on any part of the limb. The instrument is divided to 30 minutes of a degree, and by the vernier is subdivided to single minutes, one half of which, or 30 seconds, can be obtained by estimation.

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.

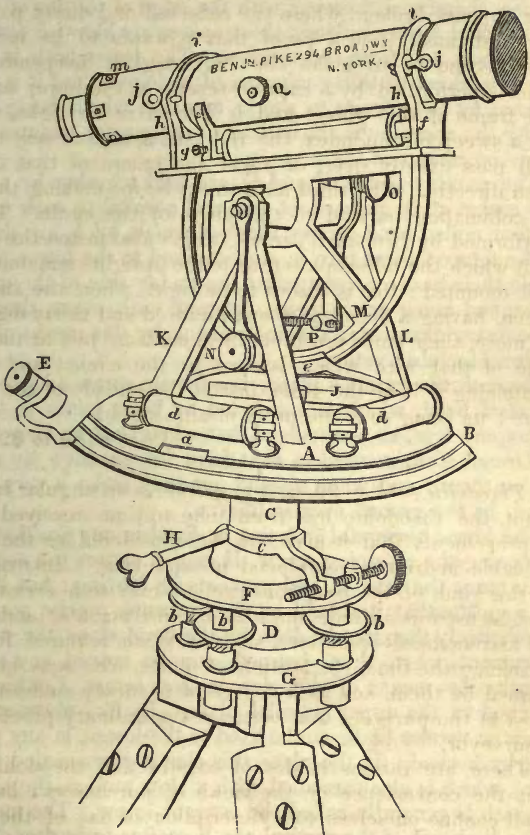
Price $150 to $200.

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.

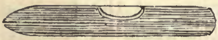
The vernier of the vertical arc may now be attended to; it is correct, if it points to zero when all the foregoing adjustments are perfect; and any deviation in it is easily rectified, by releasing the screws by which it is held, and tightening them again after having made the adjustment; or, what is 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.

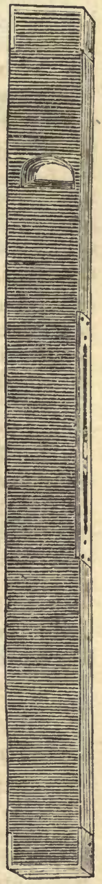
The accuracy of the indications of the level depends in a considerable degree on the regularity of the interior surface of the tube. They are commonly made of glass tubes, in the same state as they are obtained from the glass-house; but when very great accuracy is required, the inside is ground, to give 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 projections 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.

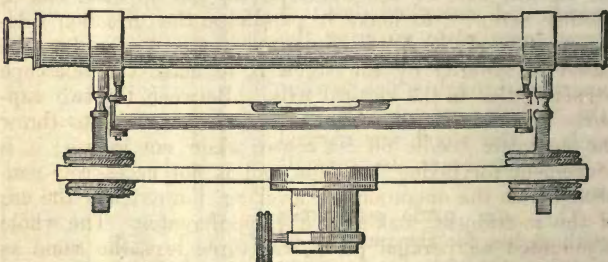
Price, 88cts. to $1.50.

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, millwrights, &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.

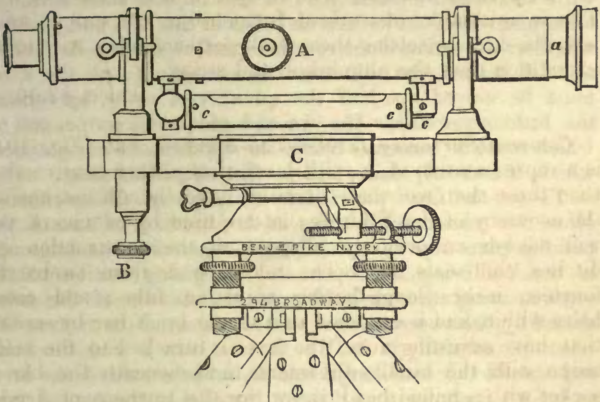
Fig. 104.



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.

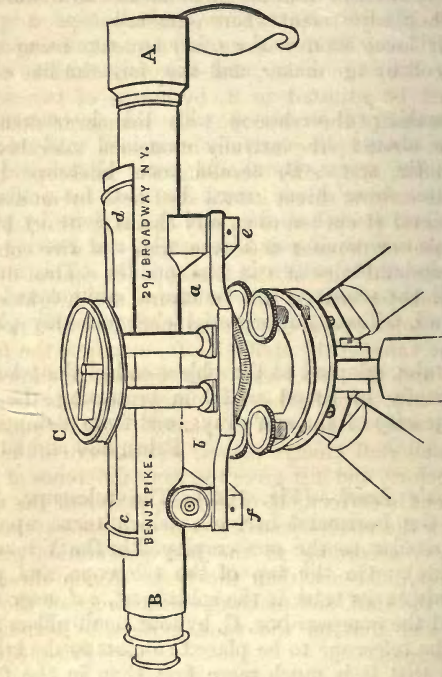
A short tube, adapted to the object-end of the telescope, will occasionally be found useful in protecting the glass from the intensity of the sun's rays, and from damp in wet weather. Price, $80 and $100.

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.

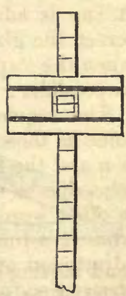


ment, and by it objects can be seen in their natural position. A cap is adapted to the object-end of the telescope, to screen the glass from the rays of the sun, or from the rain: when the cap is used, it should be drawn forwards as much as possible.

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.



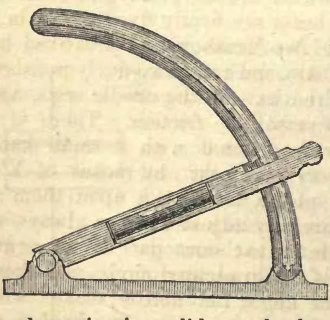
Levelling Staves.—(Fig. 107.)—A mahogany rod, about 12 feet long, and two inches wide, is divided into feet and hundredths. A target of brass, about 8 inches square, or round, slides on the rod, by means of a brass box, on the back, having a spring to give ease and regularity to the movement; on the 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.

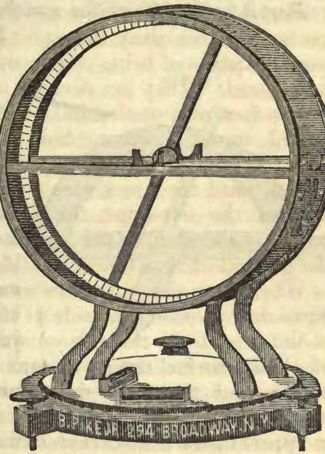
Fig. 108.



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.

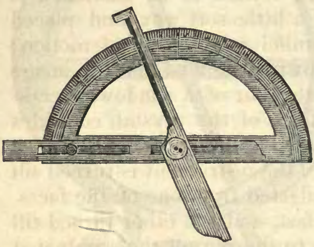


Dipping Needle.—The dipping needle (Fig. 109) is usually a flat oblong piece of steel, about 6 in. long, accurately centred, and balanced previous to being magnetized, and having a slender cylindrical axis, fixed at right angles through its centre, and moving freely on its supports. The mounting consists 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.

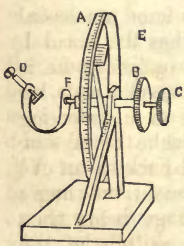
Fig. 110.



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.



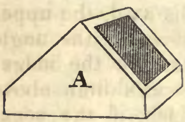
Wollaston's Reflecting Goniometer.—(Fig. 111.)—The reflecting goniometer is a very superior instrument, its indications being correct within the fraction of a degree; it is applicable also to the measurement of the angles of crystals of very small size, the only conditions required, being, that their 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;

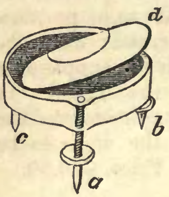
and to prevent the wind giving a tremulous motion to its surface, a piece of thin gauze, talc, or plate-glass, whose surfaces are perfectly plane and parallel, may be placed over it, when used for observation. But the most accurate kind of artificial horizon is that in which fluid quicksilver forms the 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.



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

Fig. 113.



ig. 114.

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.

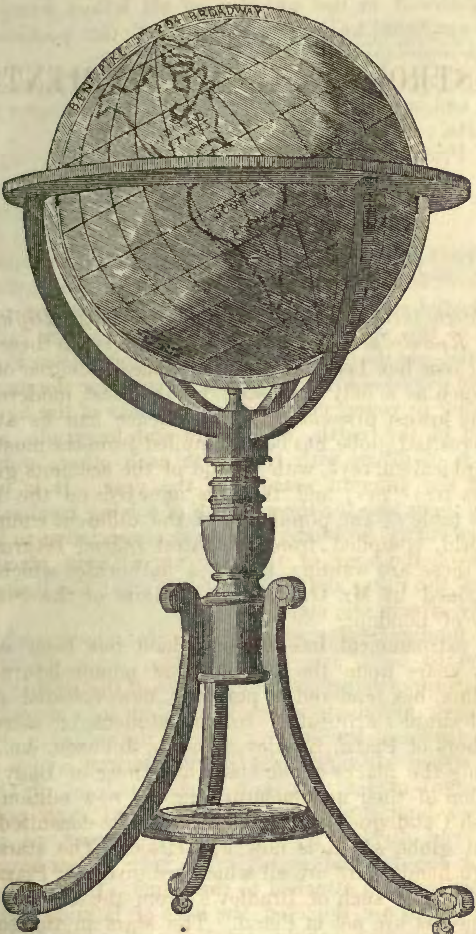
ASTRONOMICAL INSTRUMENTS.

GLOBES.

Eighteen inch Globes of the Society for the Diffusion of Useful Knowledge.—(Fig. 115, next page.)—In these globes an endeavor has been made to combine a degree of accuracy, such as is only possessed by the best modern maps, with the lowest price at which excellence can be attained. The terrestrial globe has been compiled from the most recent geographical surveys, with the aid of the accounts given by the best travellers; and there is annexed on the 18-inch globe a table of the population of the different countries in the world, compiled from the latest official returns, and, where these are wanting, the best authorities which could be obtained by Mr. G. S. Brent, Fellow of the Statistical Society of London.

The astronomical information which has been supplied of late years upon the position and nomenclature of the fixed stars, has rendered a perfectly new celestial globe a most desirable acquisition to the student of astronomy. The labors of Piazzi, Bradley, Lacaille, Johnson, &c., in determining the places of the stars, and those of Baily in the correction of their nomenclature (in the new edition of the "British Catalogue"), have been carefully consulted in the celestial globe which is now advertised. The stars in the northern hemisphere are all which are given by Piazzi, with the addition of such of Bradley's (from the Tabulæ Regiomontanæ) as are not in Piazzi. The stars in the southern hemisphere comprise all those given by Lacaille and Johnson. The magnitude of each star is that by which it is designated in the catalogue from which its place is taken: and the several orders of magnitude are so distinguished from each other as to be read, after a little practice, without the ne-

Fig. 115.



cessity of counting the number of points in the star-figure. The double and multiple stars have been marked from the catalogues of Sir W. Herschel and Sturve, and Flamsteed's numbers have been annexed as they stand in Mr. Baily's edition of the "British Catalogue;" which work has also been followed in the omission of all letters except those which are found in Bayer's maps. All the positions have been brought up to 1850.

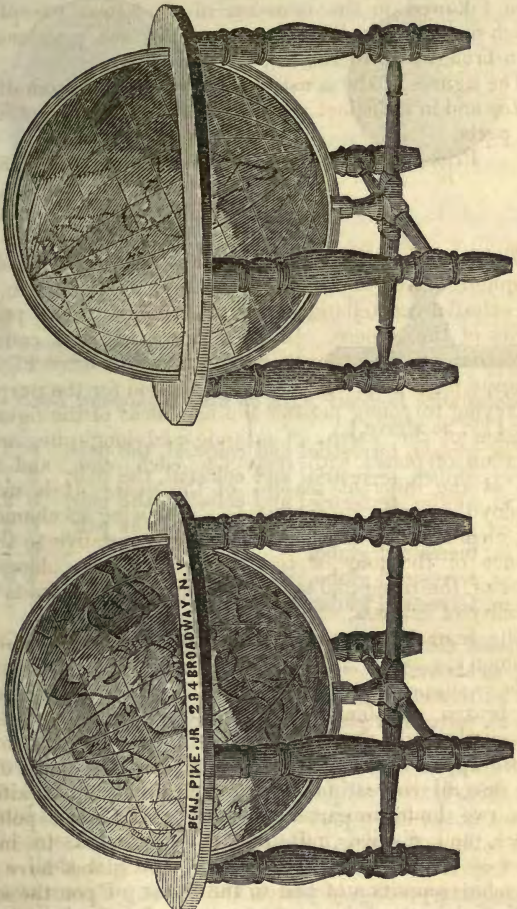
The figures of the constellations are printed from different plates and in a distinct color from that of the more important parts.

Price, on high mahogany frames, the pair, $78.00.
" " " " " and compasses, the pair, - - - $85.00.

Thirteen-inch Globes.—The artificial globe is a round body or sphere, having on its surface a map of the earth, or of the celestial constellations, as delineated, with the principal circles of the sphere. In the former case it is called the terrestrial—in the latter, the celestial globe.—(See Figs. 116, opposite page.)—Artificial globes are used for the purpose of conveying to young persons the first ideas of the figure and rotation of the earth, of latitude and longitude, and the situation of places with respect to each other, and to the sun at the different seasons of the year. It is usual to employ them also for the purpose of solving mechanically a few elementary problems of astronomy, relative to the difference of the hour of the day at different places; the times of the rising and setting of the sun; the limits of the visibility of eclipses, etc.

The fundamental parts of these instruments which are common to both, are, first, the two poles whereon the globe is supported, representing those of the world; second, the brazen meridian, which is divided into degrees, and passes through the poles; third, the wooden horizon, whose upper side represents the real horizon, and is divided into several circles; fourth, a brass quadrant of altitude; fifth, two hour circles, one moving round each pole as a centre, and divided into twice twelve hours, to indicate those of the day and night. The best globes have also a magnetic compass attached to the frame. Upon the surface of the globes are depicted the lines of latitude and longitude, the equator, ecliptic, tropics, and polar circles. On one globe, in addition to these, are the various countries, seas, etc., of the world; and on the other, the stars in their relative positions.

Figs 116.



Price, the pair,	- - - -	$25.00.
" "	with high mahogany frames,	$35.00.
" "	" " " " and compasses, -	$40.00.
" "	10 inch, - - - -	$20.00.

Fig. 117.

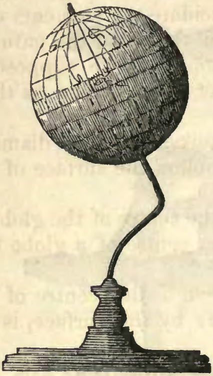
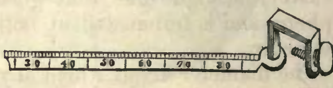


Fig. 118.

Fig. 119.



Globes with Inclined Axis, on neat Mahogany Bases.—(See Fig. 117, as above.)

9 in. globes, terrestrial and celestial, the pair,	$15.00.
6 in. globes, terrestrial and celestial, the pair,	$ 7.50.
3 in. globes, terrestrial and celestial, the pair,	$ 3.50.
5 in. globes, terrestrial and celestial, the pair,	$ 2.50.
5 in. terrestrial globe, - - - -	$ 1.25.
3 in. terrestrial globe, - - - -	$ 0.75.
5 in. terrestrial globe, with moon attached, -	$ 2.00.

Small Globes, with Brass Meridian and Horizon.—(Fig. 118, as above.)

5 in. terrestrial globe, - - - -	$ 1.50.
3 in. terrestrial globe, - - - -	$ 1.00.

Altitude or Globe Quadrant (Fig. 119, as above,) consists of a thin, flexible strip of brass, movable at one end, around a joint in the lower part of a square head, which is furnished with a tangent screw. Its use is, that when fastened on to the brazen meridian of an artificial globe, it shall indicate the relative position of places, and other purposes connected with that part of geography commonly called the use of the globes. The strip of brass is graduated from zero to 90°, and the size of the instrument must be accordant to the size of the globe with which it is to be used.

Price,	12 in. or 13 in.,	$1.25.
"	18 in., - -	$2.00.

The Armillary Sphere.—(Figs. 120 and 121, page 109.) —Of the instruments contrived to elucidate the elements of astronomy, none imprint so clearly on the mind the nature and use of those circles which astronomers have supposed to be applied to the concave sphere of the heavens, as the armillary sphere.

If the circumference of a circle be turned about its diameter as an axis, it will generate in its motion the surface of a globe or sphere.

And the centre of the circle will be the centre of the globe.

All straight lines reaching from the centre of a globe to its surface are equal.

Every straight line that goes through the centre of a sphere, and is terminated at both ends by the surface, is a diameter.

The diameter about which any sphere turns is its axis.

The extremities of such diameter or axis are its poles.

On the surface of a globe or sphere several circles may be described; those circles, whose centre is the same with the centre of the globe, are called by way of distinction great circles; these divide the sphere into two equal parts. The angular distance of two points situated on the surface of the sphere, is measured by the arc of a great circle intercepted between them.

Lesser circles divide the sphere into two unequal parts.

The sphere before you, by its real circles, serves to represent, and will enable me to explain to you those imaginary circles by which astronomers divide the heavens into the same parts or portions as you see these circles divide the sphere. If your eye could be placed in the centre of this sphere, you would see its circles upon or against those very points of the heavens where the imaginary circles of the astronomers are supposed to be situate. It is called armillary, because it consists of a number of rings of brass, called by the Latins armillæ, from their resembling bracelets or rings for the arms.

There are six great circles of the sphere: the horizon, the meridian, the equator, the ecliptic, the equinoctial colure, and the solstitial colure.

The sphere is sustained in a frame, on the top of which is a broad circle representing the horizon, which represents that imaginary circle which bounds or terminates the view of the spectator, dividing the sphere into two equal parts;

that which is above the horizon is called the upper or visible hemisphere; that which is below, the lower or invisible hemisphere. When the sun, moon, or stars, descend below this circle, we say they are set; on the contrary, when they appear above it, we say they have risen.

On the broad circle, representing the horizon, are marked the thirty-two points of the mariner's compass; the east, west, north, and south points, are principally to be regarded; these are called cardinal points.

On the inside of the horizon are two notches for receiving a strong brass circle representing the meridian.

It is suspended on two pins, at two opposite points of the meridian; these pins are a continuation of the axis of the sphere both ways, and as the sphere turns round upon them, they are considered as poles, and are called, one the north, the other the south pole.

The equator is that circle which goes round the sphere exactly in the middle between the two poles.

The ecliptic is that circle which crosses the equator obliquely; it is divided into twelve parts, each of which consists of thirty degrees.

The equinoctial colure is the great circle which passes through those two points of the equator that are intersected by the ecliptic.

The solstitial colure is the other great circle at right angles to the equator.

There are four lesser circles of the sphere, two tropics, and two polar circles; these four circles are all parallel to the equator.

The tropic of Cancer is the parallel which is on the north side of the equator, and 23½ degrees distant therefrom.

The tropic of Capricorn is situate on the south side of the equator, and also 23½ degrees distant therefrom.

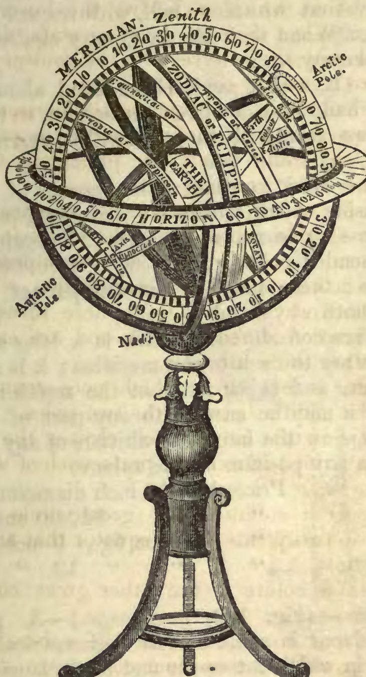
The two polar circles are at the same distance from the two poles that the tropics are from the equator, that is, twenty-three degrees and a half.

That towards the north pole is called the arctic circle, that towards the south pole, the antarctic circle.

The point in the heavens which is directly over the head of the spectator, is called the zenith. The point which is directly under his feet, is called the nadir.

To rectify the Sphere, elevate the pole till the same number of degrees is above the plane of the horizon, as the pole

Fig. 120.



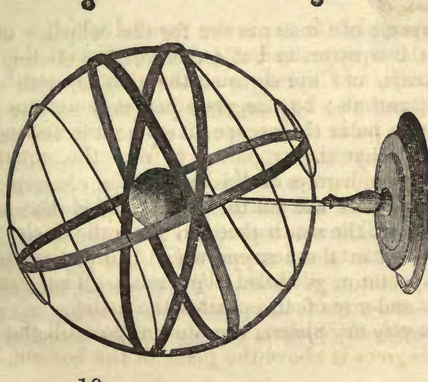


Fig. 121.

of the place you are considering is above the horizon, and then the circles on the sphere will, with respect to the globe within it, correspond with the imaginary circles of astronomers in the heavens.

The Hour Circle is a small circle fixed about the north pole, with a hand on the axis of the sphere, so that by turning the sphere on its axis the index will be carried round the circle.

This circle is used to convert the degrees of the equator into time ; it is divided into twenty-four equal parts, answering to twenty-four hours, or the time of an entire revolution of the heavens. The index, by pointing successively to those hours, shows in what space of time any part of that revolution is performed.

The Quadrant of Altitude.—This is a long slip of brass with a nut at top to fix it to the meridian ; it is divided into ninety degrees, and being fixed at the zenith it reaches to the horizon ; it may be carried to any part of the sphere, and thus will show the height or altitude of any point above the horizon in any position of the sphere.

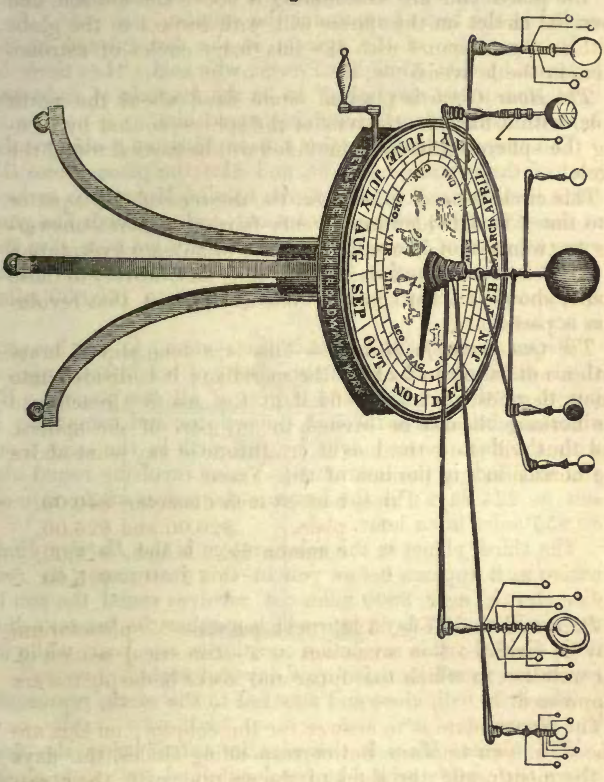
Price, best 13 inch diameter, $40.00.
" plain, $20.00 and $25.00.
" common fig., 9 inch, $ 4.00.
" " " 12 " $ 5.00.

Planetarium.—(Fig. 122, next page.)—A planetarium may be considered in some sort as a diametrical section of our universe, in which the upper and lower hemispheres are suppressed.

The upper plate is to answer for the ecliptic ; on this are placed, in two opposite but corresponding circles, the days of the month, and the signs of the ecliptic, with their respective characters ; by this plate you may set the planetary balls so as to be in their respective places in the ecliptic, for any day in the year.

Through the centre of this plate, you observe a strong stem, on which is a brass ball to represent the sun ; round the stem are different sockets to carry the arms, by which the several planets are supported. The planets are represented by white or gilt balls. We can with ease either take off, or put on, any of the planets, as occasion may require. About the primary planets are placed the secondary planets

Fig. 122.



or moons, which are in these instruments only movable by the hand.

We turn the handle, and all the planets are put in motion, moving round that ball which represents the sun. Now, if you take the earth's motion as a standard, they move with nearly the same relative velocities and periodical times that they observe in the heavens. We scarcely need observe, that it is impossible to give an idea of the proportion and distances of the planets in the compass of an instrument so small as that before you, or indeed of any instrument whatsoever.

The motions are carried on by a train of wheel-work concealed in the brass box, under the ecliptic.

In the centre of the system is the sun, placed in the heavens by that Almighty Power, who said, "Let there be light, and there was light," to be the fountain of light and heat to all the planets revolving round him.

The nearest planet to the sun is *Mercury;* observe the part of the ecliptic he is at, and also the place where the earth is situate. I now turn the handle, Mercury is arrived at the place from whence he set out, and our earth has gone over 88 days of the ecliptic; the velocity we here give the planet is inconsiderable, but in his course in the heavens he is supposed to move with a velocity equal to 100,000 miles in an hour.

Venus is the next planet in the system; in the heavens she is distinguished by the superiority of her lustre, appearing to us the brightest and largest of all the planets. By observing her course through the ecliptic, and comparing it with the days passed over by the earth in the same time, you will find, in the instrument, Venus revolving round the sun in 225 days; in the heavens she moves at the rate of 80,955 miles in an hour.

The third planet in the solar system is the *Earth;* diminutive as it appears before you in this instrument, its real diameter is near 8000 miles; it revolves round the sun in the space of 365 days, into which number the brazen ecliptic is divided; this revolution constitutes our year, while its revolution round its axis forms day and night.

The little ball, close and annexed to the earth, represents the *Moon.*

The planet *Mars* is the next in order, being the first above the earth's orbit; he revolves round the sun in about 686 days; so that our earth, as you will observe by the instrument, goes nearly twice round, while he is performing his revolution; he is supposed to move at the rate of 55,783 miles in an hour. To this planet our earth and moon will appear like two moons, sometimes half or three quarters illuminated, but never full.

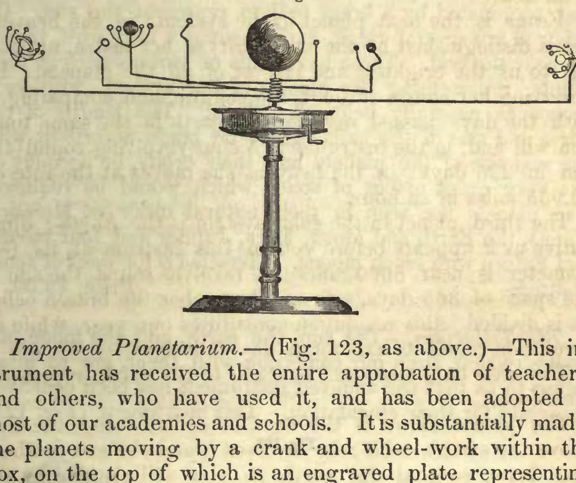
Jupiter, the largest of all the planets, is next beyond Mars; and our earth must have gone nearly twelve times round the ecliptic for one revolution of Jupiter; yet so far is its path removed from the sun, that to go round it in this space of time, it moves at the rate of 30,193 miles an hour. It is attended by four satellites, represented by four balls; they are invisible to the naked eye, but appear beautiful through a telescope.

Saturn, the next planet, is still higher in the system, performing its circuit in about thirty years of our time; it moves at the rate of 22,298 miles an hour; it is accompanied by seven satellites, and a large luminous ring.

Georgium Sidus, or Herschel, is the seventh planet in our system; it is nearly twice the distance of Saturn from the sun, round which it revolves in about 90 years; its diameter is 34,170 miles, and it is accompanied by six satellites.

Price, $50.

Fig. 123.

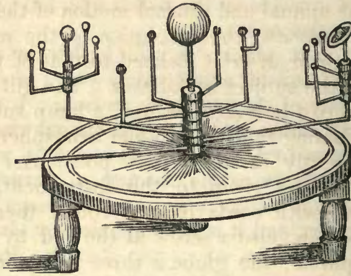


Improved Planetarium.—(Fig. 123, as above.)—This instrument has received the entire approbation of teachers, and others, who have used it, and has been adopted in most of our academies and schools. It is substantially made, the planets moving by a crank and wheel-work within the box, on the top of which is an engraved plate representing the signs of the zodiac, &c., and the whole as useful an instrument as the more costly one preceding.

Price, with brass stand, $15.00.
" with mahogany stand, $ 7.50.

The Common Orrery.—(Fig. 124.)—The following shows one of these instruments of a simple form:—It consists of a table, upon the top of which are delineated the signs of the zodiac, points of the compass, days of the month, and months of the year. In the centre is a strong wire or brass

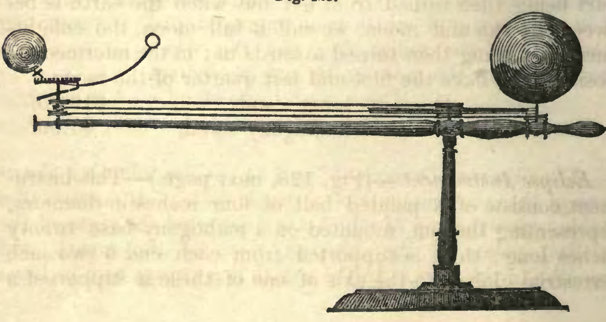
Fig. 124.



rod, terminated by a brass ball to represent the sun. On this rod are several rings, each bearing a long wire, turned up near the end. These have balls of various sizes at their points, representing the planets of our system, with such moons as naturally belong to them. The length of the wires and size of the balls cannot be made accordant with the real size of the planets and their orbits, on account of the very great extent of space which would be required. The planets are seen in their natural order of Mercury, Venus, the Earth and moon, Mars, Jupiter and four moons, and Saturn with seven moons. Herschel is for want of space omitted. Price, $5.00.

The Tellurium.—The sun, the earth, and the moon, are bodies, which, from our connexion with them, are so interesting to us that the annexed instrument has been contrived expressly for their elucidation. This instrument (Fig. 125)

Fig. 125.

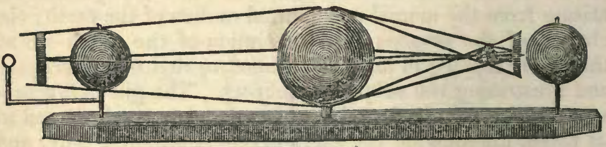


shows in an accurate and clear manner the phenomena arising from the annual and diurnal motion of the earth; the change of the seasons; the revolution of the moon round the earth, moving in an orbit inclined to that of the ecliptic, and illustrating the subject of eclipses. The gilt ball representing the sun can be taken off, and a lamp substituted in its place, illuminating the earth in one hemisphere only, and the moon differently in its various positions. There are four distinct motions given to this instrument, three by means of wheels with cords passing round them, and one with toothed wheels, also a screw at the end to tighten the cords when required; the globe is three inches in diameter, and all the continents, seas, etc., may be distinctly seen; the equator, the ecliptic, tropics, and other circles, are very visible, so that problems, relative to particular places, may be satisfactorily solved; the axis of the earth is inclined to the ecliptic in an angle of 66½ degrees, and preserves its parallelism during the whole of its revolution; when the north pole is turned directly towards the sun, the globe is in the position of the earth for the longest day in our northern hemisphere, or the 21st of June; turn the handle of the instrument till the earth and moon have revolved half round the sun, and the north pole is directed from the sun, and we have the shortest day, or the 21st of December; there are two intermediate positions in the revolution of the globe, answering to the positions on the 21st March and the 21st of September, when the two poles are equally exposed to the sun, and when the days and nights are of a length all over the earth. The phases of the moon are clearly exhibited by this instrument. When the moon is between the earth and the sun, we call it new moon, the enlightened part being then turned from us; but when the earth is between the sun and moon, we call it full moon, the enlightened part being then turned towards us; in the intermediate positions we have the first and last quarter of the moon.

Price, on brass stand, $13.50.
" on mahogany stand, $7.00.

Eclipse Instrument.—(Fig. 126, next page.)—This instrument consists of a painted ball of four inches in diameter, representing the sun, mounted on a mahogany base twenty inches long; there is supported from each end a two inch terrestrial globe; to the axis of one of these is supported a

Fig. 126.



ball, representing the moon, which is movable nearly around the globe; brass wires proceed from the sun, representing the rays of the sun's light falling on the side of the earth turned towards the sun. From this end of the instrument various eclipses may be shown. From the other side of the sun there is a ball representing the moon, by which the earth is eclipsed, and wires representing rays from the sun, for explaining the shadows called penumbra and umbra, and is a valuable instrument in explaining both solar and lunar eclipses. Price, $5.00.

The Tide Dial.—(Fig. 127, next page.)—This instrument consists of a circular piece of wood, on which there is represented a dial having the twenty-four hours of the day; connected at the centre, to an axis, is a movable disk representing the ocean, and bearing an arm having a ball attached to the end, representing the moon; the water appearing at high tide in that direction; the outer disk representing the earth. On the back of the dial is a crank, giving motion to the wheel-work, and causing the earth and moon to revolve; the earth revolving twenty-nine times faster than the moon.

The tides are occasioned by the ebbing and flowing of the sea, which are caused by the attraction of the sun and moon, but chiefly by the latter.

The attraction causes the water to assume a spheroidal figure, the longest axis being in the direction of the moon.

This oval of the waters keeps pace with the moon in its monthly course round the earth; while the earth, by its daily rotation on its axis, presents each part of its surface to the direct action of the moon, twice every day, and thus produces two flood and two ebb tides. But because the moon is in the mean time passing from east to west in its orbit, it comes to the meridian of any place later than it did the preceding day; consequently the two floods and ebbs require nearly twenty-five hours to complete them.

The tides are greatest at the new and full moons, and are

Fig. 127.

thence called spring tides, and least at the first and last quadratures, and are thence called neap tides, and the highest tides are near the time of the equinoxes. Price, $4.00.

Centrifugal Hoops for showing the Earth an Oblate Spheroid.—(Fig. 128, next page.)—An astronomical instrument, to show that the earth, if revolving at all, must revolve upon its shortest axis, and that owing to centrifugal force.

Fig. 128.

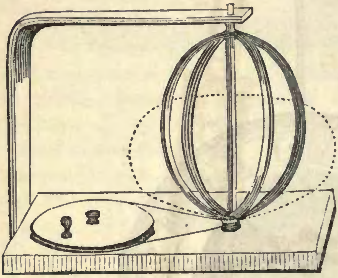
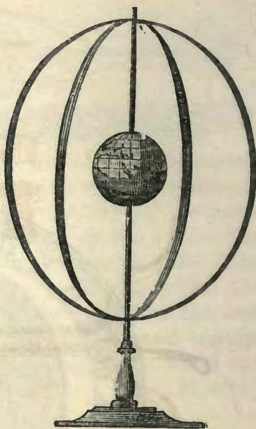


Fig. 129.



The structure of the instrument is very simple: it consists of two or more hoops of thin tin, or brass. These are fastened below to a spindle, so that they must turn with it, but move easily up and down that spindle when put in motion. The spindle has a pulley below, and is supported at top by a cross arm. The pulley is turned by a string passing over a multiplying wheel. Upon turning this wheel, the hoops being put in motion will endeavor to fly out by centrifugal force, and assume the shape represented by the dotted line; that is, will become an oblate spheroid, or a globular body flattened towards either pole.

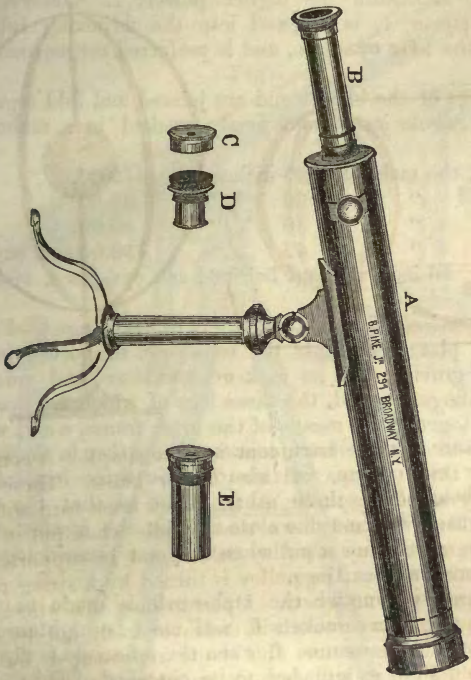
Price, $4.50.

Fig. 129, as above, represents a cheaper construction of this instrument, having a three inch globe in the centre. The motion is given by turning it rapidly with the finger.

Price, $2.50.

Astronomic Telescope on Brass Stand.—No invention in the mechanic arts has ever proved more useful and entertaining than the production of the telescope; its utility, both by sea and land, is well known; in respect to the heavenly bodies, much of our knowledge is due to the invention of the telescope.

Fig. 130.



The Astronomical Telescope (Fig. 130, as above) consists of an object and eye-glass fitted into a long brass tube. The object-glass is placed at the end of the tube nearest the object. The eye-glass is that which is nearest the eye; and when there are more lenses than one in the tube, besides the object-glass, they are called eye-glasses also. The tube is mounted on a brass stand having a joint and swivel at the top, by which the telescope may be directed to any position in the heavens.

The short tube, C, adjusts in or out the body of the telescope, by a rack and pinion, worked at A; to the end of which, the eye-tube, B, and the various powers are applied.

The eye-tube, B, contains four glasses. To increase the power, unscrew the eye-head of this tube, *b*, and take out the sliding pipe, which contains the two first glasses, and in its place substitute the higher power, 2. Observe, the highest power, 1, is screwed into the adjusting tube, C, without the long eye-tube, and is preferred for astronomical uses.

The legs of the brass stand are jointed and fold together, and the whole instrument neatly packed in a mahogany case.

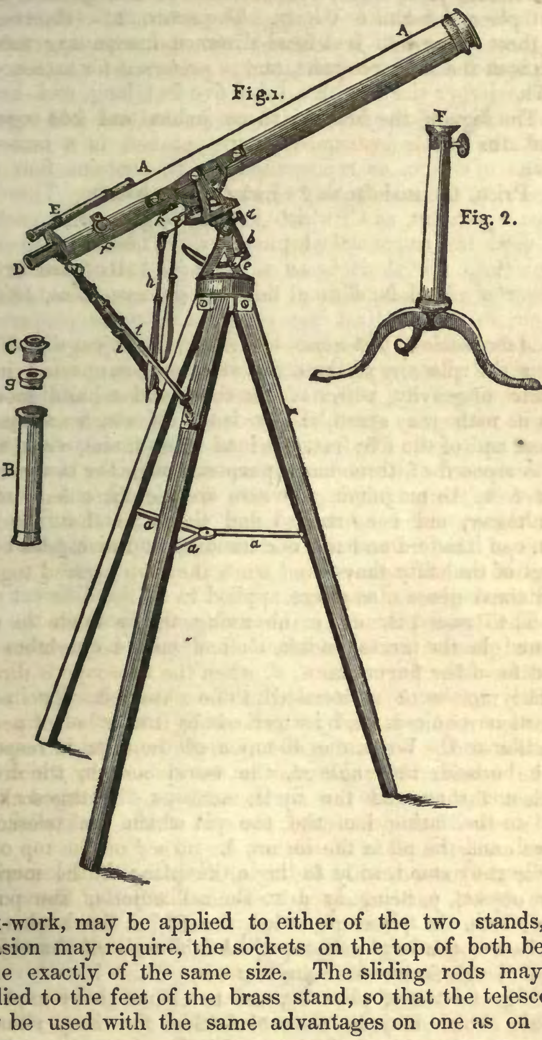
Price,	the main	tube	20	inches long,	$42.00.
"	"	"	30	"	60.00.
"	"	"	36	"	90.00.
"	"	"	42	"	150.00 and $200.
"	30 inch, without box and ast. eye-piece,				48.00.

Astronomical Telescope.—(Fig. 131, next page.)—Figure 1 in the plate represents the telescope, supported in the centre of gravity, with its rack-work motions, and mounted on its mahogany stand, the three legs of which are made fo close up together by means of the brass frame, *a a a*, which is composed of three bars, connected together in the centre piece by three joints, and also to the three legs of the mahogany stand by three other joints, so that the three bars of this frame may lie close against the insides of the legs of the mahogany stand when they are pressed together for convenience of carriage.

The brass pin, under the rack-work, is made to move round in the brass socket, *b*, and may be tightened by means of the finger-screw, *d*, when the telescope is directed nearly to the object intended to be observed. This socket turns on two centres, by which means it may be set perpendicular to the horizon, or to any angle required in respect to the horizon; the angle may be ascertained by the divided arc, and then made fast by the screw, *e*. If this socket be set to the latitude of the place at which the telescope is used, and the plane of this arc be turned on the top of the mahogany stand, so as to be in the plane of the meridian, the socket, *b*, being fixed to the inclination of the pole of the earth, the telescope, when turned in this socket, will have an equatorial motion, which is always very convenient in making astronomical observations.

Figure 2 in the plate represents a stand to be used on a table, which may be more convenient for many situations than the large mahogany stand. The telescope, with its

Fig. 131.



rack-work, may be applied to either of the two stands, as occasion may require, the sockets on the top of both being made exactly of the same size. The sliding rods may be applied to the feet of the brass stand, so that the telescope may be used with the same advantages on one as on the other.

The tube *A A* may be made either of brass or mahogany of three and a half feet long. The achromatic object-glass of three and a half feet focal distance has an aperture of two inches and three quarters.

The larger size is with a tube five feet long, and has an achromatic object-glass of three inches and one quarter aperture.

The eye-tube, as represented by B, contains four eye-glasses, to be used for day or any land objects. There are three eye-tubes, as C, which have two glasses in each, to be used for astronomical purposes. These eye-tubes all screw into the short brass tube at D. By turning the button or milled head at *f*, this tube is moved out of the larger, so as to adjust the eye-glasses to the proper distance from the object-glass, to render the object distinct to any sight with any of the different eye-tubes.

The magnifying power of the three and a half feet telescope with the eye-tube for land objects, is forty-five times, and of the five feet, for land objects, sixty-five times. With those for astronomical purposes, with the three and a half feet, the magnifying powers are eighty, one hundred and thirty, and one hundred and eighty; and for the five feet, one hundred and ten, one hundred and ninety, and two hundred and fifty times.

Stained glasses, as *g*, are applied to all the different eye-tubes, to guard the eye in observing the spots on the sun. These glasses are to be taken off when the eye-tubes are used for other purposes.

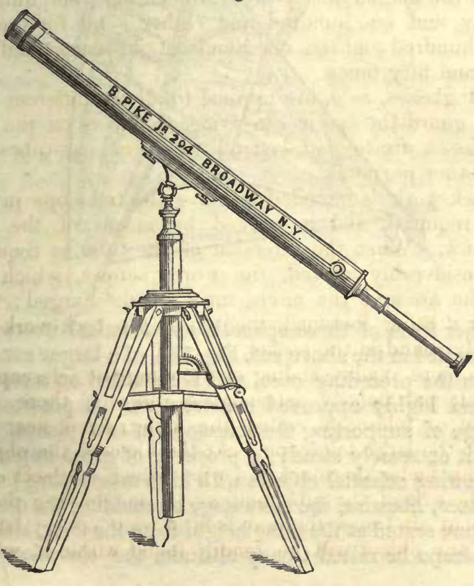
The rack-work is intended to move the telescope in any direction required, and is worked by means of the two handles at *h*. When the direction of the tube is required to be considerably altered, the worm screws, which act against the arc and the circle, must be discharged; then the screw *d* being loosened, the pin of the rack-work will move easily round in the socket, *b*.

For the more readily finding or directing the telescope to any object, particularly astronomical objects, there is a small tube or telescope, called the finder, fixed near the eye-end of the large telescope. At the focus of the object-glass of this finder there are two wires which intersect each other in the axis of the tube, and as the magnifying power is only about six times, the real field of view is very large; therefore any object will be readily found within it, which being brought to the intersection of the wires, it will then be within the field of the telescope.

In viewing astronomical objects (and particularly when the greatest magnifying powers are applied) it is very necessary to render the telescope as steady as possible; for that purpose there are two sets of brass sliding rods, *i i*, as represented in the plate. These rods connect the eye-end of the telescope with two of the legs of the stand, by which any vibrations of the tube, that might be occasioned by the motion of the air or otherwise, will be prevented, and the telescope rendered sufficiently steady for using the greatest powers. These sliding rods move within one another with so much ease as to admit of the rack-work being used in the same manner as if they were not applied.

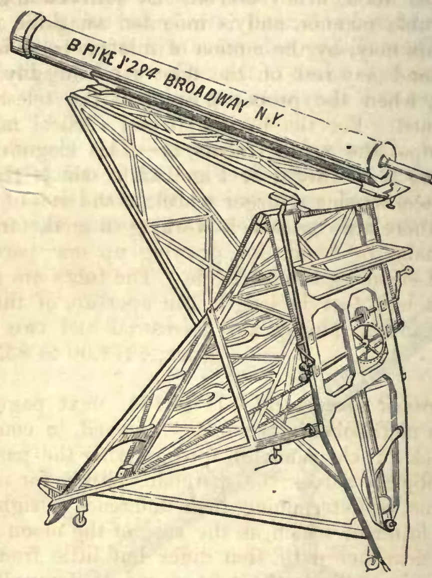
Improved Astronomical Telescopes.—This elegant instrument, represented below, in Fig. 132, is one of the latest and most approved construction; the stand is of polished mahogany, the legs jointed and supporting the telescope

Fig. 132.



conveniently and steadily, having a brass pillar movable by a tooth and wheel adjustment—by which it may be set at any height required—with vertical brass joint and horizontal motion, and rack and pinion motion to the tubes; the length of the tube is five feet, the aperture is three inches, having terrestrial and celestial eye-pieces. The construction of the various parts may be understood by reference to the one previously described. Price, $150.00.

Fig. 133.



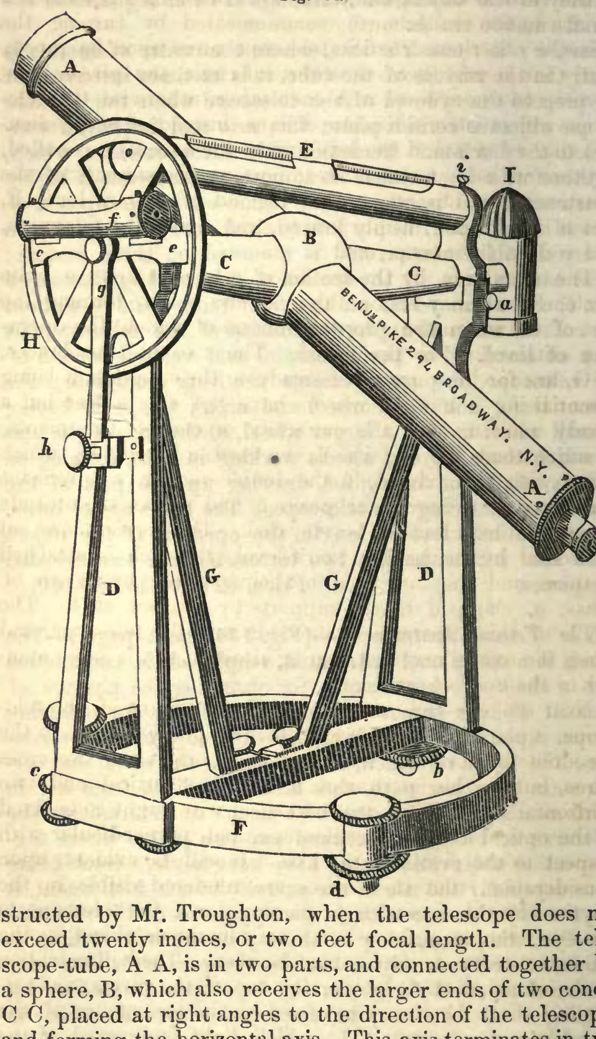
Another form of these splendid astronomical instruments is represented in the above cut, Fig. 133, of a larger construction than the preceding ones, and is mounted on a stand of a new and highly approved construction. It possesses the advantage of supporting the telescope in two places, which renders it extremely steady, a property of great importance when viewing celestial objects with high magnifying powers. It possesses, likewise, the advantage of enabling the observer to continue seated at the same height from the floor, although the telescope be raised to any altitude, the elevation being entirely at the object end, although it be changed from the horizon to the zenith.

In the other constructions, where the centre of motion is nearly in the middle of the tube, it is at times inconvenient to stoop to the eye-end of the telescope when the altitude of the object is considerable; this new and improved construction of a stand remedies this inconvenience, which, together with its unusual steadiness, recommends it highly to astronomical observers. The frame-work is composed of bars of hard wood, firmly braced, and screwed together in a very durable manner, and is mounted on three castors; these castors may, by the motion of a lever, be so arranged that the stand may rest on the floor more steadily without the rollers, when the proper position of the telescope has been obtained. For the horizontal and vertical motion of the telescope, the arrangements are very complete; the former being a toothed wheel and arch; the latter having a small wheel moving a larger wheel, at the ends of the axis of which there are cog wheels working in links, forming an endless chain, or band, for drawing up one part of the frame, and elevating the telescope. The tubes are of brass, five and a half feet in length, the aperture of the object glass four inches, having two terrestrial and two celestial eye-pieces. Price, $275.00 to $350.00.

The Transit Instrument.—(Fig. 134, next page.)—The transit is a meridional instrument, employed, in conjunction with a clock or chronometer, for observing the passage of celestial objects across the meridian, either for obtaining correct time, or determining their difference of right ascension; the latter of which, in the case of the moon and certain stars near her path, that differ but little from her in right ascension, affords the best means of determining the difference of longitude between any two places where corresponding observations may have been made. Such being more especially the use of the *portable* transit instrument, it forms a valuable accession to the apparatus of the scientific traveller, who, remaining a short time at any station, is enabled thereby to adjust his time-keepers both with ease and accuracy, and to obtain the best data for finding his longitude. It also may be employed very successfully in determining the latitude.

The following figure represents this instrument as con-

Fig. 134.



structed by Mr. Troughton, when the telescope does not exceed twenty inches, or two feet focal length. The telescope-tube, A A, is in two parts, and connected together by a sphere, B, which also receives the larger ends of two cones, C C, placed at right angles to the direction of the telescope, and forming the horizontal axis. This axis terminates in two cylindrical pivots, which rest in Y's fixed at the upper end of the vertical standards, D D. One of the Y's possesses a small motion in azimuth, communicated by turning the screw, *a*; in these Y's the telescope turns upon its pivots. But, that it may move in a vertical circle, the pivots must be precisely on a level with each other, otherwise the telescope will revolve in a plane oblique (instead of perpendicular) to the horizon. The levelling of the axis, as it is called, is therefore one of the most important adjustments of the instrument, and is effected by the aid of a spirit-level, E, which is made for this purpose to stride across the telescope, and rest on the two pivots.

The standards, D D, are fixed by screws upon a brass circle, F, which rests on three screws, *b c d*, forming the feet of the instrument, by the motion of which the operation of levelling is performed. The two oblique braces, G G, are for the purpose of steadying the supports, it being essential for the telescope to have not only a free but a steady motion. On the extremity of one of the pivots, which extends beyond its Y, is fixed a circle, H, which turns with the axis while the double vernier, *e e*, remains stationary in a horizontal position, and shows the altitude to which the telescope is elevated. The verniers are set horizontal by means of a spirit-level, *f*, which is attached to them, and they are fixed in their position by an arm of brass, *g*, clamped to the supports by a screw at *h*. The whole of this apparatus is movable with the telescope, and when the axis is reversed, can be attached in the same manner to the opposite standard.

Near the eye-end, and in the principal focus of the telescope, is placed the diaphragm, or wire-plate, which, in the theodolite or levelling telescope, need only carry two cross wires, but in this instrument it has five vertical and two horizontal wires. The centre vertical wire ought to be fixed in the optical axis of the telescope, and perpendicular with respect to the pivots of the axis. It will be evident, upon consideration, that these wires are rendered visible in the daytime by the rays of light passing down the telescope to the eye; but at night, when a very luminous object, as the moon, is observed, they cannot be seen. Their illumination is therefore effected by piercing one of the pivots, and admitting the light of a lamp fixed on the top of one of the standards, as shown at I; which light is directed to the wires by a reflector placed diagonally in the sphere B; the reflector having a large hole in its centre, does not interfere with the rays passing down the telescope from the object, and thus the observer sees distinctly both the wires and the object at the same time ; when, however, the object is very faint (as a small star), the light from the lamp would overpower its feeble rays. To remedy this inconvenience, the lamp is so constructed, that by turning a screw at its back, or inclining the opening of the lantern, more or less light may be admitted to the telescope, to suit the circumstances of the case.

The telescope is furnished with a diagonal eye-piece, by which stars near the zenith may be observed without inconvenience.

Of the adjustments.—Upon setting the instrument up, it should be so placed that the telescope, when turned down to the horizon, should point north and south as near as can possibly be ascertained. This of course can be but approximate, as the correct determination of the meridian can only be obtained by observation, after the other adjustments are completed.

The first adjustment is that of the line of collimation. Direct the telescope to some small distant well-defined object (the more distant the better), and bisect it with the middle of the central vertical wire ; then lift the telescope very carefully out of its angular bearings, or Y's, and replace it with the axis reversed ; point the telescope again to the same object, and if it be still bisected, the collimation adjustment is correct ; if not, move the wires one half the error, by turning the small screws which hold the diaphragm near the eye-end of the telescope, and the adjustment will be accomplished ; but as half the deviation may not be correctly estimated in moving the wires, it becomes necessary to verify the adjustment by moving the telescope the other half, which is done by turning the screw *a;* this gives the small azimuthal motion to the Y before spoken of, and consequently to the pivot of the axis which it carries. Having thus again bisected the object, reverse the axis as before, and if half the error was correctly estimated, the object will be bisected upon the telescope being directed to it ; if not quite correct, the operation of reversing and correcting half the error, in the same manner, must be gone through again, until, by successive approximations, the object is found to be bisected in both positions of the axis ; the adjustment will then be perfect. The collimation adjustment may likewise be examined from time to time, by observing the transit of Polaris, or any other close circumpolar star, over the first three wires, which gives the intervals in time from the first to the second, and from the first to the third wire; and then reversing the axis, observe the same intervals in a reverse order, as the wires which were the three first, in the former position, will now be the three last: if the intervals in the first observations are exactly the same as the intervals in the second, the collimation adjustment is correct; but should the corresponding intervals differ, such difference points out the existence of an error, which must be removed as before described, one half by the collimating screws, and the other half by the azimuthal motion of the instrument.

It is desirable that the central, or middle wire (as it is usually termed), should be truly vertical; as we should then have the power of observing the transit of a star on any part of it, as well as the centre. It may be ascertained whether it is so, by elevating and depressing the telescope: when directed to a distant object, if it is bisected by every part of the wire, the wire is vertical; if otherwise, it should be adjusted by turning the inner tube carrying the wire-plate, until the above test of its verticality be obtained, or else care must be taken that the observations are made near the centre only; the other vertical wires are placed by the maker equidistant from each other and parallel to the middle one—therefore, when the middle one is adjusted, the others are so too; he also places the two transverse wires at right angles to the vertical middle wire. These adjustments are always performed by the maker, and but little liable to derangement. When, however, they happen to get out of order, and the observer wishes to correct them, it is done by loosening the screws which hold the eye-end of the telescope in its place, and turning the end round a small quantity by the hand until the error is removed. But this operation requires very delicate handling, as it is liable to remove the wires from the focus of the object-glass.

The axis on which the telescope turns must next be set horizontal. To do this, apply the level to the pivots, bring the air-bubble to the centre of the glass tube, by turning the foot-screw, *b*, which raises or lowers that end of the axis, and consequently the level resting upon it; then reverse the level by turning it end for end, and if the air-bubble still remains central, the axis will be horizontal, but if not, half the deviation must be corrected by the foot-screw, *b*, and the other half by turning the small screw, *i*, at one end of the level, which raises or lowers the glass-tube (containing the air-bubble) with respect to its supports, which rest upon the pivots. This, like most other adjustments, frequently requires several repetitions before it is accomplished, on account of the difficulty of estimating exactly half the error.

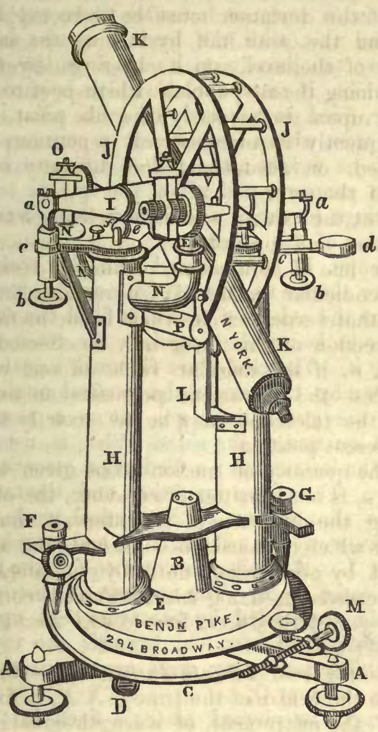
Having set the axis on which the telescope turns, parallel to the horizon, and proved the correct position of the central wire or line of collimation, making it describe a great circle perpendicular to that axis, it remains finally to make it move in that vertical circle which is the meridian.

The correction of this error may be effected by turning the screw, *a*, if the angular value of one revolution be known, unless the instrument possesses an azimuth circle, by which the telescope may be set exactly that quantity from its present position.

But if the quantity of motion to be given to the adjusting-screw, *a*, is not a matter of certainty, the observer, after ascertaining the difference of the intervals, must make the adjustment which he considers sufficient, and again proceed to verify it by observation, until, by continued approximation, he succeeds in fixing his instrument correctly in the meridian. Price, according to size, &c., $150 to $300.

The Altitude and Azimuth Instrument.—(Fig. 135, next page.)—To the centre of the tripod, A A, is fixed the vertical axis of the instrument, of a length equal to about the radius of the circle; it is concealed from view by the exterior cone, B. On the lower part of the axis, and in close contact with the tripod, is centred the azimuth circle, C, which admits of a horizontal circular motion of about three degrees, for the purpose of bringing its zero exactly in the meridian; this is effected by a slow-moving screw, the milled head of which is shown at D. This motion should, however, be omitted in instruments destined for exact work, as the bringing the zero into the meridian is not requisite, either in astronomy or surveying; it is in fact purchasing a convenience too dearly, by introducing a source of error not always trivial. Above the azimuth circle, and concentric with it, is placed a strong circular plate, E, which carries

Fig. 135.



the whole of the upper works, and also a pointer, to show the degree and nearest five minutes to be read off on the azimuth circle; the remaining minutes and seconds being obtained by means of the two reading microscopes, F and G; this plate, by means of the conical part, B, which is carefully fitted to the axis, rests on the axis, and moves concentrically with it. The conical pillars, H H, support the horizontal or transit axis, I, which being longer than the distance between the centre of the pillars, the projecting pieces, *c c*, fixed to their top, are required to carry out the Y's, *a a*, to the proper distance for the reception of the pivots of the axis; the Y's are capable of being raised or lowered in their sockets by means of the milled-headed screws, *b b*, for a purpose hereafter to be explained. The weight of the axis, with the load it carries, is prevented from pressing too heavily on its bearings, by two friction rollers on which it rests, one of which is shown at *e*. A spiral spring, fixed in the body of each pillar, presses the rollers upwards, with a force nearly a counterpoise to the superincumbent weight; the rollers on receiving the axis yield to the pressure, and allow the pivots to find their proper bearings in the Y's, relieving them, however, from a great portion of the weight.

The telescope, K, is connected with the horizontal axis, in a manner similar to that of the portable transit instrument. Upon the axis, as a centre, is fixed the double circle, J J, each circle being close against the telescope, and on each side of it. The circles are fastened together by small brass pillars; by this circle the vertical angles are measured, and the graduations are cut on a narrow ring of silver, inlaid on one of the sides, which is usually termed the *face* of the instrument; a distinction essential in making observations. The clamp for fixing, and the tangent-screw for giving a slow motion to the vertical circle, are placed beneath it, between the pillars, H H, and attached to them, as shown at L. A similar contrivance for the azimuth circle is represented at M. The reading microscopes for the vertical circle, are carried by two arms bent upwards near their extremities, and attached towards the top of one of the pillars. The projecting arms are shown at N, and the microscopes above at O.

A diaphragm, or pierced plate, is fixed in the principal focus of the telescope, on which are stretched five vertical and five horizontal wires: the intersection of the two centre ones, denoting the optical axis of the telescope, is the point with which the terrestrial object is bisected, when observing angles for geodesical purposes. The vertical wires are used for the same purpose as those in the transit telescope, and the horizontal ones for taking altitudes of celestial objects. A micrometer having a movable wire is sometimes attached to the eye-end of the telescope, but it is not generally applied to instruments of portable dimensions. The illumination of the wires at night is by a lamp, supported near the top of one of the pillars, as at *d*, and placed opposite the end of one of the pivots of the axis, which, being perforated, admits the rays of light to the centre of the telescope-tube, where, falling on a diagonal reflector, they are reflected to the eye, and illuminate the field of view; the whole of this contrivance is precisely similar to that described as belonging to the transit instrument.

The vertical circle is usually divided into four quadrants, each numbered, 1°, 2°, 3°, &c., up to 90°, and following one another in the same order of succession; consequently, in one position of the instrument, altitudes are read off, and with the face of the instrument reversed, zenith distances; and an observation is not to be considered complete till the object has been observed in both positions. The sum of the two readings will always be 90°, if there be no error in the adjustments, in the circle itself, or in the observations.

It is necessary that the microscopes, O O, and the centre of the circle, should occupy the line of its horizontal diameter; to effect which, the up-and-down motion (before spoken of) by means of the screws, *b b*, is given to the Y's, to raise or lower them, until this adjustment is accomplished. A spirit-level, P, is suspended from the arms which carry the microscopes: this shows when the vertical axis is set perpendicular to the horizon. A scale, usually showing seconds, is placed along the glass-tube of the level, which exhibits the amount, if any, of the inclination of the vertical axis. This should be noticed repeatedly whilst making a series of observations, to ascertain if any change has taken place in the position of the instrument after its adjustments have been completed. One of the points of suspension of the level is movable up or down, by means of the screw, *f*, for the purpose of adjusting the bubble. A striding level similar to the one employed for the transit instrument, and used for a like purpose, rests upon the pivots of the axis. It must be carefully passed between the radial bars of the vertical circle to set it up in its place, and must be removed as soon as the operation of levelling the horizontal axis is performed. The whole instrument stands upon three foot-screws, placed at the extremities of the three branches which form the tripod, and brass cups are placed under the spherical ends of the foot-screws. A stone pedestal, set perfectly steady, is the best support for this as well as the portable transit instrument.

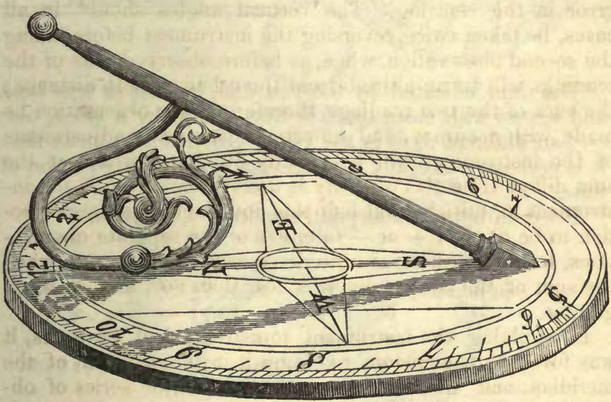
Use of the Altitude and Azimuth Instrument.—This is the most generally useful of all instruments for measuring angles, being applicable to geodesical as well as astronomical purposes. In the hands of the surveyor, it becomes a theodolite of rather large dimensions, measuring with great accuracy both vertical and horizontal angles. It does not possess the power of repetition; but the effect of any error of division on the azimuthal circle, may be reduced or destroyed, by measuring the same angle upon different parts of the arc; thus, after each observation, turn the whole instrument a small quantity on its stand, and adjusting it, again measure the required angle. A fresh set of divisions is thus brought into use at every observation, and the same operation being repeated many times, where great accuracy is required, the mean result may be considered as free from any error that may exist in the graduation. A repeating stand has, of late years, been frequently added to this instrument, and is a most powerful and convenient appendage, when great accuracy is required in the measurement of azimuthal angles. The two opposite micrometers being read off at each observation, will always remove the effect of any error in the centring. The vertical angles should in all cases, be taken twice, reversing the instrument before taking the second observation, when, as before observed, one of the readings will be an altitude, and the other a zenith distance; the sum of the two readings, therefore, if the observation be made with accuracy, and no error exists in the adjustments of the instrument, will be exactly 90°; and whatever the sum differs from this quantity is double the error of the instrument in altitude, and half this double error is the correction to be applied + or — to either of the separate observations, to obtain the true altitude or zenith distance, + when the sum of the two readings is less than 90°, and — when greater.

In applying the instrument to astronomical purposes, it was formerly the custom to clamp it in the direction of the meridian, and after taking an observation, or series of observations, with the face of the instrument one way, to wait till the next night, or till opportunity permitted, and then take a corresponding series of observations of the same objects, with the face of the instrument in a reversed position. But this method being attended both with uncertainty and inconvenience, it is now usual to complete at once the set of observations, by taking the altitudes in both positions of the instrument as soon as possible after each other.

When the meridian altitude is required, several observations may be taken, a short time both before and after the meridianal passage, with the face of the instrument in one direction, and with it reversed, noting the time at each observation; and if we have the exact time of the object's transit, its hour angle in time, or its distance from the meridian at the moment of each observation, may be deduced. This, with the latitude of the place (approximately known) and the declination of the object, affords data for computing a quantity called the reduction to the meridian, which added to the mean of the observed altitudes, when the object is above the pole, and subtracted when the object is below the pole, will give the meridional altitude of the object, and vice versa, for zenith distances. The nearer the observations are taken to the meridian, the less will the results depend upon an accurate noting or knowledge of the time.

Price, $500 and upwards.

Fig. 136.

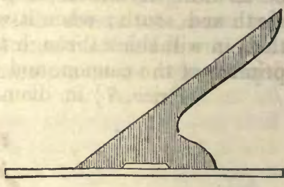


The Sun Dial (Fig. 136, as above) is an instrument for showing the hour of the day by means of the sun's shadow. In constructing this instrument, the object is to find, by means of his shadow, the sun's distance at any time from the meridian; when this distance is known, the hour is also known. Sun dials are usually constructed on a plane surface of brass or other material, placed parallel to the horizon, having a style, or gnomon, which is usually the edge of a plate of metal, or a cylindrical rod, fixed at an angle equal to the latitude of the place where the dial is to be used.

The face of the dial is divided into hours, from 5 to 12 on one side of the gnomon, and from 12 to 7 on the other; there are intermediate divisions for half, quarter hours, and minutes; also, the principal points of the compass are drawn on it. Fig. 137 represents the face of the dial, and Fig. 138 the gnomon and side view.

Fig. 137.

Fig 138.

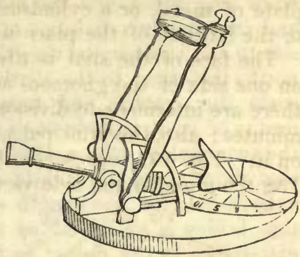


The time indicated by the sun dial, is solar or true time, and agrees with mean time, or that shown by a clock, only on four different days in the year. To find the mean time, it is necessary to apply a correction, called the equation of time.

Price,	in brass,	for any	lat.	required,	6	in.	diam.	$4.50.
"	"	"	"	"	7	"	"	$5.50.
"	"	"	"	"	8	"	"	$7.50.
"	in marble,	"	"	"	7½	"	"	$4.00.
"	"	"	"	"	11	"	"	$6.50.
"	"	"	"	"	13	"	"	$8.00.
"	"	"	"	"	18	"	"	$18.00.

The Sun Dial with Lens and Cannon.—(Fig. 139, next page.)—This instrument is so arranged, that, the heat of the sun falling through a lens, and being concentrated on the touch-hole of a loaded cannon, it will precisely at noon be fired. It consists of a slab of marble, having a sun dial of the usual construction on one portion, and on another part a brass cannon, at the sides of which there are two quadrants with movable arms, by which a lens of about two and a

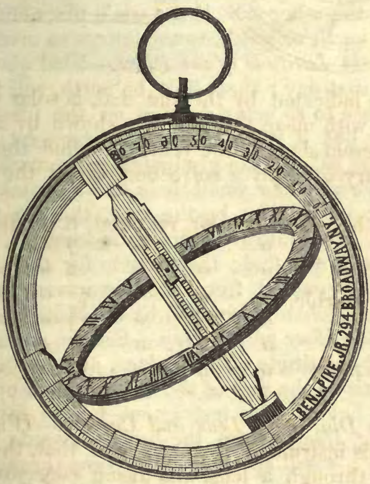
Fig. 139.



half to three inches in diameter set in brass mounting is supported; the focus of the lens corresponding to the distance of the touch-hole of the cannon. On one of the quadrants there is marked a scale, showing the altitude the lens is to be set for every day in the year, and corresponding to the declination of the sun. In setting the dial it should be as near horizontal as possible, and the 12 o'clock line north and south; when it will be found, that at 12 o'clock the sun will shine through the lens and fall exactly on the priming of the cannon, and the explosion take place.

Price, 7½ in. diam. $8.50; 9½ in. diam. $12.50.

Fig. 140.



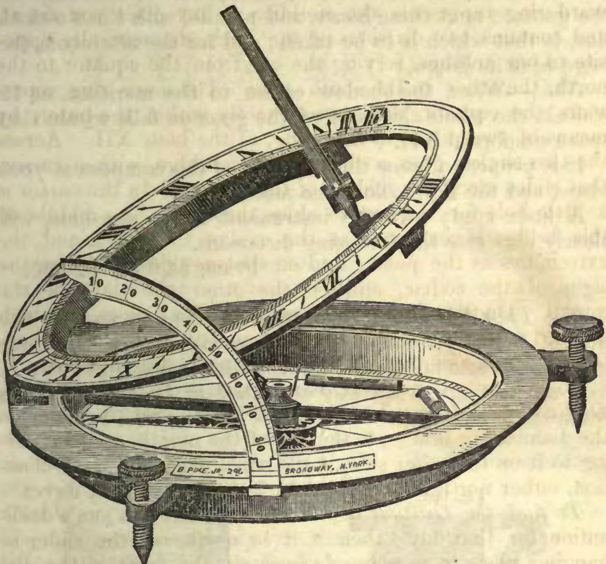
Universal Ring Dial.—The Universal or Astronomical Ring Dial (Fig. 140, as above,) is an instrument which serves to find the hour of the day in any part of the earth; it consists of two rings or flat circles, from 4 to 6 inches in diameter, and their breadth, &c., proportionable. The outward ring represents the meridian of any place you are at, and contains two divisions of 90° each, diametrically opposite to one another, serving the one from the equator to the north, the other to the south pole. The inner ring represents the equator, and turns exactly within the outer, by means of two pivots in each ring, at the hour XII. Across the two circles goes a thin reglet or bridge, with a cursor, that slides along the middle of the bridge. In the cursor is a little hole for the sun to shine through. The middle of this bridge is conceived as the axis of the world, and the extremities as the poles; and on the one side are drawn the signs of the zodiac, and on the other the days of the month. On the edge of the meridian slides a piece, to which is fitted a ring to suspend the instrument by. On the surface of the inner ring the hours and parts are engraved.

To use the Universal Ring Dial.—*To find the Sun's Declination and his place in the Ecliptic.*—Set the slider on the diameter or bridge, to the day of the month, and, answering to it on the other side, is the sun's place and his declination, either north or south, as the letters so marked direct.

To find the Latitude of the Place.—Find the sun's declination for that day; then, if it be north, set the slider or hanging piece to so many degrees on the front of the dial marked S; but if it be south declination, set the hanging piece on that side of the graduated circle marked N. Put a pin or wire in the small hole on the back side of the instrument; hold it up by the ring, the pin towards the sun, so that the shadow thereof falls amongst the divisions on the back of the dial; then watch for the greatest altitude; which, counted from the lowermost part of those degrees, the shadow so cut will be the latitude required.

To find the Hour of the Day.—Set the slider on the meridian to the latitude of the place, and the slider on the bridge or axis to the day of the month; then open the hour circle (now holding the instrument by the little ring, that it may hang freely), turn the bridge towards the sun, till you can see a small speck of light come through the slider of the bridge, and fall on the middle line of the hour circle; and that point in the middle line where the speck falls, shows the hour of the day at that place. The instrument hanging in this position, the meridian, equinoctial, poles, axis, &c., are all of them correspondent to those supposed in the heavens. Price, $6 to $20.

Fig. 141.



Universal Joint Dial and Compass.—(Fig. 141, as above.) —First set up the arc, which moves upon a joint, and contains 90° of latitude; then raise the plane of the dial that has the hours engraved upon it, to the number of degrees required for the latitude of your place.

Example.—For New York 40° 40′; suffer the compass needle to traverse freely upon its centre; then turn the compass till the north pole of the needle (which is denoted by a cross wire near the extremity) settles at the north point on the face of the compass, then level the whole by means of the three feet or adjusting screws, and the spirit levels contained within the compass.

The pole, or gnomon, must be raised perpendicular to the plane of the dial, from the 10th of March to the 11th of September, between which times your hour-shadow will fall on the plane of the dial; and from the 11th of September to the 10th of March, the pole or gnomon must be reversed, the shadow of which will then fall on the inside of the ring which contains the corresponding hours with those on the plane.

For the time in the forenoon, the shadow of that edge of the gnomon next those hours, and parallel with the 6 o'clock line, is that which is to be taken; and for the afternoon, the edge next its hours.

Note.—When the shadow comes to the meridian, or 12 o'clock, the whole thickness of the gnomon falls within that space numbered XII.

It is proper to know the variation of the compass at your place, and the right allowance made.

A little study with the instrument in the sunshine, will clearly illustrate the foregoing directions.

Price, $5.00 to $20.00.

The Time Glass.—An instrument serving to measure the flux of time, by the descent or running of sand from one glass vessel into another. Small ones running from two to five minutes are frequently mounted in bronzed metallic frames. (Fig. 142.) Price, 50c. and 63c.

Fig. 142.

Fig. 143.

Larger time glasses (Fig. 143, as above,) are mounted in frames of wood, either plain or highly polished, and may be had running quarter, half, one hour, or two hours. Hour glasses are used at sea for reckoning; also, in academies and schools where lessons are to be pursued for a given time.

Price, in plain frames, $\frac{1}{4}$ hour, 88c.; $\frac{1}{2}$ hour, $1.00; 1 hour, $1.25; 2 hours, $1.75.

" in polished rosewood frames, $\frac{1}{4}$ hour, $1.88; $\frac{1}{2}$ hour, $2.00; hour, $2.25; 2 hours, $3.

MOTION, MECHANICS,

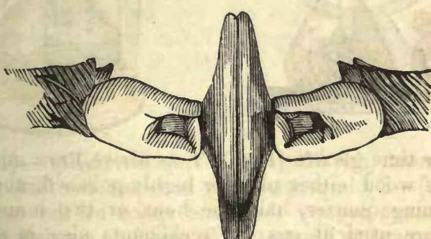
ETC.

Inertia Apparatus.—Inertia is that property of matter by which it resists any change of state, whether of rest or motion.

Fig. 144.

This interesting piece of apparatus (Fig. 144) consists of a common card and a brass ball of one inch or more in diameter, supported on a short pillar with a suitable base. To one side of the base there is fixed a steel spring, and a lever for drawing it back: on drawing the spring and suddenly relieving it, the card is struck and driven from under the ball off the pillar, while the ball rests on the pillar as firmly as though the card had not been knocked from under it. Price, $1.50.

Fig. 145.



Adhesion Plates.—These consist of two plates of glass (Fig. 145), with knobs for handles, the flat surfaces ground perfectly true. On pressing these together, they can be separated only by the exertion of considerable force, the power required being in proportion to the area of the plates. About $2\frac{1}{2}$ to 3 inches in diameter is the usual size.

Price, $1.50.

Bohnenberger's Machine.—This apparatus (See Fig. 146, below) consists of three movable rings, A B C, mounted on a stout base. The two inner rings are mounted on pivots; those on the smallest ring at right angles to the middle one; in the smallest ring is supported a metal ball, having a roller on one of its pivots; around the roller a string may be wound, and when pulled off a rapid rotary motion may be given to the ball. This motion may be given with its axis in any position required, and when communicated, the ring supporting the ball will resist considerable effort to alter its position, and whatever way the instrument may be turned, its axis will continue to maintain the position it had when set in motion, illustrating the inertia, or that property of matter which resists any change of state, whether of rest or motion. Price, $5.00.

Fig. 146.

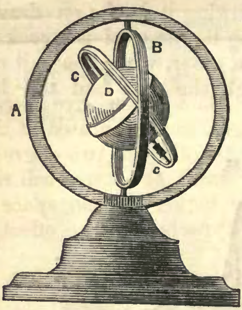
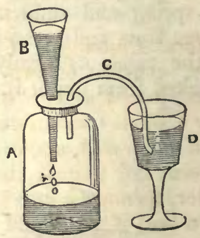


Fig. 147.



Instrument for illustrating Impenetrability.—(Fig. 147, as above.)—By impenetrability is meant the fact, that two bodies cannot occupy the same space at the same time. The instrument to illustrate this principle consists of a glass jar, A, to which is fitted, air-tight, a large cork, through which a funnel, B, with small neck, and bent glass tube, C, are inserted; one end of the latter is to be immersed in a vessel of water, D. If, now, water is poured into the funnel and enters the jar, it will be found that the same quantity of air will escape through the water, the water displacing the air, not penetrating it. Price, $1.00.

Tubes for Capillary Attraction.—(Fig. 148, as below.)—These consist of a number of small glass tubes of different sized bore, attached to a piece of wood, which may be placed in a glass vessel, allowing all the tubes to be immersed at one end. The liquid will rise to different heights in the several tubes, and highest in the tubes having the smallest bore. Price, $1.00.

Fig. 148.

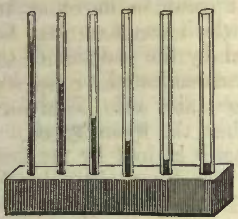
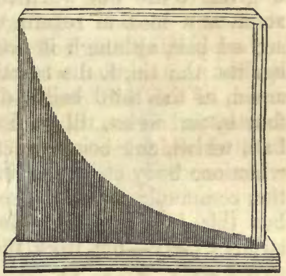


Fig. 149.

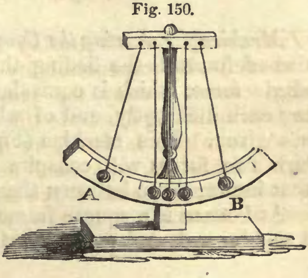


Glass Plates for Capillary Attraction.—Fig. 149, as above, consists of two plates of glass about five inches square, joined at two of their edges, and separated at the other a small space, forming an angle of about two degrees. When immersed about an inch in water, the water will rise between the plates, and will rise higher as the space is smaller, forming a curve called a hyperbole. The effect is shown best if the liquid is colored.

Price, $1.00 and $2.00.

Collision Balls for Action and Reaction.—(Fig. 150).—This apparatus consists of a number of ivory balls, suspended contiguous to each other by strings of equal length, sometimes mounted on a frame, having a graduated arch over which the balls may oscillate freely.

Fig. 150.



Let two ivory balls of equal weight be suspended by threads, as in the annexed figure; if the former be then drawn aside and suffered to fall against the latter, it will drive it to a distance equal to that through which the first ball fell; but it will itself rest, having given up all its own moving power to the second ball.

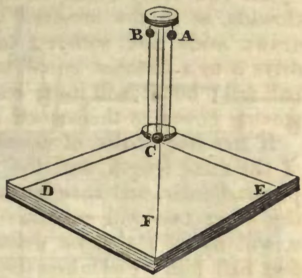
If five ivory balls, of equal weight, be hung by threads of the same length, and the ball A be drawn out from the perpendicular, and then let fall against the second, that and the other two will continue stationary; but the last ball, B, will fly off the same distance as that through which the first ball fell. For when the first ball strikes the second, it receives a blow in return, which destroys its motion. The second ball, although it does not appear to move, strikes against the third, the reaction of which sets it at rest: the action of the third ball is destroyed by the reaction of the fourth, and so on, till motion is communicated to the last ball, which, not being reacted upon, flies off. Therefore, when one body strikes against another, the quantity of motion communicated to the second body is lost by the first, but this loss proceeds—not from the blow given by the striking body—but from the reaction of the body which it struck.

Price, set of 5, ¾ inch ivory balls, -	$1.25.
" " 5, 1 " " " -	$2.00.
" " 5, 1¼ " " " -	$3.00.
" " 5, 1½ " " " -	$4.50.
" mounted on mahogany frame with graduated arch,	$7.00 to $12.00.
" set of 5, 1½ inch boxwood balls, on mahogany frame, with arch,	$3.50 to $7.00.
" set of 5, 1½ inch boxwood balls,	$1.00.

Machine for showing the Composition of Forces.—Composition of forces is the finding the quantity and direction of a single force, which is equivalent to two or more forces, acting each differently, and of which the quantity and direction are given. This machine (Fig. 151, next page) will prove how two forces will conspire to produce one motion, and that intermediate between them.

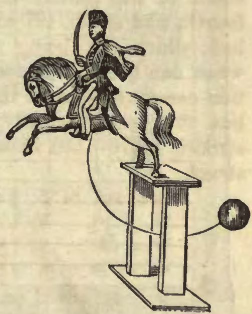
At bottom is a square frame or table; at one corner rises a slender rod, and on each side of it an upright wire, bearing a ball, which by a hole is made to slip easily up and down. In the centre beneath is a third ball, resting loosely on the table. If the ball A falls, it would strike the ball C, and drive it to D; if B falls, it would drive it to E, but if both A and B are suffered to fall at exactly the same time, the ball C would obey the impulse of both at once, and take an intermediate course; that is, be propelled across the board to E. Price, $5.00.

Fig. 151.



Rocking Horse.—(Fig. 152.)—This is an amusing figure, representing a horse and rider, and sometimes used to illustrate the effect of placing the centre of gravity very low. The figure is a light toy in the form of a horse, having a wire and heavy ball fastened to it, as represented in the cut. If the hind feet of the horse be placed on the table without the ball being attached, the centre of gravity will be beyond the table, and the horse will of course fall. But if the ball be attached the centre of gravity will be below, and the line of direction fall within the table; the horse will consequently be supported, and may be vibrated in an amusing manner. Price, 75cts.

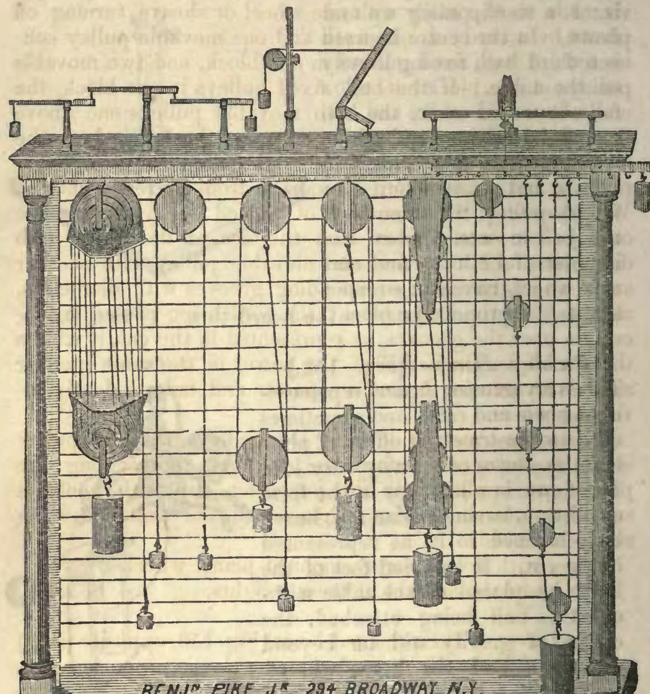
Fig. 152.



Also a variety of blocks, wheels, and figures, illustrating the centre of gravity. Price, 50cts. to $1.50.

The Mechanic Powers.—The following instruments are included under a set of mechanic powers: 1. Several systems of various kinds of pulleys. 2. The various kinds of levers. 3. Inclined plane and carriage. 4. Wheel and axle. 5. Wedge. 6. Screw. Also a set of weights to use with them.

Fig. 153.



The Pulleys.—(Fig. 153, as above.)—The pulleys are mounted on a neat polished mahogany base, 30 inches long and 8 inches wide, with turned columns, 24 inches high, behind which are fastened narrow scales, divided into inches and parts thereof, the one scale numbering from the top, and the other from the bottom, having a cord drawn across the frame at each inch, dividing the whole into twenty-four equal parts, for observing the distance each weight passes through in use. The pulleys and their mountings are made of brass, highly polished, having steel centres, connected with which is a set of brass weights from $\frac{1}{4}$ oz. to 16 ounces.

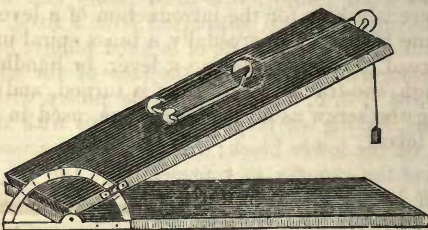
In the best instruments there are seven systems of pulleys, viz. 1. a fixed pulley with one wheel or sheave, turning on pivots by a cord; 2. one fixed and one movable pulley connected; 3. two fixed pulleys in one block, and two movable pulleys in one block; 4. two fixed pulleys in one block, the one above the other, and two movable pulleys one above the other; 5. three pulleys arranged as the last in both the moving and fixed pulley; 6. a fixed pulley and four single pulleys, having the cord supported from a fixed point; 7. White's pulley, which consists of a fixed pulley, having five or more concentric grooves on the face of the wheel, with diameters, as 1, 3, 5, and one movable pulley with another such wheel, having corresponding grooves with diameters, as 2, 4, 6, on the lower block; the cord being passed in succession over the grooves, as represented in the cut, it will be thrown off by the action of the power in the same manner as if every groove formed a separate and independently revolving wheel.

It is to be observed in using the pulleys, that the pulley is to be balanced before the weights, representing the power, are applied; for this purpose a cup with hooks is supplied, into which shot is placed till the pulley is accurately balanced.

Price, with levers, screw, inclined plane. wheel
and axis, and set of brass weights, - $35.00.

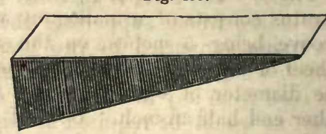
The Levers.—The principal lever (Fig. 153, opposite page) is a bar of brass about twelve inches long, supported on a steel pivot, called the fulcrum, at about four inches from one end, which end is made thicker than the longer one, that they may equally balance. On the under side of the lever is a succession of hooks, at one inch from the fulcrum, and from each other, for the whole length; and on the upper side of the lever a succession of hooks, on the longer side only. The lever is attached by its fulcrum to the upper part of the frame supporting the pulleys. Over the lever is a frame supported by two brass pillars, having a sliding pulley, which may be placed in such a manner as to carry the cord from any of the hooks on the upper side of the lever, as would be required in using the lever in the second and third order. On the top of the frame there is a series of three levers, the shorter arm of the one acting on the longer arm of the next, forming a compound lever. Also, a bent lever, having holes at the distance of one inch apart in both arms, and supported on a brass pillar, near which is placed another brass pillar, on the upper part of which there is a frame with sliding pulley, that can be set at any height required for supporting the cord from the arm of the bent lever.

Fig. 154.



The Inclined Plane.—(Fig. 154, as above.)—This consists of two flat pieces of mahogany, about twelve inches long and five inches wide, movable on a joint at one end, and having a graduated semicircular arch divided into degrees, and numbered from 0° to 90° both ways, and having a clamp, spring, and milled-head screw, to fasten it at any angle desired; at the other end of the plane is fixed a pulley. A small carriage rolling on three wheels, and of a size to move conveniently on the inclined plane, and weighing exactly four ounces, is used for showing the power gained, being attached to a silk cord, which is passed over the pulley, and the weight attached to the end; if the length of the inclined plane be twice its elevation, two ounces will balance the carriage weighing four ounces, and the smallest weight added to it will draw it up.

Fig. 155.



The Wedge.—(Fig. 155.)—This is usually formed of two equally inclined surfaces, hinged together at the base, and when open forming two inclined planes, and when closed, a wedge; is usually made of mahogany, about eight inches long. The principal use of the wedge consists in its being urged by the stroke of a hammer, mallet, &c. A smart blow of a hammer of half a pound weight, overcoming more resistance than the weight of many pounds laid on the top of the wedge.

The Screw.—(Fig. 156, as below)—This piece of apparatus consists of a screw, about 8 inches long, entering a board supported on a base by two pillars; in the top of the screw there is a hole for the introduction of a lever. Fixed in the same frame there is usually a brass spiral in the form of the thread of a screw, having a lever, or handle, projecting through the frame, by which it is turned, and is used in explaining the screw as an inclined plane, used in connexion with the lever.

Fig. 156.

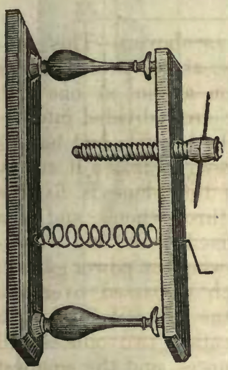
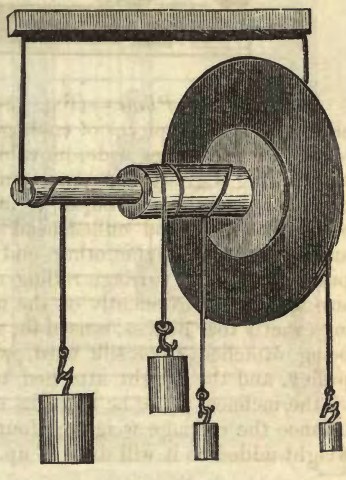
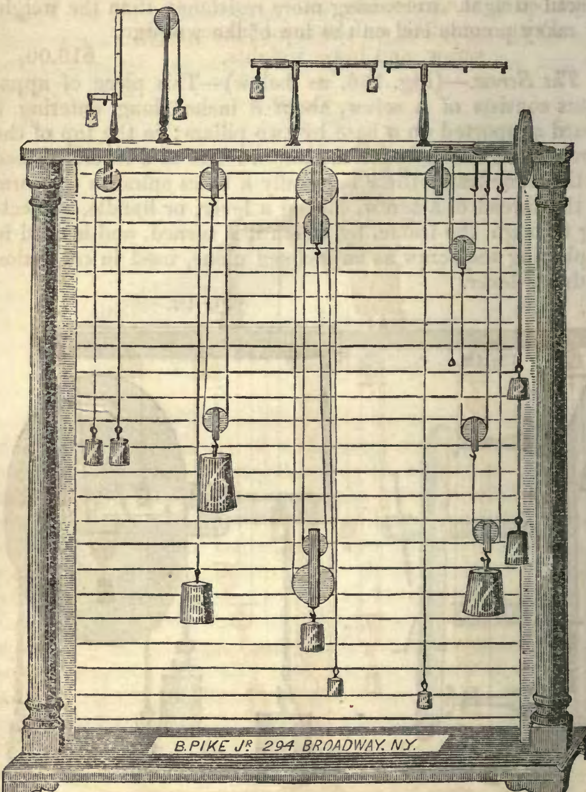


Fig. 157.



The Wheel and Axis.—(Fig. 157, as above,)—This apparatus consists of a mahogany wheel, the diameter in the groove being 5 inches, on the side of which is a smaller wheel of $2\frac{1}{2}$ inches diameter; they are mounted on an axis, the diameter of which near the wheel is one inch, and the other end half an inch. Both of these have silk cords fixed to them, for suspending the weights; the axis is supported at the ends by small pivots, moving in a brass frame, which is usually attached to the frame supporting the system of pulleys.

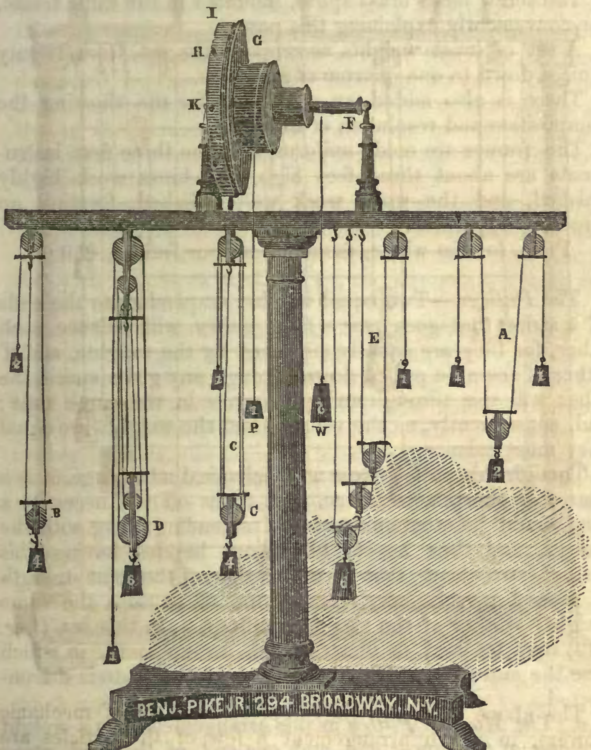
Fig. 158.



The above cut (Fig. 158) represents a set of mechanic powers, in which arrangement a few of the articles are modified, having the four most important systems of pulleys arranged as those described, and having two straight levers on the frame, and one bent lever, and a movable pulley attached to a brass pillar with a nut on the bottom, by which it can be shifted to different holes in the top of the frame, for passing the cord over, in using the lever in the second and third order, and also for the bent lever; the inclined plane, wheel and axis, wedge and screw, are the same as described in the preceding set.

Price, complete with inclined plane, wedge, screw, and brass weights, $16.00.

Fig. 159.



Improved Set of Mechanic Powers.—(See Fig. 159, as above.)—In this elegant set of mechanic powers, there are five arrangements, or systems of pulleys; others may be made by altering the cords. On the top of the frame there is mounted a wheel and axis, the axis being one inch in diameter, and there being three different diameters to the wheel, two, five, and ten inches, also having a number of spokes, or handles, on the circumference.

The levers are conveniently arranged on a separate stand, the principal one being arranged for explaining the balance.

The inclined plane and wedge are mounted also on a separate stand.

The screw has a brass spiral, mounted in the same frame, for conveniently explaining this power.

A set of brass weights accompany the set, from twenty ounces down to one quarter of an ounce.

There is also added an apparatus for the showing the composition and resolution of forces.

The frames are made uniform, and the three first instruments are about three feet high, the brass work highly finished, and the wood work well polished, forming an imposing apparatus.

Price, for the whole, mounted on four frames, $60.00.

The Pulleys.—Two equal weights suspended to the ends of a string that goes over a *fixed pulley,* will balance each other, for they are equally stretched by the weights, and if either of them be pulled down through any given space, the other will rise through an equal space in the same time; and, consequently, as the velocity and the weights are equal they must balance.

Though this pulley gives no mechanical advantage, it is a source of great convenience, as it takes off the necessity a man would be otherwise under of ascending along with the weight, and thus lessens his labor; besides having this further convenience, that by means thereof the joint strength of several persons may be made use of to raise the same weight. Either of the two first pulleys, A, in this set (Fig. 159) may be used to illustrate this arrangement, in which case the movable pulley represented in the plate is disconnected.

B. *The Movable Pulley* in this arrangement has a weight hanging at the lower end, and one end of the cord going round the pulley, is fastened to a hook in the lower part of the fixed pulley above, while the other end goes over the fixed pulley, and is sustained by the weight. The two cords support the whole weight, each supporting one half; whatever holds the upper end of either rope, sustains one half the weight. If you take hold of the cord and pull upwards you will feel only half the weight, the cord attached to the hook supporting the other half; if you put the cord over the fixed pulley, this only changes the direction, and, therefore, in pulling the cord downwards, you only feel half the weight; one ounce suspended from the cord passing over the fixed pulley, will balance two ounces from the movable pulley, and you will be enabled to lift twice as much weight by the assistance of a single movable pulley, as you could raise by your own actual strength. The power moves twice as fast as the pulley with the weight; therefore, the space described by the power will be equal to twice the space described by the weight, or the velocity of the weight is to that of the power as one to two; and it will be observed that when the weight has been raised two inches, the power has descended four inches.

C. When the upper and fixed block contains *two pulleys*, which only turn on their axis, and the lower movable block contains also two, which not only turn on their axis, but rise with the block and weight, the advantage gained is as four to one.

D. When there are three pulleys in the fixed block, and three in the movable one, D, and the number of cords six, the power is as six to one; the advantage is the same whether the pulleys are placed parallel to or under each other.

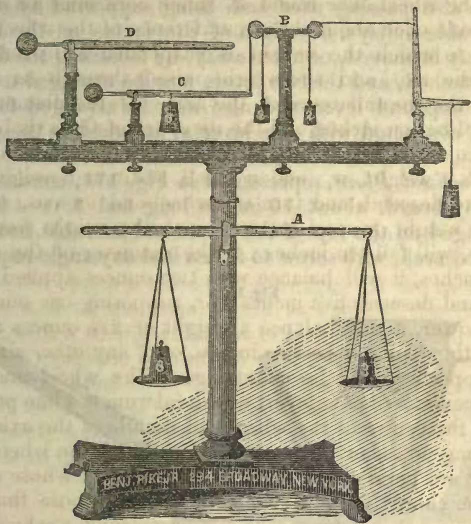
E. In this arrangement the pulleys do not, as in the preceding systems, rise together in one block with the weight, but act upon one another, so that each pulley doubles the power. A power of one ounce will be in equilibrio with two ounces at the first movable pulley, with four at the second, with eight at the third; and the velocity of the power will be eight times that of the weight.

White's pulley described in the first set of mechanic powers is sometimes added to this set.

The Wheel and Axis (Fig. 159, page 151) is a machine much used, and which is applied in a variety of forms. The power acts on the circumference of the wheel; the weight is fastened to one end of a cord or rope, whose other end winds round an axis that turns with the wheel. The axis, F, and wheel, G, in Fig. 159, are fastened together so that one cannot move without the other; when a weight, W, is to be raised by this engine, it is fixed to the end that goes round the axis, but the power, P, is applied to one of the several circumferences of the wheel. Pulling at the rope, P, to turn the wheel once round, as much cord must be drawn off as winds once about the circumference of the wheel, and the cord to which the weight is suspended will wind once around the axis, and the weight raised through as much space as the circumference of the axis. If the diameter of the wheel be ten inches, and the diameter of the axis be one inch, then one ounce acting as a power, P, will balance ten ounces as a weight, W; and a small additional weight will cause it to descend, and turn the wheel and its axis, and so raise the weight, W; and for every inch the weight rises, the power, P, will fall ten inches; if the diameter of the wheel be five inches, it will balance with two ounces applied as a power, and descend five inches; or, supposing one ounce to be the power, it will balance a weight of five ounces at the axis; if the diameter be two inches, or of any other size, the same proportions will be maintained. The wheel and axis may be considered as a lever, whose fulcrum is a line passing through the centre of the wheel and middle of the axis, and whose long and short arms are the radii of the wheel and axis that are parallel to the horizon, and from whose extremities the chords hang perpendicularly. Suppose that the power does not act by a rope winding round a wheel, but that it is moved by a man's strength applied immediately to the spokes or handles, I, H, K; if the man first lay hold of the handle, H, and push it down to K, his hand passes through the space, H K, and the handle will be brought down to K; he then lays hold of I, and pushes it to H, and so on till he has turned the wheel once round; and his hand, which is now the power, will describe the whole circumference of a circle, which is to be considered as the circumference of the wheel. A wheel and axis may therefore be considered as a kind of perpetual lever, on whose arms the power and weight always act perpendicularly, though the lever turns round its fulcrum; and in like manner, when wheels and axis move each other by means of teeth on their circumference, such a machine may be considered as a perpetual compound lever.

The Levers.—(Fig. 160, next page.)—In this arrangement of levers, there is a brass beam or lever, A, having arms of equal length, supported on its fulcrum at the side of the pillar, which pillar is attached to a mahogany base; in each

Fig. 160.



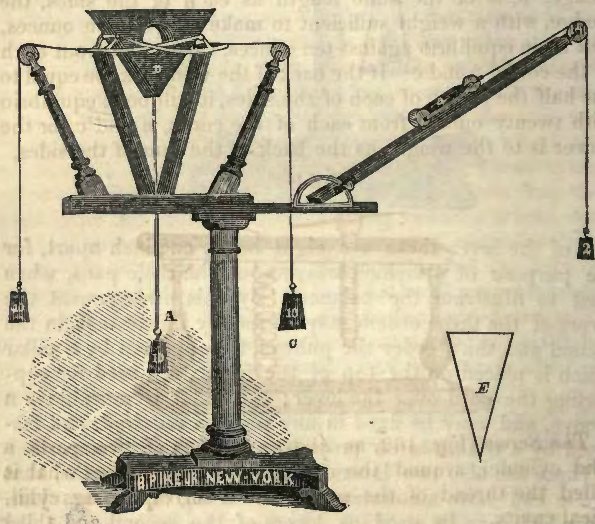
arm of the lever there are eight holes, one inch apart, for the purpose of attaching weights, or the scale pans, when used to illustrate the balance. By this arrangement the levers of the three orders may be readily illustrated; in the second and third order the pulleys, B, supported by a pillar which is placed on the top of the frame, are used for supporting the cord over the lever; this pillar is movable in a groove, and may be fixed in any position required, and fastened by a thumb-screw projecting beneath the frame.

There are also two levers, C, D, of different lengths, that at one end have a counterpoise consisting of a brass ball, and which may be used as levers of the second and third orders—the smaller one being represented in the cut as arranged in the second order, having a weight of six ounces supported at two inches from the axis, balanced by a weight of two ounces supported at six inches from the axis, the cord being supported by one of the movable pulleys, B.

The Bent Lever is represented at E, supporting a weight on the horizontal arm, of six ounces, at a distance of two inches from the axis, and balanced by a weight of two ounces at a distance of six inches on the upright arm; the cord in this case also passing over and being supported by one of the movable pulleys, B. Each of the levers on the upper frame may be moved, or taken away, by loosening the thumb screw attached, and the two levers may be arranged to illustrate a compound lever, and also may be arranged for this purpose, connected with the lever A, attached to the pillar.

The Inclined Plane, represented in Fig. 171, consists of a mahogany board, about 16 inches long and 3 or 4 inches wide, hinged on the top of the frame and movable, having a graduated arch, with screw to fasten it at any angle required.

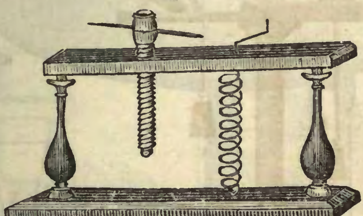
Fig. 161.



There is a pulley at the end for supporting a cord from the carriage, which carriage is on three wheels, and weighs exactly four ounces. If the inclined plane be fixed at a height equal to one-half the length of the plane and the carriage placed thereon, having a cord passed over the pulley, and a weight of two ounces attached thereto, it will be exactly balanced; or if the inclined plane be fixed at a height equal to one-fourth the length of the plane, one ounce attached to the cord will balance the carriage, weighing four ounces, and a small additional weight will draw it up.

The Wedge.—To the frame there are hinged two mahogany boards, which are drawn together by a brass frame-work, to which cords are attached, which pass over and are supported by pulleys, having weights at the lower ends of the cords. Rollers are also fixed in this frame-work, against which a wedge is introduced, having a cord and weight attached, which weight, with that of the wedge, is to be considered as that of the impelling power. The weights attached to the cords and supported over the pulleys, are to be considered as the resistance of the wood acting equally against the opposite sides of the wedge. If the back of the wedge, D, is of the same length as each of the sides, the wedge, with a weight sufficient to make it equal ten ounces, will be in equilibrio against ten ounces, suspended from each of the cords, B and C. If the back of the wedge, E, be equal to one half the length of each of the sides, it will be in equilibrio with twenty ounces from each of the cords, B and C, or the power is to the weight as the back to the sum of the sides.

Fig. 162.

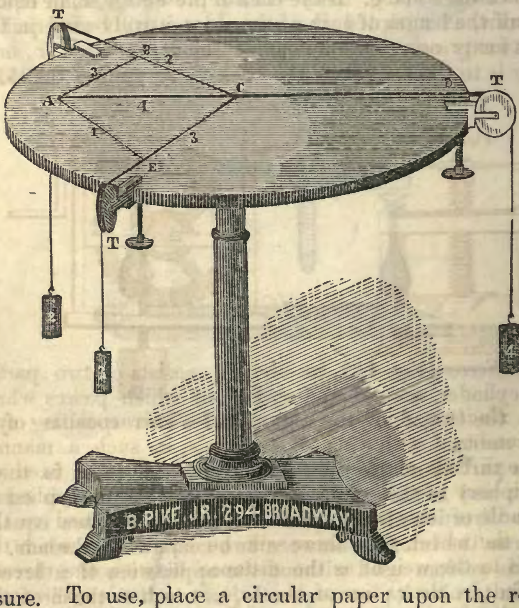


The Screw (Fig. 162, as above) consists of two parts, a solid cylinder, around the surface of which passes what is called the thread of the screw, and a corresponding cylindrical cavity.

One part is commonly fixed, whilst the other is turned round; and in each revolution the movable part is carried in the direction of the cylinder, through a space equal in length to the interval between two contiguous threads. A screw is seldom used without the application of a lever to assist in turning it; consequently, as much as the circumference of a circle, described by this handle or winch, is greater than the intervals or distance between the spirals, so much is the force of the screw. Supposing the distance between the spirals to be one quarter of an inch, and the length of the winch to be six inches, the circle described by the handle of the winch, where the power acts, is nearly 38 inches, or 152 quarter inches, and consequently 152 times as great as the distance between the spirals; and, therefore, a power at the handle, where the power acts, of no more than one pound, will balance 152 pounds acting against the screw, and as much additional power as is sufficient to overcome the friction, will raise the 152 pounds.

Apparatus for the Composition and Resolution of Forces.—(Fig. 163.)—This consists of a round table, usually about 18 inches in diameter, to the edge of which may be fixed any number of brass pulleys, varying their direction at

Fig. 163.



pleasure. To use, place a circular paper upon the round table, so that its centre may coincide with that of the table. Upon this paper a triangle A B C is delineated, whose sides are to one another, as 2, 3, and 4. Draw C E parallel to A B, and continue A C towards D.

I take three strings, which are joined in one point by a knot; and placing the point over C, stretch the strings over C D, C E, C B, and place the pulleys, T, T, T, to coincide with the direction of the strings; then putting the strings over their respective pulleys, at the end of the thread, C D, suspend a weight of four pounds, to C E three pounds, and to C B two pounds. These weights will remain in equilibrio while the knot remains over C; but if it be removed out of that point, they will not be at rest.

It is evident from this experiment, that power is always lost in the composition of forces; for here a weight of three pounds, and another of two, only counterpoise a weight of four.

Screw Press.—(Fig. 164.)—This represents a small model of a screw, as mounted in a press, extensively used in the arts, as for pressing cotton, for book-binders, etc.

Price, $2.25.

Fig. 164.

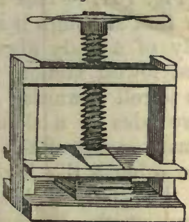
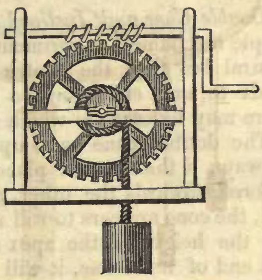


Fig. 165.



The Endless Screw.—(Fig. 165.)—This consists of a screw combined with a wheel and axle, in such a manner that the threads of the screw work into the teeth fixed on the periphery of the wheel. Suppose the power applied to the handle of the screw, and the weight attached to the axle of the wheel, then there will be equilibrium when the power is to the weight as the distance between the threads multiplied by the radius of the axle, is to the length of the lever or handle, multiplied by the radius of the wheel.

Price, in brass, $8.00.

The Capstan.—(Fig. 166.)—One of the most efficient forms of the wheel and axle is the capstan, used on board of ships and in dock-yards. It consists of a vertical spindle fixed firmly as in the deck of the vessel, but turning on its axis, and supporting a drum, or solid cylinder connected with it, and having its periphery pierced with holes directed towards its centre. It is then worked by long levers, inserted in the holes, by men who walk in succession round the capstan, and thus make it revolve; a rope or cable wound about the axle may act with force sufficient to weigh a ponderous anchor, or warp a heavy laden vessel into harbor.

Small models made in mahogany, 6 inches high, serve to illustrate the use of this instrument. Price, $2.50.

Fig. 166.

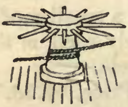
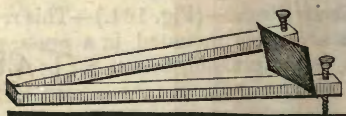


Fig. 167.



Double Cone and Inclined Plane.—(Fig. 167.)—This is a simple mechanical experiment, to show that although it is a natural law that the centre of gravity of a body always tends to, and endeavors to obtain the lowest station, yet there may be cases in which it *appears* to roll upwards.

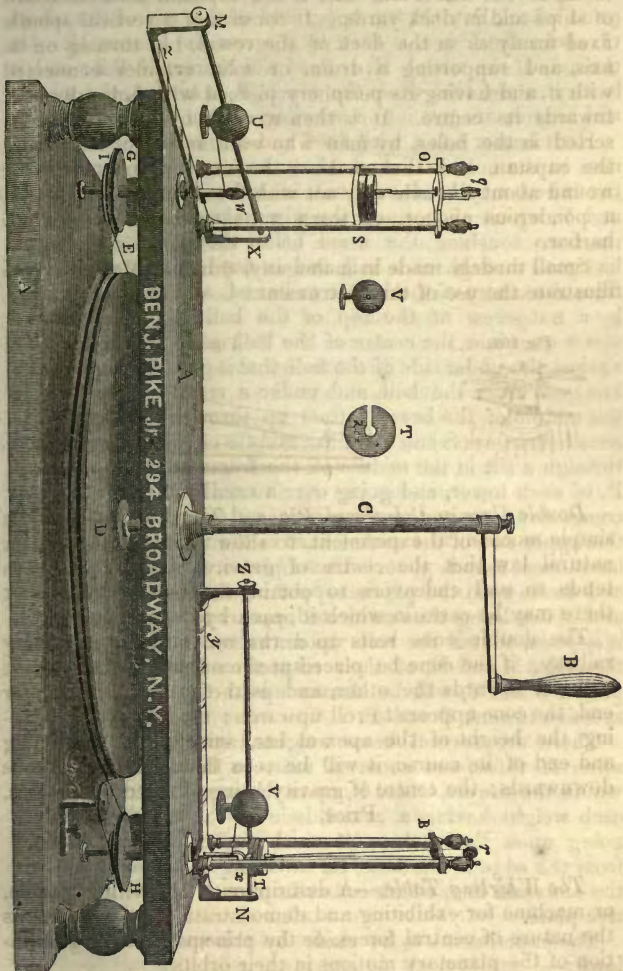
The double cone rests upon the two sides of a sloping railway; if the cone be placed at the narrow end of this, it will roll towards the other, and as the other is the higher end, the cone appears to roll upwards; though upon observing the height of the apex at each end, at the beginning and end of its course, it will be seen that in reality it rolls downwards; the centre of gravity being situated in the axis.

Price, $1.00 to $2.00.
" with screws, $3.00.

The Whirling Table.—A description of the whirling table, or machine for exhibiting and demonstrating by experiments the nature of central forces, or the principal laws of gravitation of the planetary motions in their orbits:

The whirling-table may be considered by a lecturer as an essential part of his mechanical apparatus.

Fig. 168.



(Fig. 168, as above.)—A A is a strong frame of wood, B a winch or handle fixed on the axis, C, of the wheel, D, round which is the catgut string, F, which also goes round the small wheels, G and H, crossing between them and the great wheel, D. On the upper end of the axis of the wheel G, above the frame, is fixed by a screw the bearer, M. On the axis of the wheel, H, is fixed the bearer, N T Z: and it is easy to see, that when the winch, B, is turned, the wheels and bearers are put into a whirling motion.

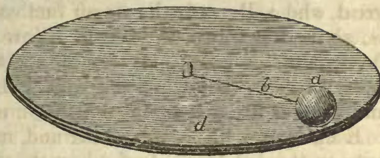
Each bearer has a wire fixed and screwed tight into it by nuts on the outside. And when these nuts are unscrewed, the wires may be drawn out in order to change balls U and V, which slide upon the wires, thus keeping the balls up from touching the wood below them. A strong silk line goes through each ball, and is fixed to it at any length from the centre of the bearer to its end, as occasion requires, by a nut-screw at the top of the ball; the shank of the screw goes into the centre of the ball, and presses the line against the under side of the hole that it goes through. The line goes from the ball, and under a small pulley fixed in the middle of the bearer; then up through a socket in the round plate, see S and T, in the middle of each bearer; then through a slit in the middle of the frame at the top, O and P, of each tower, and going over a small pulley on the top, comes down again the same way, and is at last fastened to the upper end of the socket fixed in the middle of the above mentioned round plate. These plates, S and T, slide up and down upon the pillars supporting the tower. The balls and plates being thus connected, each by its particular line, it is plain, that if the balls be drawn outwards, or towards the ends, M and N, of their respective bearers, the round plates, S and T, will be drawn up to the top of their respective towers, O and P.

There are several brass weights, some of two ounces, some of three, and some of four, to be occasionally put within the towers, O and P, upon the round plates, S and T: each weight having a round hole in the middle of it, for going upon the sockets or axes of the plates, and is slit from the edge to the hole, for allowing it to be slipt over the aforesaid line, which comes from each ball to its respective plate.

The experiments to be made by this machine are as follows:—

1. *The propensity of matter to keep the state it is in.*—Take away the bearer, M X, and fasten on the round board (Fig. 169, opposite page), and the ivory ball, *a*, to which the line

Fig. 169.



or silk cord, *b*, is fastened at one end; and having made a loop on the other end of the cord, put the loop over a pin fixed in the centre of the board, *d*. Then turning the winch, B, to give the board a whirling motion, you will see that the ball does not immediately begin to move with the board, but, on account of its inactivity, it endeavors to continue in the state of rest which it was in before. Continue turning until the board communicates an equal degree of motion with its own to the ball, and then turning on, you will perceive that the ball will remain upon one part of the board, keeping the same velocity with it, and having no relative motion upon it, as is the case with everything that lies loose upon the plane surface of the earth, which, having the motion of the earth communicated to it, never endeavors to remove from that place. But stop the board suddenly by hand, and the ball will go on, and continue to revolve upon the board until the friction thereof stops its motion; which shows, that matter being once put in motion, will continue to move for ever, if it meet with no resistance. In like manner, if a person stands upright in a boat, before it begins to move he can stand firm; but the moment the boat sets off, he is in danger of falling towards that place which the boat departs from: because, as matter, he has no natural propensity to move. But when he acquires the motion of the boat, let it be ever so swift, if it be smooth and uniform, he will stand as upright and as firm as if he were on the plane shore; and if the boat strike against any obstacle, he will fall towards that obstacle, on account of the propensity he has, as matter, to keep the motion which the boat has put him into.

2. Take away this ball, and put a longer cord to it, which may be put down through the hollow axis of the bearer, M X, and wheel, G, and fix a weight to the end of the cord below the machine; which weight, if left at liberty, will draw the ball from the edge of the whirling board to its centre.

Bodies moving in orbits have a tendency to fly out of these orbits.—Draw off the ball a little from the centre, and turn the winch; then the ball will go round and round with the board, and will gradually fly off further and further from the centre, and raise up the weight below the machine; which shows, that all bodies revolving in circles have a tendency to fly off from these circles, and must have some power acting upon them from the centre of motion, to keep them from flying off. Stop the machine, and the ball will continue to revolve for some time upon the board; but as the friction gradually stops its motion, the weight acting upon it will bring it nearer and nearer to the centre in every revolution, until it brings it quite thither. This shows, that if the planets met with any resistance in going round the sun, its attractive power would bring them nearer and nearer to it in every revolution, until they fell upon it.

3. *Bodies move faster in small orbits than in large ones.*—Take hold of the cord below the machine with one hand, and with the other throw the ball upon the round board as it were at right angles to the cord, by which means it will go round and round upon the board. Then observing with what velocity it moves, pull the cord below the machine, which will bring the ball nearer to the centre of the board, and you will see, that the nearer the ball is drawn to the centre, the faster it will revolve; as those planets which are nearer the sun revolve faster than those which are more remote; and not only go round sooner, because they describe smaller circles, but even move faster in every part of their respective circles.

4. *Their centrifugal forces shown.*—Take away this ball, and apply the bearer, M X, whose centre of motion is in its middle at *w*. Then put two balls, V and U, of equal weights upon their bearing wires, and having fixed them at equal distances from their respective centres of motion, *w* and *x*, upon their silk cords, by the screw nuts, put equal weights in the towers O and P. Lastly, put the catgut strings, E and F, upon the grooves, G and H, of the small wheels, which, being of equal diameters, will give equal velocities to the bearers above, when the winch, B, is turned: and the balls, U and V, will fly off towards M and N; and will raise the weights in the towers at the same instant. This shows, that when bodies of equal quantities of matter revolve in equal circles with equal velocities, their centrifugal forces are equal.

5. Take away these equal balls, and instead of them put

a ball of six ounces into the bearer, M X, at a sixth part of the distance, *w z*, from the centre, and put a ball of one ounce into the opposite bearer, at the whole distance, *x y*, which is equal to *w z*, from the centre of the bearer; and fix the balls at these distances on their cords, by the screw nuts at top, and then the ball U, which is six times as heavy as the ball V, will be only a sixth part of the distance from its centre of motion; and, consequently, will revolve in a circle of only a sixth part of the circumference of the circle in which V revolves. Now, let any equal weights be put into the towers, and the machine be turned by the winch, which, as the catgut string is on equal wheels below, will cause the balls to revolve in equal times, but V will move six times as fast as U, because it revolves in a circle of six times its radius; and both the weights in the towers will rise at once. This shows that the centrifugal forces of revolving bodies, or their tendencies to fly off from the circles they describe, are in direct proportion to their quantities of matter multiplied into their respective velocities; or into their distances from the centres of their respective circles. For, suppose U, which weighs six ounces, to be two inches from its centre of motion, *w*, the weight multiplied by the distance, is 12; and supposing V, which weighs only one ounce, to be 12 inches distant from the centre of motion, *x*, the weight one ounce, multiplied by the distance, 12 inches, is 12. And as they revolve in equal times, their velocities are as their distances from the centre, namely, as 1 to 6.

If these two balls be fixed at equal distances from their respective centres of motion, they will move with equal velocities; and if the tower, O, have six times as much weight put into it, as the tower, P, has, the balls will raise their weight exactly at the same moment. This shows that the ball U, being six times as heavy as the ball V, has six times as much centrifugal force, in describing an equal circle with an equal velocity.

6. *A double velocity in the same circle is a balance to a quadruple power of gravity.*—If bodies of equal weights revolve in equal circles with unequal velocities, their centrifugal forces are as the squares of the velocities. To prove this law by an experiment, let two balls, U and V, of equal weights, be fixed on their cords at equal distances from their respective centres of motions, *w* and *x*; and then let the catgut string, E, be put round the wheel, K, whose

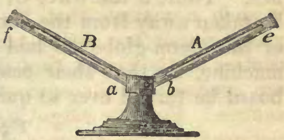
circumference is only one-half of the circumference of the wheel, H or G, and over the pulley, *s*, to keep it tight; and let four times as much weight be put into the tower, P, as into the tower, O. Then turn the winch, B, and the ball, V, will revolve twice as fast as the ball U, in a circle of the same diameter, because they are equidistant from the centres of the circles in which they revolve; and the weights in the towers will both rise at the same instant; which shows, that a double velocity in the same circle will exactly balance a quadruple power of attraction in the centre of the circle. For the weights in the towers may be considered as the attractive forces in the centres, acting upon the revolving balls; which, moving in equal circles, is the same thing as if they moved in one and the same circle.

7. If bodies of unequal weights revolve in unequal circles, in such a manner that the squares of the times of their going round are as the cubes of their distances from the centres of the circles they describe; their centrifugal forces are inversely as the squares of their distances from those centres. For, the catgut string remaining as in the last experiment, let the distance of the ball, V, from the centre, *x*, be made equal to two of the cross divisions on its bearer; and the distance of the ball, U, from the centre, *w*, be three and a sixth part; the balls themselves being of equal weights, and V making two revolutions by turning the winch, in the time that U makes one; so that if we suppose the ball, V, to revolve in one second, the ball, U, will revolve in two seconds, the squares of which are one and four, for the square of 1 is only 1, and the square of 2 is 4; therefore the square of the period, or revolution of the ball, V, is contained four times in the square of the period of the ball, U. But the distance of V is 2, the cube of which is 8, and the distance of U is $3\frac{1}{6}$, the cube of which is 32, very nearly, in which 8 is contained four times; and, therefore, the squares of the periods of V and U are to one another as the cubes of their distances, from *x* and *w*, which are the centres of their respective circles. And if the weight in the tower, O, be four ounces, equal to the square of 2, the distance of V from the centre, *x;* and the weight in the tower, P, be ten ounces, nearly equal to the square of $3\frac{1}{6}$, the distance of U from *w;* it will be found, upon turning the machine by the winch, that the balls, U and V, will raise their respective weights at the same instant of time. Which

confirms that famous proposition of *Kepler, viz.* That the squares of the periodical times of the planets round the sun, are in proportion to the cubes of their distances from him; and that the sun's attraction is inversely as the square of the distance from his centre; that is, at twice the distance, his attraction is four times less; and thrice the distance, nine times less; at four times the distance, sixteen times less; and so on to the remotest part of the system.

8. Take off the catgut string, E, from the great wheel, D, and the small wheel, H, and let the string, F, remain upon the wheels D and G. Take away also the bearer, M X, from the whirling-board, and instead thereof put the machine, A B (Fig. 170) upon it, fixing this machine to the centre of the board by its screw. In this machine are two glass tubes, *a* and *b*, close stopped at both ends, and inclined to an angle of 30 or 40 degrees; and each tube is about three quarters full of water. In the tube, *a*, is a little quicksilver, which naturally falls down to the end *a*, in the water, because it is heavier than its bulk of water; and on the tube, *b*, is a small cork, which floats on the top of the water at *e*, because it is lighter; and it is small enough to have liberty to rise or fall in the tube. While the wheel, with this machine upon it, continues at rest, the quicksilver lies at the bottom of the tube *a*, and the cork floats on the water near the top of the tube *b*. But, upon turning the winch, and putting the machine in motion, the contents of each tube will fly off towards the uppermost ends, which are furthest from the centre of motion, the heaviest with the greatest force. Therefore the quicksilver in the tube, *a*, will fly off quite to the end *f*, and occupy its bulk of space, there excluding the water from that place, because it is lighter than quicksilver; but the water in the tube, *b*, flying off to its higher end, *e*, will exclude the cork from that place, and cause the cork to descend towards the lowermost end of the tube, where it will remain upon the lowest end of the water, near *b*; for the heavier body, having the greater centrifugal force, will therefore possess the uppermost part of the tube; and the lighter body will keep between the heavier and the lowermost part.

Fig. 170.



9. *If one body move round another, both of them must move*

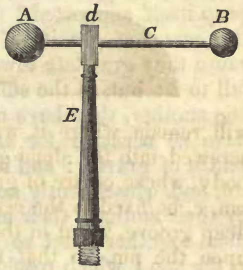
round their common centre of gravity.—If a body be so placed on the whirling-board of the machine, that the centre of gravity of the body be directly over the centre of the board, and the board be put into ever so rapid a motion by the winch, B, the body will turn round with the board, but will not remove from the middle of it; for, as all parts of the body are in equilibrio round its centre of gravity, and the centre of gravity is at rest in the centre of motion, the centrifugal force of all parts of the body will be equal at equal distances from its centre of motion, and therefore the body will remain in its place. But, if the centre of gravity be placed ever so little out of the centre of motion, and the machine be turned swiftly round, the body will fly off towards that side of the board on which its centre of gravity lies. Thus, if the wire, C, with its little ball, B (Fig. 171), be taken away from the demiglobe A, and the flat side, *e f*, of this demi-globe be laid upon the whirling-board of the machine, so that their centres may coincide; if then the board be turned ever so quick by the winch, the demi-globe

Fig. 171.

will remain where it was placed. But if the wire, C, be screwed into the demi-globe at *d*, the whole becomes one body, whose centre of gravity is now at or near *d*. Let the pin, *c*, be fixed in the centre of the whirling-board, and the deep groove, *b*, cut in the flat side of the demi-globe, be put upon the pin, so that the pin may be in the centre of A, and let the whirling-board be turned by the winch, which will carry the little ball, B, with its wire, C, and the demi-globe, A, all round the centre pin, *c i;* and then, the centrifugal force of the little ball, B, which weighs only one ounce, will be so great as to draw off the demi-globe, A, which weighs two pounds, until the end of the groove, at *e*, strikes against the pin, *c*, and so prevents the demi-globe, A, from going any further; otherwise, the centrifugal force of B would have been great enough to have carried A quite off the whirling-board; which shows, that if the sun were placed in the very centre of the orbits of the planets, it could not possibly remain there; for the centrifugal forces of the planets would carry them quite off, and the sun with them; especially when several of them happened to be in any one quarter of the heavens. For the sun and planets are as much connected by the mutual attraction that subsists between them, as the bodies A and B are by the wire C, which is fixed into them both. And even if there were but one single planet in the whole heavens to go round ever so large a sun in the centre of its orbit, its centrifugal force would soon carry off both itself and the sun. For, the greatest body placed in any part of free space might be easily moved; because, if there were no other body to attract it, it could have no weight or gravity of itself; and consequently, though it could have no tendency of itself to remove from that part of space, yét it might be very easily moved by any other substance.

10. As the centrifugal force of the light body, B, will not allow the heavy body, A, to remain in the centre of motion, even though it is twenty-four times as heavy as B; let us now take the ball, A (Fig. 172), which weighs six ounces, and connect it by the wire, C, with the ball, B, which weighs only one ounce; and let the fork, E, be fixed in the centre of the whirling-board; then hang the balls upon the fork by the wire, C, in such manner, that they may exactly balance each other; which will be when the centre of gravity between them, in the wire at *d*, is supported by the fork. And this centre of gravity is as much nearer to the centre of the ball, A, than to the centre of the ball, B, as A is heavier than B, allowing for the weight of the wire on each side of the fork. This done, let the machine be put into motion by the winch; and the balls, A and B, will go round their common centre of gravity, *d*, keeping their balance, because either will not allow the other to fly off with it. For, supposing the ball, B, to weigh only one ounce, and the ball, A, to be six ounces; then, if the wire, C, were equally heavy on each side of the fork, the centre of gravity, *d*, would be six times as far from the centre of the ball, B, as from that of the ball, A, and, consequently, B will revolve with a velocity six times as great as A does; which will

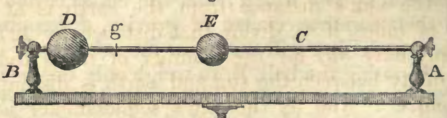
Fig. 172.



give B six times as much centrifugal force as any single ounce of A has: but then, as B is only one ounce, and A six ounces, the whole centrifugal force of A will exactly balance the whole centrifugal force of B: and, therefore, each body will detain the other so as to make it keep in its circles. This shows, that the sun and the planets must all move round the common centre of gravity of the whole system, in order to preserve that just balance which takes place among them. For, the planets being as inactive and dead as the above balls, they could no more have put themselves into motion than these balls can; nor have kept in their orbits without being balanced at first with the greatest degree of exactness upon their common centre of gravity, by the Almighty hand that made them and put them in motion.

Perhaps it may be here asked, that since the centre of gravity between these balls must be supported by the fork, E, in this experiment, what prop it is that supports the centre of gravity of the solar system, and consequently bears the weight of all the bodies in it; and by what is the prop itself supported? The answer is easy and plain; for the centre of gravity of our balls must be supported, because they gravitate towards the earth, and would therefore fall to it: but, as the sun and planets gravitate only towards one another, they have nothing else to fall to; and therefore have no occasion for anything to support their common centre of gravity: and if they did not move round that centre, and consequently acquire a tendency to fly off from it by their motions, their mutual attractions would soon bring them together; and so the whole would become one mass in the sun: which would also be the case if their velocities round the sun were not quick enough to create a centrifugal force equal to the sun's attraction.

Fig. 173.



11. Take away the fork and balls from the whirling-board, and place the frame, A B (Fig. 173), thereon, fixing its centre to the centre of the whirling-board by the screw. In

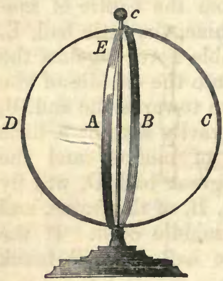
this frame are two balls, D and E, of unequal weights, connected by a tube, *f*, and made to slide easily upon the wire, C, stretched from end to end of the frame, and made fast by nut-screws on the outside of the ends. Let these balls be so placed upon the wire, C, that their common centre of gravity, *g*, may be directly over the centre of the whirling-board. Then turn the machine by the winch, ever so swiftly, and the trough and balls will go round their centre of gravity, so as neither of the balls will fly off; because, on account of the equilibrium, each ball detains the other with an equal force acting against it. But if the ball, E, be drawn a little more towards the end of the frame at A, it will remove the centre of gravity towards that end from the centre of motion; and then, upon turning the machine, the little ball, E, will fly off, and strike with considerable force against the end, A, and draw the great ball, B, into the middle of the frame, or if the great ball, D, be drawn towards the end, B, of the frame, so that the centre of gravity may be a little towards that end from the centre of motion, and the machine be turned by the winch, the great ball, D, will fly off and strike violently against the end, B, of the frame, and will bring the little ball, E, into the middle of it. If the frame be not made very strong, the ball, D, will break through it.

The earth's motion demonstrated.—From the principles thus established, it is evident, that the earth moves round the sun, and not the sun round the earth; for the centrifugal law will never allow a great body to move round a small one in any orb whatever; especially when we find, that if a small body moves round a great one, the great one must also move round the common centre of gravity between them. And it is well known, that the quantity of matter in the sun is 227,000 times as great as the quantity of matter in the earth.

Now, as the sun's distance from the earth is at least 81,000,000 of miles, if we divide that distance by 227,000, we shall only have 357 for the number of miles that the centre of gravity between the sun and earth is distant from the sun's centre. And as the sun's semidiameter is one-fourth of a degree, which, at so great a distance as that of the sun, must be no less than 381,500 miles, if this be divided by 357, the quotient will be 1268$\frac{2}{3}$, which shows, that the common centre of gravity between the sun and earth is within the body of the sun; and is only the $1068\frac{2}{3}$ part of his semidiameter from his centre towards his surface.

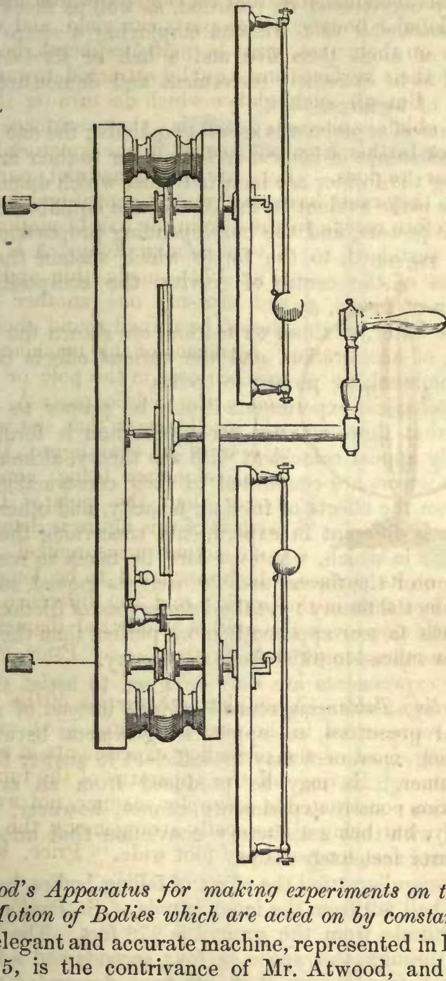
All globular bodies, whose parts can yield, and which do not turn on their axes, must be perfect spheres, because all parts of their surfaces are equally attracted towards their centres. But all such globes which do turn on their axes will be oblate spheroids; that is, their surfaces will be higher, or further from the centre, in the equatorial than in the polar regions. For, as the equatorial parts move quickest, they must have the greatest centrifugal force; and will therefore recede furthest from the axis of motion. Thus if two circular hoops, A B and C D (Fig. 174), made thin and flexible, and crossing one another at right angles, be turned round their axis, E F, by means of this machine, and the axis be loose in the pole or intersection, *e*, the middle parts A, B, C, D, will swell out, so that the whole will appear of an oval figure, the equatorial diameter being considerably longer than the polar. That our earth is of this figure is demonstrable from actual measurement of some degrees on its surface, which are found to be longer in the frigid zones than in the torrid; and the difference is found to be such as proves the earth's equatorial diameter to be thirty-six miles longer than its axis. Price, $75.00.

Fig. 174.



Whirling Table.—A simpler construction of the whirling-table is represented in the next page (Fig. 175), capable of performing most of the preceding experiments in a satisfactory manner. Having all the apparatus of the former, and the bearers constructed in a simpler manner, not working so elegantly, but being a less costly arrangement, the frame is made three feet long and one foot wide. Price, $30.00.

Fig. 175.



Atwood's Apparatus for making experiments on the Rectilineal Motion of Bodies which are acted on by constant forces.

This elegant and accurate machine, represented in Fig. 176, page 175, is the contrivance of Mr. Atwood, and renders sensible to the eye and ear, by means of a set of friction wheels, various weights, and a clock, the laws of motion uniformly accelerated or retarded, as well as those of uniform motion, and that without employing a space for the weights, of more than five and a half or six feet, which causes it to be extremely convenient and demonstrative for a course of lectures.

Mechanical experiments are of two kinds ; the one relating to the quiescence of bodies, and the other to their motion.

Among the former are included those which demonstrate, or rather make evident to the senses, the equilibrium of the mechanic powers, and the corresponding proportions of the weights sustained, to the forces which sustain them, the properties of the centre of gravity, the composition and resolution of forces, &c.

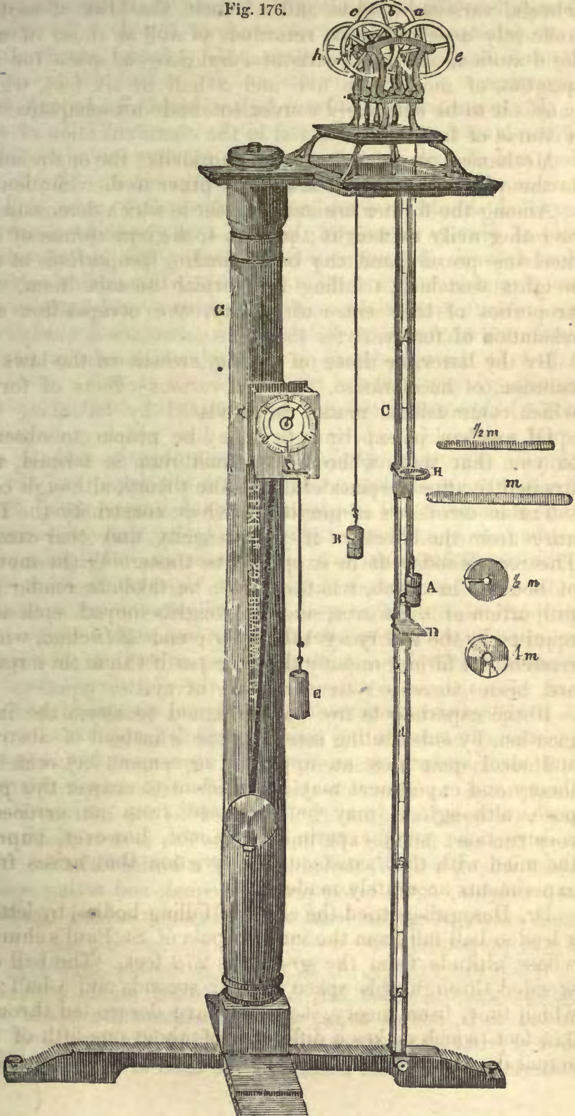
By the latter, or those on motion, are shown the laws of collision, of acceleration, and the various effects of forces which communicate motion to bodies.

Of mechanical experiments it may be proper to observe to you, that those wherein an equilibrium is formed, will frequently appear coincident with the theory, although considerable errors are committed in their construction. This arises from the effects of friction, tenacity, and other causes. The case is different in experiments concerning the motion of bodies ; in which, whatever care be taken to render the proportion of the forces, and the weights moved, such as is required by the theory ; yet the interference of friction, which renders the former apparently more perfect than they really are, causes these to differ from the theory.

If the experiments are only designed to assist the imagination, by substituting sensible objects instead of abstract and ideal quantities, an apparent agreement between the theory and experiment may be sufficient to answer this purpose, although it may be produced from an erroneous construction : such experiments cannot, however, impress the mind with that satisfactory conviction that arises from experiments accurately made.

Dr. Desaguliers tried the effect of falling bodies, by letting a leaden ball fall from the inner cupola of St. Paul's church, whose altitude from the ground is 272 feet. The ball descended through this space in four seconds and a half ; in which time, from theory, it should have descended through 325 feet, which makes a difference of about one-fifth of the actual descent between the experiment and the theory. Dr.

Fig. 176.



Desaguliers shows, in his fifth lecture, that this difference arose principally from the resistance of the air. To remedy the defects of these experiments, Mr. Atwood contrived his apparatus.

Of the mass moved.—In order to obtain an adequate idea of the laws that are observed in the communication of motion, and observe the effects of the moving force, the interference of all other force should be prevented. The bodies impelled should be conceived to exist in free space, and be void of gravity or weight; so that to a given substance various degrees of force may be applied. This indeed cannot be effected in bodies falling freely near the earth's surface; we cannot abstract the natural gravity or weight from any substance whatsoever; for the same substance is always impelled by the same force of gravity, which admits not of increase or diminution.

Yet, this difficulty may be obviated by balancing two equal weights, joined by a flexible line which goes over a pulley. The axle of the pulley must rest on wheels constructed for the purpose of diminishing friction.

The motive force of gravity being destroyed by the contrary and equal action of the weights, they will remain quiescent till some force is applied to them. When any impulse is communicated to them in a vertical direction, they will afterwards be observed to describe equal spaces in equal times, or will move uniformly; and the velocity communicated will be precisely the same, as if the same impulse had been impressed on a quantity of matter equal to the two bodies existing in free space without gravity, due allowance being made for the inertia of the wheels.

Thus, in this instrument (Fig. 176, page 175), which is constructed to illustrate this subject experimentally, there are two equal weights, A, B, affixed to the extremity of a very fine and flexible silk line. This line is stretched over a brass wheel, *a b c d*, movable round a horizontal axis. The two weights, A, B, being precisely equal, and acting against each other, when the least weight is super-added to either, it will preponderate.

When the weights, A, B, are set in motion by the action of any weight. which Mr. Atwood called *m*, the sum of A added to B, added to *m*, would constitute the whole mass moved; but then there is to be added the inertia of the materials which must necessarily be used in the communication of motion. These materials are: 1. The large wheel, *a b c d;* 2. The four brass friction-wheels, on which the axle of the wheel, *a b c d*, rests; these wheels are used to prevent the loss of motion, which would be occasioned by the friction of the axle, if it revolved on an immovable surface; 3. The weight of the line; but this is too inconsiderable to have any sensible effect.

Of the resistance from the inertia of the pulleys.—If the whole mass of the wheels were accumulated in the circumference of the wheel, *a b c d*, its inertia would be truly estimated by the quantity of matter moved. If their figures were regular, and the density distributed uniformly in each, mathematicians would furnish us with rules for finding a weight, which, being accumulated uniformly in the circumference, *a b c d*, would exert an inertia equal to that of the wheels. But as the figures are wholly irregular, recourse must be had to experiment for the discovery of such a weight.

For this purpose a weight of thirty grains was affixed to a silk line which did not weigh one-quarter of a grain; this line being wound round the wheel, the weight of thirty grains, by descending from rest, communicated motion to the wheel, and, by many trials, was observed to describe a space of thirty-eight and a half inches in three seconds. From these data we find the mass equivalent to the inertia to be two ounces and three quarters. This is a mass equivalent to the inertia of the wheel, *a b c d*, and the friction-wheels together.*

The resistance to motion, therefore, arising from the wheel's inertion will be the same as if it were absolutely removed, and a mass of $2\frac{3}{4}$ were accumulated in the circumference of the wheel, *a b c d*.

This being premised, suspend the pieces, or brass boxes, A, B, by a silk line passing over the wheel, *a b c d*, and make them balance each other; now, if I add any weight,

* Mr. Atwood proves in his work, † that the following formula will give the required mass $\frac{pttd}{s} = p - x$, where p signifies the weight, 30 gr.; t the time, 3 seconds; d the space described by a body in a second, 16 feet 1 inch, or 193 inches; s the space described by the body, 38.5 inches; and x the inertia sought.

That is in figures for the present case, $\frac{30 \times 9 \times 19}{33.5} - 30$ equal to 1323 grains, or 2 3-4 oz.

m, to A, so that it shall descend, the exact quantity of matter moved will be ascertained, for it will be A added to B, added to *m*, added to $2\frac{3}{4}$ oz.

In order to avoid troublesome computations in adjusting the quantities of matter moved, and the moving force, one-quarter of an ounce is assumed as a standard weight of convenient magnitude, to which all others are referred; this weight is called *m*. Now the inertia of the wheel, being $2\frac{3}{4}$ oz., will be denoted by 11 *m*; A and B, the pieces or boxes to which the different weights are applied, are each, together with the hooks by which they are suspended, equal $1\frac{1}{2}$ oz. or 6 *m*. We have a variety of different weights, some of which are equivalent to 4*m*, others to 2 *m*, some equal *m*, and others to aliquot parts thereof.

If then we apply 19 *m* to each of the pieces, A B, these, with those pieces, will each be equal 25 *m*, balancing themselves, and the whole mass will be 50 *m*, which being added to 11 *m*, the inertia of the wheels, the whole mass will be 61 *m*; now add *m* to both A and B, and the whole mass will be 63 *m*, perfectly in equilibrio and movable by the least weight, added to either, setting aside the effect of friction, in the same manner precisely as if the same weight or force were applied to communicate motion to the mass 63 *m*, existing in a free space and without gravity.

Of the moving force.—As the natural weight, or gravity, of any given substance is constant, and the exact quantity easily estimated, we shall apply a weight as a moving force; thus, when the system consists of a mass equal 63 *m*, I apply a weight, *m*, to A, and it communicates motion to the whole system; the whole quantity of matter moved is 64 *m*; the moving force *m*, this gives us the force which accelerates the descent of A, being $\frac{m}{6}m$, or $\frac{1}{6}$ part of the accelerated force, by which the bodies descend freely to the earth.

You see by this example, that the moving force may be altered without altering the mass moved; for, suppose the three weights *m*, two of which are placed on A and one on B, be removed, then A will balance B.

Now place the weights 3 *m* on A, and the moving force will be 3 *m*, and the mass moved 64 as before, and the force which accelerates the descent of A equal $\frac{3m}{64m}$.

To make the moving force 2*m*, remove the three weights *m*, A and B will balance one another, and the whole weight will be 61 *m;* add 1-2 *m* to A and 1-2 *m* to B, and the mass moved will be 61 *m r;* now place 2 *m* on A, and the mass moved is 64 as before, whereof the force of acceleration is equal to 1-32 part of the acceleration of gravity.

Of the space described.—The body, A, descends, as you perceive, in a vertical line, along the scale, C C, which is about sixty-four inches long, and is graduated into inches and tenths; the scale is so adjusted as to be vertical, and so placed that the descending weight may fall in the middle of the stage D, fixed to receive it at the end of the descent; the beginning of the descent is estimated from O, on the scale, when the bottom of A is level or even with O; the descent of A is terminated, when the bottom strikes the stage; the situation or distance of the stage may be varied at pleasure within the range of the sixty-four inches.

Of the time of Motion.—The time of the motion is observed by the beats of this pendulum, E, affixed to the pillar, G, and which vibrates seconds. The number of seconds is shown by the index and dial-plate above.

Many mechanical devices might be applied for letting the weight, A, begin its descent at the instant of the beat of the pendulum; but it is simpler, and Mr. Atwood thinks better, to let the bottom of the piece, or box, A, when even with O on the scale, rest on a flat rod held in the hand horizontally, its extremity being coincident with O; by attending to the beats of the pendulum, you may, with a little practice, remove the rod which supports the box, at the instant the pendulum beats, so that the descent of A shall commence at the same instant.

Of the velocity acquired.—I have only now to show you in what manner the velocity acquired by the descending weight, A, at any given point of the space through which it has descended, is made evident to the senses.

The velocity of A's descent being continually accelerated, will be the same in no two points of the space described; this is occasioned by the constant action of the moving force; and since the velocity of A, at any instant, is measured by the space which would be described by it moving uniformly for a given time, with the velocity it had acquired at that instant, this measure cannot be experimentally obtained, but by removing the force which caused the acceleration of the descending body.

To effect this, there are some weights or moving forces in form of bars or flat rods, *m*, to be laid on A ; there is also a circular frame, H, to be fixed to the scale at any proper height, in such manner that A will pass centrally through it; when A passes through this frame, it leaves the bar by which it had been accelerated on the circular part of the frame. After the moving force, *m*, has been intercepted at the end of the given space or time, there will be no force operating upon any part of the system to accelerate or retard its motion, and consequently the instant *m* is removed, A will proceed uniformly with the velocity it had acquired that instant, and the velocity being uniform, will be measured by the space described in any convenient number of seconds.

It may here be necessary to observe, that Mr. Atwood has clearly shown, that the weight of the line can have no sensible effect on the experiments, for the inequality of the motion occasioned by it does not amount to more than $\frac{1}{0\cdot 03112}$ of a second, a quantity too small to be distinguished by the senses.

The resistance of the air does not affect these experiments; for, as the greatest velocity communicated in these experiments does not exceed 26 inches in a second, and the pieces A and B being only about $1\frac{3}{4}$ inch in diameter, the resistance of the air can never increase the time of the descent in so great a proportion as 240 to 241, and will be therefore insensible in experiment.

The effects of friction are almost wholly removed by the axis of the wheel, *a b c d*, acting on the four friction wheels, *e*, *f*, *g*, *h*. If the weights, A and B, be balanced in perfect equilibrio, and the whole mass consist of 63 *m*, a weight of two grains, added to A or B, will communicate motion to the whole, which shows how inconsiderable the friction is; in some cases, however, particularly in experiments on retarded motion, the effects of friction become sensible, but may be very readily and exactly removed by adding rather less than two grains to the descending weight; the weight should be always less than what is sufficient to put the whole in motion.

The space which bodies describe in one second, by falling freely from rest, is 193 inches; but in the ensuing experiments, the space is taken at 192 inches, which will be productive of no error, in order to avoid fractions, which would render the use of the instrument less easy and intelligible.

The pendulum of the clock, which is fixed to the pillar of the instrument, vibrates seconds; it has only one wheel which immediately acts on the pendulum: the small weight which continues the pendulum's motion, after it has been wound up, is half an hour in descending to the ground. The clock will be sufficiently exact if it keep time with a common well regulated clock for this half hour.

When the axis of the wheel, *a b c d*, has been adjusted horizontal, let two equal weights, A and B, be suspended from the extremities of a silk line of proper length, the thickness of which is no greater than is just sufficient to sustain the weights. When these weights are perfectly quiescent, a small impulse being applied to either, in a vertical direction, will set the whole in motion; which will be continued uniform till one of the boxes arrives at the extremity of the scale. When the box, A, is at the bottom of the scale and quiescent, it must be observed whether the middle line on the scale be everywhere exactly opposite to the line sustaining A; or, in other words, whether the line in the middle of the scale be in the same vertical plane with the line which sustains A. If it be not, the lower extremity of the scale must be moved along the arm of the base until the adjustment is correct. It is also to be observed, whether the line be everywhere at equal perpendicular distances from the middle line on the scale: if it be not, the lower extremity of the scale must be removed further from, or nearer to the silk line, until the distances are everywhere equal. The middle line on the scale will now be vertical, and the circular frame must be so constructed, that the box, A, may pass centrally through it, when the adjustments are correct.

In letting the box, A, begin to descend at any beat of the pendulum, the observer must not wait until he hears the beat, at which he intends A's descent shall begin; for, in this case, A's descent will always commence too late; the proper method is to attend to the beats of the pendulum, until an exact idea of their succession is obtained: then the extremity of the rod being withdrawn from the bottom of the box, A, directly downwards at the instant of any beat, the descent will commence at the same instant.

Having now sufficiently explained the instrument, we shall proceed to the construction of some experiments with it.

Let two equal weights, A and B, be suspended by a line, joining them, and going over a fixed pulley. *If any weight* *be added to them, it will preponderate, and in its descent will describe spaces which are as the squares of the times of falling from rest.*

The equal weights are, in the present case, each equal 26 *m*, and the additional weight applied as a force to communicate motion *m*. Then the mass moved is $m + 52\,m +$ the inertia of the wheels 11 *m*, making in all 64 *m*. Now it will be seen, that the preponderating weight descending from quiescence during 1, 2, 3, seconds, describes in the first second, 3 inches; in two seconds, 3×4 or 12 inches; in three seconds 3×9 or 27 inches; the spaces being respectively as the squares of the time of motion.

To prove this, fix the stage to 3 on the graduated scale, bring the under surface of the piece, A, to coincide with *o*, on the scale, and let it fall at a beat of the pendulum, and you will find it strike the stage when the pendulum beats again; it has done so, having passed through three inches in one second. We shall now place the stage at 12 inches, and the weight will strike it exactly at the second second; when placed at 27, the stroke of the weight will coincide with the third second.

We subjoin a table of some experiments of the same kind, which will rivet the theory more perfectly on the mind, and render it more easy of application to particular cases. Let A hold 36.3-4 *m*; B, 36.1-4 *m*. The spaces described, &c. will be as in the following table.

A TABLE.

Moving force.	Mass moved.	Accelerating force.	Times of motion in seconds.	Spaces described from rest estimated in inches.
			1	1
			2	4
			3	9
$\frac{1}{2}$m	96 m	$\frac{1}{192}$	4	16
			5	25
			6	36
			7	49
			8	64

If different forces be successively applied to accelerate equal quantities of matter from quiescence, the spaces described in any given time will be in the same proportion with the forces.

If any body, equal to 64 *m*, fall freely, or be acted upon by its own natural weight, it will describe 192 inches in the first second of its fall; but if the same mass be impelled by only $\frac{1}{64}$ of its accelerating force, or 1 *m*, it will describe only a 64th part of the former space; that is, only three inches, a proportional effect.

To prove this, let A and B be each made equal to 25 *m*, then will A and B be equal to 50 *m;* to this add 11 for the inertia of the wheels, and we have 61 *m;* now put 2 *m* on A, and 1 *m* on B, and the mass moved will be 64 *m*, and the moving force 1 *m*.

Set the stage to three inches, and let the weight descend as before, and you will find it strike the stage at the first second.

If the same force impel different quantities of matter for any given time, the spaces described from rest will be inversely as the quantities of matter moved.

Let the force be *m*, and the mass 64 *m*, then the space described, during one second, will be three inches.

Let the force be *m*, and the mass 32 *m*, then the space described in the same time will be six inches.

If the force be increased or diminished in the same proportion with the mass moved, the spaces described from rest in the same time, will be equal.

Let *m*, 2 *m*, and 4 *m*, be the moving forces which impel the quantities of 32 *m*, 64 *m*, 128 *m*, respectively; then *m* will impel 32 *m* through six inches in a second, 2 *m* will impel 64 *m*, and 4 *m* will impel 128 *m* through the same space in the same time.

From hence you may infer, that when different quantities of matter describe equal spaces in equal times, being accelerated from quiescence, the forces must be in the same proportion with the quantity of matter moved.

If a body be moved from quiescence during any given time, it will, at the end of that time, have acquired such a velocity, as will, if continued uniform, carry it through double the space which the body has already described to acquire that velocity.

Let the mass moved be 64 *m*, the force, *m*, but let *m*, which is applied to A, as the moving force, be one of the flat rods, *m*, Fig. 176. Place the circular frame so that A may, in descending, pass through it, and its height be such, that the instant the lower surface of A arrives at 12 inches, the rod, *m*, may be intercepted by the surface of the circular frame, and thereby be prevented from the further acceleration of the system. Let the other stage be set at 36 inches, that is, 24 from the circular frame.

Now, let the weight begin to descend from *o*, on the scale at any beat of the pendulum; at the end of the second beat, you will hear the rod strike the circular frame, having described twelve inches with a uniformly accelerated motion; and at the fourth beat of the pendulum, it will strike against the square stage at 36, having described 24 inches with a uniform motion.

If the same force act on the same mass for different times, one second, two seconds, and three seconds, the velocities generated will then be six inches, 6×2 *inches, and* 6×3 *inches in a second respectively, being in the same proportion with the times wherein the given force acts.*

Set the circular frame to three inches, and the stage to nine inches, let the mass moved be 64 *m*, the moving force, *m*; the weight, A, beginning its descent at any beat of the pendulum, the rod will strike the circular frame at the next beat: here the rod is removed, and A describes the next six inches uniformly in one second, striking the stage at nine at the second beat. By trying the apparatus in other instances, you will constantly find the experiments coinciding with theory.

These experiments show, that if the force by which bodies are accelerated be the same, the velocities generated will be in the same proportion as the times wherein the given force acts.

If a body be moved from rest through the same space by different forces, the velocities generated will be in a subduplicate ratio of the forces.

Let the mass be 64 *m*, and the force *m*,—you will find the velocity acquired in describing twelve inches in two seconds, will, when the force is removed, carry it through twelve inches in one second. Now, let the mass be 64 *m*, and the force 4 *m*, and you will find that the body, in describing twelve inches, will acquire a velocity of twenty-four inches, being in the ratio of 1 to 2; whereas the accelerating forces are in the ratio of 1 to 4.

If different quantities of matter be impelled through the same space, and acquire the same velocity, the moving forces must be in the same ratio as the quantities of matter moved.

Let the quantities of matter be 64 *m* and 48 *m*, the space twelve inches,—the moving forces must be as 4 to 3. The following experiments will illustrate this truth.

Moving forces.	Quantities of matter.	Accelerating forces.	Spaces described in inches.	Velocities acquired in inches per second.
m	64 m	$\frac{1}{64}$	12	12
$\frac{3m}{2}$	96 m	$\frac{1}{64}$	12	12
$\frac{3m}{4}$	48 m	$\frac{1}{64}$	12	12

You may infer, from the two last sets of experiments, that the moving forces, which impel bodies through the same spaces, are in the joint ratios of the quantities of matter moved, and the squares of the velocities generated.

If a given quantity of matter be impelled from rest through different spaces by the action of the same force, the velocities generated will be in a subduplicate ratio of the spaces described.

Let the quantity of matter be 64 *m*, the force *m*, the spaces 3 inches and 27 inches,—the velocities will be in the ratio of 1 to 3; for it will descend in the first experiment through six inches in a second; in the next you will find it go through 18 inches in a second. Now the spaces are 3 and 27, or as 1 to 9; the velocities acquired as 6 to 18, or as 1 to 3.

Experiments on uniformly retarded Motion.—The laws observed during the motion of uniformly accelerated bodies, having been made evident to the senses by the preceding experiments, I shall now proceed to illustrate the properties of uniformly retarded motion.

When a body is thrown perpendicularly upwards from the earth's surface, it is continually resisted by a force which is equal to the body's weight; and the weights of all substances being proportional to the quantity of matter they contain, it follows, that the force which retards the perpendicular ascent of any body, being measured by its weight divided by the ascending mass, is the same, being such as destroys a velocity of $32\frac{1}{6}$ feet in each second of the body's motion. But in order to illustrate, by experiment, the general laws according to which bodies are retarded by the action of constant forces, such methods should be made use of as will enable us to apply different resisting forces to the same mass of matter, and the same resisting force to different masses of matter, both of which conditions will be satisfied by the instrument now before you.

A resisting force is to be understood as conveying precisely the same idea as the term moving force; except so far as regards the directions in which those forces act in respect to the body's motion, these directions being contrary to each other.

If equal quantities of matter be projected in free space, with any given velocity, and be resisted by different but invariable forces, the spaces described before the whole motion is destroyed, will be inversely as the resisting forces.

Let the mass projected be 61 *m*, with a velocity of 18 inches in a second, and let it be resisted successively by the forces *m*, 2 *m*, 3 *m*; the spaces described before the motion of the body is destroyed will be $\frac{1}{5\cdot6}$ $\frac{2}{25\cdot6}$ $\frac{3}{25\cdot6}$; these spaces being in the inverse proportion of the resisting forces.

Make A equal 24 *m*, B equal $25\frac{1}{2}$ *m*; apply to the upper surface of A two rods, each equal to *m*; then will the weight, A, preponderate and descend by the action of a moving force equal *m*, the whole mass moved being equal to 63 *m*. Set the circular frame to 26.44; then the weight, A, by describing from rest the space 26.44 inches, will acquire a velocity $= \sqrt{\left(\frac{4 + 193. + 26.44}{63}\right)}$ equal to 18 inches in a second; and at that instant the two rods, each equal to *m*, being removed, the weight will continue to descend with a uniformly retarded motion, which will be precisely the same as if a mass of 61 *m* were projected with a velocity of 18 inches in a second, in free space, and a force of resistance equal to *m* were opposed to its motion; wherefore A, with the other parts of the system, will lose its motion gradually, and will describe a space equal to $\frac{18^2 \times 61}{4 \times 193} = 25.6$ inches before its motion be entirely destroyed. You will, therefore, have to descend as low as 52 inches, before it begins to ascend by the superior weight of B.

If any body, moving in a free space uniformly, be resisted by a constant force, for any given time less than that in which the whole motion would be destroyed, the space described will be the difference between the space which measures the initial velocity of motion, multiplied into a number expressing the given time, and that space which the body would describe, if accelerated, during the given time, from quiescence, by a force equal to that of resistance.

Let a mass, $63\frac{1}{2}\,m$, be projected with a velocity of 11.877 inches in a second; if it be resisted by a force equal to $\frac{1}{2}\,m$, it will describe 21.95 inches in three seconds. To this end, make A equal 26 m, and B equal $26\frac{1}{2}\,m$, and apply a flat rod, $1\frac{1}{2}\,m$, to the upper surface of A; set the circular frame to 11.877 on the scale, then will A descend, the moving force being m, and the mass moved equal to 65 m. When it has described 11.877 inches, it will have acquired a velocity of 11.877 inches in a second; and the rod being at that time intercepted, A will begin to descend with a uniformly retarded motion, and will strike the square stage set at 33.83, at the fifth beat of the pendulum, and thus describe 21.95 inches in three seconds.

For the account of various other useful and scientific experiments, the reader had best consult the treatise of Mr. Atwood.

This instrument has many other uses, which it is not necessary to describe particularly here; such as, The experimental estimation of the velocities communicated by the impact of bodies, elastic and non-elastic; The quantities of resistance opposed by fluids, as well as for various other purposes; The motion of bodies, resisted by constant forces, are reduced to experiment, by means of this instrument, with as great ease and precision as the properties of bodies uniformly accelerated; and, The verifying practically the properties of rotary motion. The two last are clearly shown in Mr. Atwood's work. This very useful and illustrative instrument requires to be well made, and nicely adjusted.

The wheels and their mahogany bases can be separated from their stand, and the various weights and other apparatus, the scales, C, C: the ring, H; the stage, D; the pillar, G; and clock, E, are also made so as to be separated and packed in a portable and convenient manner.

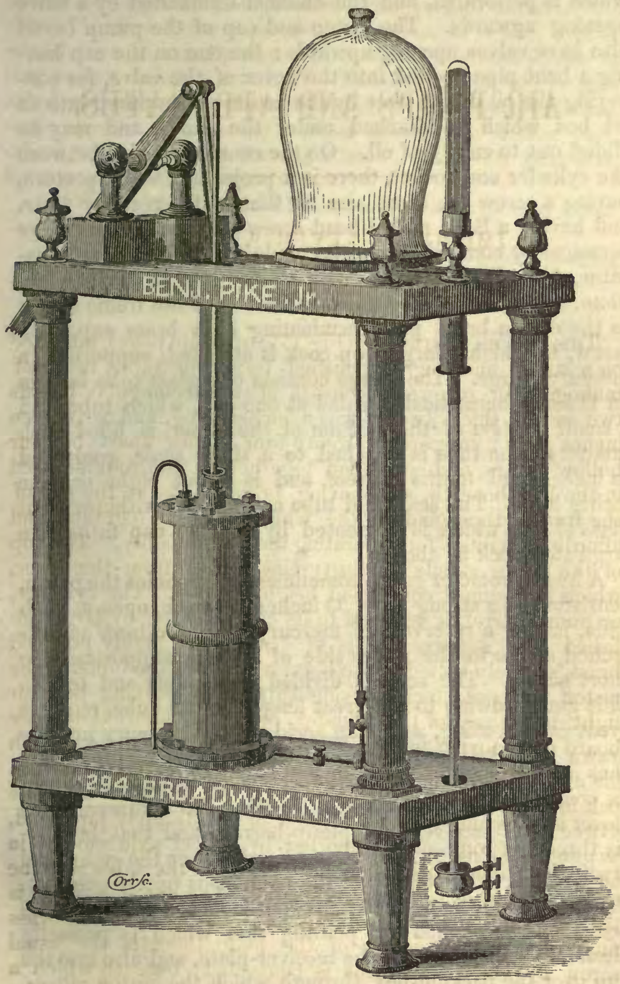
Price, with clock, $100.

AIR PUMPS AND APPARATUS.

IMPROVED LEVER AIR PUMP.

This elegant instrument (Fig.177, opposite page), mounted on a strong and highly polished frame, or table, made of mahogany or rosewood, consists of two rectangular boards two inches thick, twenty-seven inches long, and seventeen inches wide; supported twenty-four inches apart by four hollow pillars, and connected together by iron rods secured in the legs beneath, and having brass knobs at the top of the frame; thus binding the whole strongly together, and affording facilities for separating the parts readily. The top of the frame stands at thirty-nine inches from the floor, which is the most convenient height for use. The cylinder, or pump barrel, is screwed to its cap and base by large polished steel screws, and is of heavy and highly polished brass, securely bolted to the bottom board of the table. The piston rod is of steel, working through a packing box, air tight, in the cap of the cylinder, projecting above the upper board and moving in a socket attached to the frame, which has a square opening for this and the parallel motion, which is connected with the piston rod and end of the lever. The lever is of wrought iron, polished or handsomely japanned, is three feet long, and supported by a steel axle moving in two stout brass sockets, firmly bolted to the table; at the end of the lever is a turned handle. The receiver plate is truly ground, and made of brass, or stout glass set in brass mounting; in the centre of the plate there is the usual screw by which apparatus is connected; beneath which a brass connecting pipe having a stop-cock, passes to the bottom board of the table, where it is terminated in a socket, having a pipe running lengthwise with the bottom board of

Fig. 177.

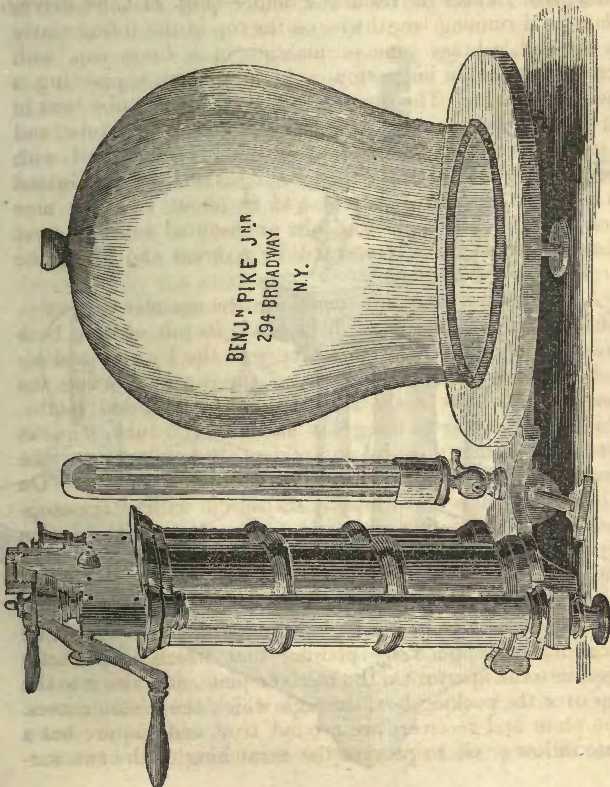


the table, and connecting with the base of the pump barrel, which is perforated, and the channel terminated by a valve opening upwards. The piston and cap of the pump barrel also have valves opening upwards; the one on the cap having a bent pipe ground into the cover of the valve, for conveying the oil driven over by the action of the pump into an oil box which is attached under the frame, and may be slided out to empty of oil. On the connecting pipe between the cylinder and socket, there is a projection, with aperture, having a screw the same size as that of the receiver plate, and having a large milled-head screw to close it, and where occasionally connexion may be made with the gauge, apparatus, &c. There is from the under part of the receiver plate, and running lengthwise on the top of the frame nearly to the end, a brass pipe terminating in a brass cap, with screw, to which a large stop-cock is attached, supporting a mercury gauge. The gauge consists of a glass tube bent in an U form, hermetically sealed at one end, which tube, and a small portion of the bottom of the other, is filled with mercury; the tube is attached to a silver scale, graduated to inches, and tenths thereof, and is about eight or nine inches long. The scale and tube are secured within a stout glass shade, which is cemented by a brass cap fitting the large stop-cock as above.

A long barometer gauge sometimes accompanies the pump, consisting of a strong tube, 33 inches in length, open at both ends, having a reservoir of mercury at the bottom, and attached above to the under side of the cap supporting the short gauge. The scale is divided into inches and tenths. This gauge, owing to the great length of the tube, requires great care in using, as, by an accident, the mercury may be drawn into the pump, materially injuring it thereby. On this account it is most usually dispensed with. The stop-cock in the connecting pipe is to close the communication between the receiver and pump-barrels, and that beneath the gauge, to close the communication between the gauge and the receiver. The length of the cylinder is nearly one foot, the diameter $3\frac{1}{4}$ inches, the plate 10 inches. Oil should be occasionally supplied by pouring that which is perfectly clean into the aperture in the receiver-plate, and also into the cup over the packing-box, through which the piston moves. The plate and receivers are ground true, and require but a little tallow or oil to prevent the scratching of the two surfaces. In experiments requiring accurate exhaustion, care should be taken that the receiver and various parts of the pump be free from moisture, the vapor of which arising would form an atmosphere, which would continue to rise as long as any moisture remained. The operator should be provided with a number of receivers, of various kinds and sizes, some open at top, having a brass plate with sliding rod; others with closed top, having a knob; also a few glass jars, for supporting fruit, &c.

Price, $70, $75, and $85, according to style and finish.

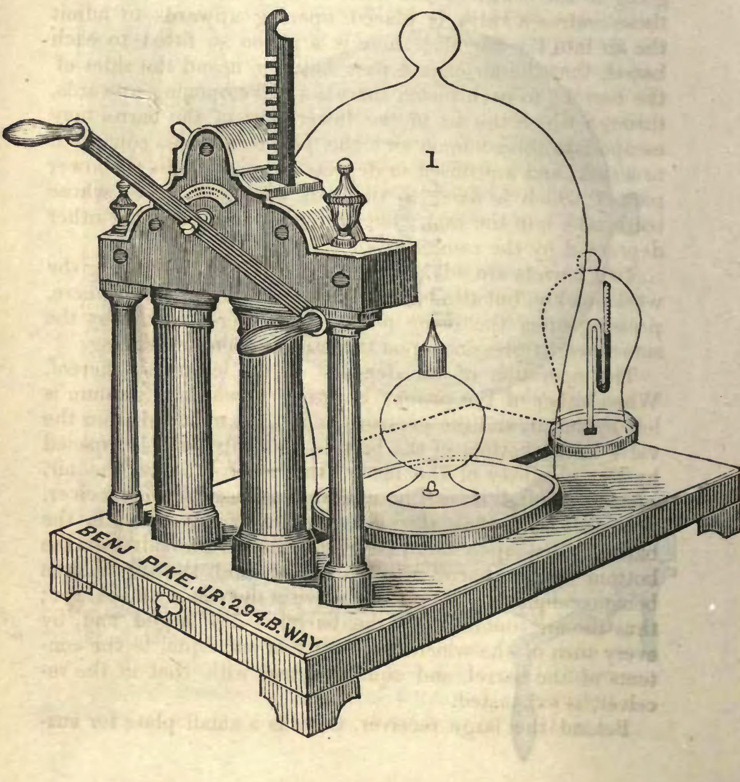
French Table Air Pump.—(Fig. 178, as below.)—This



instrument in its general arrangement is the same as the usual table air pump, but made in a more elegant style, being framed wholly of brass and highly finished. Between the pump barrels and the receiver plate, there is a large stop-cock, which, when closed, prevents any leakage from the various joints into the receiver. The mercurial gauge has a metallic scale, and is placed within a glass shade, and supported on a large stop-cock, by which communication or not may be made with the receiver.

Price, largest size, $75.00.
" smaller " $50.00.

Large Double Barrel Air Pump.—(Fig. 179, as below),



represents the usual style of the large size, double barrel, table air pump, and consists of two barrels of brass, accurately bored, and finished of a uniform calibre. These, with their bases, are firmly held in a perpendicular situation to the square mahogany base, by the mahogany head of the air pump, which is pressed upon them by screws at the top of the two brass pillars, one of which is placed each side of the barrels. In the centre of the base there is a true ground receiver plate, having in the centre a hole, with screw, for the attaching of any apparatus, and a concealed channel communicating with the point, where a screw is fixed to let in air occasionally. From the above mentioned channel there is a perforation at right angles to the former, going to the centre of the basis of each barrel; at each of these centres a valve is placed, opening upwards to admit the air into the barrels; there is a piston so fitted to each barrel, that the air cannot pass between it and the sides of the barrel; to each piston there is a valve opening upwards, through which the air in the lower part of the barrel may escape into the common air; the pistons are also connected to a rack, and are raised or depressed by a handle, the lower part of which is fixed to the axis of a cog-wheel, whose teeth take into the rack; one piston is raised, and the other depressed by the same turn of the handle.

Two barrels are advantageous, not only as performing the work quickly, but also because the weight of the atmosphere, pressing upon the rising piston, is counter-balanced by the same weight pressing upon the other piston descending.

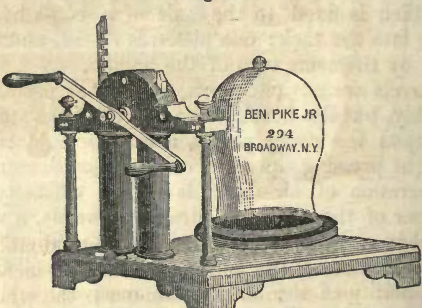
The operation of air depends on the elasticity thereof. When either of the pistons is drawn upwards, a vacuum is left behind it, and the pressure being thus removed from the valve in the bottom of the barrels, this valve will be opened by the elasticity of the air in the receiver; and the air, rushing through it, will be uniformly diffused in the receiver, the canal connecting this with the lower valve, and in the barrel. But upon depressing the piston, the valve at the bottom of the barrel will be closed, and the air therein being condensed, will open the valve in the piston and escape; thus the air contained in the barrel is discharged, and, by every turn of the winch, a quantity of air equal to the contents of the barrel, and equally dense with that in the receiver, is exhausted.

Behind the large receiver, there is a small plate for sustaining a small receiver, from the hole at the centre of this plate there is a canal communicating with that which goes from the large receiver to the barrels; under this receiver is a small tube filled with mercury freed from air, this is called the short barometer-gauge. As the air is taken out of the small receiver at the same time that it is taken from the larger one, the descent of the mercury in the tube will point out the degree of rarefaction in the receivers; the mercury does not begin to descend in this tube till near three-fourths of the air have been extracted; and the air is said to be as many times rarer than the atmosphere, as the column of mercury sustained in this tube is less than that of the mercury, at that time, in the common barometer.

Price, $40.00 and $45.00.

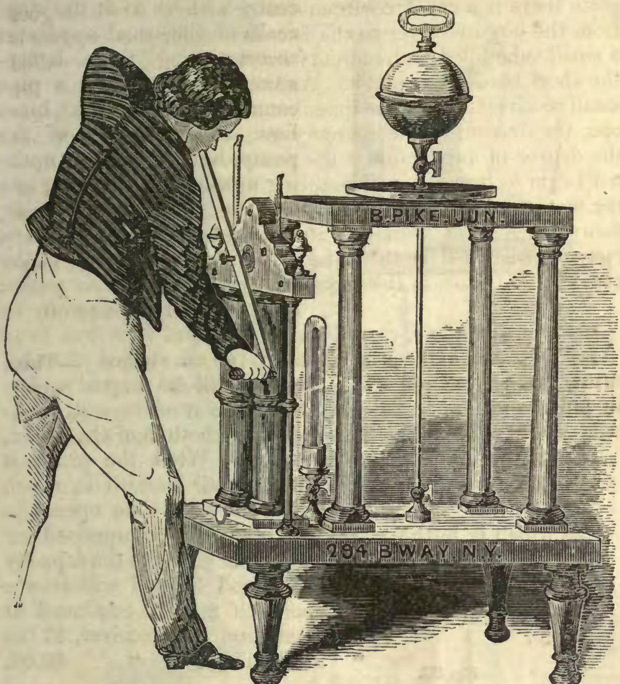
Double Barrel Air Pump.—(Fig. 180, as below.)—This cut is a representation of the usual style of the double barrel air pump described, with the omission of the gauge, and being made of a smaller size. Price, $22.50 and $25.00.

Fig. 180.



Pike's Improved Double Barrel Air Pump.—(Fig. 181, page 195.)—This instrument, in its general construction, corresponds to the preceding one described (Fig. 179), but of a larger and more elegant finish, the frame being substantially and elegantly finished, of rosewood or mahogany highly polished, conveniently mounted from the floor on four feet, and having the plate raised on a stage supported on four pillars, beneath which the gauge is attached, which is the same as described in the large lever pumps; the

Fig. 181.

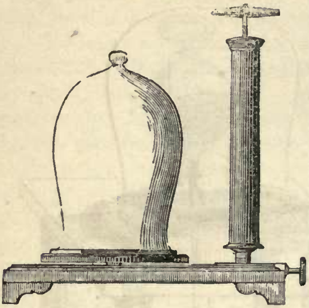


pump is conveniently worked by a large double lever handle; the barrels of the pump are thirteen inches long, two and a half inches internal diameter; the whole with the receiver standing about four feet from the floor.

Price, with mahogany frame, $65.00.
" " rosewood " $70.00.

Single Barrel Air Pump.—(Fig. 182, next page.)—This pump consists of a tube, or barrel of brass with equal bore, having a piston moving by means of a rod and handle; the barrel is attached to its base by a screw, which is firmly clamped to the square mahogany table supporting the whole; in the centre of the table there is a receiver plate,

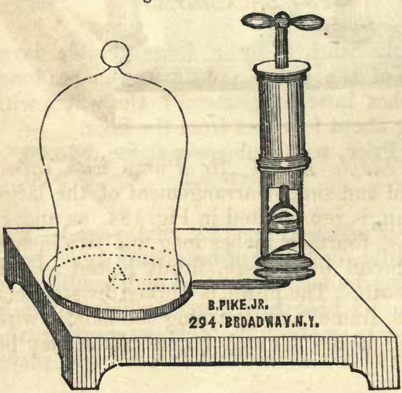
Fig. 182.



truly ground, having in the centre a screw to fit the stop-cocks of the usual apparatus accompanying these instruments, and beneath a pipe connecting with the brass base of the barrel of the pump, having a valve opening upwards, there being one also in the piston opening the same way; the action is the same as described in the large double barrel air pump. Suppose the receiver to be placed on the plate, care being taken that it is free from dust and grit, and a small quantity of oil rubbed thereon, draw the handle up, and a vacuum will be formed underneath the piston. The air then in the receiver will, by its elasticity, force against the valve at the bottom of the barrel, and rush up to fill the vacant space. When the piston is forced down again, it compresses the air beneath it, which closes the valve at bottom, and at the same time opens the valve which is in the piston itself. and the compressed air thereby escapes; thus a quantity of air equal to the capacity of the barrel is got rid of—a second lift will withdraw a second portion, and so the operation may be continued at pleasure. Price, small size, with receiver, $7.00.

" medium size, " $9.00.

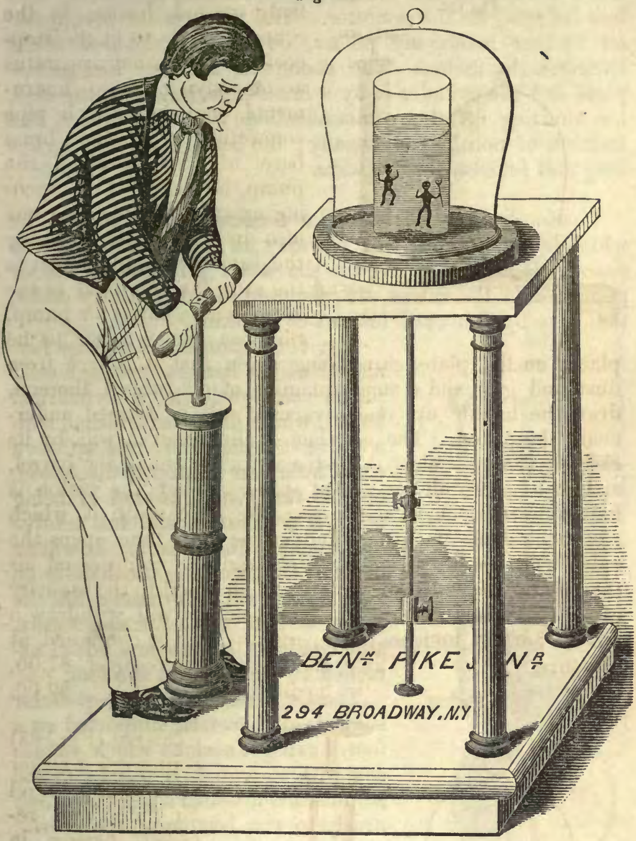
Fig. 183.



This cut (Fig.183) represents a larger size single barrel air pump and receiver, having in the drawing the barrel cut away, to show the piston and valves; the construction is the same as the one above described.

Price, with receiver, $12.

Fig. 184.



Pike's Improved Single Barrel Air Pump with raised plate.—This powerful and simple arrangement of the large single barrel air pump, is represented in Fig. 184, as above. The barrel is of brass, fourteen inches long and two inches diameter, having a broad brass base, firmly bolted to the frame by screws beneath. The piston is worked by standing with the feet on the frame and grasping the handle with both hands, by which means a much larger piston may be worked than in the ordinary construction, and being also less fatiguing to the operator. The pump plate is supported by four mahogany pillars, on a table elevated about twenty-eight inches. The connexion between the pump-plate and the cylinder is by a brass pipe, having a stop-cock for shutting off the communication when required. The frame is of polished mahogany; the base twenty-two inches long and fourteen inches wide. Price, $20.00.

Condensing Apparatus.—The condenser is a syringe by which a large quantity of air may be forced into a given space. It is constructed on the same principle as the air pump; only the valves are disposed in the contrary order, that is to open inward instead of outward.

Fig. 185.

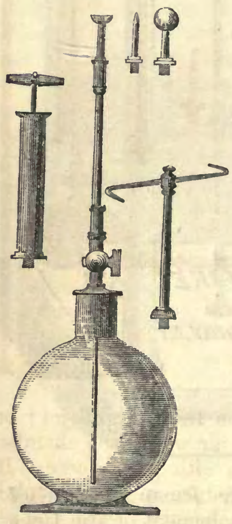
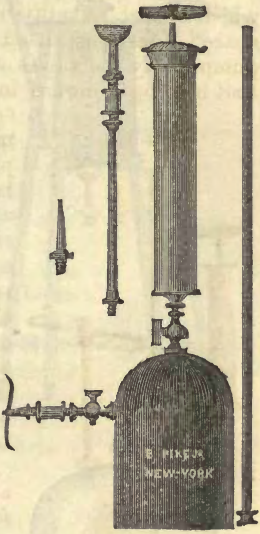


Fig. 185 represents a syringe furnished with a handle, moving a solid piston air-tightly in a cylindrical barrel, which barrel is furnished with a valve at the foot, and either a small hole near the top of the barrel, or else the piston, instead of being solid, is perforated, and has a valve also opening downwards. It will be evident, that working the handle up and down will alternately fill the barrel with air from the upper part, and condense it into any vessel attached to the screw at the foot.

The air vessel is a strong globular shaped glass vessel, supported on a foot, having a neck to which a brass cap with stop-cock is fitted; to the stop-cock is fastened a pipe, reaching nearly to the bottom of the vessel; to the upper screw of the stop-cock is attached a tube, and a variety of jets; one a plain jet, one a globular jet, pierced with many holes, another flat on top pierced with a cross; also, there is usually accompanying them, a revolving jet, as represented in the cut, which may be moved either for air or water. To use, the vessel is about half filled with water, and the condensing syringe being screwed to the tube, and the stop-cock opened, air is to be forced into the bottle, which rising through the water, will by its density press strongly on the surface of that liquid ; then after turning the stop-cock the syringe is to be removed, and a small jet-pipe being fitted to the tube, the stop-cock is to be opened, and the elasticity of the condensed air in the bottle, will drive up the liquid in a jet.

Price, $10.00.
" revolving jet, $2.00.

Fig. 186.



Air Condensing Apparatus, with Copper Chamber.—(Fig. 186.)—This condensing apparatus consists of a brass condensing pump or syringe, nine inches long, and one and a half inch diameter. A copper chamber or vessel for containing the air, having a stop-cock with screws on the top, with a tube descending nearly to the bottom, and also a stop-cock on the side near the top, there being a tube connected with this aperture descending nearly to the bottom. To the stop-cocks are attached several jets ; a straight jet, a compound jet, and a revolving jet. To use this apparatus fill the chamber about half full of water and screw on the stop-cock, connect the condensing pump, and condense the air therein, then turn the stop-cock to confine the air, and removing the pump, screw on the straight jet ; on turning the cock, the pressure of the air within the chamber will force the water out in a stream with great force. If the compound jet be used, it will produce a great number of streams, and pour out with great beauty. Also the revolving jet will form a pleasing circle in the air, as the water is rapidly forced out. All these jets may also be used on the stop-cock at the side of the chamber.

The long brass cylinder, or gun-barrel, represented in the cut, and having a screw fitting the stop-cocks, is designed to illustrate the air gun. To use, screw the barrel to the stop-cock attached to the side of the chamber, having previously condensed sufficient air therein, place a bullet, pea, or cork ball within the barrel, and quickly open the stopcock ; the ball will be thrown violently out of the barrel.

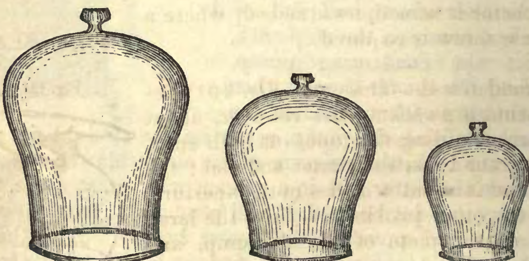
Price, of the whole apparatus, $12.00.
" condenser only, $5.00.
" smaller size, $4.00.

Fig. 187.

Lever Condenser on Frame.—In this instrument (Fig. 187), the barrel of the condenser is sunk into the air chamber, which is supported on the under side of the frame by four stout rods passing through the frame ; and also a round board at the bottom of the air chamber clamping them firmly together by means of screw nuts. The piston is worked by a lever and arm fastened to the frame ; on one side of the air chamber is a stop-cock.

Price, $20.00.

Fig. 188.



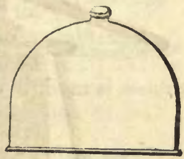
Swelled Receivers for the Air Pump.—(Fig. 188, as above.) —The receivers of the air pump are large glass vessels placed on the pump plate and over an orifice, in order to be exhausted of air ; being thus called from their being the recipients of those things on which the experiments are made.

In order that the contact with the plate of the pump may be air tight, the bottoms of the receivers are ground perfectly true. They are made of various shapes; straight sides and swelled, open top and with knob.

Price, 4 in. $0.75; 5 in. $1.00; 6 in. $1.25.
" 7 in. $1.50; 8 in. $1.75; 9 in. $2.00.
" 10 in. $2.50; 12 in. $4.00.

Low Receivers for the Air Pump.—(Fig. 189.)—These receivers are used where the articles placed under them do not occupy much height, and consequently can be exhausted quicker than where higher ones are used.

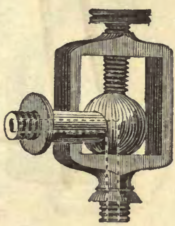
Fig. 189.



Price, 5 in. $0.75; 6 in. $1.00.
" 7 in. $1.37; 8 in. $1.75.

The Gallows Connector.—(Fig. 190.)—This convenient apparatus is used in connexion with the flexible tube, for connecting apparatus with the air pump that otherwise could not so conveniently be attached. The lower part of the ball has a socket entering the gallows, which, by loosening the screw over the ball, may be readily disconnected. The connexions are made with male screws; a double female connector is sometimes attached, where a female screw is required.

Fig. 190.



Price, $1.50.

Hand Glass.—This cut (Fig. 191) represents a swelled glass receiver, about 5 inches in diameter, open at both ends, and ground perfectly true and flat; the one end is about 4 inches in the aperture, and the other two inches. Set the large end on the plate of the air-pump, and place the hand on the small end, so as to cover the glass; then begin to exhaust, and you will feel the pressure of the air; for the air being taken from under your hand out of the glass, the external air will press your hand to the glass, so that you can scarce move it. Upon letting in the air it will be loosened again.

Fig. 191.

The spring of the air in your flesh is also shown by this experiment, the flesh of the inside of your hand swelling downwards within the exhausted glass. Price, 75 cents.

Fig. 192

The Bladder Glass.—Cover the large end of the last described receiver (Fig. 192) with a piece of wet bladder, and leave it to dry. After it is perfectly dry place the open end on the pump-plate, and exhaust the interior air till the weight of the air on the bladder causes it to burst with a loud report. If, instead of the bladder, a piece of sheet india rubber is used, it will expand and fill the glass vessel.

Price, 75 cents.

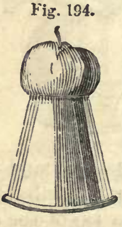
Fig. 193.

Bladder Glass with Cap and Stop-Cock.—(Fig. 193.)—This arrangement of the bladder glass when attached to a flexible tube, and connected with the air pump, admits of its being turned in any direction, and may be seen by a large audience to more advantage than when used on the pump plate. It may also be used to show the expansion of air, by closing the stop-cock, and placing under a receiver, when the bladder will be forced out, and if the exhaustion be continued, it will be broken by the expansive force of the air within the glass.

The experiment may be varied by using a piece of sheet india rubber, which will not be broken, but swell out, or be drawn in, as the instrument may be used.

Price, $2.00,

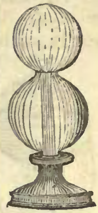
Fig. 194.



Apple Cutter.—(Fig. 194.)—This consists of a metallic cylinder, or cone, open at each end, having a base ground true, and fitting air tight the pump plate, and at its upper end a sharp edge. To use, place the cone on the air pump, an apple on the top of the cone, and exhaust the air; the pressure of the air on the outside of the apple will cause the apple to be cut, and forced through the opening.

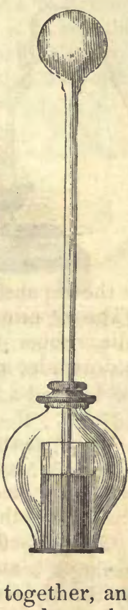
Price, $1.50.

Fig. 195.



Pressure Glass.—(Fig. 195.)—This instrument consists of a glass globe, about three and a half inches in diameter, with a neck inverted in a glass vessel of about the same size, which is to be nearly filled with water, and placed under the receiver of the air pump. As the receiver is exhausted, bubbles of air pass out of the globe through the water and escape away, but as soon as the pressure is restored the water is forced out of the lower vessel upwards into the globe. The instrument may now be used to illustrate the expansion of air, by again exhausting the receiver, when the small bubble of air left at the top of the last experiment, will expand and fill the whole globe. Price, 75cts, larger size, $1.00.

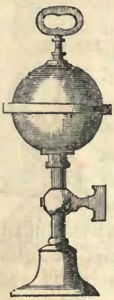
Fig. 196.



Bolt Head Experiment (Fig. 196) consists of a glass globe of four or five inches in diameter, with neck about thirty inches long, having cemented on the neck a plate fitting the open top air pump receiver. To use, the plate is set on the open top receiver with the end of the neck immersed in a jar of water, which, to render the experiment more conspicuous, is usually colored red or blue; on exhausting the air from the receiver, the air in the globe is expanded and escapes from the neck, and is seen bubbling through the water. On returning the air to the receiver, it cannot enter the globe, but pressing on the water forces it up the neck into the globe, occupying the place of the air that escaped by its expansion, and showing the quantity. Price, $1.00. Glass jar, 25c.

Magdeburg Hemisphere.—(Fig. 197, next page).—This instrument consists of two hollow hemispheres of brass, which are made to fit upon each other by a ground joint, rendered air tight by a little oil. Having screwed off the handle, put both the hemispheres together, and screw them into the pump-plate, and turn the cock so that the pipe may be open all the way into the cavity of the hemispheres; then exhaust the air out of them, and turn

Fig. 197.



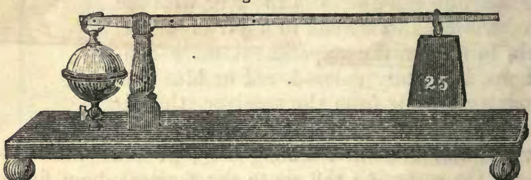
the cock; unscrew the hemispheres from the pump, and having put on the handle, let two strong men try to pull the hemispheres asunder by the rings, which they will find it difficult to do; for if the diameter of the hemispheres be four inches, they will be pressed together by the external air with a force equal to 190 pounds.

We have recently improved this article by manufacturing them of iron, which is not so liable as brass to be bent by an accidental blow.

Price, $3\frac{1}{2}$ in. brass, $4.00 ; $4\frac{1}{2}$ in. brass, $6.00.
" $3\frac{1}{2}$ in. iron, $4.00 ; $4\frac{1}{2}$ in. iron, $5.00.

Lever and Stand for weighing a column of air.—Fig. 198 consists of a strong base, having a short pillar serving as the fulcrum of a lever fixed therein; on the short end of the lever the handles of the hemispheres are supported, the stop-cock being screwed to the base. This arrangement is

Fig 198.



designed to prove the pressure of the air on the hemispheres to be about fifteen pounds on every square inch. If the diameter of the hemispheres be four inches, the area is twelve and a half inches, which multiplied by fifteen gives 187 lbs.; the power requisite to separate them when exhausted, as shown by the lever. The exhausted hemispheres will of themselves come asunder under an exhausted receiver.

Price, $5.00.

Spouting Tube.—Fig. 199 consists of a long glass tube, having a brass cup and stop-cock. To use, exhaust the air by the air-pump, and turn the stop-cock; then plunge the end of the cock in water, and open the cock, when the water will violently rush in, and nearly fill the tube.

Price, $2.50.

Fig. 199.

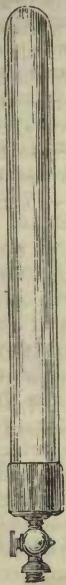


Fig. 200.

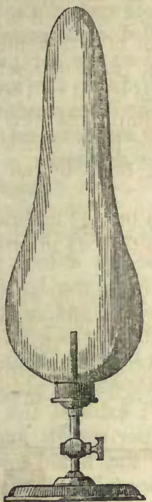


Fig. 201

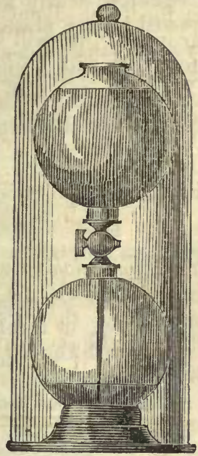
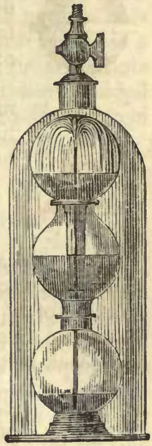


Fig. 202.



The Fountain in Vacuo.—(Fig. 200, as above.)—The fountain consists of a tall receiver, of glass, about five inches wide in the swell, but contracted at the top, and cemented by a neck at the lower end to a brass cap, having within a jet pipe attached to a stop-cock, which screws into the cap; the whole is mounted on a stand when not in use. To use, the fountain is connected with the air pump by means of the stop-cock and tube; after the air is exhausted out of the receiver, the cock is shut to prevent its return; then the whole is unscrewed from the plate of the receiver, and the lower end of the tube is immersed in a vessel of water; on opening the stop-cock, the pressure of the atmosphere on the surface of the water in the vessel having no counterpoise from the interior of the cylinder, forces up the fluid through the jet-pipe with considerable velocity, which forms a pleasing jet-d'eau, or fountain in vacuo.

Price, $4.50; larger, $5.00.

Expansion Fountain.—(Fig. 201, page 205.)—This apparatus consists of a glass globe with feet, having a cap, stop-cock, and jet, reaching down to the bottom, and an open vessel with cap screwed to the upper end of the cock. To use, the lower vessel is nearly filled with water, and the stop and jet screwed in and placed on the air pump under a receiver; as you exhaust the air from the receiver, the air in the upper part of the globe is expanded, and the liquid forced through the jet into the upper vessel: in returning the air to the receiver, the water descends.

Price, $3.50.

Three Globe Fountain, by Elasticity.—(Fig. 202, page 205.)—This consists of a double globe on a foot, with open end, having a jet pipe extending from the bottom of the lower globe to the top of the second, and another globe with a neck covering the jet pipe. To use, fill the lower globe nearly full of water, or a colored liquid, screw in the jet pipe, and cover it with the upper globe; place it on the air pump and cover with a receiver; exhaust the air, which removes the pressure from the upper vessels and expands the air in the lower globe, forcing the liquid up the pipe into the upper vessel, and from thence falling into the second. Return the air to the receiver, and the water is forced into the upper vessel, and from thence again into the lower one.

Price, $2.50.

Fig. 203.

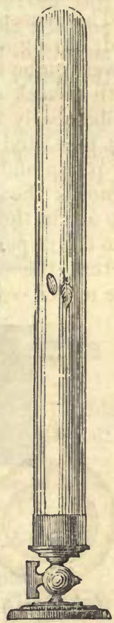
Lungs Glass.—(Fig. 203.)—An instrument or apparatus used with the air pump, intended to prove the elasticity of the air. It consists of a glass globe of about four inches diameter, with a foot to it, and also a brass cap at the top; within the glass is a small bladder, tied to a short tube, which is attached to the cap, and projects an inch or so within the glass. This tube passes out at the top, and is terminated by a small orifice. The lungs glass is placed under the receiver of the air pump, and as the air is exhausted the bladder collapses; being admitted it expands again, showing the exact action of the animal lungs in respiration. Price, $2.00.

Guinea and Feather Experiment.—(Fig. 204.)—This instrument consists of a tall glass receiver, open at the bottom, and having the top closed, so as to be air-tight, by a brass cap or cover, through which passes a wire, fitting close, but capable of being turned without admitting the air. The lower end of the wire is made to support a small stage, the two sides of which will fall and separate, when the wire is turned in a transverse direction. Then, the stage being fixed, a sovereign and a feather, or any two small bodies differing greatly in their comparative weight, may be laid on the stage, and the bell-glass, or, as it is called, receiver, being placed on the plate of an air pump, must be exhausted of the air it contained. This being done, if the two bodies are made to fall by turning the wire, it will be found that they will both strike the plate of the air pump beneath them at the same point of time.

Price, $10.00.

Fig. 204.

Fig. 205.



Guinea and Feather Tube.—This piece of apparatus (Fig. 205) consists of a strong glass tube, usually from 2 to 4 feet long, and $1\frac{1}{2}$ to 3 inches in diameter, closed at the upper end, and having a brass cap and stop-cock at the lower end, with a screw plug, of sufficient size for the introduction of a guinea and feather. To use, turn the tube up, and it will be observed that the feather is several seconds longer in falling than the guinea; connect the stop-cock with the air pump, and exhaust the tube, and it will now be found that the guinea and feather fall at the same instant. Air may also be condensed within the tube by a condensing pump, and a greater difference shown than in the first experiment.

The apparatus described as the aurora tube is often used for showing these experiments, though the ball and the point, at times, interfere with the descent of the feather, and piece of metal, which is not the case in the proper tube.

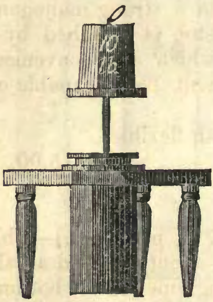
Price, $4 and $6.

Fig. 206.

Bladder and Weights.—A pneumatic instrument (Fig. 206) to show the elasticity of atmospheric air. It is formed of a circular base, hollowed out in the middle into a cup shape, having three stout brass wires connecting with the top, and between these wires, a movable box, the bottom of which is hollowed out as the base. A small bladder, with a small quantity of air in it, is placed in the cavity below the box, and the box filled with shot, or any heavy weight. The weights and cup slide easily up and down between the wires. When this instrument is put under the receiver of an air-pump, and the air exhausted from around it, the elasticity of the air within the bladder will expand it so much as to raise up the heavy weights above it, and thus show its rarefaction.

Price, $1.75 and $2.

Fig. 207.



Weight Lifter by the Expansion of Air.—Fig. 207 consists of a cylinder of brass, having a closed bottom, attached to a small frame by a flange at the top of the cylinder, within which a solid piston moves freely, to the rod of which there is a small stage, on which weights may be placed. When the piston rod is down, there is a space in the lower part of the barrel containing air, the expansion of which, when placed under a receiver and exhausted, will raise a heavy weight.

Price, $5.00.

The Improved Weight Lifter, or Upward Pressure Apparatus.—(Fig. 208, page 210.)—This apparatus consists of a very stout brass cylinder, having a stout flange at the top, set in a stand supported on three iron legs about thirty inches in height. The piston is accurately fitted to the bore of the tube, and a ring attached to the under side of the piston, from which weights are attached by a stout leather strap. The stop of the glass cylinder is ground perfectly flat, and has a brass plate also truly ground to cover it, having a hole in the centre with screw, to which one end of an elastic tube or hose is fixed; the other end of the tube being connected with the hole in the centre of the pump plate. The air being then exhausted from the tube, the piston with the weights will be raised the whole length of the cylinder. The number of pounds that can be raised, may be ascertained by multiplying the number of square inches contained in the area of the cylinder by fifteen. The iron legs unscrew for convenient transportation.

Price, with 3 inch cylinder, $6.00.
" " $3\frac{1}{2}$ " " $8.00.
" best flexible tube with screw connectors, $2.50 to $3.50.

Large Weight Lifter.—(Fig. 209, page 210.)—The construction of this instrument is nearly the same as the preceding, but of a larger make; the cylinder is twelve inches long and four inches wide, mounted on a strong mahogany frame over five feet high. To the piston is attached by a leather strap, a large platform, on which any convenient weight may be placed. The instrument being capable of raising over one hundred pounds.

Price, complete, with best English flexible tube, 3 feet long, - - $15.00.

Brass Barrel Weight Lifter.—(Fig. 210, page 210.)—This consists of a brass cylinder, or barrel, about two and a half inches in diameter, and eight inches long, open at the bottom, and screwed to a mahogany frame by a flange around the lower end of the cylinder, within which there is a solid piston, having a stout rod which is bent in the form of a hook at the end, to which a heavy weight may be attached; the upper end of the cylinder has a brass cap and stop-cock, to which a flexible tube, proceeding from the air pump, may be attached; on exhausting the air, it will be found, that the atmosphere pressing on the under side of the piston will raise it, and a weight of about fifty pounds.

Price, $7.50.

Fig. 208.

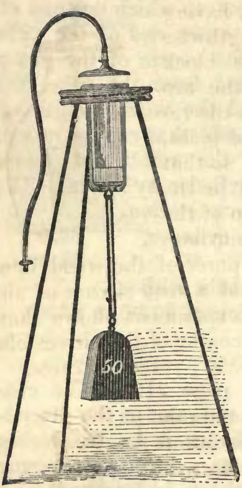


Fig. 210.

Fig. 209.

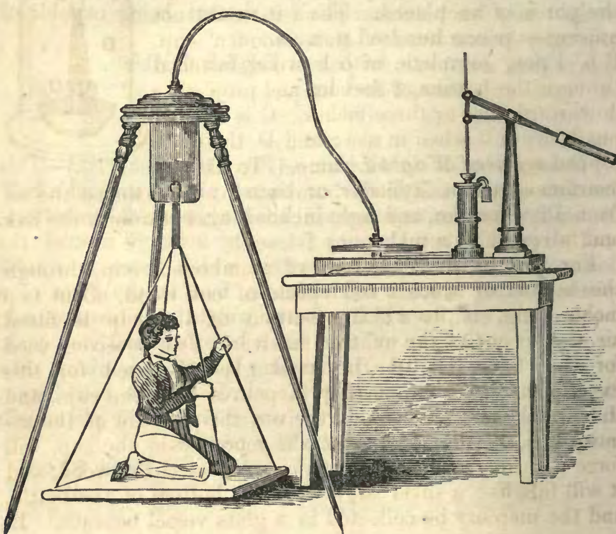
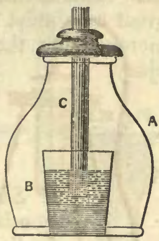
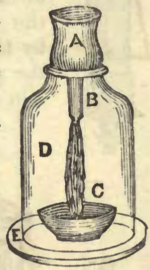


Fig. 211.



The Air Shower.—(Fig. 211.)—This apparatus consists of a block of wood, having a long piece of wood, C, fixed lengthwise through it, the under side of the block being turned perfectly true, to fit the top of a receiver, A. To use, place it in the receiver, A, which is also used as a hand glass, place a tumbler of water, B, under, so that the end of the wood is immersed in the water; place your thumb on the top of the wood, and while the receiver is exhausting, you will see the air pass out of the pores of the wood into the water. Take off your thumb, and a vast stream of air will flow through the wood. This experiment shows that wood is pervious to air, and that the course of the air vessels is lengthwise. Price, 75cts.; receiver, 75cts.

Fig. 21'.



Mercury Shower.—A pneumatic apparatus, to show that, if the pressure of the atmosphere be removed from an under surface, the pressure still remaining on the surface above has the effect of driving a fluid readily through the pores of such substance as it would not otherwise penetrate. A is a wooden cup. B is a plug or nozzle of oak wood fastened through the bottom of the cup and projecting downwards two or three inches. C is a vessel put beneath it when in use; and D the open topped receiver of an air pump. To use the instrument, put a little mercury into A, and exhaust the air from D, when the mercury will soon filter through the oak and fall into the cup C.

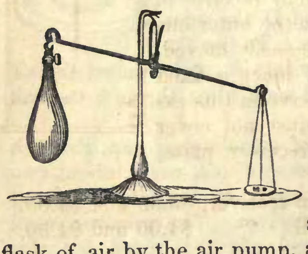
Fig. 212, as above, consists of a mahogany cup, through the bottom of which a solid piece of oak wood, about two inches long, is fixed; the bottom of the cup is fitted air tight on the top of the receiver. The receiver used for the hand, called the hand glass, is used for this experiment. When mercury is poured into the cup, and the air exhausted out of the receiver, the pressure of the atmosphere on the surface of the mercury in the cup, will force it through the pores of the solid piece of wood, and it will fall like a silver shower to the bottom of the bottle, and the mercury be collected in a glass vessel beneath. In this experiment, and in all others where mercury is used, great care must be taken to prevent the introduction of any mercury into the air pump, as it would cause considerable njury. Price, $1.00; receiver, 75cts.

Fig. 213.

Shower of Mercury Tube.—(Fig. 213.)—This consists of a glass tube, about one and a half inch in diameter, and from twelve to twenty-four inches long, with a cap and screw at one end, fitting the air pump on the inside, having a small glass tube with a hole at the side, for preventing the mercury being drawn into the pump, and at the top of the tube a hard wood cap, within which a piece of oak wood is supported, having a funnel or cap of hard wood screwing over it, into which the mercury is placed; on exhausting the tube by the air pump, the mercury will pass through the pores of the wood, and descend into the tube in a silver shower.

Price, $4.00 and $5.00.

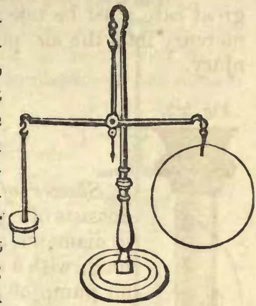
Fig. 214.



Flask for Weighing Air.—Fig. 214 consists of a glass flask or globe, having a cap and stop-cock fitting the air pump, supported by a hook to a scale beam. To use, first weigh the flask of air, as represented in the cut, by placing the requisite weights in the scale pan; then exhaust the flask of air by the air pump, and weigh it again in the same manner; the difference in the weights will give the weight of air, or gas taken out.

Price, flask with stop-cock, - - $2.00.
" mounted with steel beam and stand, $6.00.

Fig. 215.



Balance Beam and Cork Ball.—(Fig. 215.)—This consists of a balance, to one end of which is suspended a piece of lead, in equilibrio with a piece of cork, or other light material, at the other end of the beam. Place the beam and stand under a receiver, and having exhausted the air, the cork will preponderate; for, as its bulk is greater than that of the piece of lead, it must be more sustained by the air; re-admit the air, and the equilibrium will be restored. Price, $3.50.

Fig. 216.

Sliding Rod Receiver.—(Fig. 216.)—A receiver for the air pump of any convenient size or shape, having a brass cap cemented to the neck, and a rod passing air tight through a collar of leathers secured in a cavity, and covered with a screw; the rod has a ring or handle at the top, and a hook on the end within the receiver. One of the many experiments for which this receiver is used is the following: suspend a small receiver from the hook of this, and exhaust it of air; now let down the small receiver in contact with the plate. While the outer one is fixed, the inner one may be easily moved, but on letting in the air, the inner is fixed and the outer one loose; observe in this experiment the small receiver must not cover the hole in the centre of the receiver plate, but be placed at the side.

Price, with plain receiver, $3.50 and $4.00.
" with swell " $4.00 and $4.50.

The Bell Glass Receiver with Sliding Rod.—This piece of apparatus (Fig. 217, next page) consists of a swelled bell glass receiver, usually about 10 inches in diameter, having an opening in the top of 2½ to 3 inches in diameter, accurately ground to fit a brass plate of a little larger size, having a screw in the centre, into which a packing-box, with

Fig. 217.

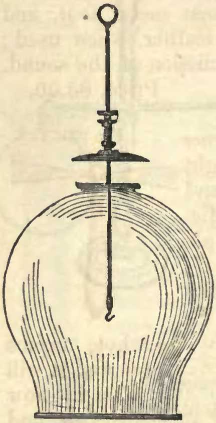


Fig. 218.

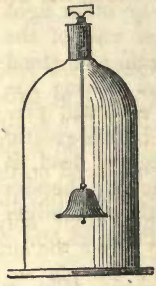
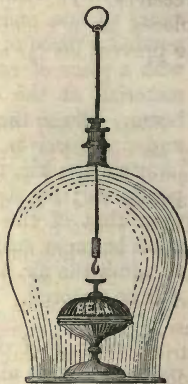


Fig. 219.



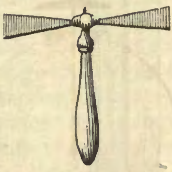
rod movable, though perfectly air-tight, may be fixed ; on the outer end of the rod there is a ring, serving as a handle for depressing the rod, and within a hook for suspending from. This, or a similar arrangement, is used with the improved bell, flint and steel, &c., and parts of this may be used for other experiments, the screws being made uniform in their size. Price, complete, $5.00.
" plate, with slide rod, $3.00.

Bell in Vacuo.—(Fig. 218, as above.)—This is an apparatus to show that sound is not propagated in vacuo, and thereby to prove that sound is but the air in vibration. It consists of a small bell mounted within a glass receiver, and supported from the top by a wire attached to a plug moving air tight in a socket, and having a handle above the cap, by which the bell may be rung ; when rung in a vacuum a great diminution of the sound will take place, and were it possible to produce a perfect vacuum, and insulate the bell from all sonorous bodies, no sound would be heard. Three sizes. Price $2.25, $2.50 and $3.00.

Improved Bell in Vacuo.—This form of the bell in vacuo (Fig. 219, as above) has a spring-lever hammer, working within the bell, and rung by depressing the rod having a cap on the top, by means of a sliding rod attached to the receiver. The bell is mounted on a neat metal foot, and placed on a round piece of wood, or leather, when used; to prevent, as far as possible, the transmission of the sound.

Price, $3.00.

Fig. 220.



Float Wheel for showing the resistance of the air.—Fig. 220 consists of two light metal floats, or vanes, fixed to a centre and turning freely on a pin fixed in a handle. These vanes may be so placed on the pin that their whole surface may strike the air; or, on the contrary way, that only the edge of the vanes may strike the air. To use, place the vanes on the pin so that the whole surface strikes the air, and give it motion with the finger, and it will soon stop, owing to the resistance of the air. Place it now in the position in which the edge only strikes the air, and give it motion, and it will be continued for several minutes.

Price, $0.75.

Torricellian Experiment.—(Fig. 221, next page.)—A stout barometer tube of thirty-one inches in length, hermetically sealed at the upper end; the lower end immersed in a cup of mercury; the whole covered by a tall bell glass receiver. On exhausting the air in the receiver, the air in the tube is expanded, and escapes through the mercury; on returning the air to the receiver, the mercury is supported in the tube to a height proportioned to the degree of exhaustion obtained therein. Price, with receiver, $5.00.

Torricellian Experiment with Sliding Tube.—(Fig. 222, next page.)—This drawing represents a more perfect arrangement for the Torricellian experiment. The tube is supported in the neck of a swelled bell glass receiver, having a brass cap with packing-box and screw, containing collars of leather through which the tube slides readily. To use, the tube is exhausted with the end out of the mercury, and then immersed by sliding down the tube through the collar of leathers; on returning the air to the receiver the mercury rises in the tube, showing the exact degree of exhaustion obtained. Price, $3.50 and $4.00.

Fig. 221.

Fig. 222.

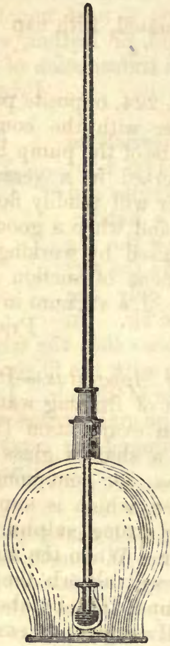
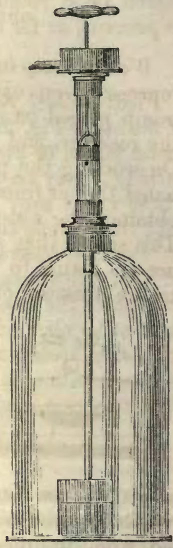


Fig. 223.

Fig. 224.



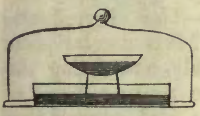
Torricellian Experiment with Flexible Tube.—(Fig. 223, as above.)—This apparatus consists of a stout barometer tube of forty inches in length, bent at one end as represented in the drawing, and having a stop-cock with flexible tube for connecting with the air pump. The barometer tube is graduated to thirty-one inches, marked on the glass. To use, the lower end of the tube is immersed in a cup of mercury, and the stop-cock connected with the air pump by a flexible tube; on exhausting the air the mercury will rise in the tube in proportion to the degree of exhaustion.

Experiments in the condensation of air, may also be illustrated by this apparatus; close the stop-cock, pour mercury in the long end of the tube, to the height of thirty inches above the surface of the mercury in the shorter leg. It will be found that the air in the shorter leg has been compressed into half its former bulk; being pressed by one additional atmosphere.

Price, of the tube, graduated, with cap and stop-cock, - - - $5.00.

Water Pump in Vacuo.—(Fig. 224, opposite page.)—This represents an open top receiver with the common water pump placed on the top; the tube of the pump being within the receiver, and the end immersed in a vessel of water. On working the piston the water will readily flow; but exhaust the air from the receiver, and when a good vacuum is obtained the water cannot be raised by working the pump. This shows that all the phenomena of suction and pumps are not owing to the abhorrence of a vacuum in nature, but to the pressure of the air. Price, $8.00.

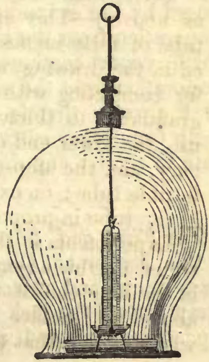
Fig. 225.



Freezing Apparatus.—Prof. Leslie's experiment of freezing water in vacuo, by its own evaporation (Fig. 225) is shown by a shallow glass vessel, as a watch-glass, for containing the water to be frozen, which is supported over a wide glass basin, containing strong sulphuric acid, the whole covered by a low receiver. When the air is exhausted from the receiver, the acid will absorb the vapor from the water as rapidly as it is found, thereby abstracting the sensible heat from the water, till congelation ensues.

Price, $1.50 and $2.00.

Fig. 226.



Freezing Apparatus with Thermometer.—(Fig. 226.)—The same apparatus as the last described, used under the receiver with sliding rod, in place of the low receiver, and having a delicate thermometer with exposed bulb dipping into the water, indicating the gradual reduction of temperature during the process.

Price, - - - $3.00.
" with slide rod receiver, $5.00 and $7.00.
" thermometer only, $1.00.

Fig. 227.

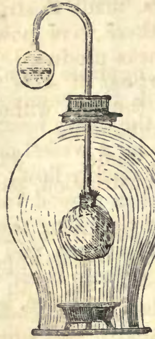
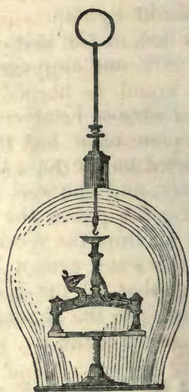


Fig. 228.



Wollaston's Chryophorus in Vacuo.—The chryophorus in this arrangement (Fig. 227, as above) has a circular piece of brass, truly ground on the under side, and fitting the open top receiver, and also having in the centre a block of wood, well varnished, to render air-tight and surrounding the tube of the chryophorous; by this contrivance one of the balls may be introduced within the receiver, and a vacuum obtained.

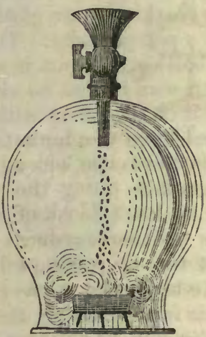
To use: cover the interior ball with a sponge, or cotton, which may be tied on, and wet it well with ether; turn all the water in the upper ball. On exhausting the receiver, the vapor in the interior ball of the chryophorus will be condensed by the evaporation of the ether, which will produce evaporation from the surface of the water in the upper ball, which vapor continues to condense, producing continual evaporation from the surface of the water in the upper ball, till the water therein is frozen. To prevent injury to the pump from ether entering therein, a cup is placed on the plate to receive any drops from the sponge.

Price, $5.00.

The Flint and Steel in Vacuo.—In the best construction of this instrument (Fig. 228) a gun lock is supported in a brass frame, and attached by a pillar to the centre of the pump plate; the lock has a brass arm terminated in a small cup at one end, and at the other fixed to the lever of the cock ; the whole is covered with the receiver having a sliding rod, and let off by depressing the rod on the cup. If the receiver be exhausted, and the flint be made to strike the steel, no sparks will appear ; and if there were powder in the pan it would be burned. The sparks produced by the flint and steel, are owing to small portions of steel struck off by the percussion, and burning in the air ; without the air the combustion of the steel cannot take place.

Price, with brass frame, $5.00.
" common construction, $3.00.

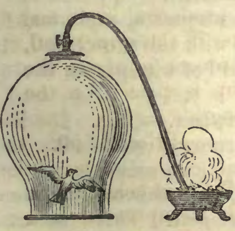
Fig. 229.



Apparatus to fire Gunpowder in Vacuo.—(Fig. 229.)—This apparatus consists of a bell glass, with brass cap, having a large stop-cock and funnel ; in the key of the stop-cock there is a cavity, into which a small quantity of powder falls ; on turning the key a little, the aperture is entirely closed, and when half round the powder falls on a round piece of iron, previously made red hot, and supported on a stand within the bell glass receiver. The powder will burn, but no explosion takes place ; the smoke remaining at the bottom. Caution is required in performing the experiment, and the bell glass should be exhausted after each charge is burnt.

Price, $4.50.

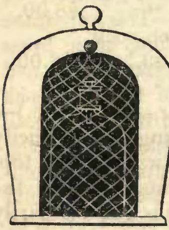
Fig. 230.



Apparatus for showing the effects of burnt air.—(Fig. 230.)—This apparatus consists of a glass receiver, with aperture in the top about three inches in diameter, truly ground, covered by a brass plate with stop-cock, to which a bent metallic tube is screwed. To use, place a pan of lighted charcoal so that the end of the tube may be in the flame ; first having exhausted the receiver, then open the stop-cock, and the burnt air will pass through the tube into the receiver, with which it may soon be filled. Take off the plate and pipe, and if any animal be let down into the receiver it will immediately be killed. If a candle be let down into the receiver when filled with the air, it will go out, but will purify the air as far as it goes; for you may let it down the second time lower than the first, and so on till the whole air is purified. The receiver and plate used with the slide rod apparatus before described, answer for this experiment by connecting the tube thereto.

Price of the whole apparatus, $6.00.
" bent tube only, - $1.50.

Fig. 231.

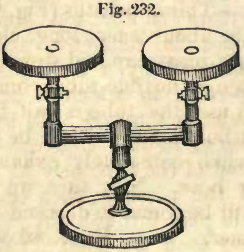


Bursting Squares, or Crushed Bottle.——(Fig. 231.)—These are thin square glass bottles, of about half a pint capacity. To use, take one of the bottles and put in a cork; then seal it with wax so that no air can escape; then set it on the pump with a receiver over it: and when you begin to exhaust, the air within the bottle will expand itself so as to break it.

Or, cement on the neck of the bottle a brass cap, with valve opening outwards; place under the receiver and exhaust the air, which will escape from the bottle also; return the air to the receiver, and the valve closes and prevents the air from entering the bottle, which is broken; the square sides not being strong enough to resist the pressure of the atmosphere. A wire guard is sometimes used to cover the bottle, and prevent the breaking of the receiver. When you have made this experiment, wipe the pump plate so that none of the glass remain, as it may spoil another experiment.

Price, glass squares, each, $0.16.
" cap with valve, each, $0.31.
" guard of wire gauze, $0.75.

Fig. 232.



Transferer.—(Fig. 232.)—An instrument used with the air pump, as a movable portion or plate, for numerous purposes of experiment. There are single transferers and double transferers; the latter of which is shown annexed. It consists of two plates, ground truly flat, and having pipes beneath, communicating with each other by connecting tubes, and a large pipe and cock below, which fits on to the table of the air pump. If a glass receiver be placed over each transferer plate, they may be exhausted of air, and the lower cock being turned, they may be removed from the air pump, and set aside, that the continued result of the experiment, whatever it may be, may be noted afterwards, and the air pump in the interim used for other purposes.

Price, large size, with two gallon receivers,						$15.00.
"	"	"	half	"	"	$12.00.
"	"	"	quart		"	$10.00.
"	"	"	pint		"	$8.00.
" single transferer plate, with stop-cock and stand,				-	-	$3.50 to $6.00

Fig. 233.

Fountain by Elasticity of Air.—(Fig. 233.)—A pneumatic apparatus, showing the elasticity of the air. It is a glass vessel with a brass top, and a tube within it, extending to near the bottom of the glass. When this glass is partly filled with water, and placed under a tall receiver of the air pump, the air being exhausted by the action of the pump, the elasticity of that air which remains within the vessel, drives the water through the tube, and makes it play into the receiver like a fountain. This action continues either until almost all the water is driven out, or else until the air has become so rarefied that it no longer has sufficient force to overcome the resistance.

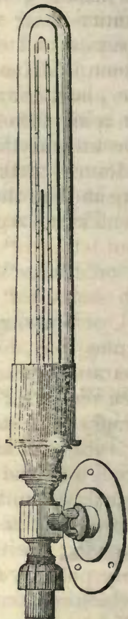
This apparatus should only be used with a transferer, as the water is liable to be drawn into the air pump, and the pump injured thereby. Price, $2.00.

Water Hammer with Stop-cock.—This apparatus (Fig. 234, next page) consists of a glass tube about 2 feet long, closed at one end, and the other having a brass cap and stop-cock, to which may be connected a hose or flexible tube, communicating with the air pump. To use, the tube is half filled with water and exhausted, when bubbles of air will be seen to rise with great rapidity; when completely exhausted turn the cock and unscrew the hose. Now turn up and down the tube, and the water will be found to descend with a force like the stroke of a hammer. Price, $2.50.

Fig. 234.

Fig. 235.

Fig. 236.



The Water Hammer.—(Fig. 235.)—This consists of a glass tube usually about twelve inches long and one inch in diameter, having three or four inches of water included in it, above which a vacuum has been formed, and then hermetically sealed. On shaking such a tube vertically, the water, rising a few inches and sinking suddenly to the bottom of the tube, produces a sound like that arising from the stroke of a small hammer on a hard body, whence the name of this instrument, the action of which depends entirely on the exclusion of the air, so that the water moves in a dense mass.

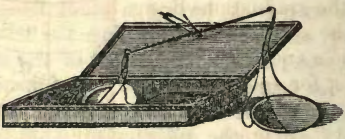
Price, 12 inch, $0.75 and	$1.00.
" 24 "	$1.50.

Pressure Gauge.—(Fig. 236.)—The pressure gauge is an instrument to determine the pressure exerted in hydrostatic or pneumatic machines, as the hydrostatic press, the air pump, steam engine, etc. When the pressure is very great, it is usual to measure it by the compression of a certain quantity of air contained in a tube of sufficient strength. It consists of a stout glass tube, the bore about one tenth of an inch in diameter, closed at one end, and bent up at the other, having a ball about twice the capacity of the tube, with a small hole on the side or top, and which is half filled with mercury; the tube is attached to a silvered plate, graduated to the various pressures, which are represented in pounds to the square inch; the scale and tube are inclosed in a stout glass shade, two inches in diameter, and about ten inches long, cemented to a brass cap, and screwing on a large stop-cock, having a stout flange at its side, with holes for screws for supporting the whole from the wall, or posts, etc.; at the lower end of the stop-cock is a coupling box, for connecting a pipe communicating with the apparatus or engine, the stop-cock closes the communication when required; under the ordinary pressure of the air the mercury will stand at O on the scale, near the bottom of the tube; under a greater pressure the mercury will be forced into the tube, and when occupying one half the original space, will indicate the additional pressure of our atmosphere, or fifteen pounds to the square inch; when occupying one third, a pressure of thirty pounds; one fifth, ninety pounds, etc. Price, $12.50.

Vacuum Gauge, or Indicator.—The arrangement of this instrument is the same as represented in Fig. 236, in regard to the exterior mounting, but having the tube entirely filled with mercury under the pressure of atmosphere, and on the removal of the pressure the mercury falls, and the approach to a vacuum is indicated by the scale, which is graduated to correspond to the common barometer; thirty inches being assumed as a vacuum. Price, $12.00.

HYDRAULICS AND HYDROSTATICS.

Fig. 327.



Scales and Weights.—Small scales and weights (Fig. 237) used for weighing in chemical experiments, packed in a small case; the weights ranging from half a grain to a quarter of an ounce. Price, - $1.25; fine quality, $2.50.
" larger scales, with stand, on mahogany box, with weights, &c. - $10.00

The Hydrometer.—(Fig. 238, next page.)—Hydrometers are instruments used by dealers in wines, spirits, acids, alkalies, syrups, and all commercial liquids, for ascertaining their comparative strength.

This instrument, as represented in the figure, consists of a hollow glass ball, B, with a smaller ball, C, appended to it, and which, from its superior weight, serves to keep the instrument in a vertical position, to whatever depth it may be immersed in a liquid. From the large ball rises a cylindrical stem, *a d*, on which are marked divisions into equal parts; and the depth to which the stem will sink in water, or any other liquid fixed on as the standard of specific gravity, being known, the depth to which it sinks in a liquid whose specific gravity is required, will indicate, by the scale, how much greater or less it is than that of the standard liquid.

Those most celebrated, are the scales of Baumé, Cartiér, Twaddell, and Guy Lussac. Most of these scales are arbitrary, and formed after the ideas of their projectors, but having no particular reference by which they may be understood.

Fig. 238.

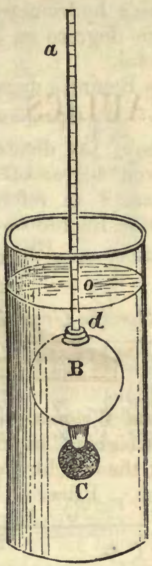
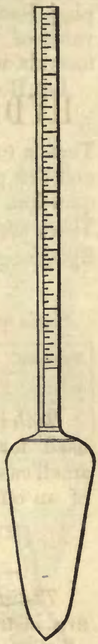


Fig. 239.



The centesimal hydrometer, by Guy Lussac, is an exception, the extreme points being water and absolute alcohol; this space is divided into one hundred parts, thus showing in alcoholic mixtures the percentage of alcohol in the liquid. They are made of glass, brass, and silver, usually from six to ten inches long, of the form represented in the cut (Fig. 239), the graduations being marked on the stem.

Price, Baumé's and Cartiér's, for spirits, in glass,	$0.50.
" " " " in brass,	$3.50.
" " " " in silver,	$5.50.
" " " acids, " "	$6.00.
" " " " in brass,	$4.00.
" " " " in glass,	$0.75.
" Twaddell's, " "	$1.50. / $1.75.
" Guy Lussac, " "	$1.00.
" " " in brass,	$6.00.
" " " in silver,	$9.00.

Table showing the Comparative Scales of Guy Lussac and Baumé, with the Specific Gravities and Proof, at the Temperature of 60 *Degrees.*

	Guy Lussac's Scale.	Baume's Scale.	Specific Gravity.	Proof.	
Per Centage of pure Alcohol.	100	45	796	100	Per Centage over proof.
	95	40	815	92	
	90	36	833	82	
	85	33	848	72	
	80	31	863	62	
	75	28	876	52	
	70	26	889	42	
	65	24	901	32	
	60	23	912	22	4th proof.
	55	21	923	12	
	50	19	933	0	Proof.
	45	18	942	8	Under proof.
	40	17	951	18	
	35	16	958	29	
	30	15	964	35	
	25	14	970	48	

Explanation of Baumé's Scale.—Manufacturers who employ Baumé's hydrometer, or have occasion to know the value of the degrees on his scale, may find the following formula useful.

Let B = Baumé's degree, and 100 = water. Then

$$\text{Specific gravity} = \frac{144}{144-B}$$

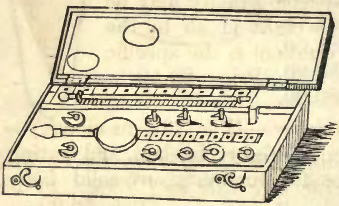
That is to say, 144 divided by the difference between 144 and the given degree of Baumé, is the specific gravity in question, stated in reference to water assumed = 100. Thus, suppose Baumé = 66°. Then,

$$\text{Specific gravity} = \frac{144}{144-66} \text{ or } \frac{144}{78} = 1.846 = \text{specific gravity.}$$

Scale of Specific Gravities indicated by Twaddell's Scale.

Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.	Twaddell.	Sp. Gr.
0	1000	50	1250	100	1500	150	1750
10	1050	60	1300	110	1550	160	1800
20	1100	70	1350	120	1600	170	1850
30	1150	80	1400	130	1650	180	1900
40	1200	90	1450	140	1700	190	1950

Fig. 240.

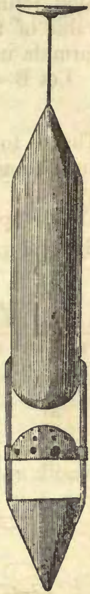


Hydrometer with Weights.—(Fig. 240.)—There is a variety of kinds of hydrometers, with weights; the principal ones are Dica's and Sike's, they are used for ascertaining the strength of spirituous liquors. One packed in a case is here represented, and is formed wholly of brass, and may be described as consisting of three parts; the scale, the ball, and the stem, which terminates in a small knob, intended to keep the instrument upright when in use. Upon this being put into a long glass, containing spirits of wine, etc., it will sink to a certain depth. If the spirit be very weak, it may not sink low enough to cover the ball, in which case one of the weights is placed above the knob of the lower stem. According to the weight used, and the degree to which the instrument sinks, reference being had also to the temperature of the fluid, the degree of strength is ascertained.

Price, $12 to $25.

Fig. 241.

Fig. 242.



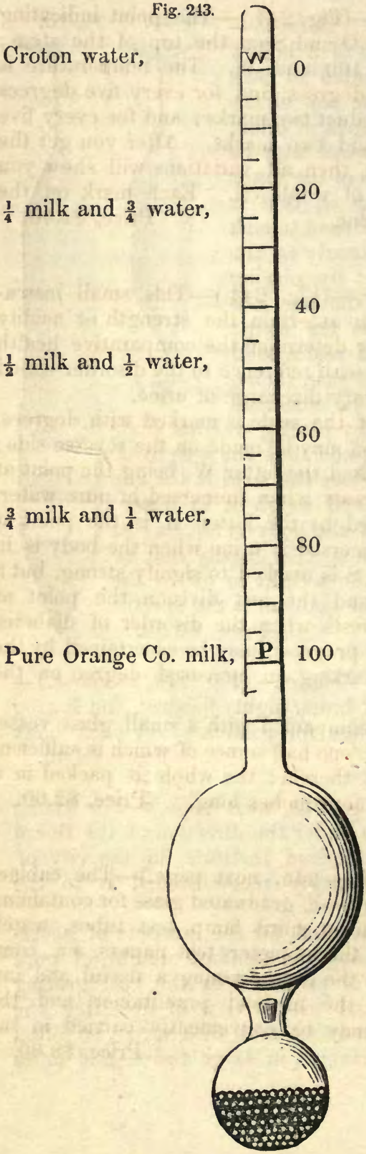
Nicholson's Portable Balance.—(Fig. 241.)—This consists of a hollow cylinder of metal terminated at each end by a cone; from the top of the upper cone rises a small stem of brass, terminated by a cup, *a*, which may be slipped off; from the end of the lower cone is suspended a cup, *e*, that is loaded with a weight, sufficient to sink the instrument in water nearly to the base of the upper cone; by placing weights in the cup, *a*, at the top, it is immersed to the mark on the stem; if the weights be removed and a solid body, whose weight is less than theirs, placed in the cup, it may be immersed again to the same mark, by placing weights along with the solid in the cup, and thus the weight of the solid obtained; now place the solid in the cup attached to the weight and weigh it in water; having now the weight of the body in air, and its loss of weight in water, its specific gravity may be ascertained by dividing the weight in air by the loss of weight in water, the quotient is the specific gravity. Price, $3.50.

Nicholson's Hydrostatic Balance.—(Fig. 242, as above.)—This instrument is made of brass, highly finished, and having a cage over the counterpoise for confining any solid body that is lighter than water. Price, $6.00.

Frye's Lactometer.—(Fig. 243, next page.)—For testing the quality of milk; made under the direction of the Board of Agriculture of the American Institute, in the city of New York, who have strongly recommended it to the public patronage.

This instrument was invented for the purpose of ascertaining the density, and fixing the standard weight, of pure unadulterated milk, as it is produced in the best grazing districts in the country, and with a view of detecting the frauds practised by adulterating milk with water, so often complained of by the consumer, in large towns and cities throughout the Union.

Fig. 243.



Directions for using the Instrument.—Fill the tin tube, which accompanies the instrument, with the milk to be tested at a temperature of about 60 degrees, and suspend the lactometer in the milk, and if the milk is proof, the instrument will sink to the degree marked 100 on the scale, or P, showing that the milk is at par; but if the milk has been adulterated with water, or has been taken from cows that have been fed on slops from breweries, and kept confined in stables in warm weather, the instrument will, in all such cases, sink below par, and show the per centage of adulteration, which, in some instances, will be 25 per cent. below par; but if the milk is superior, the instrument will rise above P, and show the per centage above par, which, in some instances, will be 10 per cent. Each division on the scale is 5 per cent.

Any person can test the correctness of the lactometer by mixing water with pure milk, and note the per centage of water which they use, and suspend the instrument in the mixture, and it will give the proportion of water added.

To farmers the instrument has proved to be very valuable, as a ready means of testing the relative quality of their cows, by inspecting their milk, and also showing the effects produced by a change of the animals' food, as its quality will change the density of the milk.

Price, $1.00.

Fig. 244.

The Oleometer.—(Fig. 244.)—The point indicating pure sperm oil, is O and S on the top of the stem; that of whale oil, 100 and W. The temperature is graduated at 60 degrees, and for every five degrees colder you will deduct two marks; and for every five degrees warmer, add two marks. After you get the correct graduation, then all variations will show you the per centage of whale oil. Each mark on the stem is two per cent. Price, $2.00.

The Urinometer.—(Fig. 244.)—This small instrument is intended to ascertain the strength or acidity of the urine, and thereby determine the comparative health of the body, particularly with reference to the disorder called diabetes, or the involuntary discharge of urine.

The graduated side of the scale is marked with degrees, by which the comparison may be made on the reverse side; at the upper part is marked the letter W, being the point at which the instrument rests when immersed in pure water. The next division, marked by the letter H, is the point at which it rests when immersed in urine when the body is in good health; the letter S is marked to signify strong, but a less degree of health; and the last division, the point at which the instrument rests when the disorder of diabetes has taken place, and its progress, may be ascertained by the surface of the fluid marking an increased degree on the scale.

This instrument is accompanied with a small glass vessel for containing the urine, one half ounce of which is sufficient to float the instrument therein; the whole is packed in a small round case about four inches long. Price, $2.00.

Urinary Cabinet.—(Fig. 245, next page.)—The cabinet consists of urinometer in case, graduated glass for containing the urine, bottles for acids, spirit lamp, test tubes, watch glasses, dropping tube, thermometer, test papers, &c., complete, as represented in the cut; forming a useful and important apparatus for the medical practitioner, and the whole of a size that may be conveniently carried in the pocket. Price, $8.00.

Fig. 245.

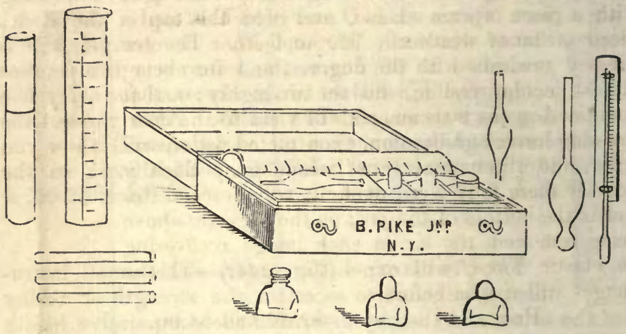
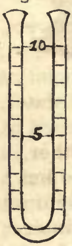


Fig. 246.

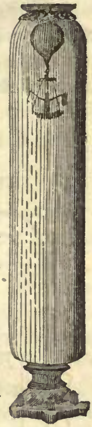


Tube to show the Relative Weight of Fluids.—Fig. 246 consists of a glass tube, bent and graduated as represented in the margin; on pouring into the upright branches, equal quantities by weight of the respective liquids, their relative weights would appear on inspection; being inversely as the heights to which they would rise in the branches of the tube. The accuracy and utility of such an instrument are augmented by filling the lower portion of the tube with mercury, and the graduated branches being of equal diameter, given weights of any liquids, which would not act chemically on the mercury, will show, by their respective heights on either side, how much greater space an ounce, a dram, or any other quantity of one liquid would take up than an equal quantity of the other; and hence it would appear how far the specific gravity of the latter exceeded that of the former.

Price, $0.75 and $1.50.

Hydrostatic Figures.—(Fig. 247, opposite page.)—This consists of a tall glass jar, supported on a foot, and nearly filled with water, or alcohol and water, to prevent its freezing in cold weather, into which small hollow glass figures, as men, a balloon and car, etc., are floated; they are made of variously colored glass and curiously ornamented; they have a small hole in the lower part, through which they are partly filled with water, till they will just float in the liquid, and the addition of a little more weight would cause them to sink. The jar is covered at its mouth air-tight with a piece of gum elastic, over which is tied a piece of fancy leather. If the leather be now pressed inwards with the finger, the water being almost incompressible, and the air highly so, that contained in the little images will yield to the compressing force, and becoming contracted water, will enter, and the images thus becoming specifically heavier than they were at first, will descend towards the bottom of the jar; on the pressure above being removed, the air in each image recovering its elastic force, will expel the water, and the images will rise as before.

Fig. 247.

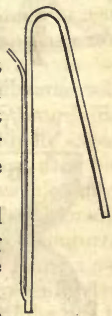


Price, - - $2.50 and $4.00.
" Figures, only, $1.00 and $2.00.

The Siphon (Fig. 248) is an instrument used to decant fluids, or convey them from one place, over an obstacle that is higher than their surface, to another that is lower; its form is exceedingly simple, being nothing more than a crooked tube.

If a common siphon, with one side longer than the other, be filled with water, and inverted or held with the open ends downward, the atmospheric pressure acting equally on both sides, and the liquid columns being unequal, the water will escape through the longest leg, falling in virtue of its specific gravity; but if, when such a siphon is filled, its shortest leg be plunged beneath the surface of the water, not only will the liquid all run out of the longer leg, but it will also rise in the shorter and be discharged from the other in a continued stream, till it sinks below the open end of the shorter leg; if the siphon be used without previously filling it with the liquid about to be decanted, though the liquid will rise in the shorter leg, it will not ascend beyond its own level so as to pass over the bend in the tube and escape, unless it be drawn out of the longer leg.

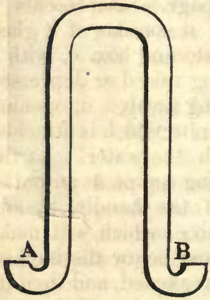
Fig. 248.



The siphon represented here has an additional tube, open at the upper end, and communicating below with the longer leg of the siphon; the shorter leg then being plunged in any vessel of liquor, the opening in the longer leg is to be

stopped with the hand or otherwise, and by suction at the end of the additional tube, the liquor may be made to pass over the bend, and fill the longer leg, when, being suffered to escape, it continues to flow as long as the extremity is immersed in it. Price, in glass, $0.75 and $1.00.
" in metal, $0.75 and $1.25.
" without suction tube, $0.37.

Fig. 249.

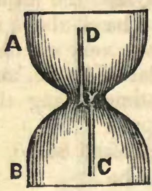


The Wirtemberg Siphon.—This instrument (Fig. 249), when once filled with liquid, will remain so, and hence may be hung up in that state ready for use. One leg being plunged into a vessel of the liquid to be drawn off, it will escape through the open extremity of the other leg, in consequence of the additional pressure of the liquid in the vessel. Siphons can only be used for transferring liquids from higher to lower levels.
Price, 38 cts. and 75 cts.

Fig. 250.

Tantalus Cup.—Fig. 250 consists of a cup with a siphon so adapted to the cup, that the short leg being in the cup, the long leg may go down through the bottom of it. When a liquid is poured into the cup, it will rise in the cup until the height of it is above that of the bend of the siphon, when the siphon will begin to act, and the whole of the water run out. It is called Tantalus Cup, because the siphon is usually concealed by a small figure endeavoring to drink, but who is foiled, for immediately the water reaches his mouth it flows away.
Price, $2.50.

Fig. 251.



Double-bodied Vessel.—(Fig. 251.)—This cut represents a piece of apparatus called a double-bodied vessel, the only communication between the upper and lower portions of which is through the tubes C and D; if the part B be filled with water to the neck, and A with port wine, so as to rise above the tube, D, still no mixture or alteration in the state of the liquids will take place, for the lightest occupying the highest situation will retain it undisturbed. But if the lower part be filled with port wine, and the upper with water, the former fluid will ascend through the tube, D, and the latter descend through the tube, C, till they have entirely changed places. Price, $1.50.

Lifting Pump.—(Fig. 252, next page.)—Represents a model of the common or lifting pump; it consists of a glass cylinder or chamber, B C, having a piston or box, C, with a valve opening upwards, the piston being raised or depressed by the rod D and handle E; also, having a valve, H, opening upwards, at the bottom of the chamber, to which is attached a pipe, A, of sufficient length to reach the water. At the top of the chamber is a reservoir, having a pipe as an outlet for the water. To use, take hold of the handle, E, and thereby draw up the bucket from B to C, which will make room for the air in the pump, all the way below the bucket, to dilate itself, by which its spring is weakened, and then its force is not equivalent to the weight or pressure of the outward air upon the water in the vessel below; and, therefore, at the first stroke the outward air will press up the water into the lower pipe, and after a stroke or two, will penetrate through the valve, H, and occupy the cylinder or barrel, B C. Upon depressing the bucket again, the water cannot return, because any force applied above will necessarily close the valve, H, and the bucket in returning will press upon the water, until the pressure of the water upon the under surface of the valve in G, will open the valve at that part, and escaping through the hole, will occupy a space above the bucket G. The next stroke of the handle will have a double effect, it will draw up the water from the well, as in the former instance, so that it shall again fill the cylinder, but with fresh water; for it will be readily seen, that the lifting of the bucket after the water has obtained access above it, does not replace that water as before, but the very circumstance of lifting the handle will close the valve above, and the water will be lifted up at the same time, filling the reservoir, D, which will discharge by the pipe, F.

Price, $3.00 and $4.50.

Fig. 252.

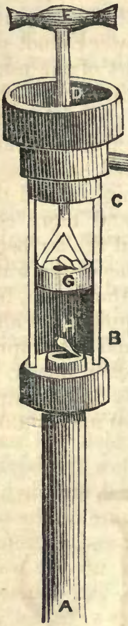
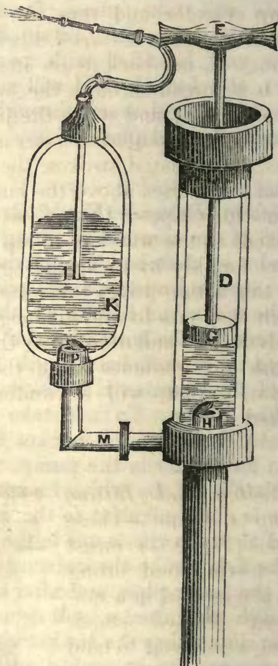
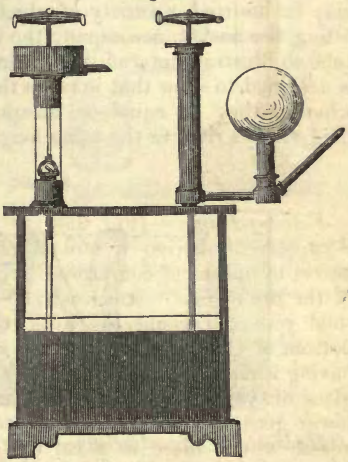


Fig. 253.



Forcing Pump.—(Fig. 253, as above.)—A pump which is capable of driving a stream of water above the pump barrel by means of compressed air, and illustrates the action of the fire engine. It consists of a glass cylinder, D, with solid piston, G, connected by a rod to a handle, E; at the bottom of the cylinder there is a valve, H, opening upwards, having a pipe for communicating with the water, a strong glass air vessel, K, at the top of which is a cap and jet, the lower part, I, extending nearly to the bottom of the air vessel, where there is a valve, P, opening upwards, and a bent tube, M, connecting the air vessel with the cylinder of the pump; the jet is sometimes made so that it may be turned in any direction. To use, the pump-handle and piston are drawn up; a vacuum being produced below the piston, the pressure of the atmosphere on the water of the well drives the water through the valve at the bottom of the pump cylinder, and thus the cylinder is filled with water; when the piston is forced down again, the water cannot pass through it, nor back again into the lower part of the pump, and it is forced through the bent pipe into the air vessel, K, or condenser; and when the piston is raised again the valve shuts, and prevents the water in the air vessel from returning. Thus, by repeated strokes, the water is forced into the air vessel till it rises above the end of the jet pipe, I, and then begins to compress the air, which is more and more compressed, as the water rises up the pipe, and the air begins to act forcibly by its spring against the surface of the water, and this action drives the water up through the pipe, I, from which it spouts to a great height, and is supplied by alternately raising and depressing the handle, E; and as the spring of the air continues while the piston is being raised, the stream, or jet, will be uniform as long as the pump is worked. Price, $5.00 and $6.00.

Fig. 254.

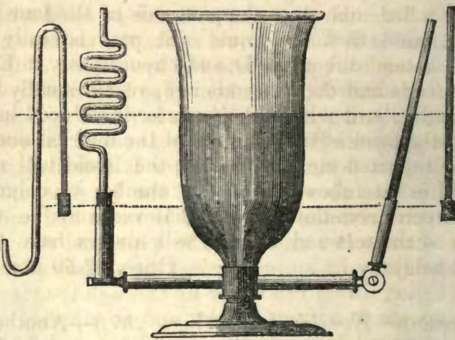


Forcing and Lifting Pump in Frame.—These models (Fig. 254) consist of a forcing and lifting pump, mounted in a mahogany framed stand, having a reservoir to hold water. In the forcing pump there is a variation from the former description, the jet pipe being connected near the neck of the air vessel, and not on the top, as before described.

Price, $10.00 and $12.00.

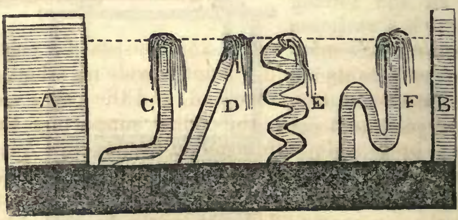
Hydrostatic Instrument for showing the Rise of Water to its Level, and other Experiments.—This instrument (Fig. 255, next page) consists of a large glass vessel, with a neck on the lower part cemented into a brass cup, and supported

Fig. 255.



on a brass base; to the sides of the brass cup are soldered brass tubes, about one inch in diameter, and five inches long; at the end of one there is a joint having a long glass tube, which may be inclined to any angle; the other tube is terminated in a socket, into which tubes of various shapes may be inserted, a variety of which, each attached to a cork fitting the socket, accompany the instrument; also a siphon tube to illustrate intermitting springs, etc. This instrument is designed to show that in tubes that have a communication, whether they be equal or unequal, short or oblique, the fluid always rises to the same height. Price, $7.50.

Fig. 256.



Hydrostatic Equilibrium.—(Fig. 256, as above.)—This arrangement consists of a tin box, A B, formed as represented in the cut, with the two raised extremities open at top; the sides are made of glass, water tight, having four differently shaped tubes, cemented into caps, on the surface of the oblong part. To use, fill the vessel with water to the height marked by the horizontal line marked in the cut, which is a little above the upper ends of the four tubes; it will be found that the liquid will pass laterally into the tube, C, ascend directly in D, and circuitously in E, while it first descends and then ascends in F, rising equally in all the tubes, and spouting out till the water is reduced in the side tubes to the level of the summits of the internal ones, when, the equilibrium being established, the liquid will remain at rest. Thus, it follows, that any number of columns of a liquid, freely communicating, whatever may be their respective diameters and figures, will always have the same vertical height. Price, $2.50 and $4.00.

Hydrostatic Equilibrium.—(Fig. 257.)—Another apparatus to exhibit the same effect as the last, in which a small column of water supports a much larger quantity.

Price, $3.00

Fig. 257.

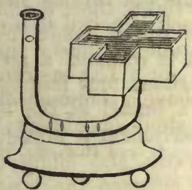
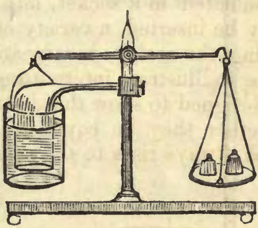
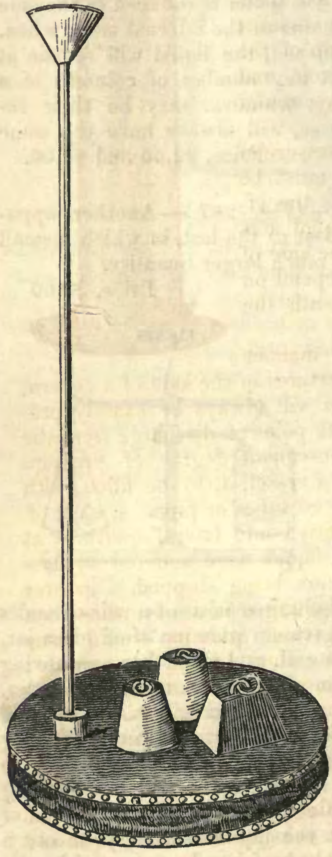


Fig. 258.



Hydrostatic Paradox.—Fig. 258 consists of a pair of scales mounted on a brass stand, having a wide mouthed glass jar, or cup, suspended from one end, and the other end having the usual scale pan. On the pillar supporting the scales, there is a brass slide with a milled-head screw for fastening it at any height required, to which there is an arm bearing a round block of wood loosely fitting the glass vessel. To use, let the jar, nearly filled with water, be poised by loading the opposite pan with the requisite weights; then after marking exactly the height the liquid stands, pour out a part of it and immerse the block of wood, supported by the arm free from the sides and bottom, just deep enough to raise the remaining liquid to the same height as at first, at which it is screwed fast, when the balance will be again exactly equipoised. This effect of the vertical pressure of liquids may be variously exhibited, and the results are curious and important. Price, $5.00.

Fig. 259.

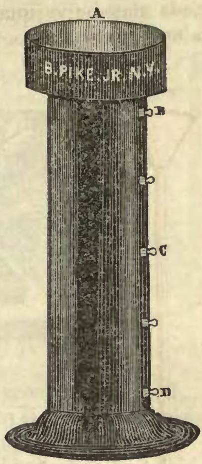


The Hydrostatic Bellows.—(Fig. 259.)—This instrument is sometimes called the hydrostatic paradox, from the fact, that a very great weight may be balanced by a small weight of water. It consists of two round boards, from one foot to one and a half in diameter, attached to one another by leather going all round them, and making the space within them water tight; there is a hole in the upper board over which is screwed a metal pipe, about four feet long, with a funnel at the top, for conveniently introducing water, and filling the space between the boards till the water stands to a height of three or four feet in the tube, when it will sustain the weight of one or two men without forcing the water out. The leather is stout, and prepared so as to be water tight under a great presure; the tube jointed that it may be more portable, and also showing the effect of a column of water of a less height.

Price, - - $5.00.
" extra large, $7.00.

Vessel for Spouting Fluids.—(Fig. 260.)—This instrument consists of a japanned tin vessel as represented in the cut, usually from twenty-four to thirty inches high, having five pipes or jets, with exactly the same sized apertures fixed on the side of the vessel at equal distances apart; the top of the vessel is enlarged for a reservoir, and the whole is mounted on a circular base.

Fig. 260.



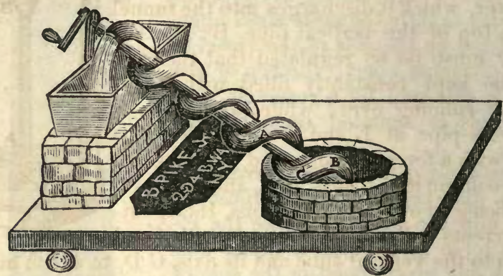
In estimating the lateral pressure of liquids, the vertical height must be taken into the account; since the effective force with which a liquid acts against any given point in the side of the containing vessel will depend on the depth of that point beneath the surface of the liquid.

This will appear from the manner in which water flows from apertures in the side of a cistern, as the velocity of the stream will always be exactly proportioned to the distance of the point of discharge from the superior surface, and the consequent degree of pressure which takes place. Suppose a vessel, A, to be filled with water, and to have three or more tubes or pipes, B, C, D, of equal lengths and diameter, fitted into lateral apertures at different heights; then if the liquid were suffered to flow from the pipe D alone, the others being stopped, a greater quantity of water would be discharged in a given time than by the pipe C alone, and a greater quantity would issue from the latter in the same time than by the pipe B only; the water being kept at the same level, so as to maintain an equality of pressure during the whole time it was flowing. And if all the pipes were opened together, the water would spout to a greater distance from the pipe D than from either of the others.

The quantity of water spouting from any hole in a given time, must necessarily be as the velocity with which it flows; and if, therefore, the hole D is supposed to be four times as deep below the surface A, as the hole B is, it follows that D will discharge twice the quantity of water, that can flow from B in the same time, because 2 is the square root of 4.

So in like manner, if D had been nine times the depth of B, three times the quantity of water would issue from it, 3 being the square root of 9. Price, $5.00.

Fig. 261.

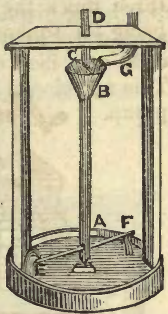


Archimedes' Screw (Fig. 261, as above) is a machine for raising water; it is represented and described as follows:

A is a hollow pipe, coiled around a cylindrical axis; which axis is inclined at an angle with the ground, and supported at each end upon pivots, the upper pivot being furnished with a handle. When this is turned round, the lower end of the pipe dips into the water in the well below, and turning upwards directly scoops up some of the water. When the end points up, the part B will become lower than it; therefore the water will fall to B. Another half turn of the handle brings C to the lowest point, and the first water will occupy that part of the tube; at the same time more water will be scooped up at the end. In a number of turns of the handle, equal to that of the coils of the tube, the first water will reach, and flow out at the top; and from that time a flow will take place at every revolution of the machine. Price, $9.00.

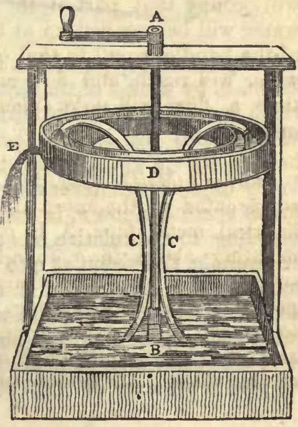
Barker's Mill.—(Fig. 262, next page.)—This engine, as represented in the annexed figure, consists of a hollow cylindrical metal pipe, A B, of considerable height, and terminating above in a funnel-shaped cavity. The pipe is supported in a vertical position, by resting below on a pointed steel pivot, turning freely in a brass box, adapted to receive it; and the upper part has a cylindrical steel axis, C D, passing through a board, supported by uprights at the sides. The hollow tube, A B, communicates with a

Fig 262.



cross tube, E F, closed at the extremities, but having adjustible orifices at the opposite sides, near each end of the cross tube. A pipe, G, above, communicates with a supply of water, which it discharges into the funnel at the top of the vertical pipe, B; and the supply must be so regulated that the pipe may be kept constantly filled with water without running over; while the orifices in the cross-pipe at E and F will deliver the water with a force proportioned to the height of the column in the tube, A B, and the apertures being in opposite directions, the spouting currents will communicate a centrifugal motion to the vertical tube and its axis, C D, to which may be attached a toothed wheel connected with any other machinery. The action of this machine does not, as sometimes stated, depend on the resistance of the atmosphere to the jets from the cross-pipe; but is wholly owing to the hydrostatic pressure of the column of water in the vertical tube, which, exerting great force on the interior of the horizontal tube, and that force being removed from the points whence the water issues, the pressure on the corresponding points, on the opposite parts of the interior of the tube, tends to make it revolve, the action of both jets producing motion in the same direction. Price, $5.00.

Fig. 263.

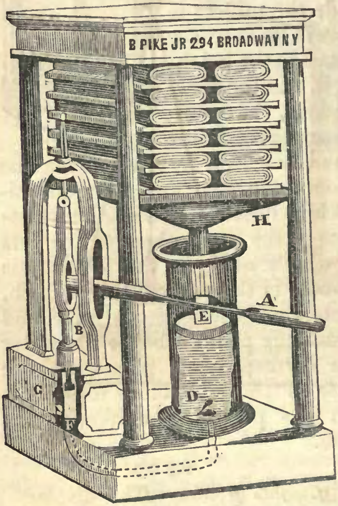


Centrifugal Pump.—(Fig. 263.)—A machine for raising water, dependent upon centrifugal force, combined with the pressure of the atmosphere. It consists of one, two, or more arms, erect below, and branching out above, joined to a vertical axle. Near the upper extremity of each arm is a clack valve opening upwards; while near the bottom of the vertical tube, or the bottom of each (if there are more than one), is a similar valve, also opening upwards. Water be-

21

ing poured into the machine before using, and a rapid motion being given to it by a handle at top, the water in the arms acquires a centrifugal force, opens the valves at the end, and flies out into a circular trough prepared for it. This machine is simple, but not so effective, as a well-made pump. Price, $10.00.

Fig. 264.

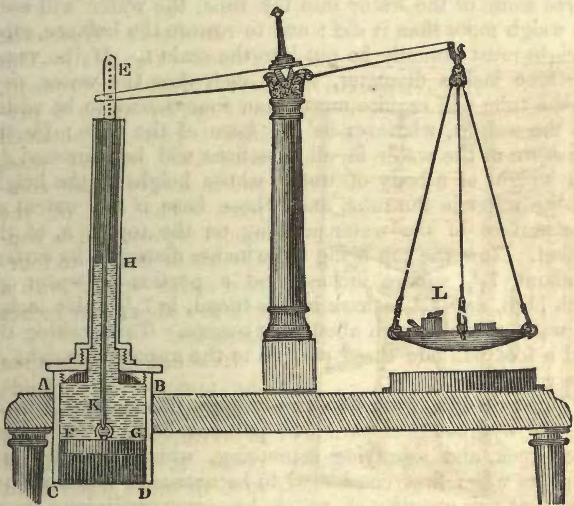


Brahma's Hydraulic Press.—(Fig. 264.)—This is a valuable instrument, and one by which a prodigious power is obtained with the greatest ease, and in a very small compass. The size of the model represented is usually about twelve to fourteen inches square, with a cylinder about four inches diameter.

Its action depends upon the principle that fluids transmit pressure equally in all directions. A solid piston, E, is constructed so as to move water-tight in a cylinder. The space beneath the piston is filled with water, and communicates by a small pipe with a forcing pump, worked by the piston, B, by means of the lever, A, and by which the water, which is contained in the cistern, G, is forced through the valve, D, into the large cylinder. The large piston being thereby driven up, carries with it the bed, H, and presses closely together whatever may be above it. Whatever pressure is exerted upon B, is transferred to E, and is increased according to the relative size of the two pistons. Suppose, for example, the piston at B to have a superficial area of one inch, and the large cylinder of ten inches, then every ten pounds pressure put upon B, will be increased by E ten-fold, and become one hundred pounds; and as a person may exert a force of fifty pounds on the lever, this weight alone will give a pressure of 100×50 pounds, or more than 2 tons, and that with a pump, the large cylinder of which is not more than 4 inches diameter; and by decreasing the smaller tube from one inch diameter to half an inch the power will be increased four-fold, or to nearly 9 tons.

Price, $40.00.

Fig. 265.



Hydrostatic Paradox with Movable Piston.—The displacing of any portion of fluid by a fixed solid, whatever be the weight of the solid, produces no difference in the weight of the fluid, provided it stands at the same height as before, and raising the height of the fluid by plunging a solid into it, increases its pressure, or apparent weight. If the fluid is raised by pressing or forcing it upwards, in however thin a column, provided the vessel be kept full, and closed in all directions, the pressure of the fluid and the apparent weight of the vessel will be increased, although nothing whatever, either solid or fluid, is added to it. To illustrate this principle, the instrument represented in the above cut (Fig. 265), is used. The cylindrical vessel, A B C D, has a glass tube closely fitted into its top, and a rod, E C, fixed to a plate, F G, moving up and down, water-tight, in the cylinder which is represented fitted to a frame with the end of the rod, E, attached to one end of a balance.

The plate being at the bottom, C D, water is poured into the vessel, so that it rises nearly to A B, but does not rise in the tube. It is then balanced by a weight in the scale, L. If the rod E K is drawn up so as to raise the plate and force some of the water into the tube, the water will seem to weigh more than it did ; and to restore the balance, more weight must actually be put into the scale L. If the vessel is three inches diameter, every inch that the water rises in the tube will require more than four ounces to be added to the weight, whatever be the bore of the tube ; for the pressure of the water in all directions will be increased by the weight of a body of water, whose height is the height of the water in the tube, and whose base is the extent of the surface of the water pressing on the top, A B, of the vessel. Now the top being three inches diameter, its surface is about $7\frac{1}{15}$ square inches; and a portion of water one inch high, and $7\frac{1}{15}$ square inches broad, is $7\frac{1}{15}$ cubic inches of water, which weigh about four ounces. Thus, raising the rod a foot will add three pounds to the apparent weight of the water.

This principle, from its extraordinary illustrations, is called the hydrostatical paradox; paradox being a word from the Greek, and signifying something, which, though true, appears when first considered to be untrue. When we are told that any quantity of water, however small, may be so employed as to balance any quantity of water, however great, we are at first startled by the apparent impossibility of the statement. But when we come to examine it more closely, we find it to be accurately true ; for the small tube in the foregoing figures may be made ever so narrow, and to hold ever so little water, while the wide tube communicating with it may be made ever so large, and holding ever so much water ; and the level at which the water stands in both tubes will be the same. So in the scales you may plunge as large a body as you please into the vessel of water, and leave as little water in the vessel as possible ; still, if what you leave stands as high as the whole quantity stood, it will, by weight and pressure together, produce as much effect as the whole quantity of fluid.

Everything, under these circumstances, depending upon the height and the surface, and very little upon the bulk of the fluid, we may easily perceive what mischief may be done by a very small quantity of water, if it happens to be applied or distributed, so as to stand high, in however thin a body or column, and to spread over a wide but confined and shallow space.

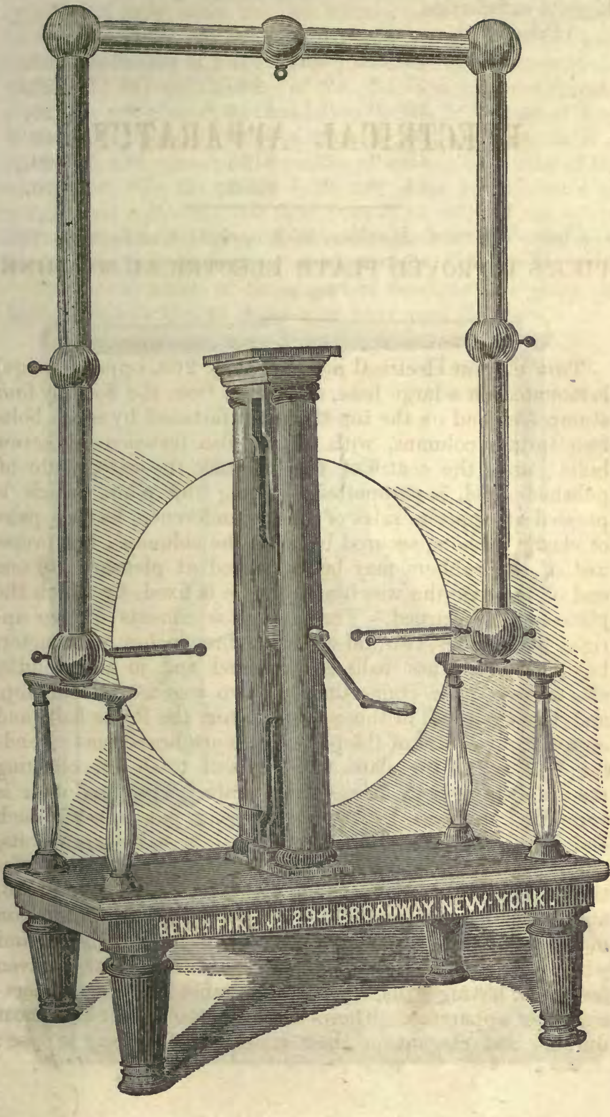
Price, with balance and frame, complete, $25.00.

ELECTRICAL APPARATUS

PIKE'S IMPROVED PLATE ELECTRICAL MACHINE.

THIS elegant electrical machine (Fig. 266, opposite page) is mounted on a large base, supported from the floor by four stump feet, and on the top there are fastened by screw bolts two turned columns, with a cap also fastened by screw bolts; near the centre of the columns, the axle, made of polished steel, is supported, bearing the plate, which is pressed at opposite sides of its circumference, by two pairs of elastic rubbers, secured between the columns; the pressure of the rubbers may be regulated at pleasure; to one end of the axle the winch and handle is fixed, by which the plate is easily turned. The conductor consists of two upright brass tubes, two and a half to three inches in diameter, having large brass balls at each end and in the middle, also a cross tube connecting the two together at the top, and having a ball in the centre. From the lower balls and opposite the centre of the plate; there are brass arms extending half across the plate, with rows of teeth for collecting the fluid from both sides of the plate. The conductor is supported on bases, by four strong glass pillars, set at each end in brass sockets, and secured to the base by screw bolts, all of which may be taken apart for convenient transportation. These machines are made with plates of 24, 27, 30, 36, and 44 inches in diameter, with framework in proportion made of mahogany or rosewood, handsomely polished, and with conductors of brass, highly finished, from four to seven feet high, having balls, wires, and suitable holes for connecting other apparatus. These machines are by far the most durable and elegant in their construction of any in use;

Fig. 266.



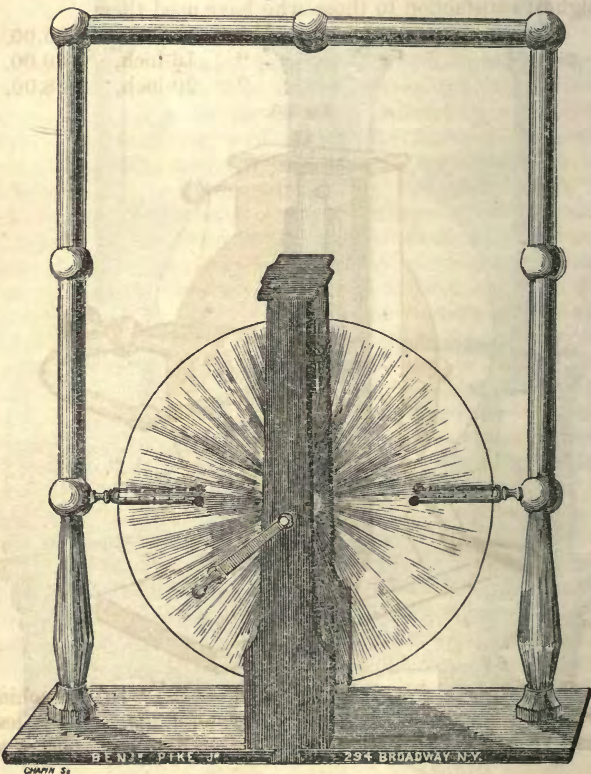
many of our first institutions are using them with the highest satisfaction.

Price, with mahogany frame,

24 inch plate,	$75;	in rosewood,	$85.
27 " "	$85;	"	$95.
30 " "	$110;	"	$120.
36 " "	$130;	"	$140.
40 " "	$165;	"	$180.
44 " "	$200;	"	$220.

Plate Electrical Machine, with upright Conductor.—This plate (Fig. 267) represents a convenient and substantial

Fig. 267.

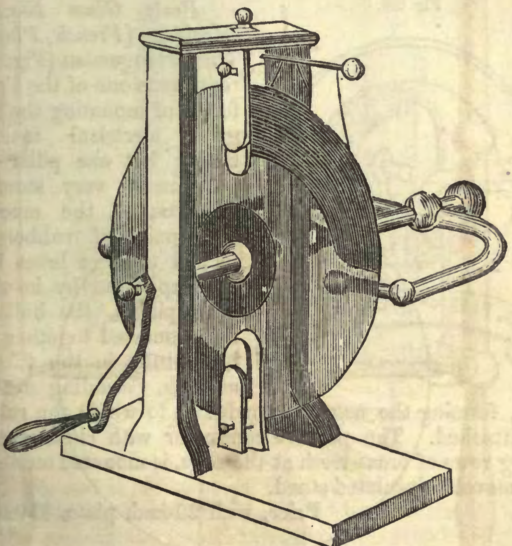


mode of constructing the conductor of a plate machine, occupying but little room on the lecture table. The machine, as regards the mounting of the plate, is arranged as Cuthbertson's, having a longer base and stout glass supports at each end; beyond the edge of the plate and opposite thereto, on which are placed the conductor, which is formed of long brass tubes about 2 inches in diameter, having large balls at each end, and connected together at the top by a tube of the same size. To the lower balls are arms, having rows of points, and collecting the fluid from both sides of the plate. There are suitable holes in different parts of the conductor for inserting electrometers, wires, &c.

This construction of the electrical machine has given the highest satisfaction to those who have used them.

Price,	13-inch,	$25.00.
"	16-inch,	$30.00.
"	20-inch,	$38.00.

Fig. 268.



Cuthbertson's Plate Electrical Machine.—This machine (Fig. 268, as above) consists of a plate of glass, of not less than 12 inches diameter, turning on an axis that passes at right angles through its centre. It is rubbed by two pair of cushions, fixed at opposite parts of the circumference by elastic frames of thin mahogany, which are constructed so as to press the glass plate between them with the requisite force, by means of regulating screws. A brass prime conductor, supported by a stout glass rod, is fixed to the frame of the machine, terminated at one end by a wire, with a brass ball, and having branched extremities opposite each other, and near the extreme diameter of the plate, in a direction at right angles to the vertical line of the opposite cushions. The branched extremities of the conductor are furnished with pointed wires, that serve to collect the electricity from the surface of the excited plate. This form of the plate electrical machine is now little used, the more modern style being preferable. Price, 12 inch, $25.00.

" 15 " $30.00.

" 18 " $38.00.

Fig. 269.

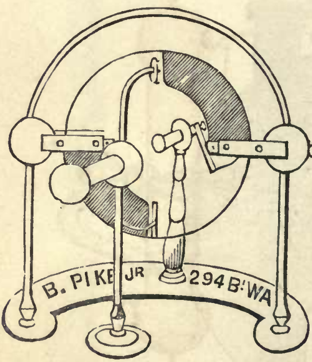


Plate Glass Electrical Machine (French Plan).—This arrangement (Fig. 269) represents one of the French forms of mounting the plate glass electrical machine, having but one pillar support, made very stout, to the axis of the machine. Two pairs of rubbers attached to large brass balls, are supported by insulated glass pillars, the balls being connected together by a brass tube, in the form of an arch, extending over the plate, forming the negative conductor to which the rubbers are attached. The positive conductor with circular arms, having rows of brass teeth at the ends, is mounted on a separate movable insulated stand.

Price, with 20-inch plate, $50.00.

Plate Electrical Machine, for positive and negative Electricity.—This electrical machine, having a frame of mahogany or rosewood, in the form of a cross, is represented in

Fig. 270.

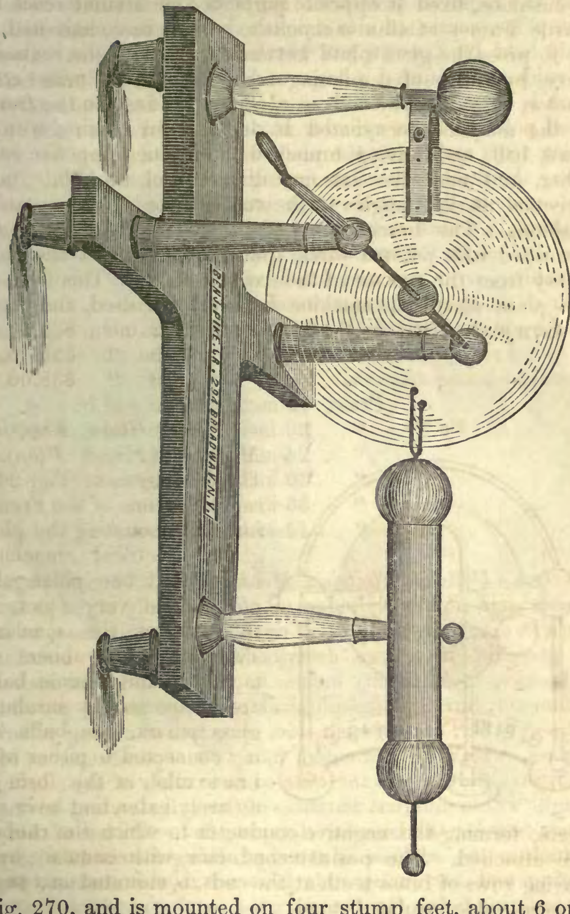
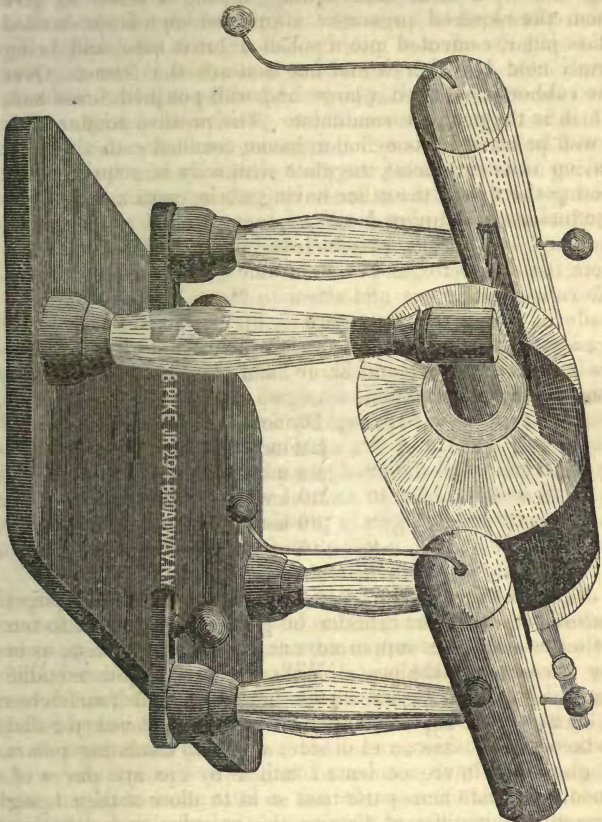


Fig. 270, and is mounted on four stump feet, about 6 or 8 inches from the floor, or table, on which it is used. On the shorter arms of the frame, two pillars are attached by screw nuts for receiving the axle of the plate, which axle is made of polished steel, with a brass crank and rosewood handle. The rubbers consist of two cushions of leather, connected together by a stout brass spring, having a screw to give them the required pressure ; supported on a stout swelled glass pillar, cemented into a polished brass base, and being firmly held by a screw and nut beneath the frame. Over the rubber is mounted a large and well-polished brass ball, which is the negative conductor. The positive conductor is a well polished brass cylinder, having swelled ends ; the one having arms embracing the plate with rows of points for collecting the fluid ; the other having a wire with a ball. The conductor is supported on a stout swelled glass pillar, mounted in a socket, by which the pillar can be separated from the conductor, and at the frame cemented in a base, as the rubber, with nut and screw to fasten. The frames are made of mahogany or rosewood, highly polished, and the brass work elegantly finished. The plate and all the pillars are attached by nut and screw, and may be taken off for convenient transportation.

Price, 16-inch, $20.00 and $25.00.
" 20-inch, $34.00 and $38.00.
" 24-inch, $50.00.
" 30-inch, $85.00.
" 36-inch, $130.00.
" 42-inch, $200.00.

Nairne's Cylinder Electrical Machine (Fig. 271, next page) consists of a hollow cylinder of glass, usually eight to ten inches in diameter, supported on a rectangular base, as in the preceding machines described. Two hollow metallic conductors, about twenty inches in length and four inches in diameter, having hemispherical ends, are placed parallel to the cylinder, one on each side, upon two insulating pillars of glass, which are cemented into two separate pieces of wood, that slide across the base so as to allow of their being brought within different distances of the cylinder, and having screws entering the base for clamping fast. To one of these conductors the cushion is attached, being fastened to it by a spring and two brass rods fastened to the cushion, the rods entering holes for the purpose in the conductor, and moving freely therein ; the spring causing it to press equally against the cylinder in every part of its revolution. The pressure of the cushion is also further regulated by the adjusting screw at the base. From the upper edge of the cushion there proceeds a flap of black silk, which is sewed

Fig. 271.



on the cushion about a quarter of an inch from the upper edge; it extends over the upper surface of the glass cylinder to within an inch of a row of metallic points, proceeding like the teeth of a rake from a horizontal rod, which is fixed to the adjacent side of the opposite conductor. The motion is given by a simple handle—formerly a multiplying wheel was used, but it has many disadvantages and is more laborious. The conductors are usually made of metal, japaned black, perforations being made at the ends and on the top about the size of a quill, for the purpose of attaching wires and other kind of apparatus. This machine is the best for showing the effect of positive and negative electricity. The conductor to which the rubber is attached is the negative, and the one having the points the positive or prime conductor. If it be required to accumulate positive electricity, a chain must be carried from the negative conductor to the floor. If, on the other hand, negative electricity be required, then the positive conductor must be put in connexion with the ground, and the other insulated.

Price, with two conductors, 8 inch, $22.00.
" " " " 9 inch, $25.00.
" " " " 10 inch, $28.00.

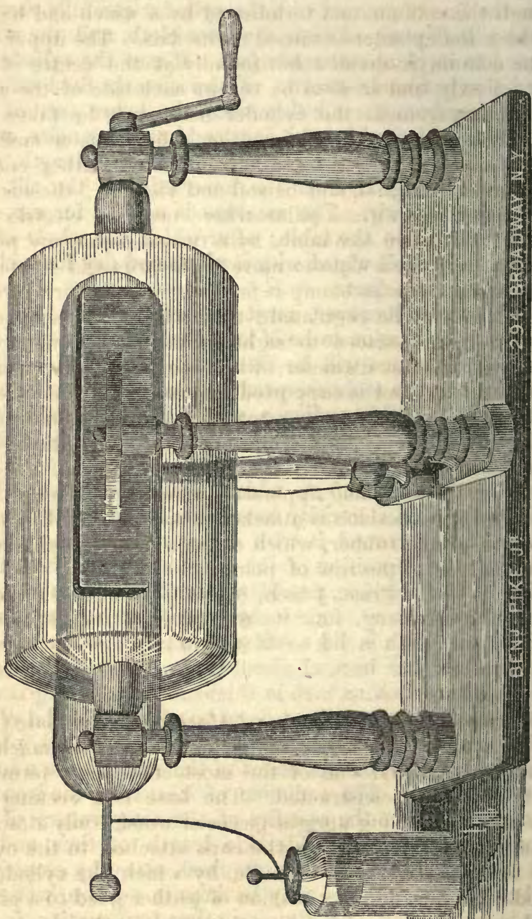
To use the Electrical Machine.—Let the machine be carefully wiped with a clean silk or linen cloth, to free it entirely from dust; spread a little amalgam evenly along the cushion, turn the machine with rapidity for some time, observing if the whole surface of the cushion is covered with the amalgam ; remove all the amalgam adhering to the glass, attach a chain to the rubber to connect with the floor, or place the hand on the rubber, gently pressing it, frequently wiping the whole machine with a silk cloth free from dust, which in an excited state it readily attracts.

The most powerful excitation of the machine is produced as follows. Let the machine be placed within the influence of a good fire, but not so near as to injure any of its parts by the action of the heat. With a flat round-pointed knife spread a little amalgam evenly along the cushion, and return it to its place; turn the cylinder a few times round ; then take off the cushion, and observe carefully those parts on its surface that have not been touched by the cylinder while revolving; on these parts put a little more amalgam, and repeat the process of turning the cylinder, and supplying the defective parts with amalgam, till every point of that part of the surface of the cushion which presses on the cylinder appears to be properly supplied with amalgam. Take now a piece of leather, about five or six inches square, and spread over one side of it a quantity of amalgam; throw back the silk flap, and, turning the machine gently round, applied the amalgamed side of the leather to the cylinder, for the space of two minutes or more, as circumstances may require, during which time the excitation will be observed to increase rapidly. The cylinder must next be wiped perfectly clean with an old silk handkerchief, and afterwards with a soft dry linen cloth. Let the cushion be again removed, and the amalgam which appears above and below the line of contact with the cylinder carefully scraped off, the silk flap wiped with the linen cloth, and the whole returned to its place and made fast. If now the cylinder be turned slowly round, streams of the electric fluid will be seen rushing from the silk flap round the lower part of the cylinder, attended with a hissing and snapping noise, while large brushes of the same, of several inches in length, may be observed flying off from the lower edge of the silk into the surrounding air. The machine is now fit for use, and may be fastened to the table; after which the whole of its parts are to be well wiped with a warm and dry linen cloth, to free them from dust.

The operator, however, must not expect this high and rich state of excitation to be of long duration. The cylinder will soon cool; dust will be attracted by the action of the machine; and the moisture produced in the air of the room by the breaths of his audience, will, by their united effects, render all his efforts to produce a copious supply of electricity entirely fruitless.

To remedy this defect, which gentlemen who deliver public lectures on electricity have often found to be a grievous one, and surround it with a dry atmosphere entirely preventing the deposition of the moisture of the room from settling on the machine, provide a box of thin plate iron, ten or twelve inches long, four inches wide, and one inch and a half in depth, with a lid to fit very easily over it. In this box a piece of bar iron, of about six inches in length, three in breadth, and half an inch in thickness, after being heated in the fire to a dull red heat, is to be placed, the lid of the box put on, and the whole, on a suitable iron stand, placed under the cylinder, on the board of the machine, in a longitudinal direction. The radiation of heat from the iron will effectually preserve the equality of the temperature of the surrounding air for a considerable length of time, and indeed for any length of time required, since, by employing two bars of iron, the one may be kept in the fire, while the other is in the box, and thus no other interruption in the course of the experiments will be necessary beyond what is occasioned by the changing of the irons. By this means the machine may be made to act in full vigor under the most disadvantageous circumstances.

Fig. 272.

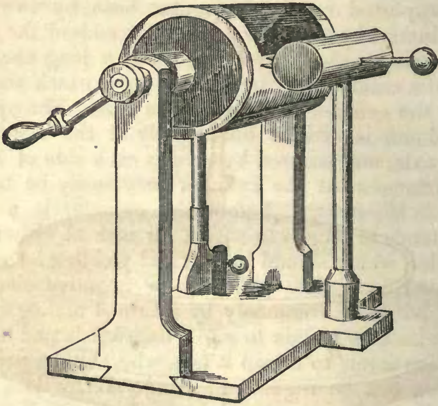


The Cylinder Electrical Machine (Fig. 272, as above) consists of a hollow cylinder of glass, usually about six tc ten inches in diameter, and from eight to fourteen inches in length, supported on a rectangular base by two upright turned columns, by means of caps on the ends of the cylinder, the one having a short pivot, the other a long one, passing through the column, and terminated by a winch and handle by which the cylinder is turned on its axis. The upper part of the column is divided horizontally at the centre of the pivot, or axle, and secured by screws each side of the axle; by this arrangement the cylinder may easily be taken out and put in the frame. Before the cylinder is a cushion, which extends in length to within an inch of either end of the cylinder, which should be soft and yielding; the cushion is supported by a glass pillar where negative electricity is required, but more commonly by a turned mahogany pillar, having at its base a slide to move backwards and forwards, with a stout screw to clamp it fast, whereby the pressure on the cushion can be regulated; the conductor is a cylinder of metal from fourteen to eighteen inches in length, and about four inches diameter, with rounded ends, usually japanned black, and is supported on the side of the cylinder opposite the rubber, having a row of brass points on the side towards the cylinder for collecting the fluid; there are sockets with holes at each end of the conductor, and also on the top for attaching apparatus, wires, &c. To the upper edge of the cushion is attached a piece of black silk, of the width of the rubber, which extends over the cylinder to within an inch of the row of points.

Price, 4	inch,	$ 8.00;	5	inch,	$10.00.
" 6	"	$12.00;	7	"	$14.00.
" 8	"	$16.00;	9	"	$18.00.
"			10	"	$22.00.

The Small Cylinder Electrical Machine.—This plate (Fig. 273, next page) represents the cylinder electrical machine, in the simplest and one of the most convenient forms in which it can be constructed. The base is a rectangular piece of wood, having upright pieces of wood firmly attached at the base, and supporting the caps attached to the cylinder; to one of which is a handle, by which the cylinder is turned. On one side is a cushion of leather fixed to a pillar, and having a screw at the base to regulate the degree of pressure on the cylinder. On the other side of the cylinder is a metal cylinder with rounded ends, supported by a glass

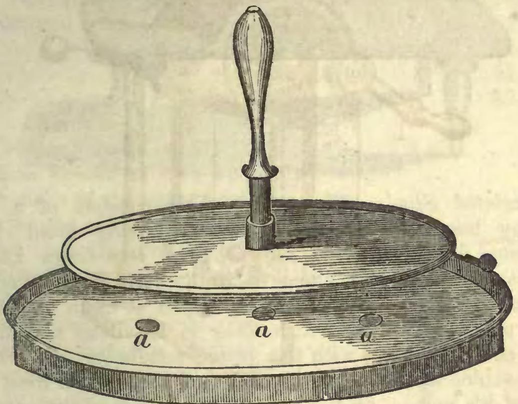
Fig. 273.



rod. On one side is a row of sharp points, to draw the electricity from the glass; and on the other, a hole, having a wire with a brass ball thereon. A flap of black silk, or oiled silk, is attached to the rubber, to prevent the dissipation of the electricity from the surface of the cylinder before it reaches the points. Price, 4-inch, $8.00.
" 5-inch, $10.00.
" 6-inch, $12.00.

The Electrophorus.—(Fig. 274, next page.)—The electrophorus is certainly a very remarkable source of electrical accumulation, and is an instrument which, for many light experiments, forms a good substitute for the electrical machine. It consists of a metallic plate, with a rim about half an inch deep, containing a resinous plate, formed of equal parts of shellac, rosin, and Venice turpentine melted together, and about ten to fourteen inches in diameter, and half an inch thick, on which rests a brass or metal plate, from eight to twelve inches in diameter, having well-rounded edges, and a glass handle at the centre about ten inches long, for the purpose of lifting without drawing off the electricity; a wire with a brass knob is usually connected with the plate for taking the sparks; *a, a, a,* represent brass rods connected with the lower plate having their tops level with the plate of resin, by which is avoided the trouble

Fig. 274.



and tediousness of establishing a communication between the insulated cover and the earth by means of the finger.

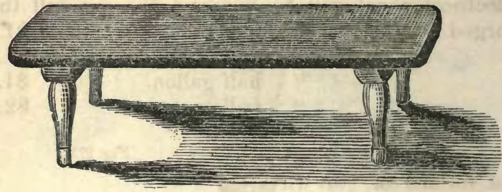
To use the electrophorus, rub the upper surface of the resinous plate with a piece of dry fur (cat's skin is reckoned the best), and it will be excited negatively. Place the upper conductor upon it, and then raise the same by its insulating handle; it will be found to exhibit very faint, if any electrical signs. Replace the conductor, and whilst it lies on the surface of the excited plate, touch it with a finger or any other uninsulated conductor, and then raise it again by its handle.

It will now be positively electrified, and afford a spark; if it be then replaced on the resinous plate, touched, and again raised, another spark will be procured, and this process may be repeated for a considerable time without any perceptible diminution of effect. Jars may be charged by bringing them in contact with the conductor each time it is lifted; with an instrument of this kind, only six inches in diameter, Cavallo charged a jar several times successively, and such was the strength of the charge that it was capable of piercing a card.

This instrument, properly constructed, has been known to retain its electricity so long as three weeks, without requiring fresh excitation.

Price, $3.00 to $6.00.

Fig. 275.



Insulated Stool.—(Fig. 275.)—This consists of a mahogany board of well-baked wood, having stout legs, cemented in sockets for the purpose, sometimes having screws for separating them from the top, for convenient transportation. To use; having wiped it clean and dry, let a person stand upon it, holding in his hand a chain or wire communicating with the prime conductor; on setting the machine in action, sparks of fire may be drawn from any part of his person, he becomes indeed a part of the conductor, and is strongly electrified; his hair will stand on end, and if he hold in his hand a silver spoon, containing some warm spirits of wine, another person may set it on fire by touching it quickly with his finger.

Price, $3.00; with legs in brass sockets to unscrew, - $4.00 and $4.50.

Fig. 276.

Legden Jar—(Fig. 276)—is so called from the circumstance of its properties having been first observed at Leyden. It consists of a glass jar of any convenient size, usually a quart, having the outside and inside coated with tin foil to within two or three inches of the top, and a brass wire, the upper part of which terminates in a ball of the same metal, and the lower part in a fine chain, or a piece of fine wire, that it may touch the inside of the jar, passing through a cap of baked wood which fits into the mouth of the jar. If a jar thus constructed be held by the lower part with the hand, and the knob be brought into contact with the prime conductor while the machine is in action, it will become charged; and if a communication be then formed between its outside and inside coatings, by the other hand being brought to the knob, that sensation called the electrical shock will be felt, and the jar will thus be discharged. Price, pint, $1.00 and $1.25.

" quart, $1.25.

" half gallon, $1.75.

" gallon, $2.50.

Discharger.—(Fig. 277.)—This is formed of two wires with balls at the outer ends, and jointed at the lower ends where they are received into a socket, into which a glass handle is fastened. Hold the common discharging rod firmly, and discharge a phial by it, he will not receive a shock. If the phial be a very large one, or if he hold it lightly, he will feel perhaps a slight tingling of the fingers when the shock passes, but this is all. If he be furnished with the glass-handled discharging rod, or jointed discharging rod, as it is called, he may, by setting its knobs at a proper distance, discharge even the largest battery without danger. It is usual for the sake of convenience to fasten a chain to one of the arms of the discharging rod, which communicates with the outside of the phial.

Fig. 277.

Price, - - - $1.25 to $2.00.

" with moveable joints, $3.00 and $4.00.

Pith Ball Electrometer—(Fig. 278, next page)—consists of a small stand, supporting a glass rod, bent at right angles at the top, and having a hole to attach a pith ball, which is suspended by a silk string. If an excited glass tube be held near the electrometer, the ball will be attracted, and after adhering for a short time, it will be repelled to a considerable distance, nor will it again be attracted until it has touched some body connected with the earth, and thus given up the electricity which it had acquired from the tube, or until, by remaining undisturbed for some time, it has lost it by dissipation into the atmosphere. Price, 50 cts.

Fig 278.

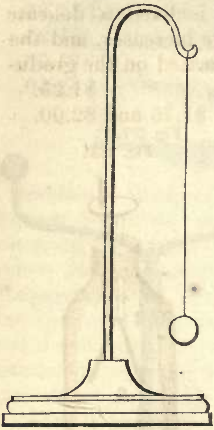
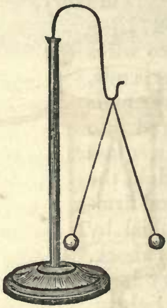
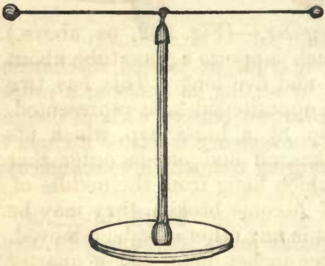


Fig 279.



If two pith balls be suspended by two silk threads, and excited either by glass or by resin, on removing the exciting material, they will no longer fall into the vertical position, but repel each other in the manner shown in Fig. 279, the balls acquiring a property relative to each other similar to that which the glass and single ball exhibited after contact in the preceding experiment.
Price, 50 cts.

Fig. 280.



Simple Balance Electrometer.—(Fig. 280.)—This is an instrument of great delicacy. It consists of a fine beam of metal, suspended on a pivot affixed to a glass rod in the centre. It is accurately balanced, and has at each end a pith ball. The glass rod must be very dry when the instrument is to be used; an excited stick of sealing-wax or glass held towards one end will occasion it to move round its centre, and thus indicate plainly the excitement of the wax, or glass. Price, $1.00.

The Quadrant Electrometer.—This instrument (Fig. 281, next page) consists of an upright stem of wood, furnished at the lower end with a brass ferule and pin, by which it may be inserted in the conductor. To the upper part of the stem is affixed a graduated semicircle of box wood, or ivory, at the middle of which is supported on an axis, an index, which consists of a very slender ivory rod, and reaches from its

axis at the centre of the graduated plate, to the ferule at the end of the stem; and to its extremity is fixed a delicate pith ball. This index rises as the charge increases, and the strength is determined by the degree indicated on the graduated circle. Price, in box wood, $1.25.
" in ivory, $1.75 and $2.00.

Fig. 281.

Fig. 282.

Fig. 283.

Bennett's Gold Leaf Electrometer.—(Fig. 282, as above.) —Consists of a brass foot, which supports a glass tube about two and a half inches wide and five long. This has two slips of tin foil pasted on the opposite sides, as represented. The cylinder is closed at top by a brass cap, which fits tight round the sides, but takes off and on, in order that if the two slips of gold leaf which hang from the middle of the cap in the inside should become broken, they may be repaired. The cap should not in any other case be removed. The gold leaves are about three inches long, and a quarter of an inch wide; they are best fastened on by a little piece of flatted brass, soldered to the inner side of the cap, and the leaves attached by gum water, gold size, paste, or anything similar. They should hang so as to touch each other when not in an electrified state, and when divergent, as shown in the cut, they should approach to the slips of tin foil on the glass. The cap has occasionally a point which screws upon it, as shown; this, however, is never used, except in trying experiments upon the electricity of the atmosphere.
Price, $2.50.

Saussure's Gold Leaf Electroscope, which is represented in Fig. 283, as above, differs from the former in the manner in which the gold leaves are insulated. The cap is a flat plate with a wire soldered beneath. The gold leaves are soldered at the lower end of the wire, and the whole wire is inclosed in a glass tube. The outer surface of this tube is best covered with sealing-wax, as the insulation of resinous substances is much better in damp weather than that of glass, which rapidly attracts the moisture of the breath, or of the apartment. The diameter of the glass may be four inches, the height of it eight inches. The size of the plate at top from two to four inches, as most convenient. The cap which incloses the top of the glass, and into which the glass tube is cemented, may be of wood or metal.

Price, $2.00.

Volta's Condenser (Fig. 284) shows a pair of these condensing plates attached to a gold leaf electroscope. The plate, A, is connected with the cap, and is of course insulated. The plate, B, is supported upon glass, but is connected with the ground by the chain; it turns upon a joint at C. It is sometimes connected with another condenser when the plate B becomes insulated by taking off the chain. The two plates have a thin coat of gum lac varnish on their inner sides, to prevent contact, and in consequence entire dispersion. To use the instrument, touch the cap or plate, A, with the excited body, B being withdrawn, then approach B to A, and touch A again; it may afterwards be made to touch a third or fourth time, or more, until the gold leaves show signs of divergence. Price, $6.00.

Fig. 384.

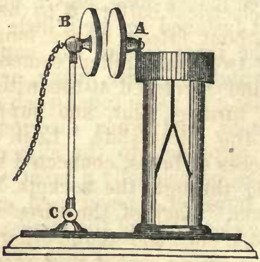
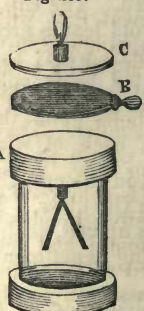


Fig. 285.



Bennet's Electrical Doubler.—(Fig. 285, as above.)—This instrument is an improvement upon Volta's, it being more susceptible. It consists, as the cut represents, of a simple gold leaf electrometer, the top of which is a flat metallic plate, marked A, of a similar plate, B, which has a glass handle, and of a third plate, C, also with a glass handle. The plates C and B are covered on their under-sides with sealing-wax varnish. To use the instrument; first put the plate B upon A, touch the plate B with the finger, and then, before the finger is removed, touch the plate A with the object to be tested. Take away the object, and also the finger; take up B by its handle; place C on B, and touch C with the finger. By this a portion of the electric fluid is disturbed in C, so that C becomes electrified plus, or minus, in the same manner as A. Place B upon A, and touch B with the finger, and apply the edge of C to A; the electricity of C will then flow to A. Remove C, take the finger from B, and raise B from A. Proceed in the same manner for three or four times more, until so much electricity is accumulated in A as to occasion the divergence of the gold leaves.

Price, $5.00.

Fig. 286.

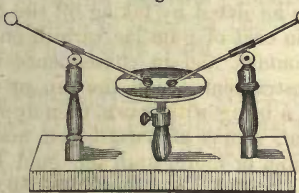
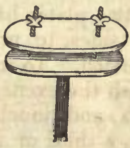


Fig. 287.



The Universal Discharger.—(Fig. 286, as above.)—An instrument that will be found convenient in a great variety of experiments in which the electrical battery is to be used. It consists of a flat board, about fifteen inches long, four broad, and one thick, having two glass pillars cemented in two holes upon the board, and furnished at top with brass caps, each of which has a turning joint, and supports a spring tube, through which the wires slide. Each of the caps is composed of three pieces of brass, connected so that the wires, besides their sliding through the sockets, have a horizontal and vertical motion. Each of the wires is furnished with an open ring at one end, and at the other it has a brass ball, which, by a short spring socket, is slipped upon the pointed extremity, and may be removed. There is a circular piece of wood, having on its surface a slip of ivory inlaid, and furnished with a foot, which is fastened in the middle of the bottom.

To this discharger belongs the small press (Fig. 287, previous page), the stem of which fits into the socket, instead of the circular table. On the top of the stem are two oblong boards, which are pressed together by means of two screws. Between these boards may be placed any substance which requires to be pressed while the electric fluid is sent through it.

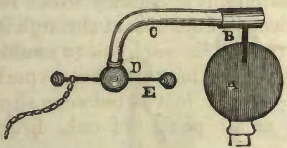
The construction of this instrument is such as to enable the operator to use it with advantage in numerous experiments, such as the oxidation of metallic leaves between slips of card or of glass; splitting small pieces of oak, firing gunpowder, &c.

By far the most interesting and brilliant application of the powers of the Leyden jar is the melting of metallic wires. When a strong charge is passed through a slender iron wire, the wire is ignited or dispersed in red-hot globules. The power of large batteries was formerly considered essential to the production of this effect; but if the wire be sufficiently fine, a single jar, exposing a coated surface of about 190 square inches, will be found sufficient to exemplify the experiment. Price, $6.00 and $7.50.

Fig. 288.

Medical Jar.—(Fig. 288.)—This is like an ordinary Leyden jar, covered and lined to a certain height with tin-foil, as at B. A wooden cap is then prepared for it, and a hole just admitting a glass tube, A, is bored in the middle of the cap. The tube reaches below to within two inches of the bottom, and projects upwards above the cap, about three inches. This tube is also partly lined and covered with tin-foil, so placed that rather more than an inch of the glass is left uncovered at the lower end, and about two inches at the upper end. The tube is cemented to the top of the bottle, and a smaller cap cemented on the top of the glass tube; but before this last is cemented on, three holes are drilled in it; one for a hook wherewith to suspend the phial from the conductor, the two others are to be left open; one of them to admit a wire to touch the inner coating of the tube, the other a second wire, sufficiently long to reach to the coating of the phial—these are shown in the cut at C and D. A wire is also twisted round the outer coating of the inner tube, which projects outwards sufficiently to touch the inner coating of the phial. On the outer coating of the phial is fastened a hook, marked F, for the convenience of attaching a chain. Price, $2.50.

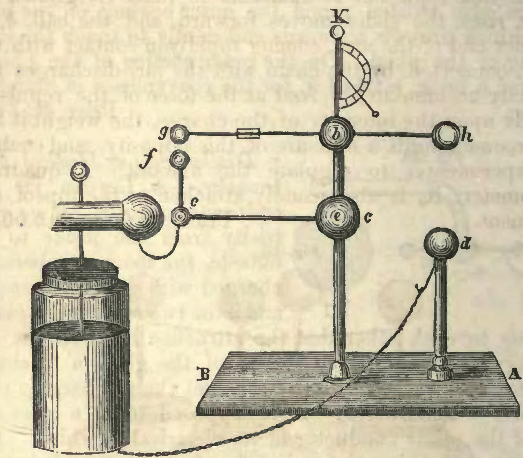
Fig. 289.



Discharging or Medical Electrometer.—A Leyden jar will endeavor to throw off its electricity from the inside to the outside, the more as it becomes charged with greater intensity; and if the two coatings be placed so close to each other that the attraction between the two coatings overcome the resistance of the glass, a discharge necessarily takes place. On this fact the discharging electrometer is constructed. A is supposed to be a cross section of the prime conductor of an electrical machine. B is a brass cap, forming the end of the electrometer. It is made with a wire beneath to fit the hole of the conductor. C is a bent glass tube. D a brass ball at the end of it. E is a wire with a brass ball at each end, which wire is movable backwards and forwards. When a shock is to be taken, the ball E is placed at a certain distance from the surface of A. A is connected with the inside of the Leyden jar, which communicates the shock, and the chain is connected with the outside of the jar. When the jar is charged to such a degree of intensity as to acquire force enough to strike across from A to E, the discharge will spontaneously take place. The ball at E must be set at a greater or less distance from A, according to the strength of shock required. If a shock is to be given to a company, when this electrometer is to be used, they must form part of the circuit between the outside of the bottle and the electrometer. Price, $2.00.

Cuthbertson's Balance Electrometer (Fig. 290, next page) is an excellent and elegant regulator of the strength of the charge requisite for fusing different lengths of wire, experimenting on metallic oxides, &c. It consists of a mahogany base, A B, about eighteen inches long, and six inches wide, in which are fixed two glass supports, mounted with brass balls, the one, *c*, set in the middle of the base, and the other,

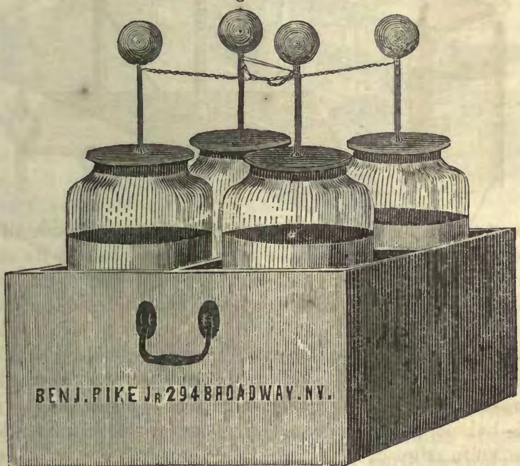
Fig. 290.



d, about seven inches therefrom ; under or at the side of one of the balls, *d*, is a hook ; the other ball, *e*, has at its side a brass rod, *c e*, with upright arm, *c f*, about four inches long, each having balls, *c f*, at their ends ; the rod is about seven inches long, extending in a direction opposite to the insulated ball with a hook ; also connected by a brass tube about four inches long with another ball, *b*, formed of two hemispherical brass cups, the one fitting within the other, and within this is balanced a brass rod, *g h*, about fourteen inches long, with a knife edge centre in the middle, placed a little below the centre of gravity, and equally balanced with a hollow brass ball, *g h*, at each end, the centre or axis resting upon a proper shaped piece of brass fixed in the inside of the ball, each part of the hemisphere being cut out to permit the end towards the insulated brass ball to descend, and the other to ascend ; to the arm is attached a small slider moving freely over a line divided into 60 grains, the slider to be set at the number of grains the experiment requires.

To use the instrument ; suppose the slider to be set at 15 grains, it will cause the arm, *g h*, bearing the slide, to rest on the ball, *f*, beneath, with a pressure equal to that weight ; as the charge increases in the jar, or battery, the balls become more and more repulsive to each other, and when the force of this repulsion is sufficient to raise 15 grains, the arm, *g*, rises, the slider moves forward, and the ball, *h*, at the other end of the arm, coming rapidly in contact with the ball, *d*, connected by the chain with the jar, discharges the electricity accumulated. And as the force of the repulsion depends upon the intensity of the charge, the weight it has to overcome affords a measure of this intensity, and enables the experimenter to regulate the amount. A quadrant electrometer, K, is also usually attached to the top of the instrument. Price, $8.00 to $10.00.

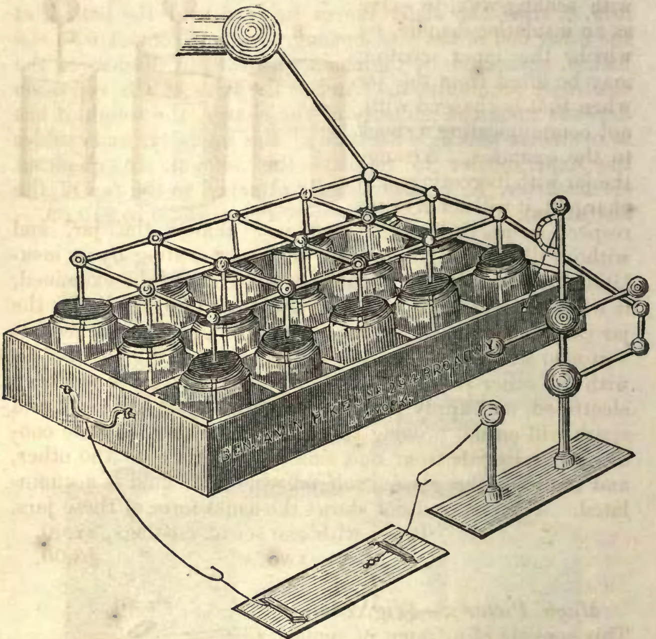
Fig. 291.



Electrical Battery, with four Jars.—(Fig. 291.)—When great force is required from the electric fluid, a number of jars of the above description are placed on a metal coating which forms a communication between their outside coatings and the earth, and the insides of the jars have conducting wires which pass to the prime conductor. In this manner any number of jars may be charged with the same facility as a single one, and from the powerful effect of the electric fluid when it is thus collected, it is called an electric battery. One with four jars is represented in the above figure.

Price, four gallon jars, $10.00.
" half " $8.00.
" quart " $6.50.

Fig. 292.

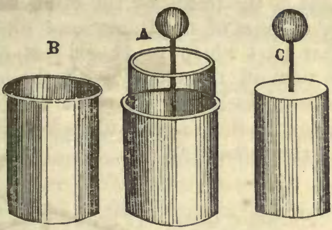


Electrical Battery, with fifteen Jars.—(Fig. 292.)—This represents an electrical battery of fifteen jars in the act of being charged from the conductor of an electrical machine, with Cuthbertson's balance electrometer, and an arrangement for striking metallic oxides attached.

Price,	fifteen quart	jars,	$22.50.
"	half gallon	"	$30.00.
"	gallon	"	$40.00.

Leyden Jar with Movable Coatings.—(Fig. 293, next page.)—This consists of a glass jar, with a double set of movable coatings, either of which may be adapted to it at pleasure, the outer coating being a tin case large enough to admit the jar easily within it, and the inner coating a similar case sufficiently small to pass readily in the inside of the jar. The charging wire of the inner coating should be surrounded

Fig. 293.



by a glass tube covered with sealing-wax, to serve as an insulating handle, by which the inner coating may be lifted from the jar when that is charged without communicating a shock to the operator. Arrange the jar with its coatings, and charge it, it will act in every respect as an ordinary coated jar; charge the jar, and without discharging it, remove the inner coating by its insulating handle. If this coating, when removed, be examined, it will be found not at all, or but slightly electrified ; lift the jar carefully from within its outer coating, and examine that —it also will evince no sign of electricity. Fit the jar up with the other pair of movable coatings, that have not been electrified, and apply the discharging rod ; an explosion and spark will ensue, proving that the coatings are only the conducting materials from one side of the glass to the other, and that it is the glass itself on which the fluid is accumulated. The annexed cut shows the usual form of these jars.

Price, with one set of coatings, $2.00.
" " two " " $3.00.

Fig. 294.

Magic Pictures.—(Fig. 294.)—This consists of a frame of mahogany, or other wood, about twelve inches square, sometimes having a handle on one side to hold by, having in a groove a plate of glass confined, about ten inches square, the middle of which is coated with tin-foil on both sides of the glass to within one or one and a half inches of the edge, one side of which is connected with the frame and handle, and the other having a picture pasted over the tin-foil. To use, lay a piece of money on the picture, and holding it by the frame or handle, charge the picture by presenting a ball from the conductor to the money. When charged, take hold of the frame by the other hand, at the handle or some other part of the frame, and direct another person to hold that part which you have just quitted with one hand, and to take off the money with the other. His attempt to do so will discharge the sheet of glass, and he will receive a shock in the fingers, while he will be quite unable to take off the money. Price, $1.75.

Sulphur Cone.—(Fig. 295, as below.)—This apparatus is formed from a large wine glass. This is cleaned, and a part of the outside, as represented, covered with tin foil. A wire is twisted round this covered part, and bent so as conveniently to hold a pair of pith balls suspended on very fine wires, or on linen threads. Within the glass is poured melted sulphur, to about the same height, or a little above the edge of the tin foil, and the end of a glass rod, or else of a silk cord, dropped into the sulphur while melted.

Fig. 295.

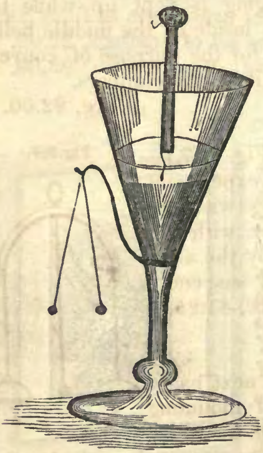
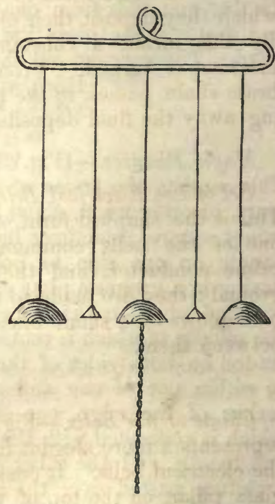


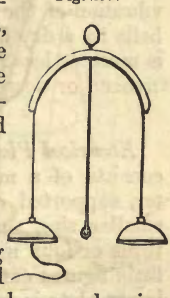
Fig. 296.



To use, lift up by the glass handle, the sulphur within the conical glass, and, at the moment of separation, the pith balls will diverge, or separate from each other. Let the sulphur drop down again into the glass, and this action of the balls will cease. Again produce separation of contact, and they will again diverge; and thus, for a considerable time, the alternate action will be kept up, even indeed for days and weeks. Price, $0.75.

Electrical Bells.—(Fig. 296, previous page.)—The electrical bells furnish a pleasing illustration of the attraction and repulsion of the electric matter. They are variously constructed, but the form exhibited in the figure is one of the simplest. The two outer bells are suspended by brass chains; the middle bell and the two clappers by fine silk threads. When the bells are attached to the conductor, and the machine is turned very slowly, the fluid will pass along the chains to the two outer bells, but will not pass along the silk to the clappers and middle bell. Thus the outer bells being charged with an extra quantity of electricity, will attract the clappers, but the moment they touch the bells they become charged, and are repelled with such force as to cause them to strike against the middle bell, on which they deposit their electricity, and are again attracted. By this means a constant ringing is kept up while the machine is turned. From the inside of the middle bell a brass chain passes to the table, for the purpose of conveying away the fluid deposited on it by the clappers.
Price, $2.00.

Fig. 297.



Set of two Electrical Bells.—(Fig. 297.)—This is the simplest form of the experiment, one of the bells communicating with the prime conductor, and the other with the ground; they are made to ring by the alternate blows of a small brass ball suspended between them. Price, $1.25.

Chime of five Bells.—Fig. 298, next page, represents a more elegant form of mounting the electrical bells. It consists of a swelled glass pillar, on the top of which is cemented a cap, bearing a brass cross; the four outer bells are affixed to the ends of this by wires, and the clappers are suspended from the middle by silk cords; the middle bell communicates with the ground by the mahogany foot which supports the

Fig. 298.

Fig. 299.

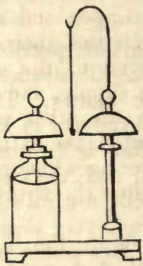


Fig. 300

whole. To use, the cross is connected by a chain with the prime conductor, when a pleasing chime will commence.

Price, $4.00.

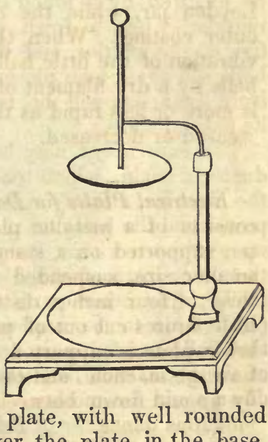
French Arrangement for illustrating the Chiming of Bells by Electric Action.—Fig. 299 represents the apparatus, one of the bells being in connexion with the interior coating of a Leyden jar, while the other bell communicates with the outer coating. When the jar is moderately charged, the vibration of the little ball, which is suspended between the bells by a dry filament of silk, produces the chiming, which is more or less rapid as the distance between the bells is increased or decreased. Price, $4.00.

Electrical Plates for Dancing Images.—Fig. 300, as above, consists of a metallic plate six or eight inches in diameter, supported on a stand, and another plate of somewhat smaller size, suspended to the prime conductor at about three or four inches distant. Place on the lower plate any little figures cut out of paper or pith. Take care that the lower plate is supported upon some conducting substance; turn the machine, and the figures will raise themselves, and fly up and down between the two plates, forming a most ludicrous dance.

Support the lower plate upon a glass bottle, or other insulator, and although all the rest of the apparatus remain as before, yet the figures will not dance. The reason is this, the upper plate being charged by its connexion with the machine, the figures are attracted by it, they becoming charged are repelled by the upper, and attracted by the lower plate. When they touch this their charge is removed by that contact, and conveyed to the earth, while the figures jump again for a fresh supply, and thus they move alternately from the one to the other plate. When the lower plate, however, is insulated, the extra portion brought to it cannot escape, and it becomes charged in the same manner as the upper one, therefore the figures have no tendency to move between them.

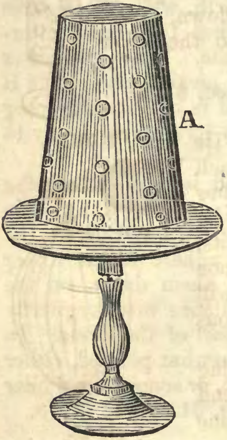
If in cutting out the figure the head is heavier than the feet, it will dance head downwards; damping the feet in the mouth will usually remedy the defect, but this, at the same time, gives them a tendency to adhere to the upper plate, while wetting the head makes them dance on the lower plate. Female figures usually dance more regularly because of the weight of the lower part of the dress. In all the figures the head should be somewhat pointed, either by the adjunct of a steeple-crowned hat, or something similar put upon it. Price, in copper, $1.25 and $1.50.

Fig. 301.



Electrical Plates for Dancing Images, with adjusting Rod.—A more elegant arrangement for dancing images (Fig. 301) consists of a polished mahogany base, about 8 inches long and 10 inches wide, on which is fastened a metallic plate, about 8 inches in diameter, having a hook connected with the plate from the under side of the base. A glass pillar, attached to a brass base at the bottom, and having at the top a cap, supporting a curved wire, terminating in a ball having a hole, through which a rod slides vertically, one end of which has a knob, and the other a metallic plate, with well rounded edges, and supported directly over the plate in the base, and may be placed at any distance therefrom, and fastened by a screw attached to the ball through which the rod passes. Price, $3.50.

Fig. 302.



Dancing Pith Balls.—(Fig. 302.)—The dancing pith ball experiment is exhibited as follows. Fasten to the conductor of the electrical machine, a pointed wire. Hold a dry and warm tumbler over the point and turn the machine. After a few turns the tumbler will be charged withinside with positive electricity. Place upon the metallic plate (the larger plate used for the dancing images will answer) about a dozen pith balls, and cover them over with the charged tumbler; they will now jump up and down, each one conveying some of the fluid away from the glass, and not towards it. They will continue to dance for a long time, and when their motion has ceased altogether, it may be renewed by a touch of the hand to the outside of the tumbler, when a fresh portion of electricity will be set free on the interior, and the attraction and repulsion of the balls will again take place, and thus for many times successively the action will be renewed until the glass returns to its natural state.

The experiment may be varied thus. Hang to the conductor a chain, which touches this tumbler; upon turning the machine, although glass intervenes between the exciting power and the balls acted upon, yet the balls will fly rapidly up and down within the glass tumbler. In this instance, the outer part of the glass is by contact electrified positively; the inner part, therefore, will be, by induction, (afterwards to be explained), electrified negatively; and the balls are flying up and down to supply the deficiency of the glass, each ball coming to deposit its load, and flying down again for another.

Price, pith balls per dozen, $0.25.

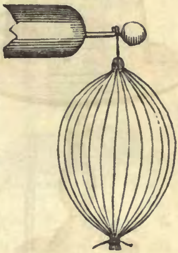
Cylinder for Dancing Pith Balls.—(Fig. 303.)—This electrical apparatus consists of a glass cylinder having metallic ends, one end supported on a small stand, the other having a knob, or hook, to connect with the prime conductor of an electrical machine; on exciting the machine, the pith balls placed within the cylinder will dance up and down, carrying the electricity from the upper to the lower plate.

Price, $1.50.

Fig. 303.

Diverging Threads.—(Fig. 304.)—Tie twenty fine linen threads together at each end, so that there may be about 8 inches distance from knot to knot; hang this by a wire loop, fastened to one of the knots, to the conductor of the machine. Upon charging the conductor, the threads will recede from each other, forming a curious balloon-shaped body.

Fig. 304.



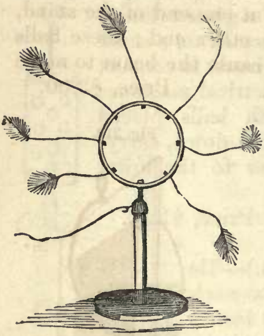
Expanding Threads.—Instead of tying the threads at both ends, let the lower end be loose, and upon turning the machine they will form a brush. Price, 25 cts.

The Head of Hair.—(Figs. 305 and 306.)—These are usually carved figures of wood, having long hair on their head. They are supported by a wire from the prime conductor. When electrified, the hair stands on end in the most grotesque manner. Each fibre is in a state of repulsion to its neighbor, but present the point of a penknife, and they will all fall down. Price 75 cts. and $1.00.

Fig. 305.

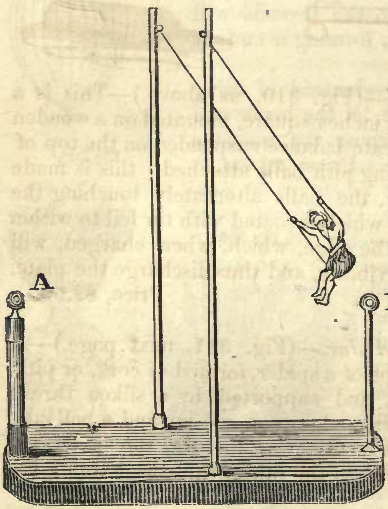
Fig. 306.

Fig. 307.



Radiating Feathers.—(Fig. 307.)—This is a metallic ring, supported on a glass pillar, and at six or eight equally distant points around this ring tie a thread, not silk, a few inches long, the other end of which bears a feather. Connect the metal ring with the conductor of the machine, by a wire or chain, and the feathers being electrified will repel each other until they will stand at equal distances like the spokes of a wheel. Price, $1.50.

Fig. 308.



The Electrical Swing (Fig. 308) is another amusing instrument, and acts, as will be immediately perceived, upon the principle of attraction and repulsion. The insulated brass ball, A, is connected with the prime conductor, while the opposite ball, B, communicates with the earth. The light figure represented as sitting on a silken cord is first drawn towards A, where it receives a charge which it discharges on B, and thus is kept swinging between the two balls. Price, $3.00.

Electrical See-Saw.—(Fig. 309, next page.)—Consists of a mahogany base about one foot long, supporting at its centre a brass beam, after the manner of a scale beam, made very light, and supporting near its extremities small figures. A glass pillar supports a brass ball at one end of the stand, and a metal rod another ball at the other end; these balls connected with the Leyden jar, will cause the beam to move up and down with a pleasing effect. Price, $3.00.

Fig. 309.

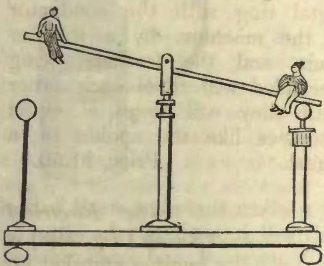
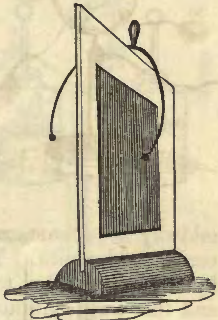


Fig. 310.



Electrical Pendulum.—(Fig. 310, as above.)—This is a plate of glass about ten inches square, mounted on a wooden base, and having a delicate balance suspended on the top of the plate, the ends having pith balls attached; this is made so as to vibrate easily, the balls alternately touching the sides of the glass plate, which is coated with tin foil to within an inch and a half of the edge, which, when charged, will cause the pendulum to vibrate, and thus discharge the plate. Price, $2.50.

Electrical Spider and Jar.—(Fig. 311, next page.)—A small object in the shape of a spider, formed of cork, or pith, having legs of thread, and supported by a silken thread between two Leyden jars, or between one jar and a ball connected with the outside coating of the jar, the spider will be attracted from the one to the other, thus discharging the jar. Price, $2.75.

Jar with Ball from Outer Coating.—(Fig. 312, next page.) —There is attached to the outside coating of the jar, *a*, exposing about a square foot of coated surface, a curved wire, *b*, terminated by a metallic ball, *c*, rising to the same height as the knob of the jar, *d*; charge the jar, and suspend

Fig. 311.

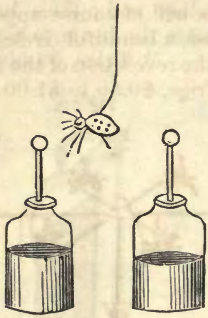
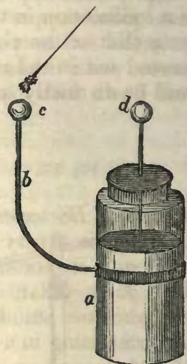
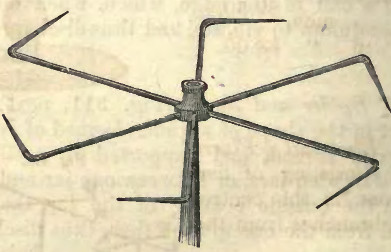


Fig. 312.



midway between *c* and *d* by a silken thread, a small ball of cork or elder pith. The ball will immediately be attracted by *d*, then repelled to *c*, again attracted, and again repelled, and this will continue for a considerable time: when the motion has ceased, apply the discharging rod to the jar, no spark or snap will result—proving that the phial has been gradually discharged by the pith or cork ball, the motion of which from *d* to *c* likewise proving the opposite electrical states of the outer and inner coatings. Price, $2.50.

Fig. 313.



Electrical Flyer.—The electrical fly (Fig. 313, as above) represents a light brass fly, consisting of fine wires proceeding from a common centre, and having their pointed ends turned back at right angles, and all in the same direction. If this fly be poised on its centre on a pointed wire inserted in the prime conductor, and the machine be put in action, a stream of fluid will issue from each point, and produce a locomotion in the fly, propelling it in a direction contrary to that of the points: the points will of course appear luminous, and if the room be darkened, a beautiful circle of fire will be distinctly seen, formed by the revolution of the fly.

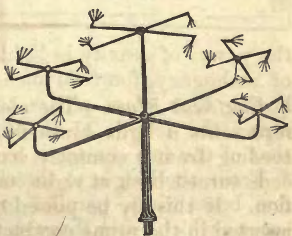
Price, $0.50 to $1.00.

Fig. 314.

Revolving Horsemen.—(Fig. 314.)—This is a very pleasing experiment; it consists of a swelled glass pillar, mounted on a mahogany stand, having a cap terminating in a point, on which is balanced an electrical flyer about twelve inches wide, as described Fig. 313; to each of the points is attached small figures of horsemen; to the cap is attached a hook for connecting with the prime conductor, which, when excited, will cause the horsemen to revolve with great rapidity.

Price, with 4 horsemen, $2.50.
" " 6 " $3.00.

Fig. 315.

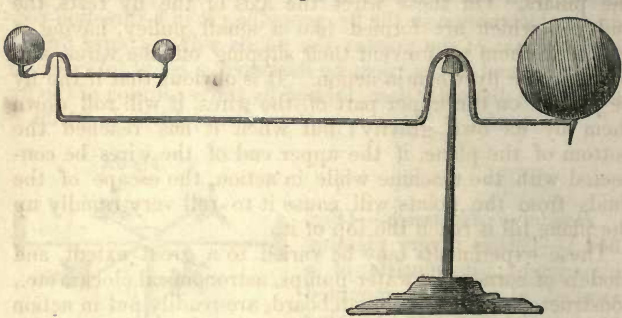


Set of Electrical Flyers (Fig. 315), consisting of five mounted; one in the centre, and four on branches from the centre.

They sometimes are made having one large flyer, and four small ones, revolving on the revolving flyer, causing revolutions within revolution.

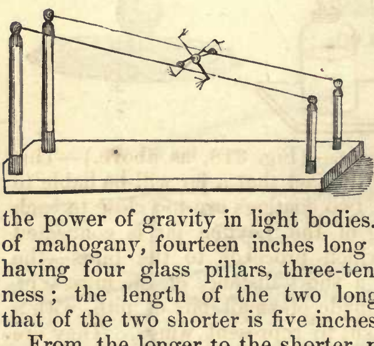
Price, $4.50.

Fig. 316.



Electrical Orrery.—(Fig. 316.)—This apparatus is seen above. It represents the sun, earth, and moon. The earth and moon are balanced at their centre of gravity, upon a pointed wire, bearing at its other end the sun: this wire has a point projecting sideways near its furthest extremity. The moon also bears a side point, thus (every part being nicely balanced), the earth and moon revolve round each other, and both together round the sun—making one of the best possible illustrations of the real motion of these heavenly bodies. Price, $2.50.

Fig. 317.

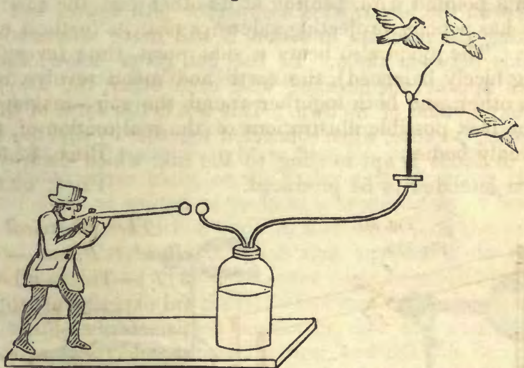


The Electrical Inclined Plane. — (Fig. 317)—This is a beautiful experiment, and satisfactorily shows that the electrical matter issuing from a number of points possesses force sufficient to counteract the power of gravity in light bodies. It consists of a board of mahogany, fourteen inches long and four inches broad, having four glass pillars, three-tenths of an inch in thickness; the length of the two longer is seven inches, and that of the two shorter is five inches.

From the longer to the shorter pillars are stretched two fine brass wires, parallel to each other, and tightened by screws which pass through the brass balls which surmount the pillars. On these wires the axis of the fly rests, the ends of which are formed like a small pulley, having a groove in them to prevent their slipping off the wires, and to guide the fly when in action. It is obvious that if the fly be placed on the upper part of the wires, it will roll down them by its own gravity; but when it has reached the bottom of the plane, if the upper end of the wires be connected with the machine while in action, the escape of the fluids from the points will cause it to roll very rapidly up the plane till it reach the top of it.

These experiments may be varied to a great extent, and models of corn-mills, water-pumps, astronomical clocks, etc., constructed of cork and pasteboard, are readily put in action by directing against their main wheels a stream of electricity from a strong pointed wire inserted into the prime conductor. Price, $3.00.

Fig. 318



The Electrical Sportsman.—(Fig. 318, as above.)—This experiment is to illustrate the fact that a jar will be liable to discharge itself when the two coatings are too close to each other. The inner coating of the Leyden jar is connected with two wires, one of which proceeds to the birds—the other proceeds to within a short distance of the muzzle of the gun. The birds are made of small bits of pith, with a portion of feathers to each, to represent wings. They are attached to pieces of linen thread, four or five inches long. The gun is connected with the outer coating of the wire proceeding from it to the figure, and a slip of tin-foil which is

pasted along the figure to the muzzle. Connecting the wire with the electrical machine in action it will of course become charged, during which time the birds will elevate themselves by electrical repulsion ; when the bottle is charged to a certain extent, the distance between the muzzle of the gun and ball near it will not be sufficient to restrain the passage of the fluid, which will therefore pass between them, occasioning at the same time a flash of light, a loud report, and the falling of the birds. Price, with Leyden jar, $3.00.
" without " " $1.50.

The Electrical Rope-dancer.—(Fig. 319.)—This consists of two stout brass rods, having knobs at each end, and about a foot long. The upper rod is connected with the conductor by a small chain or hook ; the lower one is hung to this, at the distance of two or three inches, by a silk thread at each end ; the lower wire is also connected with the ground by a chain. Place on the lower wire a paper or pith figure, and upon putting the machine in action, it will move alternately and briskly between them. In the cut given below, the two wires appear unconnected with each other, the lower one having a stand of its own. This is a better form of the apparatus, because, when connected together by silk, the figure put to dance is apt to cling to the silk, which destroys the effect intended to be produced. Price, $2.00.

Fig. 319.

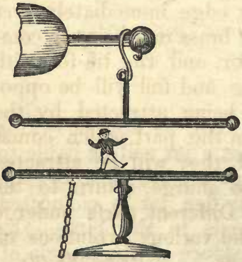


Fig. 32l.

Electrical Swan.—(Fig. 320, as above.)—This is a small metallic swan, made light and capable of floating on water. Let the swan float in a basin of water, which is supported upon a glass stand; suffer a chain to fall from the prime conductor to dip into the water; turn the machine, and hold a piece of bread to the swan, it will immediately turn to it, and approach as if to eat the bread. Price, $0.50.

Fig. 321.

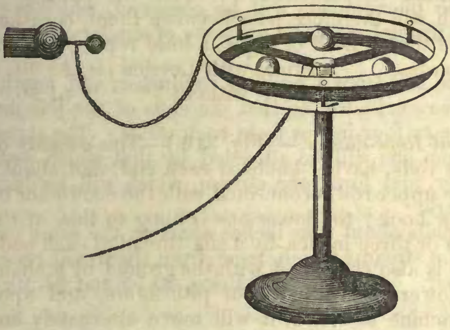


Fig. 322.

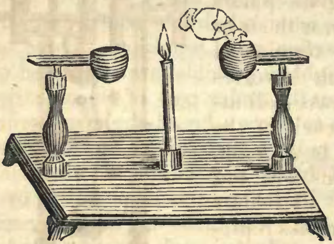
Rolling Glass Balls.—(Fig. 321, as above.)—This instrument for rolling glass balls is an admirable contrivance for illustrating electrical attraction and repulsion. Three or four glass balls made as light as possible, are supported on an insulated glass plate, on the under part of which strips of tin-foil are so pasted as to form a broad circle or border near the margin, and four radii to that circle; on the upper part of the plate is a flat brass ring supported on small glass pillars, so as to have its inner edge immediately over the exterior edge of the tin foil. The brass ring being in communication with the prime conductor, and the tin-foil with the rubbers of the machine, the ring and foil will be oppositely electrified. The glass balls being attracted by the ring, become positively electrified in the part which comes in contact with it. Thus electrified, they will be attracted by the foil, and communicating the charge, return to the ring to undergo another change. Different parts undergo in succession these changes, and the various evolutions of the balls are very striking and curious. Price, $5.00.

The Electrical Pail.—(Fig. 322, as above.)—This consists of a small pail, two or three inches in diameter, with a spout near the bottom, in which is a hole just large enough to let the water out by drops; it is to be filled with water and made fast to the prime conductor; on turning the machine, the water, which before descended from the spout in small drops only, will fly from it in a stream, which in the dark appears like a stream of fire; or a sponge saturated with water may be suspended from the prime conductor, when the same phenomenon will be observed, which is referable to the mutual repulsive property of similar electrified particles.

Suspend one pail from a positive conductor, and another from a negative conductor, so that the ends of the jets may be about three or four inches from each other. The stream proceeding from one will be attracted by that which issues from the other, and form one stream, which will be luminous in the dark.

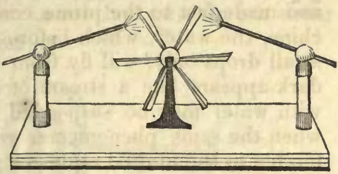
Hang two pails about four inches apart on the same conductor, and the streams which issue from them will recede from each other. Price, $0.75 and $1.50.

Fig. 323.



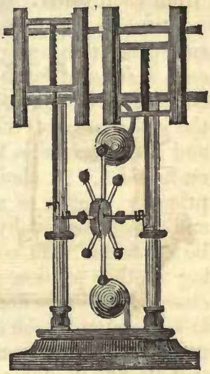
The Phosphorus Cup.—Fig. 323 represents two hollow brass balls, about three quarters of an inch in diameter, insulated on separate glass pillars, by which they are supported at a distance of about two inches from each other; the upper part of each ball is hollowed into a cup into which a small piece of phosphorus is to be put. A small candle has its flame situated midway between the balls, one of which is connected with the positive, and the other with the negative conductor of a powerful machine. When the balls are electrified, the flame is agitated, and, inclining towards the one which is negative, soon heats it sufficiently to set fire to the phosphorus it contains, whilst the positive ball remains perfectly cold, and its phosphorus unmelted. On reversing the connexions of the balls with the machine, the phosphorus in the other ball will now be heated, and will inflame. Price, $3.50.

Fig. 324.



Electrical Wheel.—(Fig. 324.)—This arrangement is mounted on a wooden base, having at each end a glass pillar with a ball at the top, supporting pointed wires, which are fastened towards each other, and about four inches apart, in the centre of which a very light vertical wheel, with floats on the edge, is supported by a suitable stand. Upon connecting the wires with the electrical machine, the one with the positive conductor, and the other with the negative conductor, and putting it in motion, the wheel will turn from the positive to the negative side. Price, $5.00.

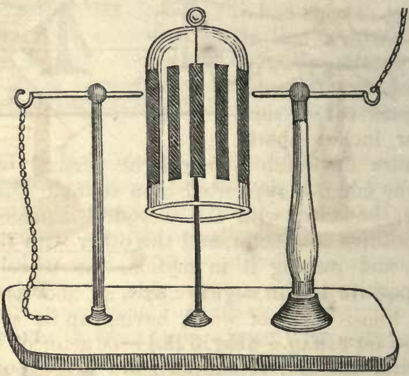
Fig. 325



Electrical Saw Mill.—(Fig. 325.)—The electrical saw mill represented in the cut, consists of two brass pillars, supported on a mahogany base; from near the centre of the glass pillars there is supported an axle, with six or eight glass spokes, each terminated with a metallic ball; this revolves easily just over a large brass ball attached to the base. On each of the pivots of the axle there is a crank, turned in opposite directions, with rod attached to each; these alternately draw up and down light frames representing saws, which are movable in a framework supported on top of the glass supports; another large brass ball being supported from the framework.

To use, connect the upper brass ball with the prime conductor, and the lower ball with the table, or ground; on exciting the conductor, the nearest ball on the wheel will be attracted by a large ball connected with the conductor, and on being fully charged will be repelled by it, and thus bring the next ball near, which in turn will be repelled; these, in coming near the lower ball, will be attracted and discharged; thus a constant carrying of electricity from the upper to the lower ball will take place, and a rotary motion in the wheel be produced, which, by means of the cranks and rods, will move the saws up and down. Price, $6.00.

Fig. 326.



Rotating Bell Glass.—(Fig. 326.)—To a mahogany base is supported two uprights, one of metal and the other of glass, each having a brass cap and socket, with sliding rod, the outer ends of the rods being formed into hooks. Between the inner ends of these rods there is supported on a point, and metal centre, a bell glass, having pieces of tin foil pasted on its sides. A chain, connecting the insulated rod with the prime conductor of an electrical machine, will cause the rod, and glass covered by one of the strips nearest to the rod, to be electrified, and consequently to be repelled; thus bringing another portion near the rod, which in like manner is charged, and repelled; and thus each portion will be charged in succession; each of which, in revolving near the rod connected with the ground, will be discharged, and thus a continued rotary motion produced. Price, $4.00.

Electrical Vane.—(Fig. 327.)—This is a light wheel of paper or pasteboard, suspended on a stand by a delicate point, having a support to sustain it in a horizontal plane; on the edge of the wheel are a number of floats, which when placed before the end of a point attached to the prime conductor, will be put into rapid rotary motion.

The wheel may be suspended vertically, instead of horizontally, and a system of wheelwork put in motion by the same means. Price, $2.00.

Fig. 327.

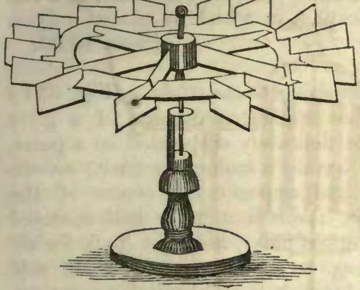
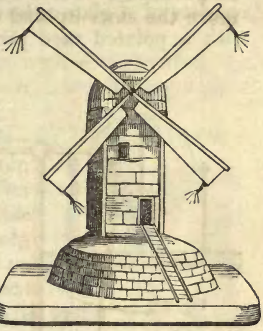


Fig. 328.



Electrical Windmill.—(Fig. 328, as above.)—This consists of a house made of wood, having up its centre a wire, the lower end fitting a hole in the conductor of an electrical machine, the upper end supporting a pivot, put crossways, so that its end projects through the mill, bearing the sails, which are of paper or pasteboard, a fine wire running along the back and end of each, having a point projecting beyond the outer edge; upon turning the machine the mill will revolve rapidly. Price, $5.00.

Fig. 329.

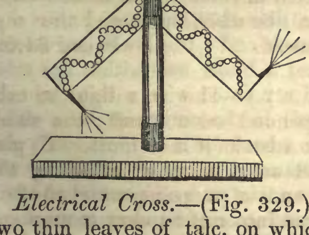
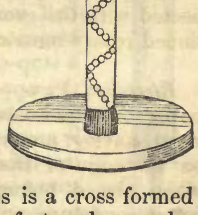


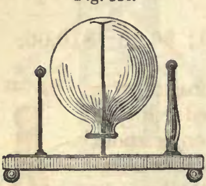
Fig. 330.



Electrical Cross.—(Fig. 329.)—This is a cross formed of two thin leaves of talc, on which are fastened spangles of tin-foil nearly touching each other and having a wire point at each end; the cross supported delicately on a suitable support. Price, $2.50.

Spiral and Flyer.—(Fig. 330, preceding page.)—This consists of a glass tube coated as a spiral, and having a cup with a pointed wire projecting, in which is placed a flyer.
Price, $3.00.

Fig. 331.



Revolving Glass Globe.—(Fig. 331.)—This apparatus consists of a glass globe delicately suspended on a point, and having a mahogany base; on one side and opposite the centre of the globe, there is a brass ball mounted on a glass pillar, having a hook for attaching a chain; on the other side there is a brass ball with metallic support, having a point projecting towards the centre of the globe. To use, connect the insulated ball with the conductor of the electrical machine by a chain, and the other ball with the floor, or ground; give the glass globe a rotary motion with the hand; the globe, on passing the insulated ball, will on that side be charged, and repelled; but on coming near the point on the opposite side, will be attracted, and the fluid drawn off, thus keeping up a continued rotary motion. Price, $2.50.

Fig. 332.

The Aurora Tube.—(Fig. 332.)—This interesting and beautiful experiment is shown by a glass tube of from twenty to forty inches in length, and from one and a half to two and a half inches in diameter, having brass caps cemented on each end; the lower end having a stop-cock and a brass ball within the tube, the upper end a pointed wire within the tube and a brass ball on the outer end; the whole is mounted on a base for a support. To use, the tube is exhausted of air by attaching the stop-cock to an air pump; present the ball to the prime conductor of an electric machine, when the fluid will pass in a continued and beautiful stream, the appearance presented being exactly that offered by the aurora borealis in high latitudes. To insure success, the tube should be thoroughly dried previous to use, to free it from all dampness.

This apparatus is also commonly used for showing the guinea and feather experiment in pneumatics, having a piece of metal and feather within the tube.

Price, three sizes, $4.50; $6.00; $10.00.

Fig. 333.

Aurora Flask.—(Fig. 333.)—This consists of a glass flask, holding about a quart, coated with tin foil at the end of the globular part, covering about one-third of the sphere to the neck. There is cemented a brass cap, with screw, for attaching to the air-pump, and having a valve on the end of the screw to prevent the return of the air, over which a nut is screwed to prevent any leakage. To imitate the aurora borealis—make the flask very hot before the fire, hold it by the tin foil, and hold its ball to a charged prime conductor. Very long and brilliant flashes will pass along the partly exhausted flask. The flashes will continue long after the removal of the tube from the machine. Price, $2.50.

Fig. 334.

The Luminous Discharger.—(Fig. 334.)—This consists of a bent glass tube, having a brass ball at each end, connected by an iron chain which passes through the tube, and having a wooden handle.

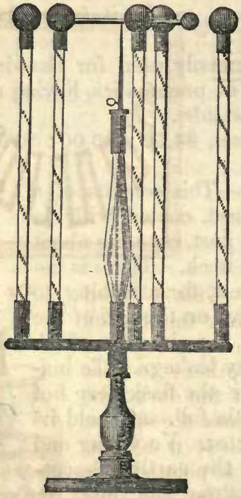
Discharge any Leyden jar with this discharging rod, and it will appear beautifully luminous. Price, $2.00.

Spiral Tube.—(Fig. 335, next page.)—This consists of two glass tubes, placed one within the other. On the outside of the inner tube are fastened spangles of tin-foil; the two ends of the tubes are wrapped round with tin-foil, and cemented each into a brass cap. To use the spiral tube, hold one end in the hand and the other apply to the conductor, when a spark will pass along the whole length.

Price, $2.00 and $2.50.

Fig. 335.

Fig. 336.



Set of Spirals.—(Fig. 336.)—This is an instrument of extreme beauty. It consists of five spirals, enclosed in glass tubes, about 14 inches long, connected by brass sockets to a handsome polished mahogany stand; on the top of each spiral is a cap terminating in a brass ball; in the centre of the stand is a swelled glass pillar with a cap, and terminating in a pointed wire, on which is mounted to turn easily, a wire terminated by balls, so that as it revolves it shall come very near to each of the spiral tubes in succession; to the cap of the swelled pillar there is a hook, to attach a wire to the prime conductor; if the movable flyer be started it will continue to revolve, communicating a spark to each of the spirals, and they will be rapidly illuminated.

Price, $10.00.

Luminous Word.—(Fig. 337, next page.)—The luminous word is formed by pasting strips of tin foil on a plate of glass, having portions cut out as represented in the cut. The side of the glass coated is protected from injury by another glass plate, and both fixed in a frame, having a handle, or mounted on a stand. A brass knob and wire connect with the first piece of foil, and a hook and chain with the last. On presenting the knob to the conductor, the chain being connected with the ground, lines of fire representing the word, occasioned by sparks passing at the same moment through all the spaces, will be seen.

Price, $3.00.

Luminous Crescent.—(Fig. 338, next page.)—This is the same instrument in principle, and formed in the same manner, having a frame about fourteen inches square representing luminous lines in the form of a crescent. Price, $3.00.

Fig. 337.

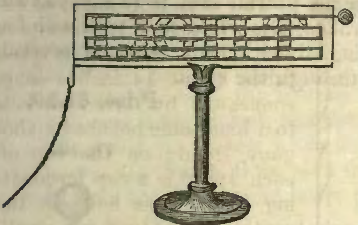
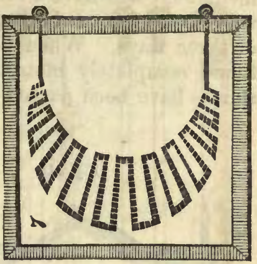
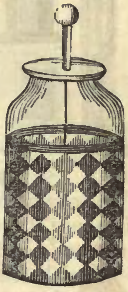


Fig. 338.



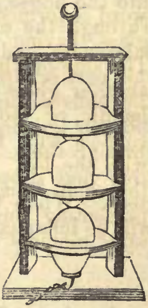
Spotted Jar.—(Fig. 339.)—This is fitted up like the Leyden phial, only the tin-foil coating is gummed on in little square pieces at some distance from each other; so that when the bottle is charged in the dark, the sparks will be seen flying across the spaces, from one square to another. If it be discharged gently, by bringing a pointed wire gradually to the knob of the jar, the fluid will pleasingly illuminate the uncoated parts, and make a crackling noise in passing the spaces. Price, pint, $2.25.
" quart, $3.00.

Fig. 339.



The Egg Stand.—(Fig. 340.)—This consists of a wooden frame, with a piece of metal let into the bottom; a chain attached to this is connected with the outside of a Leyden jar. There are three wooden slides to hold as many eggs. A wire and ball pass through the upper part of the frame, so as to touch the top egg, and the eggs are to touch each other. A shock is passed through the eggs by touching the upper ball with a discharging rod, which reaches to the inside of the charged jar, whose outside is united to the chain at bottom. The eggs will become beautifully luminous, and the shock in passing will make a sound as if the egg shells were broken, as indeed they will be if the shock be large. A quart jar is quite sufficient for this experiment. The eggs, if eaten im-

Fig. 340.



mediately, will have a strong taste of phosphorus; and will very soon afterwards become putrid, that is to say, in two or three days. When broken, the white and yelk will be found completely intermingled with each other, if several shocks have been passed through the eggs.

Price, $1.50.

Fig. 341.

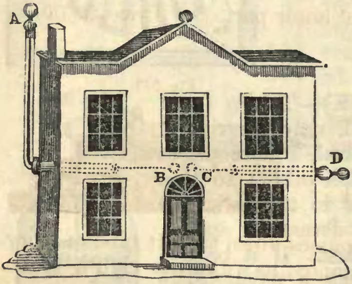
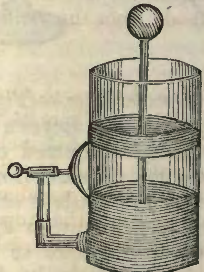


Fig. 342.

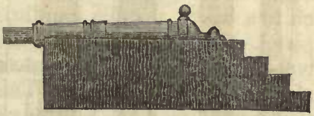


Electrical Fire House.—(Fig. 341.)—This is a neatly-made tin house, having in the front five windows and a door, which are handsomely painted, and the front crossed off to represent brick or stone. On the one side of the house, attached to the chimney, there is a glass tube, terminated by a brass ball, A, within which is a wire, proceeding down the tube into the house, where it is terminated by a second ball, B. Through the opposite side of the house is a second glass tube, wire, and two balls, marked at C and D. The wire of this part is capable of sliding backwards and forwards, that the balls withinside may be made to approach each other more or less according to the strength of shock to be passed through them. The balls C and D are loosely covered with tow, and dipped in or sprinkled with powdered yellow rosin. When the shock is passed from A to D, the rosin will be inflamed, and the fire appear through the windows.

Price, $3.50.

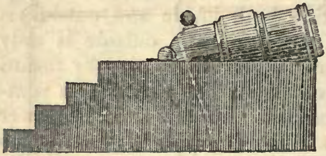
The Belted Bottle.—(Fig. 342.)—This is a glass jar coated as represented in the figure, having an arm attached to the bottom supporting a rod of glass, to which a sliding piece is attached, to connect the belt with the lower part. This instrument shows the passage of the fluid during the charging of the bottle. The coating both inside and outside is put on as represented. The belt on the outside is only put in contact with the lower part of the coating by means of the sliding piece on the outside. The wire within is attached to the inside of the bottom. In charging, the lower part becomes charged first, and the fluid will be seen to pass upwards inside in flashes, while if the connecting piece be withdrawn, the fluid will be seen to pass downwards on the outside from the belt to the lower part. Price, $3.00.

Fig. 343.



The Electrical Cannon.—(Fig. 343.)—This is a brass cannon, about five inches long and one inch in diameter, mounted on a wooden stock; the ball at the top has a wire attached to it, which passes down a short tube of ivory into the chamber of the cannon, to within an eighth of an inch of the opposite side, and through this space the spark passes to explode the gas, which may be formed by putting a handful of iron nails, or the same quantity of pieces of zinc, into a wine bottle; to these add half a pint of water and a wine glass full of sulphuric acid. Have ready prepared for the bottle a cork which fits it, and through which the stem of a tobacco pipe passes. The mixture will soon throw up bubbles of gas; when it is supposed that these have displaced the air of the phial, cork it up, so as to suffer the gas to pass out only through the stem of the pipe. Here it may be collected in a collapsed bladder fastened to the other end of the stem, or, if preferred, the bladder may be tied to the top of the cork itself. The gas will soon fill the bladder. When enough for use has been collected, the stem may be broken, so as to separate the bladder and the bottle; then holding the cannon with the mouth down, press the gas into the cannon, which, by its levity, will partially displace the atmospheric air, mixing therewith, and producing an explosion when the spark is passed through. The mouth of the cannon must be well corked to prevent the escape of the gas previous to firing. Price, $2.00.

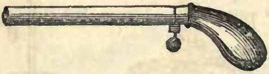
Fig. 344.



Electrical Mortars.—(Fig. 344.)—These are formed as the preceding, only in the shape of a mortar.

Price, $3.00.

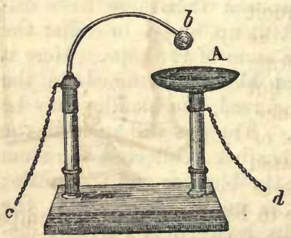
Fig. 345



Electrical Pistol.—(Fig. 345.)—The simplest and best form of the hydrogen pistol is seen in the cut. It consists of a tube of brass, about an inch in diameter, and eight inches long, fastened on to a baked wooden handle, shaped like that of a common pistol. Where the trigger is ordinarily placed, is a short ivory tube, which fastens into the brass tube, so as to reach about half way across it. This piece of ivory is pierced so that a wire may pass through it. The inner part of the wire is at a small distance from the inner part of the top of the tube, and the outer end of it is terminated by a small ball. If then a spark be taken by the barrel, and at the same time that the finger touches the ball of the trigger, a spark will pass from the tube to the point of the wire inside, and thence to the trigger to the hand.

Price, $2.00 and $3.00.

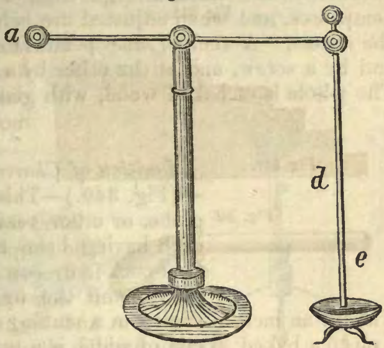
Fig. 346.



Apparatus for Firing Gunpowder by the Electrical Spark—(Fig. 346)—consists of a mahogany base, about six inches long and four wide, supporting two insulating glass pillars; to the one is attached a bent wire, terminating in a small brass ball, and the other a wooden cup for the powder, each having a crook for attaching a chain. The powder is placed in the wooden cup, A, either dry or made up into a pyramidal form with a little water. The brass ball, *b*, is brought immediately over it; the chains, *c d*, being connected with the outer and inner surfaces of a Leyden jar. The discharge takes place, and the powder is inflamed.

Price, $3.50.

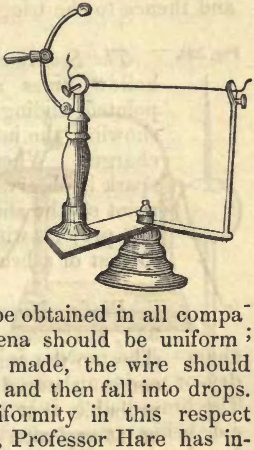
Fig. 347.



Apparatus to Fire Spirits of Wine, or Ether.—(Fig. 347.)—This consists of a rod, having a knob at each end, supported horizontally on an insulated stand. Through one of the balls slides a wire, vertically, with a knob at one end, beneath which is placed a metallic cup for the spirits.—To use, place it so that the ball, *a*, can receive sparks from the prime conductor. Pour spirits of wine into the cup, *e*, till the bottom is just covered. Place the cup under the wire, *d*, then turn the machine, and the sparks that are received by *a* will fly from the wire through the cup, and inflame the spirits. Warming the spirits will cause it to take fire more readily.

Price, $2.25.

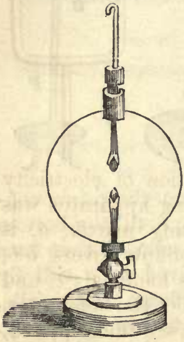
Fig. 318.



Stand for the Fusion of Wire by the Electric Spark.—(Fig. 348.)—The fusion of wire is sometimes employed as the test of electrical power, in which case it should be taken that the length of the circuit is always the same, and that the degrees of ignition are uniform; for a wire may be melted with but slight variations of appearance, when very different quantities of electricity have been transmitted through it. The lowest degree of perfect ignition ought therefore to be obtained in all comparative experiments, and its phenomena should be uniform; that is, as soon as the discharge is made, the wire should become red hot in its whole length, and then fall into drops. In order to ensure a perfect uniformity in this respect throughout a series of experiments, Professor Hare has invented the apparatus shown in the cut. This consists of two bent arms, which diverge from a centre, as a pair of compasses, and when adjusted are held tight by a screw at the centre. A reel of fine pendulum wire is fixed at one end by a screw, and at the other by a small pair of nippers. The whole is of baked wood, with glass supports.

Price, $3.00.

Fig. 349.



Ignition of Charcoal Points in Chlorine.—(Fig. 349.)—This consists of a glass globe, or other vessel, having two necks, each having brass caps, the lower one a stop-cock for connecting with the air pump, and the upper one a brass rod sliding in a stuffing box, on the interior end of which is a pair of forceps for holding a charcoal point, another similar point being fixed to the stop-cock below. To use, fill the vessel with chlorine gas, and adjust the wires, so that their points shall nearly touch each other. When the electric current is made to pass through the wires, the charcoal points will be ignited, becoming of a red heat, yet the chlorine will not be affected, however long the action may be pursued.

Price, $6.00.

Fig. 350.

The Sphere and Point.—(Fig. 350.)—Faraday's hollow brass sphere and tubular handle, with pointed sliding wire within, for the purpose of showing the influence of surfaces in electrical discharges. When the sphere is employed a bright spark is observable at each discharge, provided the point of the sliding wire be within the sphere, but if it projects without, the discharge changes its form to that of a brush. Price, $1.50.

Biot's Movable Hemispheres and Ball.—(Fig. 351, next page.)—For showing that electricity resides on the surface only. When a substance becomes charged with electricity, it is extremely probable that the fluid is confined to its surface, or, at any rate, that it does not penetrate into the mass to any extent. A ball formed of any material will be equally electrified whether it be solid or hollow, and if it be hollow, the charge which it receives from any source of electricity will be the same whether the shell of matter of which it is formed be thick or thin.

Fig. 351.

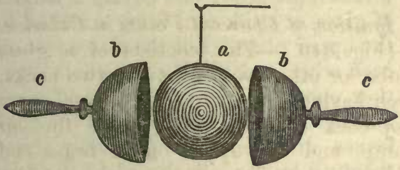
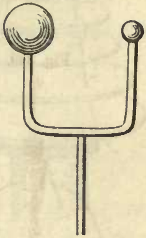


Fig. 352.



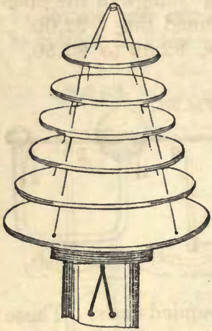
To demonstrate practically the distribution of electricity on the surface of a conductor, the following apparatus was contrived by Biot. A sphere of conducting matter, *a*, is insulated by a silk thread, and two thin hollow covers, *b b*, of brass or copper, are provided with glass handles, *c c*, and correspond with the shape and magnitude of the conductor. The sphere, *a*, is electrified, and the covers are then applied, being held by the glass handles. After withdrawing them from *a*, they are found to be charged with the same kind of electricity as was communicated to *a*, which will be found to have lost the whole of its charge, proving that it resided on the surface only.

But although electricity may be considered as confined to the surfaces of bodies, its intensity is not on every part the same. On a sphere, of course the symmetry of the figure renders the uniform distribution of electricity upon it inevitable; but if it be an oblong spheroid, the intensity becomes very great at the poles, but feeble at the equator.

Price, - - - - - $4.00.
,, mounted on an insulated stand, $5.00.

Faraday's Bent Electrical Conductor.—(See Fig. 352, as above.)—Faraday's bent brass electrical conductor, with two different sized balls at the extremities, for illustrating that between conducting surfaces, the spark, in disruptive discharges, is modified by the differences of the dimensions of the discharging or receiving surfaces. Price, $1.75.

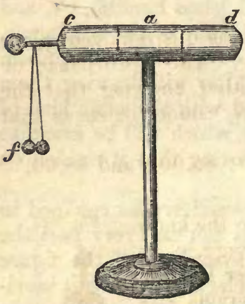
Fig. 353.



Apparatus to show that extending the Surface diminishes the Quantity of Electricity.—This instrument (Fig. 353) consists of a series of metallic plates, increasing in size from the top, and suspended from each other by metallic threads, the upper one having a handle of glass, or a silk cord being attached to the upper plate. Let the plates rest on each other, and placing the whole together upon the top of a gold-leaf electroscope, electrify them so that the gold leaves diverge; then gradually draw them up by the silk thread at the top, when the diverging will diminish in proportion, and again increase when let down as at first.

Price, $2.00.

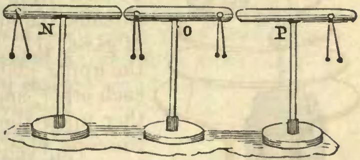
Fig. 354.



Insulated Conductor for showing Electricity by Induction. — (Fig. 354.)—This is formed of a cylinder of brass or tin, with well rounded ends, and supported on a glass stand, and furnished with a pith ball electroscope, and let *e* be an excited glass tube. On approaching this tube within about six inches distant from *d*, the pith balls will instantly separate, indicating the presence of free electricity. Now, in this case the electric, *e*, has not been brought sufficiently near to the conducting body to communicate to it a portion of electricity, and the moment that it is removed to a considerable distance the balls fall together, and appear unelectrified; on approaching *e* to *d* the balls again diverge, and so on. The fact is, this is a case of what is termed induction, the positive electricity of *e* decomposes the neutral and latent combination in *d a c*, attracting the negative towards *d*, and repelling the positive towards *e*, and the balls consequently diverge, being positively electrified. On removing *e* the force which separated the two electricities in *d a c* is removed, the separated elements re-unite, neutrality is restored, and the pith balls fall

together. The electricity of *e* induces a change in the electric state of *d c*. Price, japanned tin, $2.00.
" brass, $2.50 to $3.50.

Fig. 355.

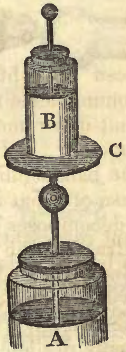


Set of three Conductors for Experiments on Induction.—(Fig. 355.)—This arrangement consists of three conductors mounted on glass pillars, with mahogany stands; the conductors are formed of brass, or japanned tin, with well rounded ends. These instruments, when excited either by the proximity of a charged conductor, or by an excited glass rod held towards them, beyond the conductor, N, draw away the central conductor, and also the excited rod; the central conductor, O, will not be charged at all, that marked P will be positive, and that at N negative.

When charged as before, as soon as O is removed, place the conductor, N, so as to touch P. The disturbance of both will be neutralized by each other, showing that the quantity which is plus in one, exactly counterbalances that which is deficient in the other.

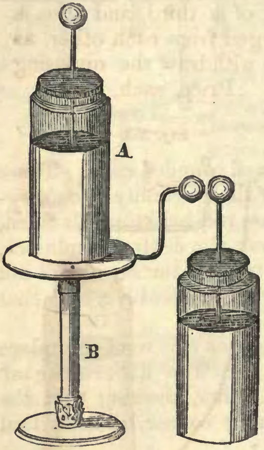
Price, $3.00; $5.00; and $8.00.

Fig. 356.



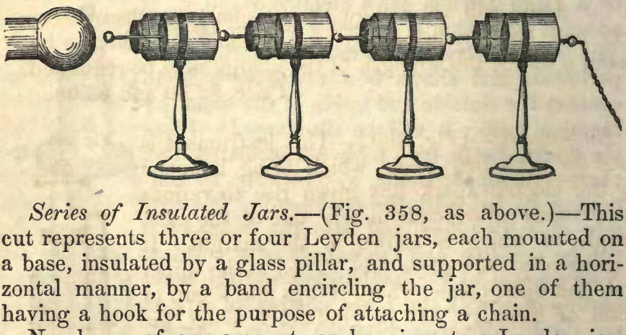
The Double Jar.—(Fig. 356.)—To the knob of a large Leyden jar a metallic stage, C, is adapted on which is placed a smaller Leyden jar. This instrument is used for various experiments, and shows how necessary it is to connect the outside and inside of the same jar together, before it will be discharged. Place the double bottle on a table not insulated, and charge the upper bottle, A, positively, by connecting its ball with the conductor. The outside of A, therefore, and also the inside of B will be negative, and the outside of B positive. Now connect by the discharging rod the outer coating of B with the inner coating of A, and no shock will pass between them. Again, connect the outside of B with the inside of B, and a shock will pass. Now connect the inside of A with the inside of B, and a second shock will be obtained. A series of bottles may thus be arranged, and a series of shocks obtained by one charge only. Price, $3.00.

Fig. 357.



Insulated Stand.—(Fig. 357.)—This is a metallic plate having a brass knob, and insulated by a glass pillar cemented into a mahogany base, and useful in many experiments. Place the jar, A, on the insulating stand, B, and attempt to charge it from the prime conductor, you will find it impossible: now apply the knuckle to the outside coating, and continue to turn the machine: for every spark that enters the jar, one will pass between the outside coating and the knuckle, and on applying the discharging rod, the jar will be found to have received a charge. Instead of the knuckle, the knob of a second uninsulated jar, C, may be applied, and both jars will receive a charge. Price, $2.00.

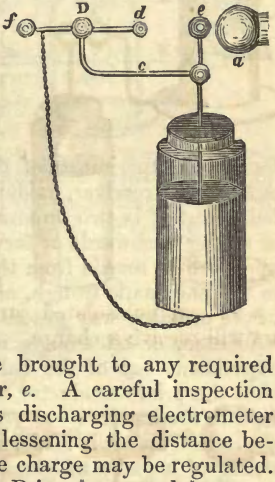
Fig 358.



Series of Insulated Jars.—(Fig. 358, as above.)—This cut represents three or four Leyden jars, each mounted on a base, insulated by a glass pillar, and supported in a horizontal manner, by a band encircling the jar, one of them having a hook for the purpose of attaching a chain.

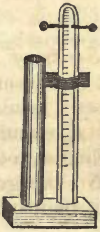
No charge of any amount can be given to a Leyden jar, if it be insulated; for, in proportion as the positive electricity is communicated to its interior coating, it is necessary that the same quantity should be removed from the exterior, which would otherwise counteract the negative electricity by which the charge is sustained. To effect this, a communication is established with the earth, or with the interior coating of a second jar, the outside coating of which again may communicate with the interior of a third, and thus a series of insulated jars may be charged from each other, as shown in the figure, taking care to withdraw the opposing electricity from the last. Price, each, $2.25.

Fig. 359.



Leyden Jar with Discharging Electrometer.—Fig. 359 represents the arrangement for producing a series of discharges from a Leyden jar, for any particular purpose, without the interference of the operator, and also the mode of use; *a*, represents the prime conductor of an electrical machine; *b*, a Leyden jar; on the wire communicating with the interior is fixed an arm of glass, *c*, on the end of which is cemented the brass knob D, through this knob a wire, *f d*, slides, so that the ball *d* may be brought to any required distance from the knob of the jar, *e*. A careful inspection of the figure will show how this discharging electrometer acts, and how, by increasing or lessening the distance between *d* and *e*, the strength of the charge may be regulated. Price, $2.50 and $3.00.

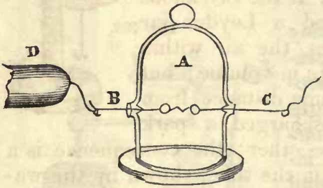
Fig. 360.



Eudiometer.—(Fig. 360.)—This instrument is used for exploding gases, which being inflamed by the electric spark has given rise to various instruments called eudiometers, one of the most simple of which is shown in the margin. It consists of a thick glass tube closed at the upper end, and open below, where it dips into a cup or basin of mercury. It is graduated along the side, and has two wires through the upper part which approach each other. The tube may be supported in any convenient manner. The tube is filled with mercury or water (according to the kind of gas to be operated upon); it is then reversed, and the gas to be operated upon suffered to ascend the tube, until a certain quantity has been introduced. The electric spark or shock is then passed from the one wire to the other, when the gas is inflamed. The result is seen by the product left.

Price, $3.00 ; graduated, $4.00 ; stand, $1.00.

Fig. 361.



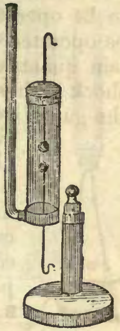
Apparatus for passing an Electrical Spark through Gases.–Pass a spark through a vessel filled with nitrogen, and it becomes intensely brilliant, and of a splendid blue color, equal to that of burning brimstone. The apparatus, which is convenient, for trying experiments of this kind, is as follows (Fig. 361). A is a glass receiver, holding about a pint; it has a wire and ball inserted in two opposite sides, B and C. B is capable of sliding backwards or forwards, so that it may be made to approach or recede from the other. The receiver is placed in the pneumatic trough, and is filled with the required gas, in the ordinary way practised by chemists. For some gases a mercury or oil trough must be employed. During the experiment one of the balls must be connected by a wire with the prime conductor, as at D, and the wire of the other held in the hand.

An instrument is made, answering the same purpose, consisting of a globe of glass having two necks, one of them attached to a cap connected with a stop-cock, and having a brass ball entering the neck of the globe. The other neck a cap with sliding rod, having brass balls at each end. The globe is exhausted of air by the air-pump, and the gas to be experimented with introduced.

Price, $3.00 to $6.00.

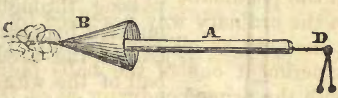
Kinnersley's Electrical Air Thermometer.—(Fig. 362.)— This is an instrument for showing the expansion of air when an electrical shock is passed through the instrument. It consists of a glass tube, ten inches long and two inches in

Fig. 362.



diameter, closed air-tight at both its ends by two brass caps; a small glass tube, open at both ends, the lower one bent at a right angle, passes through the bottom cap, and enters the water contained in the lower portion of the large tube. Through the middle of each of the brass caps a wire is introduced, terminating in a brass knob within the tube, and capable of sliding through the caps, so as to be placed at any distance from each other. If the two knobs be brought into contact, and a Leyden jar discharged through the wires, the air within the tube undergoes no change in volume; but if the knobs are placed at some distance from each other when the jar is discharged, a spark passes from one knob to the other; the consequence is a sudden rarefaction of the air in the tube, shown by the water instantaneously rising to the top of the small tube, and then suddenly subsiding; after which it gradully sinks to the bottom of the tube, the air slowly recovering its original volume. Price, $3.00.

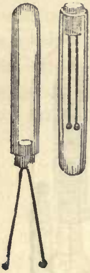
Fig. 363.



Cavallo's Rain Electroscope (Fig. 363), represented in the cut. A is a strong glass tube, about two feet and a half long, having a tin funnel cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube is wholly covered with sealing wax; C is a piece of cane, round which brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. The cane is fixed into the tube, and a piece of wire proceeding from it, goes through the tube, and is terminated by a ring, upon which a pair of pith balls are suspended. This instrument is suspended by the side of a window frame, with the funnel projecting outwards, while the pith balls are preserved dry within. Price, $2.50.

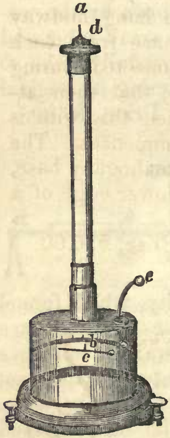
Cavallo's Bottle Electroscope (Fig. 364, next page) is formed by two silver wires, each carrying at one of its

Fig. 364.



ends a little ball made of pith; the other ends of the wires being suspended from a cork, which is rather long and tapering at both ends, so as to fit either way into the mouth of a varnished glass tube, serving both as a handle to the instrument when in use, and as a case for it when carried in the pocket. When it is to be employed as an electroscope, the cork is so placed that the wires hang out of the tube, and will indicate by their divergence any electricity that may be communicated to them. When not in use, reversing the cork closes up the instrument, and renders it more portable. Price, $0.50.

Fig. 365.

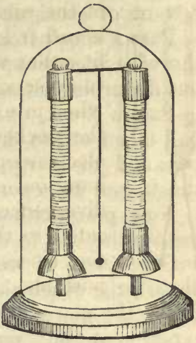


Coulomb's Tortion Balance.—(Fig. 365.)—This delicate contrivance consists of a thread of silk, *a b*, from which a needle of shellac, *c*, is suspended; it is attached to the screw, *d*, by which it can be twisted round its axis; the needle carries a ball of pith gilt, which is balanced by a counterpoise on the other; *e* is a metallic wire passing through the glass shade, and terminated by a metallic ball at each end; the ball of the needle and the interior brass ball of the wire are brought into contact by turning the screw, *d*, and the index then points to the *o* on the scale, which is marked on the circumference of the glass. When the ball, *e*, is electrified, it acts on the ball within that is attached to the needle, repelling it to a certain distance, which distance, and consequently the degree of electrization, is indicated by the graduated scale.

Price, $12.00.

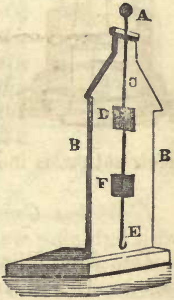
The Dry Pile, or Electrical Chime.—(Fig. 366, next page.)—This instrument consists of a number of alternations of two metals, with paper interposed; the elements may be circular discs of thin paper, covered on one side with gold or silver leaf, about an inch in diameter, and similar

Fig. 366



sized pieces of thin tin-foil, so arranged that the order of succession shall be preserved throughout, viz. zinc, silver, paper, zinc, silver, paper, etc.; about one thousand pairs of such discs, inclosed in perfectly dry glass tubes, terminated at each end with brass caps and screws, to press the plates tight together, will produce an active arrangement; the positive end of one column is placed lowest, and the negative end of the other, their upper extremities being connected by a wire, that they may be considered as one column. A small bell is situated between each extremity of the column and its insulating support; a brass ball is suspended by a thin thread of raw silk, so as to hang midway between the bells, and at a very small distance from each of them. For this purpose the bells are connected, during the adjustment of the pendulum, by a wire, that their attraction may not interfere with it; and when this wire is removed, the motion of the pendulum commences. The whole apparatus is placed upon a circular mahogany base, in which a groove is turned to receive the lower edge of a glass shade, with which the whole is covered.

Price, $20.00.



Thunder House.—(Fig. 367.)—This ingenious article is made of an upright piece of baked mahogany, formed like the gable of a house, as B B, and placed upon a wooden stand. A wire marked C, runs downwards throughout its whole length. It is terminated above by a ball, A, which being unscrewed shows a point beneath it. In one or two parts of the gable are square pieces of wood cut out. These are a quarter of an inch thick, and one inch square on the side. They are shown at D and F; are made so as to fit loosely into a hole cut partly into the gable to receive them, and have a wire running across each, so placed, that putting in the pieces in one way, the wires shall with C E form a continuous and uninterrupted line; and when put crosswise, there shall be a want of contiguity at that place, as shown at D.

Pass a shock from A to E, while the ball remains on and the wire is continuous, and it will make a loud report without disturbing either piece of wood.

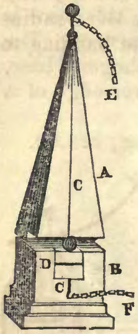
Pass a shock, or rather endeavor to do so, with the upper ball taken off, so that the point is displayed. The fluid will pass and discharge the jar, but not in the manner of the shock, and no report will be heard.

Now place either of the pieces of wood crosswise, and restore the ball to the top. The shock will pass and throw out the piece of wood that was placed crosswise, but not disturb the other piece.

Let the piece of wood be placed crosswise, as in the last experiment, but remove the ball. Upon discharging the Leyden jar, a real shock will pass, and the wood will be displaced, although a point terminates the apparatus.

Price, $1.75 and $2.50.

Fig. 368.

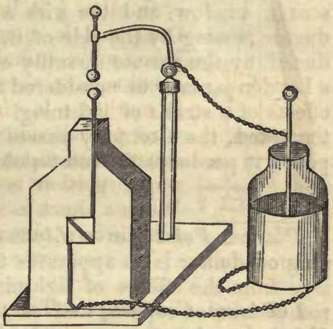


Electrical Pyramid.—(Fig. 368.)—This is an apparatus of the same nature as the last, and is to be used in the same manner. A is a four-sided pyramidal piece of wood, or more usually consists of four pieces fitting on to each other. A line runs down the whole in front, and is, moreover, continued down the base, B; continuity being occasioned by a small square, as in the thunder house. This is marked D in the cut, and is seen with its wire placed sideways. Upon this movable square, and upon the back of the base, the upper portion is supported by three balls. When a shock is sent from E to F, the square D is thrown out, and the upper part of the pyramid falls. Price, $2.00 and $3.00.

Lightning Conductors.—The identity of the electric fluid with lightning was one of the first established facts relative to atmospheric electricity, and as it was the first in time, so it is also in importance to us, teaching not merely the origin and properties of that mighty power of nature, but also how to escape from its direful effects. The very appearance of lightning would induce us to attribute it to electricity, nor is this supposition in any way weakened by our experimental researches. If we compare the properties of electricity with those of lightning, we shall find them closely analogous, or rather identical. To Franklin, whose active mind was constantly directed to practical application of the facts disclosed by science, we are indebted for the suggestion of a method of partially defending buildings from the dreaded effects of lightning. His method was, to erect by the side of the building to be protected, a continuous metallic rod, in perfect communication with the earth; and experience has fully demonstrated the value of this precaution.

The conductor should penetrate the ground sufficiently deep to be in close contact with a stratum of moist soil, and be carried above the highest point of the building. Great care should be taken that every part of the rod be *perfectly continuous*, and that its substance be sufficient to prevent any chance of its being melted; perfect security on this head is arrived at by having a rod three quarters of an inch thick. It has been proved, that conductors erected with these precautions will protect a circular space of a radius double the height above the highest point of the building to which they are attached.

Fig. 369



The little arrangement (Fig. 369) amusingly illustrates the use of a continuous conductor. A board, about three quarters of an inch thick, and shaped like the gable end of a house, is fixed perpendicularly upon another board, upon which a glass pillar also is fixed in a hole about eight inches distant from the gable-shaped board. A small hole, about a quarter of an inch deep, and nearly an inch wide, is cut in the gable-shaped board, and this is filled with a square piece of wood of nearly the same dimensions. It should be *nearly* of the same dimensions, because it must go so easily into the hole, that it may drop off by the least shaking of the instrument. A brass wire is fastened diagonally to this square piece of wood, and another of the same dimensions, terminated by a brass ball, is fastened on the gable-shaped board, both above and below the hole. From the upper extremity of the glass pillar a crooked wire proceeds, terminated also by a brass ball, and sufficiently long to reach immediately over the ball or the wire of the board. The glass pillar is loosely fixed in the bottom board, so that it may move easily round the axis. It is evident that, with this arrangement, a shock from a Leyden jar may easily be sent over the square hole by connecting the exterior coating with the wire in the gable-shaped board below it, and the interior with the wire on the glass pillar which comes within the striking distance of the wire in the gable-shaped board below it.

Suppose now the square piece of wood to be placed in the hole in such a manner that the wire attached to it diagonally shall be in *contact* with the wires above and below it, a shock may evidently be transmitted without any disturbance taking place; but if it be put into the hole in an *opposite* direction, so that the shock from the jar shall be obliged to pass over it altogether in the form of a spark in its passage from wire to wire, the concussion it will occasion will throw the square piece of wood to a considerable distance from the apparatus. The square piece of wood may here be supposed to represent a window, and the wire a continuous or broken conductor passing by the side of it, and the violent effects produced by the minute quantity of electricity accumulated in a Leyden jar may be considered as an humble imitation of the effects of a stroke of lightning. When the passage is uninterrupted, the electricity passes quietly down, but when impeded it produces the most violent effects.

Price, $4.00.

Platina Point for a Lightning Conductor.—The lightning conductor is an apparatus to preserve ships and buildings from the effects of lightning. It consists of a pointed rod of iron or copper, half or three-quarters of an inch in diameter, pointed at top, and projecting two, three, or more feet above the chimney, or other highest part of the building, the lower end being inserted four or five feet in the ground. Its action is as follows:—Should lightning approach the building, it would most likely be drawn away silently by the pointed wire; or, if it should strike the building, the conductor would convey it to the earth without its doing any injury.

Fig. 370.

The most usual way that lightning rods terminate is by merely pointing the rods, sometimes gilding them; the action of the weather on these in a short time destroys the point, and the utility of the rod is in part, or wholly destroyed. To remedy this defect, a copper cone about six inches long, terminated in a platina point (Fig. 370), about one inch in length, is fastened to the top of the rod; this metal will undergo no change by the action of air and water, and will not even tarnish, however long exposed to the action of the weather, and is always used where rods are put up in the best manner.

Price, each, $4.00; small, $3.00.

Powder House. — An electrical apparatus, to show, in an amusing manner, the firing of gunpowder by electricity, and thereby proving the effect of lightning upon buildings in setting them on fire.

Fig. 371.

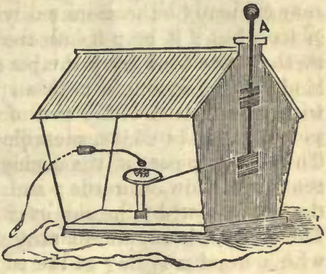


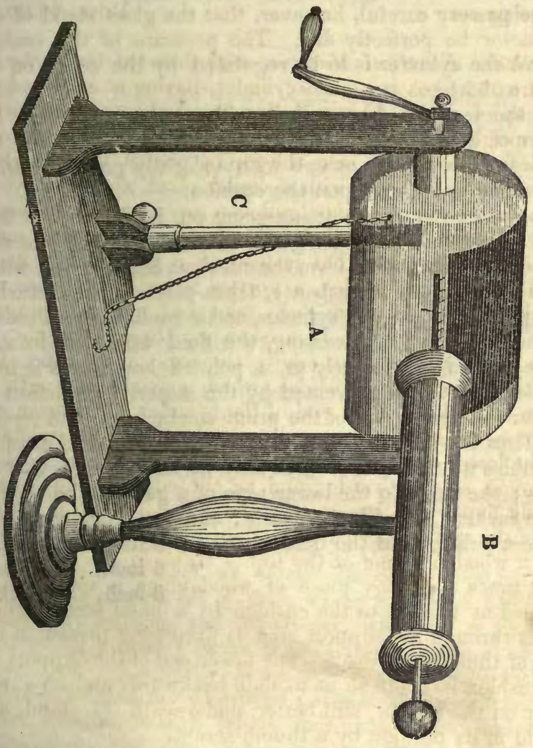
Fig. 371 represents a perspective view, the side next the eye being omitted that the inside may be more conveniently seen. The front is fitted up like the thunder house and used in the same manner. The house itself is made of seven pieces of mahogany, joined together by hinges, so as to be capable of falling flat on the table; a small projecting ridge along the top of the roof holding it up until the powder is fired. A is a ball of brass with wire reaching partly down the house, and across it, inside to the brass top of the table C. This has the gunpowder placed upon it. Immediately above the powder is a second ball, which leads by a wire to the outside of the house at the opposite end, passing through the wood at the end of the house. Then follows the wetted thread, E, and afterwards the chain, B. Passing an electrical shock from A to B, the powder will be fired and the house thrown down.

To insure success in this experiment, it is necessary to pass the charge from the jar, through a few inches of water, disconnecting the metallic wire or chain, dipping it in the water, or pass it through a few inches of wet linen thread connected with the wires or chain through which the discharge passes. Price, $6.00.

Cylinder Electrical Machine, with detached Conductor.—(Figure 372.)—A is a glass cylinder, having at each end of it a cap of wood or brass, and supported by a stand, with two uprights. The end of one cap is turned with a pivot, which fits into a hole near the top of one of the uprights. The other cap is turned with a similar pivot, and has beyond this a flange and a square gudgeon upon which a handle fits. This end of the cylinder is supported in a similar manner to the other end, but instead of a hole merely being bored in the upright leg, a portion is cut away, that the cylinder may be the more easily taken out, and put up again in its place; it may be secured, when there, by a pin run through the upright just above the axis of the cap. Behind the cylinder is a *cushion*, which extends in length to within an inch of either end of the cylinder; it is from one to two inches in width, according to the size of the cylinder. On the lower part of the cushion is glued a flap of leather, the rough side outwards; and on the edge of the leather the silk flap which passes over the cylinder when in action. The cushion is supported sometimes by a thick rod of glass with a wooden spring at the top of it, as in the figure; at other times a springy piece of wood alone is used. It is fastened at the top to the cushion by a hand-screw, which passes through the support, and is fixed by a thread in the back of the cushion itself. The lower end of the support for the cushion is made so as to slide backwards and forwards, either on the top, or, still better, underneath the stand, and is held in its position by a thumb-screw.

B represents the prime conductor, formed either of wood covered neatly with tin foil, or of metal. It has round and smooth ends, at one of them a ball and wire for the suspending of various apparatus, at the other a projecting wire furnished with a row of points to collect the fluid when disturbed by the cylinder. It is necessarily supported upon a glass pillar, sometimes attached at the lower end to the same stand as the rest of the machine, in which case the conductor runs parallel to the cylinder, and has the points in the side instead of the end. At other times it is fixed to a separate foot, as is to be seen in the figure below.

Fig. 372.



To Work the Machine.—Warm the whole well before the fire, and cleanse it from all damp and dust. Take off the cushion, scrape away all dirt, spread evenly upon it some fresh amalgam, put it back in its proper place, and fasten to the screw which connects it with its upright a brass chain, the other end of which reaches to the table or floor, or the walls of the apartment. Upon now turning the handle, streams of fluid will be seen to issue from the cushion, and passing under the silk. to fly off at its edges. To collect the fluid, place the conductor with its points about a quarter of an inch from the edge of the silk, which will so readily attract the fluid from the cylinder, that sparks proportionate to the extent of the glass surface rubbed may be taken from it; being very careful, however, that the glass stand of the conductor be perfectly dry. The pressure of the cushion against the cylinder is to be regulated by the screw on the stand at bottom.

If the machine be small, it will require warming; the power of a machine is generally increased by rubbing the cylinder for a minute or two with a slightly greased rag, or by putting one hand upon the cushion.

The rationale of the action going on, is this:—The fluid passes from the earth through means of the floor, walls, &c., to the chain suspended from the cushion; here friction, which is the cause of the disturbance, takes place. The disturbed fluid passes to the glass cylinder, and is confined from escape by the silk flap; that ceasing, the fluid would fly to anything around, particularly to a pointed body, or a lighted candle; but this is prevented by the superior attraction for it from the nearer end of the prime conductor put to receive it. Thus it will be at once seen that an electrical machine resembles a pump; the earth may be likened to a well of water; the chain to the lower pipe of a pump; the cushion is the sucker; the silk the nozzle; and the prime conductor is like a pail to hold the fluid. Price, 5-inch, $10.00.
" 6-inch, $12.00.
" 8-inch, $16.00.

MEDICAL ELECTRICITY.

It is true, that like every other simple medicine which has proved beneficial to mankind, electricity met with much opposition from the interested views of some and the ignorance of others, has been treated with contempt, and injured by misplaced caution. We shall recommend to those who thus oppose it, not to condemn a subject of which they are ignorant, but to hear the cause before they pass sentence; to take some pains to understand the nature of electricity; to learn to make the electrical machine act well, and then apply it for a few weeks to some of those disorders in which it has been administered with the greatest success; and there is no doubt but they would soon be convinced, that it deserves a distinguished rank in medicine, which is the offspring of philosophy.

The science of medicine and its practitioners have been reproached with the instability and fluctuations of practice; and on this ground it has been predicted, that, however great the benefits which may be derived from electricity, it would still only last for the day, and then be consigned to oblivion We must confess that we cannot be of this opinion, noi easily led to think a set of men, whose judgment has been matured by learning and experience, will ever neglect an agent which probably forms a most important part of our constitution. Electricity is an active principle, which is neither generated nor destroyed; which is everywhere, and always present, though latent and unobserved; and is in motion night and day to maintain an equilibrium that is constantly varying.

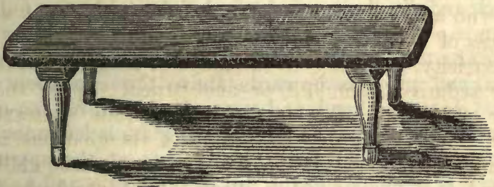
As the science of medicine knows of no specific, so we are not to suppose that electricity will triumph over every disorder to which it is applied. Its success will be more or less extensive, according to the disposition of the subject, and the talents of those who direct it; it cannot, therefore, appear surprising, that many disorders have been refractory to its powers, and others have only yielded in a small degree, or that the progress of the cure has often been stopped by the impatience or prejudice of the diseased; but at the same time, it must be acknowledged, that even in its infancy, when it had to combat against fear, prejudice, and interest, its success was truly great; we have surely then the highest reason to expect a considerable increase of success, now that it is cultivated and promoted by professional men of the first merit.

Electricity should always be administered gently at first, and its power only increased when the gentle application is found ineffectual, except in cases of paralysis, or when used to remove obstructions, its full power may be at once administered; but even here the shock of a quart Leyden jar will be sufficient; the frequency of the "shocks," and not the strength of them being most to be relied upon. Also, we would remark, that no danger can arise from the administration of electricity; and let it not be thought that the remedy is worse than the disease, as those who subject themselves to the powerful shocks given by the electrical apparatus of our various institutions are apt to believe. On the contrary, it may be administered to sleeping children without waking them; and even when awake, its application may be made a source of gratification rather than of apprehension. To administer electricity properly requires considerable skill and tact in the operator, and as this is seldom found so surely as among medical men, and as they neither like the trouble of operating, nor are taught anything of the curative effects of the fluid during their medical studies, they who are best able to administer it with effect are regardless of it altogether.

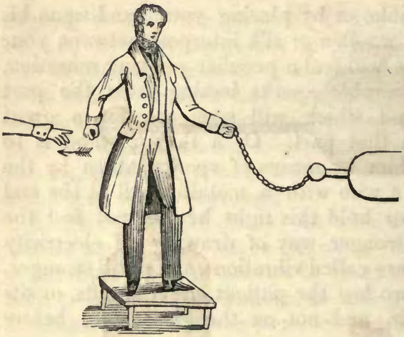
Electricity, according to the mode of its administration, is either sedative, stimulant, or deobstruent; hence the propriety of its application to diseases of quite contrary character. We have applied it to palsies, rheumatisms, inflammations, contractions of the muscles, amaurosis, chilblains, tumors, sprains, and other diseases and accidents. The methods of electrifying are five; first, simple electrization, or merely subjecting the person to the action of electricity, by placing him on a glass-legged stool, and connecting him with the electrical machine when in use, as represented in the cut. Second, drawing the fluid from the particular part of his body which may be affected; this is either done holding towards him a wooden point, when a cooling and refreshing breeze is perceptible, or by placing your hand upon his clothing, when if any woollen or silk interpose between your hand and his body he will feel a peculiar pricking sensation, occasioned by innumerable sparks issuing from the part beneath the hand, and which will soon occasion a great degree of warmth in that part. Or a third method is to draw the fluid from him by means of sparks, taken by the knuckle, or else by a wire with a metallic ball at the end of it. If the operator hold this tight he will not feel the sparks himself. A stronger way of drawing off electricity is by means of what are called vibrations, and a still stronger, sparks. For these two last the patient either stands, or sits on an ordinary chair, and not on the glass stool before mentioned.

The following apparatus is all that is essentially necessary, though many other articles have been described and recommended. The first essential is a glass-legged stool (Fig. 373); if required for cheapness it may be a piece of board, made smooth, and with round edges, supported upon four wine bottles, pegs being driven into the under-side of the board to fit the necks of the bottles; solid glass are, however, infinitely better. In using the stool, a large sheet of brown paper or pasteboard, or, still better, a piece of oil-cloth, larger than the stool itself, is to be placed beneath it on the floor, to prevent the filaments of the carpet, or the dust of the floor, from drawing away any of the fluid accumulated.

Fig. 373.



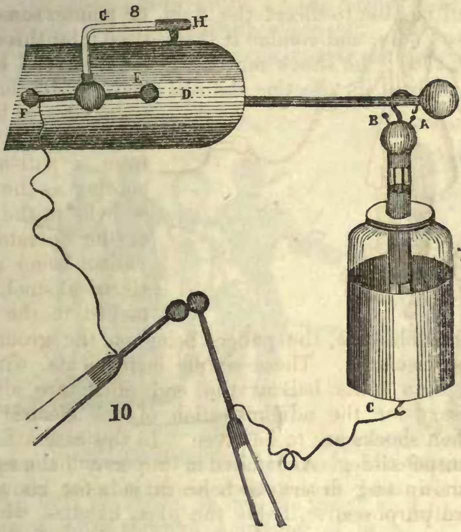
The next requisite is a flexible tube, or connector, as a chain; the stool should be connected to the machine by a chain which is sewed up in silk, and afterwards varnished or covered with India rabber; thus there will be no loss of fluid. But for numerous purposes the instrument called a flexible tube is much better.



A wooden or metal point is sometimes used; by this a gentle stream of electricity, called the electrical aura, or breeze, is given to or taken from a patient, according as the point is held in the hand of the operator, the patient being on the electrical stool, or attached to the glass-handled flexible tube, the patient being on the ground, or rather not insulated. These simple instruments, with the exception of a brass ball at the end of it, are all that are necessary for the administration of the electric fluid, except when shocks are to be given. In this case a Leyden jar is indispensable. Any Leyden jar may be used, but the one shown and described beneath, is most convenient for medical purposes.

Medical Jar.—(Fig. 374.)—The medical jar here represented, A C, is a bottle of about a quart in capacity, represented in the cut as hanging from the projecting knob of the prime conductor of a machine, and having other apparatus attached to it. It is like an ordinary Leyden jar, covered and lined to a certain height with tin foil. A wooden cap is fitted to it with a hole just admitting a glass tube. The tube reaches below to within two inches of the bottom, and projects upwards above the cap about three inches. If is also lined and covered with tin-foil, so placed that rather more than an inch of the glass is left uncovered at the lower end, and about two inches at the upper end. The tube is cemented to the top of the bottle, and a smaller cap cemented on the top of the glass tube; but before this last is cemented on, three holes are drilled in it; one for a hook wherewith to suspend the phial from the conductor, the two others are to be left open; one of them to admit a wire to touch the inner coating of the tube, the other a second wire, sufficiently long to reach to the coating of the phial—these are shown in the cut at A and B. A wire is

Fig. 374.



also twisted round the outer coating of the inner tube, which projects outwards sufficiently to touch the inner coating of the phial. On the outer coating of the phial is fastened a hook, marked C, for the convenience of attaching a chain. E F G H (Fig. 374) is a medical electrometer; its use is to regulate the strength of the shock, for this depends upon the intensity with which the phial is charged, no less than the size of the phial itself. H, is a socket, and a wire attached to it laterally. Into this socket is cemented a bent glass tube, G; at the opposite end of this is a second socket of metal, also cemented to the glass. A hole is made through this socket to admit the wire, which holds the brass balls E and E. This wire is capable of sliding backwards and forwards, parallel with the horizontal part of the glass tube. D, is supposed to be the prime conductor. When in use, to the outer ball, F, of the electrometer, and also to the hook, C, of the bottle, are attached chains, leading to a pair of glass-handled directors; the upper part of which is seen in Fig. 374, and a pair of directors complete in the Fig. 375.

We will now show the use of this apparatus. The directors are for two purposes ; first, that by means of their balls they shall be able to direct the fluid, or shock, to any particular part only, and confine it thereto, as in the following cut (Fig. 376) ; the shock may be given from the knee to the foot without its affecting the rest of the body.

Fig. 375.

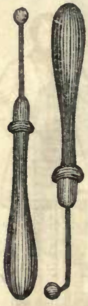
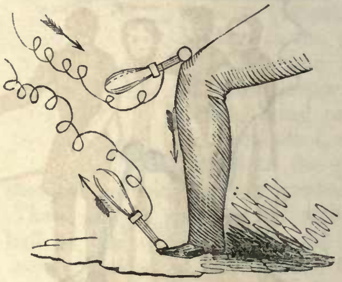


Fig. 376.



The use of the glass handles is to prevent the operator from participating in the shock he intends for his patient. The operator, of course, holds the glass handles, while the balls are made to touch the extreme points of that line through which the shock is to pass. One director is usually straight, and the other bent. We will now suppose that the ball, E, of the electrometer has been placed so as to touch the conductor, the whole apparatus being dry, and in good working order ; and indeed that the whole is as represented in the cut ; the knobs of the directors touching, and the wires, A and B, being in their place. Turn the machine and the bottle will not charge, because the outside is in close contact with the inside, there being no interruption in the circuit anywhere. Now remove the ball, E, a short space from D ; upon turning the machine a second time, the bottle will become charged, because its inside is not connected by conducting substances with its outside. A vacancy occurs between D and E, and exactly in proportion to the size of that vacancy will be the strength of the shock which passes through the chains, or the balls of the directors ; and as those balls are applied to different parts of the body, so of course will be the strength of the shock which will be felt. The above supposes that both wires are in the bottle ; now if we draw out the longer wire, the only one left will be that which touches the inner coating of the tube, and this tube being so small, the shocks which will pass will be less energetic than those given by the larger bottle, and will altogether have a different character. They are, indeed, intermediate in effect, between sparks and shocks, and are called vibrations.

Fig. 377.

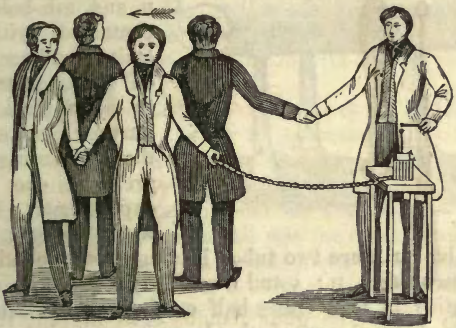
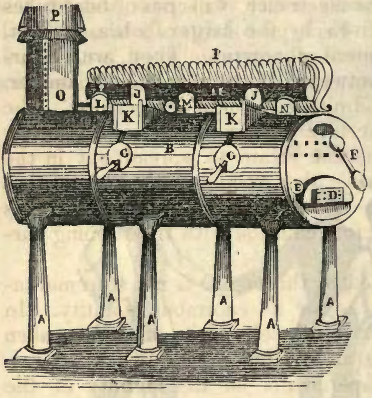


Fig. 377, as above, shows the usual method of administering a shock through a number of persons at once, supposing we have not the apparatus above described, and that we desire only amusement. The phial on the table is charged ; a chain connects its outside to the first person, he by joining hands to the second, and so on to the end ; the last person touching the knob of the phial with a wire and ball. If the persons shocked turn their backs to the phial, the shock will reach them more unexpectedly

Hydro-Electrical Machine.—The production of electricity by the passage of steam through a small jet, was unknown till 1840. Professor Faraday concludes that it is the effect of the friction of globules of water against the sides of the opening, urged forward by the rapid passage of the steam ; the effect of this is to render the steam or water positive, and the pipes from which it issues negative.

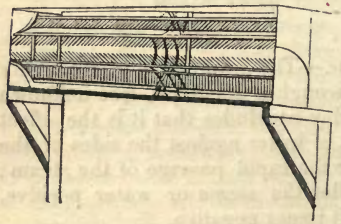
In the following cut (Fig. 378, next page), A, A, A, A, A, A, are six green glass supports, three feet long ; B is a cylindrical tubular boiler of rolled iron-plate, $\frac{5}{8}$ inch thick ; its extreme

Fig. 378.



length is seven feet six inches, one foot of which is occupied by the smoke chamber, making the actual length of the boiler six and a half feet; its diameter three and a half feet. The furnace, D, and ash-hole, C, are contained within the boiler; and are furnished with a metal screen to be applied for the purpose of excluding the light during the progress of one class of experiments; F is the water gauge; E, the feed-valve; J J, are two tubes leading from the valves, K K, to the two tubes, H; A and I, are forty-six bent iron tubes, terminating in jets, either half or the whole of which may be opened by means of the lever, G G; L, is a valve for liberating steam during the existence of the maximum pressure; M, is the safety valve; N, is a cap covering a jet, that is employed for illustrating a certain mechanical action of a jet of steam; O, is the first portion of the funnel; P, the second portion, which slides into itself by a telescope joint, so that the boiler may be insulated when the experiments commence. The boiler is cased in wood.

Fig. 379.



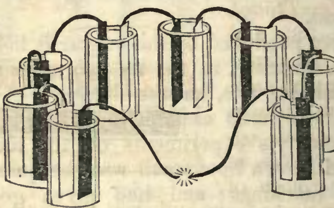
The next figure (379), which may be called the prime conductor, but which is not used for the purpose, is a zinc case, furnished with four rows of points. It is placed in front of the jets, in order to collect the electricity from the ejected vapor; and thus prevent its returning to restore the equilibrium of the boiler. The maximum pressure at the commencement of the experiments is 80 lbs.; which gradually gets reduced to 40, or lower.

The portion of the apparatus, which is peculiarly connected with the generation of the electricity, is a series of bent tubes with their attached jets. Each jet consists of a brass socket, containing a cylindrical piece of partridge wood, with a circular hole or passage through it, $\frac{1}{8}$ of an inch in diameter, into which the steam is admitted through an aperture. The peculiar shape of this aperture appears to derive its efficacy from the tendency it gives the steam to spread out in the form of a cup, on entering the wooden pipe, and by that means to bring it and the particles of water, of which it is the carrier, into very forcible collision with the rubbing surface of the wood.

The electricity produced by this engine is not so remarkable for its high intensity, as for its enormous quantity. In no case, antecedent to this, has the electricity of tension taken so rapid a stride towards assimilating with galvanic electricity. Mr. Faraday's experiments on the identity of the electricities had shown how small was the quantity obtained from the best machines; and had given good reason to expect that chemical effects would be exalted when the quantity could be increased. And such is the case here; a very remarkable experiment in illustration of this is, that not only is gunpowder ignited by the passage of the spark, but even paper and wood shavings will be inflamed when placed in the course of the spark passing between two points —such an effect was never before produced with common electricity. In like manner, chemical decompositions are effected much more readily by means of the hydro-electric, than by that from the common machine.

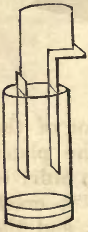
GALVANIC INSTRUMENTS.

Fig. 380.



Simple Galvanic Series.—This series, sometimes called *Couronne De Tasse*, is a simple galvanic battery, and consists of a number of glasses, jelly pots, or similar vessels, in each of which are placed two pieces of metals, of dissimilar electric properties; for example, zinc and copper; the zinc of one vessel being connected with the copper of the other. The outer cups, or vessels, having a wire only to its extreme plate of metal; the wire, therefore, of one extremity being joined to the wire of the other extremity, completes the electric circuit, and causes the fluid to circulate around the whole series. Price, in porcelain jars, 25 cts. each series.

Fig. 381.



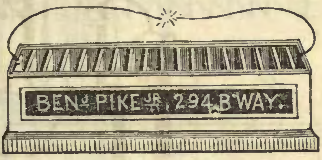
Faraday's Apparatus for showing the Phenomena of an Electric Current independent of the Contact of dissimilar Metals.—(Fig. 381.)—It consists of a glass or porcelain trough for the dilute acid, a bent clean zinc plate, and a platinum plate furnished with a curved wire. If a small piece of filtering paper, moistened with iodide of potassium, be placed on the zinc, and the end of the wire be pressed against it when the plates are immersed in the trough, the iodine is thrown down on the filtering paper by voltaic action. Price, $2.

Fig. 382.

Zinc and Copper Plates, with Glass Handles.—(Fig. 382.)—Pair of circular zinc and copper plates, with glass insulating handles, for showing, by the aid of a very delicate condensing electroscope, electricity developed by two dissimilar metals that have been in contact and are separated.

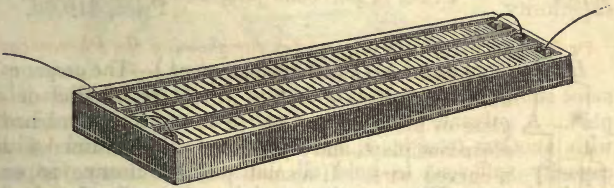
Price, $2.00.

Fig. 383.



Cruikshank's Trough Battery (Figs. 383 and 384) consists of plates of zinc and copper, united by their flat surfaces by soldering, and cemented into grooves in the sides of a trough of baked wood, so as to leave sufficient intervals to hold small quantities of fluid, usually about half an inch wide; they must of course be arranged so that all the zinc surfaces shall be on one side, and all the copper surfaces on the other. The battery is charged by filling the cells with a saline solution, or with dilute acid, and the galvanic circuit completed by bringing the two wires proceeding from the ends of the battery in contact with one another. One of the figures represents a trough having three rows of plates connected together by wires. Troughs of this construction are ex-

Fig. 384.



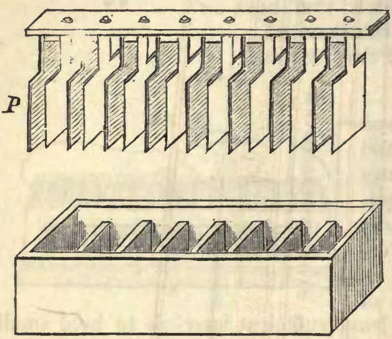
ceedingly liable to get out of order, from the action of the liquid on the wood, which it tends to warp. The plates require to be fixed into the grooves by cement, in order to render them water tight; but this cement is apt to crack from the warping of the wood and other causes, and the

28

liquid insinuating itself into the fissures impairs the power of the instrument by destroying the insulation of the cells. They are superseded by more modern instruments.

Price of a set of 20 plates, $12.00.

Fig. 385.

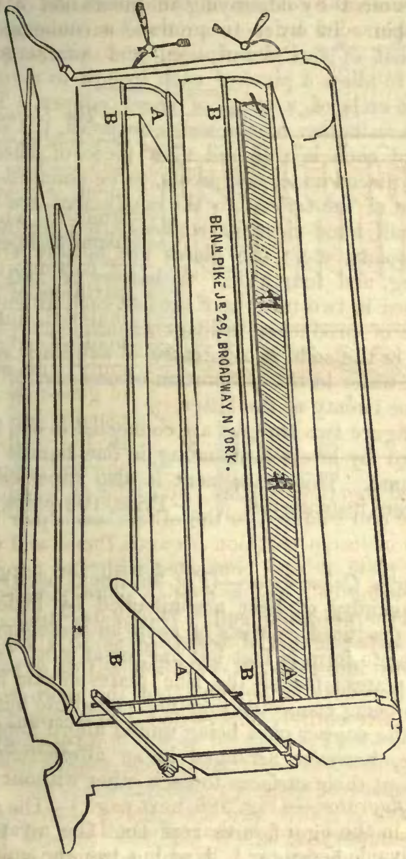


The Galvanic Battery--old form.—(Fig. 385.)—This instrument consists of a trough, which has usually been made of earthenware, with partitions of the same material, but may be made of baked mahogany with partitions of glass; each trough usually has eight or twelve cells. The zinc and copper plates are connected together in pairs, by a slip of metal passing from the one and soldered to the other; each pair being so placed as to inclose a partition between them, and each cell containing a plate of zinc, connected with the copper plate of the succeeding cell, and a copper plate joined with the zinc plate in the preceding cell. The plates are connected together by a bar of baked wood, so as to allow of their being let down into the cells, or lifted out together. This battery was formerly much used, but the more recent improvements have entirely superseded it on account of their superiority.

Price, $10.00.

Hare's Deflagrator.—(Fig. 386, next page.)—The arrangement shown in the figure, is that of Dr. Hare, of Philadelphia. A galvanic series, A, A, fixed in a trough, is combined with another trough, B, B, destitute of plates, and of a capacity sufficient to hold all the acid necessary for an ample charge. The trough containing the series is joined to the other lengthwise, edge to edge; so that when the sides of the one are vertical, those of the other must be horizontal. The advantage of this is, that by a partial revolution of the two troughs, thus united, upon pivots that

Fig. 386.



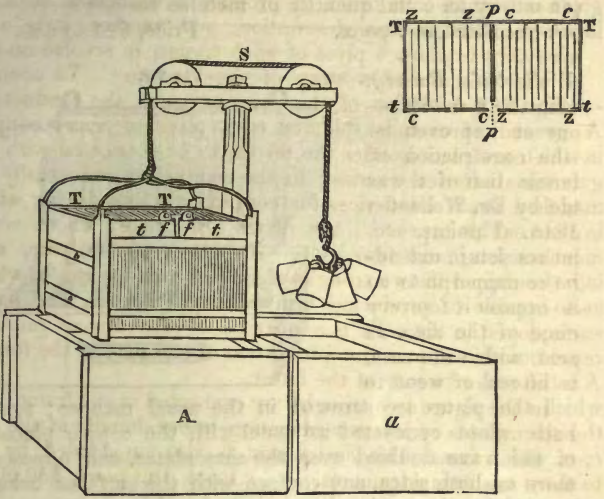
support them at the ends, any fluid which may be in one trough must flow into the other, and, reversing the movement, must flow back again. The galvanic series being placed in one of the troughs, and the acid in the other, by a movement such as has been described, the plates may all be instantaneously subjected to the acid or removed from it; the pivots are made of iron, coated with brass or copper, as less liable to oxydizement. A metallic communication is made between the coating of the pivots and the galvanic series within. In order to produce a connexion between one recipient of this description, and another, it is only necessary to allow a pivot of each trough to revolve on one of the two ends of a strap of sheet copper. To connect with the termination of the series or poles, the conductors, one end of each is soldered to a piece of sheet copper, which are placed under the pivots, to be connected with the termination of the series; to the conductors are usually attached small hand-vices for conveniently introducing wires, charcoal points, etc.; the plates are usually about seven inches long, and four wide. A battery of 300 pairs may be contained in two troughs of six feet each in length, which is capable of producing brilliant experiments. The liquid employed in the cells is a mixture of sulphuric or muriatic acid, with water in the proportion of one part of the former to fifteen or twenty of the latter.

In the figure two troughs are connected in one frame, and both moved by levers terminating in one handle at the end of the frame. This instrument is also superseded by the more modern instruments. Price, 100 pairs, $80.00.

Dr. Hare's Calorimotor—(Fig. 387, next page)—in which a great quantity of heat accompanied by little electrical tension is produced, consists of such an arrangement of the elements as to form in fact but one, or at most, two pairs of separate plates; for all the zinc plates in one half of the apparatus being connected together, constitute but one plate, while all the copper ones being united afford another. The plates are, however, arranged in an alternating series, so as to present their surfaces to each other without occupying much space.

The accompanying figures represent the arrangement of parts in the calorimotor. A and *a* are the cubical boxes containing the one acidulated and the other pure water; *b b b b* is the wooden frame containing the zinc and copper plates alternating with each other, and from $\frac{1}{4}$ and $\frac{1}{2}$ an inch apart; T T *t t*, are masses of tin cast over the protruding edges of the sheets which are to communicate with each other. The smaller figure, representing a horizontal section through the plates, shows the manner in which the junction

Fig. 387.



between the several sheets and the tin masses is effected. Between the letters *z z*, the zinc only is in contact with the masses. Between *c c* the copper alone touches the tin. At the back of the frame, ten sheets of copper between *c c*, and ten sheets of zinc between *z z*, are made to communicate by a common mass of tin, extending the whole length of the frame between T T; but in front, as shown in the larger figure, there is an interstice between the mass of tin connecting the ten copper sheets, and that connecting the ten zinc sheets. The screw forceps, *f f*, may be seen on each side of this interstice, holding the wire which is to undergo ignition. A wooden partition, *p p*, separates the two sets of plates of which the apparatus is seen to be composed. The swivel at S permits the frame to be swung round after being taken out of the acid in A, and to be lowered into the pure water in *a*; this is for the purpose of washing off, after an experiment, the acid which might otherwise too rapidly corrode the plates.

Dr. Hare, the inventor, regards this as furnishing an extreme case of great heating power with low electric intensity, and also as showing that the quantity of heat evolved in single large pairs is greater, but its intensity less than that given out by an equal quantity of metallic surface arranged in several successive pairs. Price, $25 to $40.

Wollaston's Battery.—(Figs. 388 & 389.)—A great improvement in the construction of galvanic batteries was made by Dr. Wollaston in 1815. This improvement consists in extending the copperplate so as to oppose it to every surface of the zinc, as represented in the cuts. A is the rod of wood to which the plates are screwed in the usual manner; B, B, the zinc plates connected as usual with the copper plates, C, C, which are doubled over the zinc plates, and opposed to them on both sides, any contact with the surfaces being prevented by pieces of cork or wood placed between.

Fig. 388.

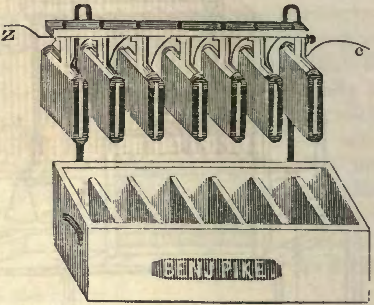
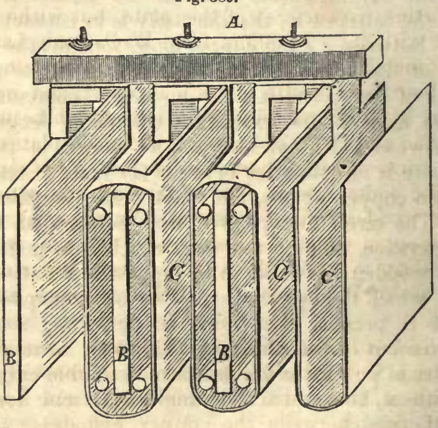


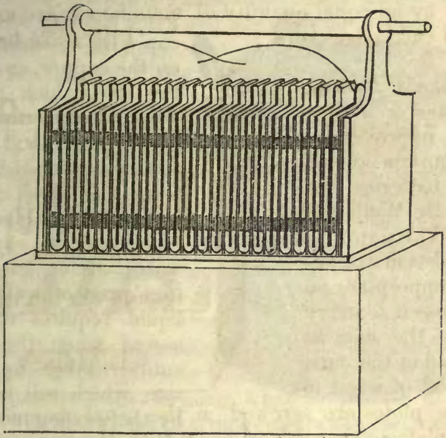
Fig. 389.



This construction of the galvanic battery is no more used, by reason of the superiority of the new instruments.

Price, 50 pairs, $50.00.

Fig. 390.



Van Melsen's Battery.—(Fig. 390, as above.)—This cut represents a useful arrangement of copper and zinc plates for a galvanic battery; the copper soldered to the zinc in each pair envelopes the zinc of the following pair, so as to be exposed to the two surfaces of this plate, but without being in contact with it. It differs from Wollaston's battery in having the metallic plates much nearer to each other; they are only about one-twelfth of an inch apart, and are maintained thus by small pieces of cork interposed between the plates of zinc and those of copper; while the plates of copper of the consecutive elements are separated by squares of glass of the same size as the plates; all the squares are placed in a wooden frame (represented in the cut), which is well varnished, in which they are easily retained, without it being necessary to attach them by screws to a bar of wood, as in the case of Wollaston's. Price, 25 pairs, $20.00.

The Cylindrical Pot Battery.—(Fig. 391, next page.)—The cylindrical pot battery consists of a double cylinder of copper, with a bottom of the same metal, and a movable cylinder of zinc, between the copper cylinders; the zinc cylinder is supported by three branches. The branches are covered with wood to insulate them from the copper, and are formed in the shape of rollers, with grooves entering

Fig. 391.

the edge of the outer copper cylinder; there is a cap with a binding screw on the copper, and also on the zinc, which form the poles, that at the zinc being negative, and the one at the copper being positive. The liquid employed is a solution of blue vitriol, (sulphate of copper) in water, about two ounces to a quart of water. The liquid requires to be renewed when the acid is entirely taken up by the zinc, which will be known by there being no deposit on the zinc, after being immersed for some time. The zinc cylinder should be left in the solution only while in use, as it soon becomes coated with a deposit, which, after used for an hour or two, should be scraped off with an old knife, as a clean surface of zinc is requisite to the proper action of the battery. The solution may remain in the copper vessel any length of time, as it does not act on it. There is no unpleasant smell from the use of this battery, and the acid will not injure if spilt on furniture or clothing.

A battery five and a half inches high, and five inches diameter, is of sufficient power for most experiments in electro-magnetism, for which this battery is best adapted; where more power is required two or more may be united and used together. Price, - - - - $2.50.

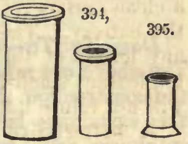
" smaller sizes, $1.75 and $1.50.

Fig. 392.

Daniell's Single Cell Sustaining Battery.—(Fig. 329.)—This instrument consists of a cylinder of copper, with a bottom of the same metal, containing a cup formed of unglazed porcelain, which has a solid rod or cylinder of well amalgamated zinc, supported in its centre. The cylinder is furnished with a perforated shelf, upon which a supply of crystals of sulphate of copper are placed; so that the battery being once charged, will maintain an equal action for many hours. To the rod, or cylinder of zinc, and also to the copper cylinder, are attached brass cups with binding screws, forming the poles of the battery. The zinc is negative, and the copper positive. The exterior copper vessel is usually about six inches high, and four wide; the porous tubes are filled with dilute sulphuric acid (about one part of acid to one of water); and the copper cylinders are filled with a strong solution of sulphate of copper, also acidulated by sulphuric acid; so that the acid in the generating cell is separated from the solution of sulphate of copper, but the porosity of the tubes allows of their becoming so far imbued with the acid liquid as to admit of the passage of electricity. Price, $1.75.

Porous Cells for Galvanic Batteries.—The most important modification of the galvanic battery, is that of the introduction of porous cells, forming what is termed a constant battery. In all the other arrangements the electrical power is liable to fluctuation, and for many investigations are inconvenient and even useless; by the introduction of these cells those inconveniences are to a great extent obviated, and although it is more complicated, its constant and regular action, when it is properly constructed, amply repays the additional trouble and expense.

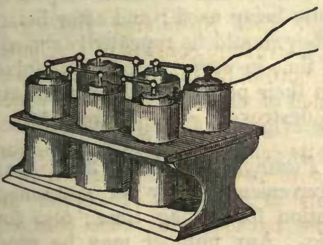
Figs. 393, 394, 395.



They consist of cells, or cups, of unglazed porcelain (Figs. 393, 394, 395), of such sizes as may suit the battery for which they are intended; and though they separate the acid in the outer cell from the inner part, the porosity of the porcelain allows sufficient to penetrate through to produce a considerable galvanic action.

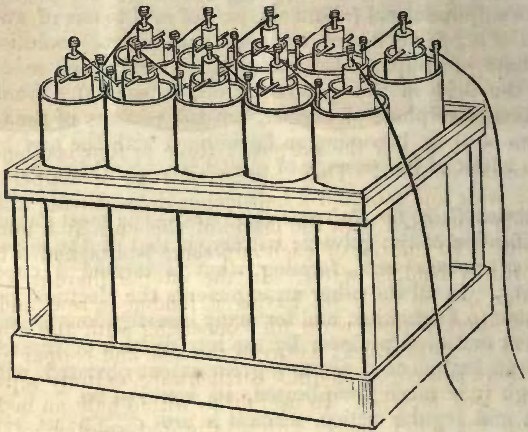
Price, small size, 10 cts. each.
" large " $12\frac{1}{2}$ cts. "
" for Daniell's battery, 25 cts. each.

Fig. 396.



Daniell's Six-cell Sustaining Battery.—(Fig 396.)—The annexed cut represents a set of six of the above batteries. The copper cylinder is connected in this arrangement by wires with the zinc cylinder of the next series, and so in succession, through the arrangement, the unconnected zinc forming the negative pole, and the unconnected copper the positive pole. Price, $12.00.

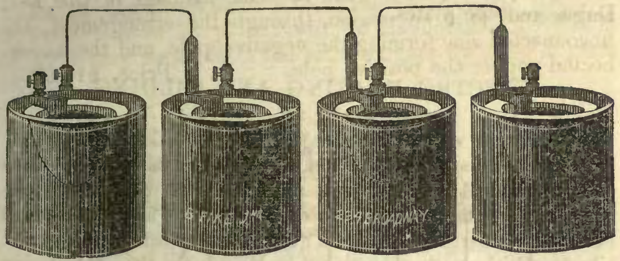
Fig. 397



Daniell's Ten-celled Sustaining Battery.—(Fig. 397.)—The above cut represents a set of ten large batteries united; the construction the same as the preceding. The cells of this sustaining battery must be plentifully supplied with sulphuric acid, without which the power is but feeble. Mr. Daniell recommends a mixture of eight parts of water and one of sulphuric acid which has been saturated with sulphate of copper for the copper cell, the internal tube being filled with the same acid solution without the copper. The porous cells should be well soaked in dilute sulphuric acid for an hour or two before being used; and after being removed from the battery, they should be repeatedly rinsed, or allowed to soak for some time in warm water, to dissolve out all the metallic salt from their pores. If this be not attended to, they will be soon destroyed. Price, $25.

Sustaining Battery for Plating, &c.—(Fig. 398, next page.)—This represents a convenient battery for sustaining magnetic instruments in action for a long time; also for plating with gold, silver, &c. Any number may be used

Fig. 398.



as may best answer the purpose ; three or four combined is the usual number. They consist of cups of copper, four inches wide and four and a half inches deep, having a lip at the side connected with the inside of the cup by a number of holes. To the rim of each cup there is attached a brass cup with a binding screw. In the interior there is a zinc cylinder, one in each set having a binding screw, and the others, stout copper wires for connecting with the copper cups of the next series ; between the zinc and copper cylinders there is a cup of porous earthenware, entirely separating the two metals. To use, fill to within half an inch of the top the outer space, with a saturated solution of blue vitriol (which may be about one ounce to each cup), and put some pieces of blue vitriol in the lip to keep the solution saturated, and in the interior of the porous cup, put a table spoon full of common salt, or Glauber's salt, and nearly fill with water ; connect the zinc of the one with the copper of the next throughout the series, the disconnected copper and zinc being the poles of the battery. This battery will maintain nearly a constant action for a week (if properly supplied with blue vitriol, and a little salt stirred in the interior once a day), without disconnecting the series ; though when convenient, it is preferable to clean the zinc cylinders oftener. In many cases a much weaker solution of blue vitriol may be used than that described. Price, of a set of 3, $5.25.
" " " 4, $7.00.

Grove's batteries, of three different sizes of four cells each, are conveniently arranged for gilding.

Price, small size, $4.50.
" second " $5.50.
" large " $6.50.

Smee's battery, also used for plating; particularly for Daguerreotype plates. Price, $2.25.

ELECTRO PLATING AND GILDING.

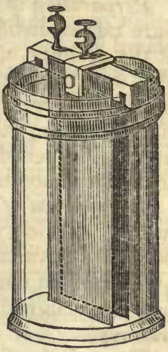
Preparation of the Solution of Silver.—Take one pint of pure rain or distilled water; add to it one and a half ounces of the cyanuret of potassium; shake them together occasionally, until the latter is entirely dissolved; and allow the liquid to become clear. Then add a quarter of an ounce of oxide of silver, which will very speedily dissolve; the dissolution may be hastened by heat, and, after a short time, a clear transparent solution will be obtained.

Preparation of the Gold Solution.—Warm a pint of pure rain or distilled water, and dissolve in it one and a half ounces of cyanuret of potassium as before; then add a quarter of an ounce of oxide of gold. The solution will at first be yellowish, but will soon subside to colorless transparency.

The solution is made in a glass or earthen vessel, the article to be plated attached to the wire connected with the zinc pole of the battery, immersing the other wire from the copper pole of the battery, which should be tipped with gold or platina, a little way in the solution.

An improved way for plating, and preferable in use, is to prepare, as above, the solution, by dissolving one and a half ounces of cyanuret of potassium in a pint of rain water, and attach a thin plate of silver to a wire connected with the copper pole of the battery, and immerse it in the solution; now dip the wire from the zinc side of the battery in the solution, but not in contact with the silver plate, and a rapid decomposition of the metal will take place, and a saturated solution will be obtained, which may be known by the deposition of silver on the wire from the zinc side of the battery. Attach the articles to be plated, as before, to the wire from the zinc pole, allowing the silver plate to remain in the solution to supply the silver released from the solution and deposited on the article plated. Articles not exposed to wear may be coated in a few minutes; spoons, watch-cases, and articles exposed, will require from four to six hours, the thickness of the deposit depending on the length of time immersed. Should bubbles of gas appear about the zinc pole, or articles attached to it, less of the surface of the silver plate is to be immersed in the solution, or the article to be plated will be discolored. A solution of gold may be made in the same manner by using a plate of gold, etc.

Fig. 399.



Smee's Battery.—(Fig. 399.)—A piece of platinized silver has a bar of wood fixed on the top to prevent contact with the zinc, and is furnished with a binding screw. A stout plate of well amalgamated zinc, of the width of the silver, is placed on each side of the wood, and both are held in their place by a binding screw sufficiently wide to embrace the zincs and the wood. This arrangement is immersed in a jar or glass, containing dilute sulphuric acid, in the proportion of one of acid to seven of water, and not the slightest effect is produced till a communication is made between the metals, when it instantly hisses and bubbles, and an active galvanic battery is obtained. This battery is simple in its construction, manageable in its application, and neat in its appearance; and although it has not the constancy of Daniell, or the wonderful activity of Grove, it may be kept in active operation for several days.

Price, small size, $2.25.
" larger " $5.00.

Grove's Battery, as arranged by Benj. Pike, Jr.—The most powerful galvanic battery that has yet been brought before the public, is that of Professor Grove, who was led to the discovery of a galvanic combination much more powerful than any previously known.* The elements used, are a

* The manufacturer had occasion to use one of these batteries at a public lecture, by Dr. Lardner, at the Tabernacle in New York, before a large audience, The battery consisted of eighteen series, contained in a small case that could be conveniently lifted about by one person. The effect of the battery when the charcoal points were used was most brilliant, illuminating the whole building; and when steel watch springs and iron turnings were burned, the most brilliant scintillations were produced. Also exhibited one in Niblo's Garden, at the Fair of the American Institute, in Oct., 1845, before a number of distinguished scientific gentlemen; the battery pro-

strip of platinum immersed in strong nitric acid, and separated by a porous cylinder, or cell, from well amalgamated zinc cylinders immersed in dilute sulphuric acid; the zinc of the one cell being attached to the platina of the succeeding cell.

Description of Grove's Galvanic Battery.—(Fig. 400, next page.)—This consists of slips of platina, placed in porous porcelain cups, the cups surrounded with thick zinc cylinders, placed in a glass, or glazed porcelain vessels. The platina in each cup is attached to the zinc cylinder in the next, except at the extremities or poles, the platina being the one pole, and the zinc the other; to each of which, supports are attached with brass cups, having binding screws, to receive conducting wires for experimenting with.

The power of this instrument is about twenty times as great as the common zinc and copper arrangement; its price not one quarter in proportion to its effect; and a powerful in-

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ducing the most brilliant light with the charcoal points, insupportable to the naked eye, burning the metals and decomposing water with rapidity. *A silver medal was awarded for the battery.* Also constructed one of about one hundred series for Prof. Ellet, of the University of S. C., who sent the following letter:—

South Carolina College, June 10th, 1845.

Dear Sir,—In reply to your request for information as to the working of the "Grove's Galvanic Battery" you constructed for me last summer, it gives me great pleasure to assure you, that it has more than equalled the high expectations I entertained.

With the whole arrangement connected in series, the effect in the deflagration of metals, charcoal, &c., was surprisingly brilliant, as you may judge from the fact, that the light was so intense as to produce an inflammation of the eyes, which confined me to my room for several days, and required active medical treatment.

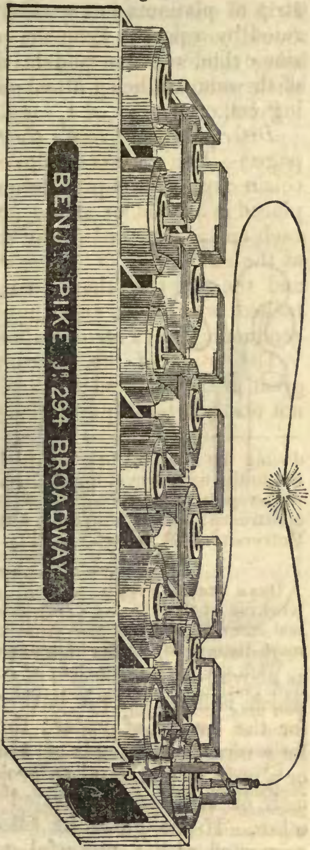
I would suggest to you as the result of much experience with the instrument, that so extended an arrangement as mine is neither necessary nor desirable for the greater number of purposes for which a galvanic battery is required. A series of from fifteen to twenty pairs of plates is as much as can be used to advantage for chemical decomposition, which it effects far more vigorously than any of the old arrangements of much greater extent: while it is at the same time quite sufficient for producing brilliant deflagrations. One or two pairs are enough for nearly all the experiments in Electro-Magnetism, including that of working Prof. Morse's telegraph.

Apart from the neatness and compactness which form so important a feature in Grove's instrument, I have no hesitation in saying, that I believe the experimenter will find it the most economical form of the galvanic battery he can employ.

I am, dear Sir, very respectfully yours,

To Benj. Pike, Jr. WILLIAM H. ELLET.

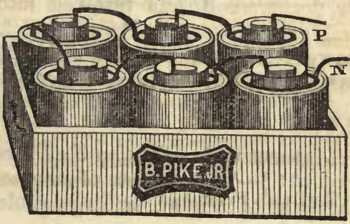
Fig. 400.



strument is contained in a case two feet long, one foot wide, and six inches in depth.

Mode of using.—The plates being properly arranged in the cells, the external glass vessels are to be nearly filled with sulphuric acid, previously diluted with from 12 to 15 times its bulk of water, and the interior porcelain cups with strong and pure nitric acid. The wires are to be secured in the brass cups with screws at the poles of the battery, and when steel shavings, fine wires, watch springs, etc., attached to one of them, are brought in contact with the other, combustion, with brilliant scintillations, will be exhibited. Gold, silver, or copper leaves, interposed between their extremities, will burn with bright and varied colors. Water, with a little sulphuric acid or common salt added to it, may be rapidly decomposed by employing the wires tipped with platina, and the gases collected in the glass globe furnished with the instrument.

Fig. 401.



Charcoal points attached to the wires can be burned with a brilliant light. The coal should be of hard wood, and recently burned. After using, the whole should be taken out of the case, the different parts well washed in water, and replaced. Care should be taken to keep the platina slips from injury, they being thin, and the metal valuable. They are packed in black walnut boxes with cover, and handles at the ends.

Price, of a	series	of	4,	small size,	$4.50;	large size, $6.50.
"	"	"	6,	"	$6.00;	" $9.50.
"	"	"	12,	"	$10.00 and $12.00.	
"	"	"	12,	large size,	$16.00 and $18.00.	
"	"	"	18,	"	$24.00 and $27.00.	

Fig. 402.

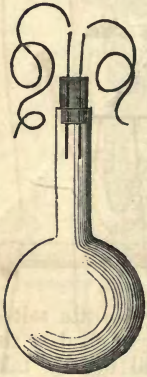


Fig. 403.

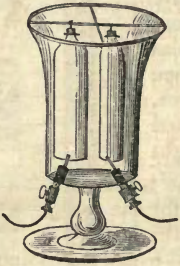


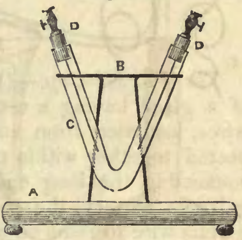
Fig. 404.

Apparatus for the Decomposition of Water.—(Fig. 402, as above.)—This consists of a globe of glass with a neck, to which is fitted a cork having a small aperture at the side for the escape of water; through the cork is passed two long wires, to the ends of which are soldered platina wires, or a strip of platina plate projecting within the globe for an inch or two, and separated a short distance from each other. If the globe be filled with water, and the wires connected with a powerful galvanic battery, the water will be decomposed, and resolved into its elements, hydrogen and oxygen gases. Pure water has but little conducting power; the addition of a little sulphuric acid, or common salt, will greatly increase the evolution of the gas.

Price, $0.75.

Apparatus for collecting the Gases Separately.—(Figs. 403 and 404.)—This consists of a glass vessel having a foot in the form of a bowl, or large goblet, holding about a quart, having two holes in the bottom, through which are inserted two screw cups for receiving wires from the galvanic battery, and which terminate on the inside of the glass vessel in platina wires, or strips of platina plate; over these are suspended by a frame resting on the rim of the glass vessel, two small receivers, for collecting the separate gases. The tube collecting the hydrogen will be found to contain double the volume of that collecting the oxygen; the hydrogen and oxygen gases being in water exactly as two to one in their proportions. Price, $4.00; larger size, $5.00.

Fig. 405.

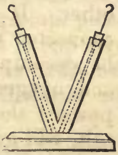


Tubes for the Decomposition of Water by the Galvanic Battery.—(Fig. 405.)—This apparatus consists of a glass tube, C, bent in the form of a V, to each end of which a cork, D D, is fitted, air tight, through which cups with binding screws are fixed, and on the interior are soldered slips of platina; in the bend of the tube is a small hole for the escape of water. To use, the instrument is filled with water—usually containing a little salt—and the poles of a powerful galvanic battery applied to the cups. The decomposition of the water will rapidly take place; the hydrogen occupying the one tube, and the oxygen the other.

The instrument is represented in the cut on a mahogany base, having a wire support.

Price, with stand, $2.00; without stand, $1.50.

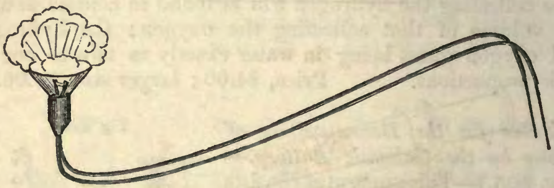
Fig. 406.



Decomposition Tubes.—(Fig. 406.)—This apparatus, used to show the decomposition of a neutral salt by galvanism, consists of a glass tube in the form of a letter V, having corks fitted to each end, with small binding screws to receive wires from the battery, and wires or slips of platina descending into the tubes; the whole is mounted on a stand. The solution of a neutral salt, colored by litmus, is poured into the tube; a galvanic current being made to pass from wire to wire through the liquid, decomposes it, drawing the alkali to one pole, and the acid to the other, as is made visible by the

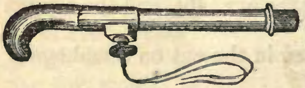
changes of color produced in the different ends of the solution; it being reddened on one side, and rendered green at the other. Price, with binding screws, $1.75.
" without " $1.25.

Fig. 407.



The Powder Cup.—(Fig. 407, as above.)—This consists of a glass having a neck through which the ends of two wires, insulated from each other, are passed, and are connected together within the cup by a fine platina wire. On connecting the long ends of the wires with the poles of a galvanic battery, the passage of the current heats the fine platina wire to redness, and explodes any powder placed in the cup. A piece of sulphur or phosphorus may also be easily burned therein. Price, $0.50.

Fig. 408.

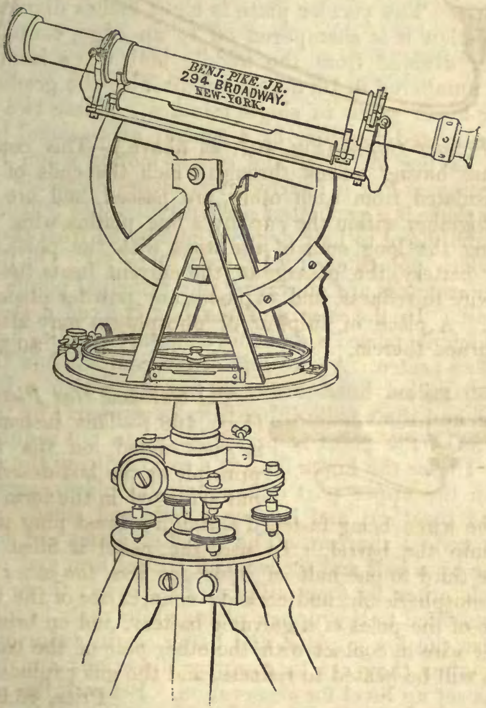


The Galvanic Gas Pistol.—(Fig. 408.)—This instrument is constructed on the same principle as the last described, but arranged in the form of a pistol, the wires being fastened through a brass plug which screws into the barrel. To use, the pistol is filled with from one third to one half of hydrogen gas, the other part being atmospheric air, and corked; connect one of the wires with one of the poles of a galvanic battery, and on bringing the other wire in contact with the other pole of the battery the wire will be heated to redness, and the gas exploded.

Price, $3.00.

SUPPLEMENT.

Fig. 783.



Pike's Improved Theodolite.—(Fig. 783.)—This instrument is particularly well adapted to the purposes of instruction, as well as for practical use. All its parts are made large and substantial, for the measuring of horizontal and vertical angles; and for levelling it is very much approved; by the addition of a pair of small sights it is sometimes used as a surveyor's compass. For this instrument the author received, a few years since, from the American Institute, a silver medal; and another was awarded the last year, by the New York State Agricultural Society, at its annual fair held in the city of New York.

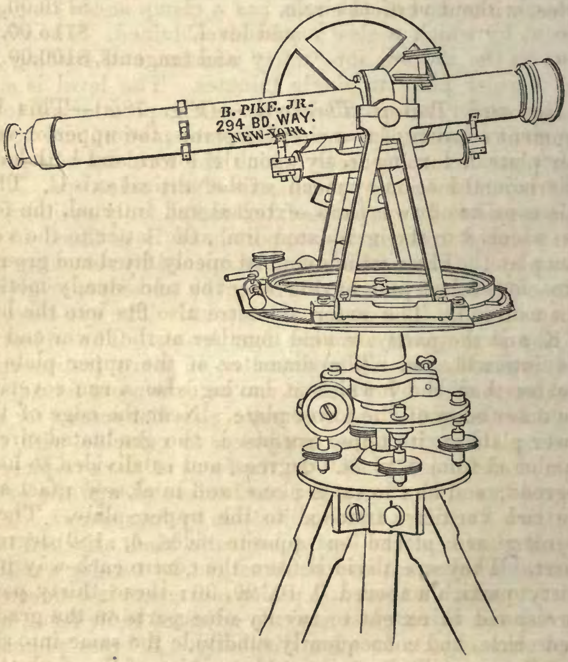
The horizontal plate is nine and a half inches diameter, graduated into degrees and half degrees, numbered from 0 to 360. The vernier plate is eight inches diameter; at one portion it is shampered off to an edge, containing a vernier divided from the middle both ways into thirty parts, numbered 0, 10, 20, 30, subdividing the graduations on the lower plate to single minutes. These two plates are connected together by a conical axis ground in each other, having an even and steady motion when turned. The compass-box is nearly seven inches diameter, within which there is a graduated circle divided into 360 degrees, and subdivided to half degrees, numbered from the north and south points each way, from 0 to 90. On the face of the compass are engraved the principal points of the compass. In the centre of the box is fixed a steel pin, on which is poised a delicate magnetic needle, having a jewelled centre. At the side of the compass-box there is a small milled head-screw, by turning which a lever is raised, and the needle lifted from its support; by this the fineness of the point is preserved when not required for use. Under the lower limb is a socket fitting the conical pin on the upper part of the parallel plates, accurately ground together, and having a true and steady motion when turned thereon. The parallel plates are held together by a ball and socket, and are set firm and parallel to each other by four milled-head screws; these turn in sockets fixed to the upper plate, while their heads press against the lower plate, and being set in pairs opposite each other they act in contrary directions and by this means set up level for observation. Beneath the parallel plates are securely jointed three mahogany legs about four and a half feet long, square at the joint but round below; these when spread support the instrument at a proper height for use. The lower limb can be fixed in any position by tightening a clamp-screw, which causes a collar to embrace the socket, and prevents its moving, but may be moved in any small quantity, by means of a slow motion or tangent-screw, when required to be set in any more exact position than the hand alone could set them. In the same manner the upper or vernier plate may be clamped to the lower, and a slow motion given by the tangent-screw. On the vernier plate are two spirit-levels, about three inches long, placed at right angles to each other, and having adjusting screws. A frame rises on each side of the compass-box, firmly fixed on the vernier plate, which supports the pivots of the axle of the vertical arc, or semicircle, on which the telescope is placed; one end of the axis has a clamp and a tangent-screw, by which a slow motion is obtained. The divisions on the arc are into thirty minutes, and reading by the vernier plate to single minutes. The level is supported under and parallel to the telescope attached to it, by screws having at one end lateral motion, and at the other parallel motions, by which the level may be properly adjusted to the optical axis of the telescope. The telescope has two collars of bell-metal, truly cylindrical, on which it rests in its supports, and is confined in its place by the clips, which may be opened by removing the pins, for the purpose of reversing the telescope, or giving it a motion on its axis for adjustment. The eye-piece is of the best quality, having four lenses. The object is seen upright, and not reversed as in many instruments, and has a slide by which it can be drawn out for adjustment to the eye of the observer; also four screws for adjusting the axis of the eye-piece, to coincide with the axis of the object-glass. In the focus of the eye-piece is placed two spider lines, the one horizontal, and the other vertical, fixed in a frame adjustible by four screws. The object-glass is of the best achromatic kind, attached to a moveable tube that may be thrust out, by turning a milled head, to which a tooth and pinion movement is connected; by this the object-glass may be adjusted to its focus, and show the objects in view distinctly. A brass plummet and line are usually had with the instrument, which is suspended from a hook under its centre, by which it can be placed exactly over the station whence the observations are to be taken. The instrument is securely packed in a mahogany case. Price $130.00.

With sights to the compass-box, plumb-bob, and magnifying glass for reading the divisions more closely.
Price $135.00.

Also an instrument of the same construction, having the same size telescope and level, but with plate 7 inches diameter, vernier plate 6 inches, compass-box 4 inches, vertical arch, 6½ inches. Price $125.00.

The same instruments, with the tangent-screw and rack-work motions omitted. Price $100.00.

Fig. 784.



Transit Theodolite.—(Fig. 784.)—This instrument is constructed, in most of its parts, as the last described; the telescope and level are of the same size, and having the glasses of the best quality; the tripod-stand, parallel plates, sockets, clamps, and tangent-screws, are the same;

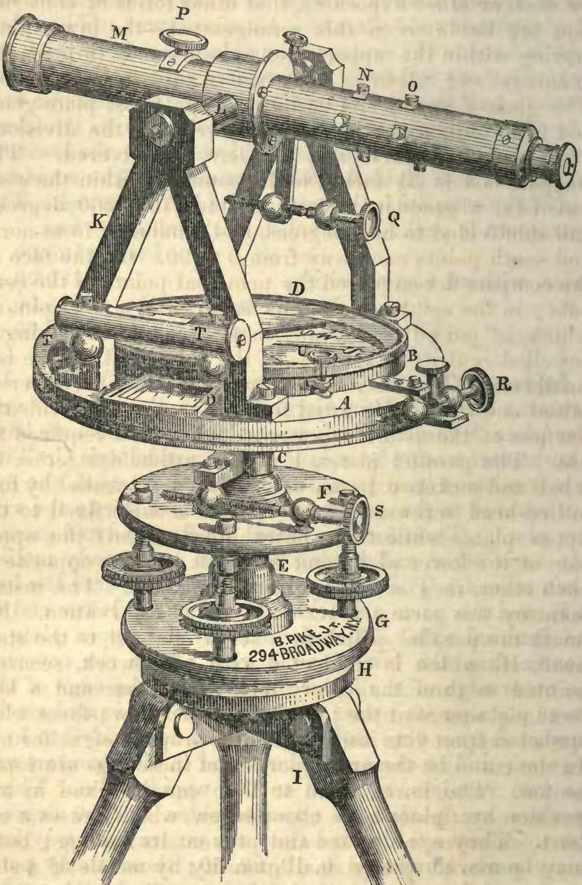
the horizontal limb is 7 inches in diameter, having on the vernier plate two levels, and a 4-inch compass. The telescope is fixed in the centre of the axis, and may be reversed by turning one end over. A complete vertical circle, graduated to half degrees, is on the axis of the telescope outside of its supports, with the vernier fixed to its branches, and reading to single minutes. The vernier on the horizontal plate is also divided to single minutes. The construction of the compass is the same as the last described. The instrument is packed in a substantial mahogany box.

Price $125.00.

Price, without vertical circle,	$120.00.
" " " " and level,	$115.00.
" " " " " and tangents,	$100.00.

Improved Transit Theodolite.—(Fig. 785.)—This instrument consists of two circular plates, 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, the latter to the vernier plate. Their form is conical, nicely fitted and ground into each other, and having an even and steady motion when turned. The external centre also fits into the ball at E, and the parts are held together at the lower end of the internal axis. The diameter of the upper plate is greater than the lower one, having also a rim covering the outer edge of the lower plate. Near the edge of the lower plate on its upper surface is the graduated circle, numbered from 0 to 360 degrees, and subdivided to half degrees; and on the same plane, and in close contact are the two verniers, attached to the upper plate. These verniers are placed on opposite sides, or 180 degrees apart. They are divided from the centre each way into thirty parts, numbered 0, 10, 20, 30; these thirty parts correspond in extent to twenty-nine parts on the graduated circle, and consequently subdivide the same into single minutes. The verniers and a portion of the graduated circle are visible through openings in the upper plate, covered by a light brass frame, and a closely-fitting glass, in form corresponding to the arc of the circle. The particular use of this arrangement of the graduated circle and verniers is that they may be protected from injury

Fig. 785.



A, horizontal plates; B, compass-box; C, Vertical axis; D, D, verniers; E, ball and Socket; F, upper parallel plate; G, lower parallel plate; H, staff-head; I, mahogany tripod legs; K, supports for axis of telescope; M, telescope; N, cross-hair with screw adjustment; O, screw adjustments for eye-piece; P, milled-head turning pinion for adjusting focus of object-glass; Q, tangent-screw for vertical motion of telescope. R, tangent-screw for horizontal motion of telescope; S, tangent-screw for moving vertical axis; T, T, spirit-levels; U, milled-head screw for compass-stop.

by dust, or other exposures, that other forms of construction are liable to in this arrangement—the lower plate moving within the upper one, and only seen through the openings and glasses; they are completely protected. The glass covering the verniers is the finest plate-glass, and is no obstruction in accurately reading the divisions. The graduated circle and verniers are silvered. The compass-box is 5½ inches in diameter. Within the compass-box, a graduated circle, divided into 360 degrees, and subdivided to half degrees, and numbered from north and south points each way from 0 to 90. On the face of the compass are engraved the principal points of the compass; in the centre of the box is screwed a steel pin, on which is poised a delicate magnetic needle having a jewelled centre; at the side of the compass U, there is a small milled-head screw, by turning which, a lever is raised and the needle lifted from its support; by this the fineness of the point is preserved when not required for use. The parallel plates, F and G, are held together by a ball and socket, at D, and are set firm and parallel by four milled-head screws. These turn in sockets fixed to the upper plate, while their bases press against the upper side of the lower plate, and being set in pairs opposite to each other, they act in contrary directions. The instrument by this means is set up level for observation. Beneath the parallel plates is a screw adapted to the staff-head, H, which is connected with brass-work, securely jointed to three mahogany legs, about four and a half feet long, square at the joint but round below; these when spread support the instrument at a proper height for use. In the cut only the upper portion of these legs are represented. The lower plate or limb can be fixed in any position by tightening a clamp-screw, which causes a collar to embrace the socket and prevent its moving; but it may be moved in any small quantity by means of a slow motion or tangent-screw, S, when required to be set in any more exact position than the hand alone could set them. In the same manner the upper or vernier plate may be clamped to the lower, and a slow motion given by the tangent-screw, R. On one side of the vernier plate is a spirit-level, and at right angles on the supports of the telescope is another; these levels have at their ends adjusting screws by which they may be accurately fixed. The telescope is fixed to a horizontal axis; it has a free vertical movement, and may be reversed by turning over. There is a clamp-screw near the axis for fixing it, and a tangent-screw, Q, for slow motion. The focus of the cross hairs is adjusted by sliding in or out the eye-piece. The object-glass is brought to a proper focus by turning the milled head, P. The central adjustment of the cross hairs is made by four screws, N, at opposite points in the body of the telescope, and the eye-piece fixed central by the four screws, O. These instruments when delivered are all accurately adjusted, but should they at any time be deranged, directions for their adjustment equally applicable to these instruments may be found under the article *Theodolite* (Fig. 99), in this work, page 85.

When required, a vertical circle is fixed to the axis, as in the preceding instrument, and also a level attached to the tube of the telescope; the former would cost about ten dollars additional, and the latter five dollars. In the construction of the transit instrument these are not usually wanted. These instruments are finished bright, or polished brass, and dark or bronzed, the latter being preferred by some on account of its being more agreeable to the eye in a bright sun. A brass plumb-bob accompanies the instrument which is packed in a mahogany case. Price $150.

Chamberlain's Patent Draughting Board (Fig. 786), For engineers, surveyors, designers, builders, &c., &c.

Description of Chamberlain's Patent Draughting-Board.—(Fig. 786).—No. 1. Moulding, A, B, C, D; scales, *e, f, g, h;* draught sheet space, *a, b, c, d;* ketch-heads, *i, i, i, i;* equator, E, F; meridian, G, H; design, J, J; title, A; copyright, B; device, D; points of compass, C.—No. 2. Ketch-shanks, *i, i, i, i, i, i, i;* ketch-bars, *o, o, o, o;* legs, *l, l, l, l;* spring bale, *n, n, n, n, n, n;* brackets, *k, k;* connections, *m, m, m, m;* panel, *a, b, c, d.*—No. 3. T rule; tongue, T, T; right-angled back, U, U; multangular back, V, V; adjusting screw, S; size of board, 23 by 29 inches. The moulding guards the surface and guides the T rule. The scales of degrees and inches are extensive and minutely divided. They are numbered each way from the centres, E, F, G, H, and the subdivis-

Fig 786.—No. 1. Front View of the Board.

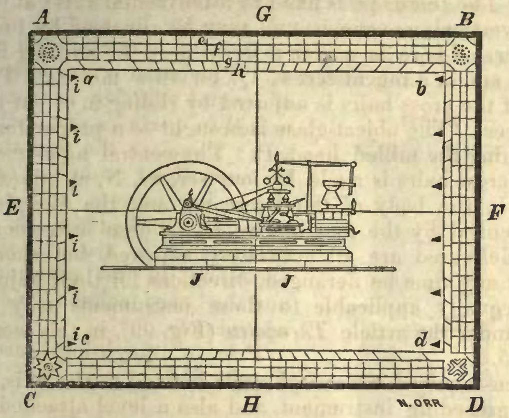


Fig. 786.—No. 2. Back View of the Board.

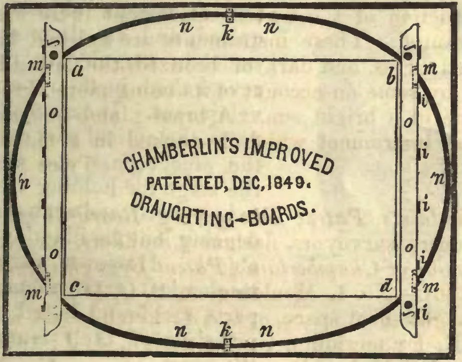
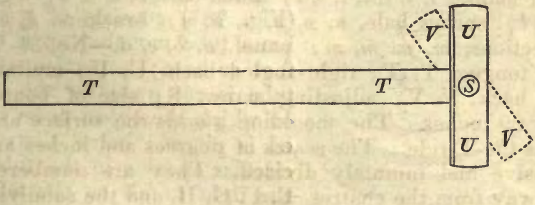
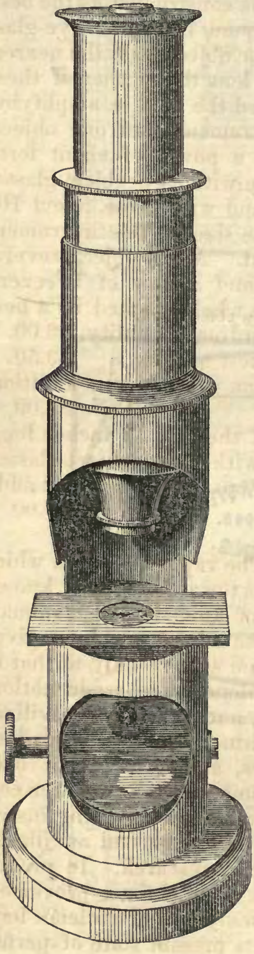


Fig. 786.—No. 3. Outline of T Rule



ions have a clear and open appearance. The design, J, J, is permanent on the board, showing its method of use. A sheet of drawing-paper is inserted by pressure at 'n, 'n, alternate, in a few moments. The board is a combination of several valuable instruments, united to qualities decidedly its own; therefore the operator in its use will set aside the use of single instruments, and act at once on general principles. The best materials are thoroughly combined in its construction, and the board makes a handsome appearance.

Fig. 787.



Price of draughting-board and T rule, $10.

The *Compound Microscope* is employed where the investigation of minute objects are required, and an observer wishes sufficient magnifying power to reveal them in their perfect development. It consists of three parts, the optical part containing the object-glass and eye-piece, the stage for holding the object to be viewed, and a mirror or condensing lens for illuminating the object. However various the mechanical arrangement, these parts are found in all, and the principle of their management the same.

The *Compound Microscope* (Fig. 787) consists of a stout brass tube mounted on a brass foot or base; a portion of the tube is cut away for the stage on which the object to be viewed is placed; below there is a circular opening in the tube for the light to fall on the mirror,

which is placed within the tube and is moveable by a milled head on the outside; the upper portion of the tube supports the optical part which is made to fit within a short tube, in which it may be easily moved with nicety and steadiness, for bringing the object into the focus of the glasses. This instrument, though of low price, is constructed as the best, having three lenses in the compound body, the eye-glass being the one nearest the eye, the object-glass the nearest the object viewed, and a larger lens than either of these intermediate between them, called the field or amplifying glass. In the lower-priced instruments but one object-glass accompany them, having a power of about forty diameters, or 1,600 times; those with two object-glasses magnify nearly twice as much, and with three, about 100 diameters, or 10,000 times. The size of this instrument is one third larger than the cut. A test-object, several glasses for laying objects on, and a pair of tweezers, accompany the instrument; the whole packed in a neat mahogany box. Price, ordinary quality, $3.00.
" best quality, $3.50.

Larger size, one half larger than cut, with one additional object-glass. Price $5.00.

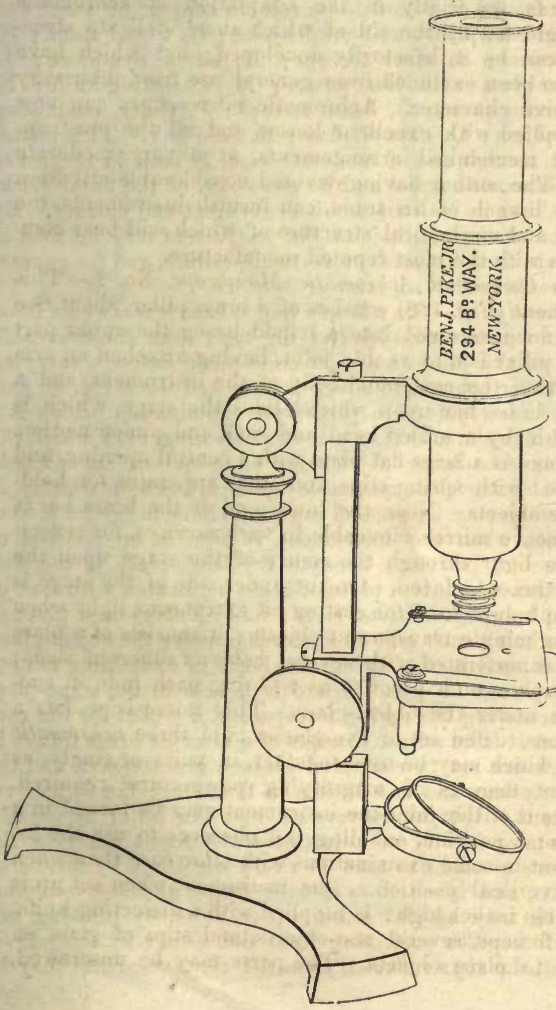
Largest size, twice the size of the cut, 11 inches long, body tube 2 inches diameter, with three object-glasses, condensing lens for illuminating opaque objects, and additional test-object and glasses. Price $9.00.

Achromatic Microscopes.—"The rapid advances which have been made in modern times toward a correct knowledge of the intimate structure of animate and inanimate bodies, by the employment of the microscope, have given to this instrument an importance second only to that of the telescope. By its agency alone, have crude notions and theories been swept away, and science in civilized countries made to stand on a firmer basis. In this land of machinery and manufactures, artists have not been found wanting to devote their time and talents to the conversion to what might once have been an amusing instrument or a toy, into one of the most powerful auxiliaries that can be employed in scientific research. In proportion to its use, such has been the demand for improvement in its construction, that both amateur and optician have labored together to bring it to its present state of perfection."

Microscopic investigation being now considered indispensable in the various scientific researches in anatomy and physiology, important improvements have been effected in the optical and mechanical construction of these instruments, especially in the adaptation of achromatic object-glasses, by the aid of which alone, delicate structures can be satisfactorily developed; but which have hitherto been excluded from general use from their very expensive character. Achromatic microscopes can now be supplied with excellent lenses, and all the most approved mechanical arrangements, at a very moderate cost. The author having devoted considerable attention to this branch of his trade, can furnish instruments, the optical and mechanical structure of which will bear comparison with the most reputed manufacture.

Ross Compound Achromatic Microscope, No. 1.—This instrument (Fig. 788) consists of a brass pillar, about five inches long, screwed into a tripod base; the upper part of the pillar is a moveable joint, having attached an arm supporting the compound body of the instrument, and a square brass bar upon which slides the stage, which is moveable by a milled head and rack and pinion motion. The stage is a large flat plate with a central opening, and provided with spring clips and other apparatus for holding the objects. Near the lower end of the brass bar is the concave mirror, moveable in various ways, for reflecting the light through the centre of the stage upon the object thereon placed. On the under side of the stage is the diaphragm, used for cutting off extraneous light when viewing minute transparent objects; it consists of a plate of brass perforated with several holes of different sizes; this revolves on a pivot so as to bring each hole in succession under the object-glass. This microscope has a well-constructed set of eye-glasses, and three *achromatic lenses*, which may be used together, in pairs or singly, as different degrees of magnifying power are required. By means of the joint the instrument may be turned in a horizontal position, enabling the observer to use the instrument in some examinations with more ease than when in the vertical position. The instrument when set up is about ten inches high; is supplied with a dissecting-knife, point, forceps, several test-objects, and slips of glass on which to place objects. The parts may be unscrewed, and are compactly filled in a neat mahogany case; size, eight inches long by six inches wide, and three inches deep. Price $22.50.

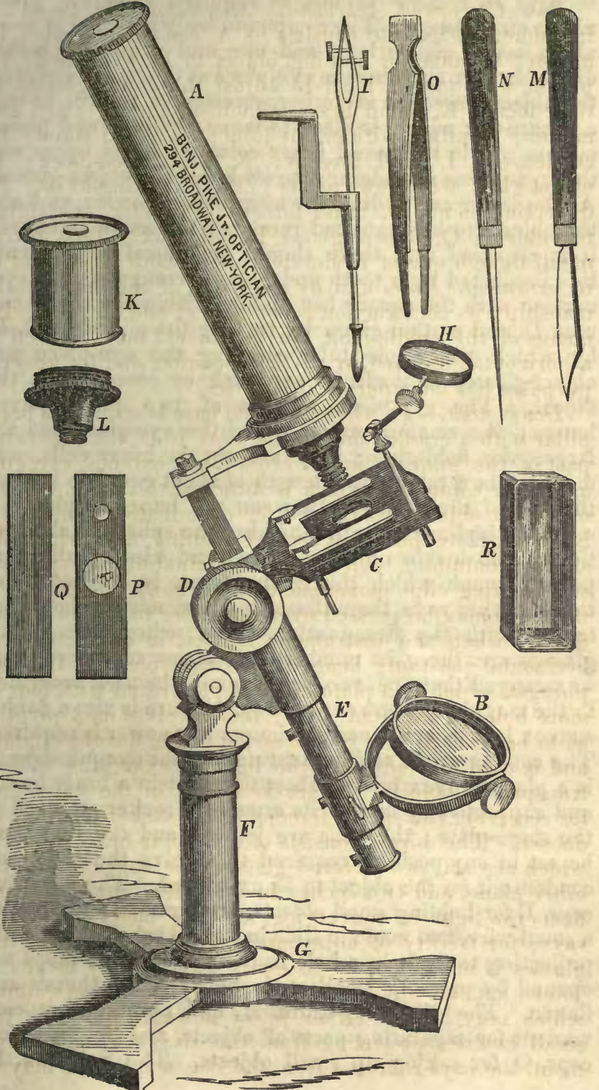
Fig 788



Ross Compound Achromatic Microscope, No. 2.—This instrument (Fig. 789) consists of A, compound body; B, mirror; C, stage for holding object to be examined; D, pinion with milled head to adjust the object-glasses to their focus; E, round brass column supporting stage and mirror; F, pillar, with cradle-joint; G, tripod stand; H, condenser; I, steel forceps; K, extra eye-piece; L, object-glass with low power; M, dissecting-knife; N, dissecting-point; O, brass forceps; P, slider, containing test-object; Q, slips of glass; R, fluid box. This instrument, though one of moderate cost, is both in respect to its *achromatic lenses* and its *mounting*, of the finest workmanship; its construction is convenient and elegant. By means of the cradle-joint the instrument may be used in a horizontal, inclined, or vertical position, and for general purposes has no superior at its price.

Description.—To a heavy tripod base is screwed a brass pillar with a cradle-joint at the top; from the moveable part of the joint an arm or cross-piece extends, carrying a circular column, to which is attached the stage, or part on which objects are placed for examination, which is a large flat plate, having a central opening, over which the sliders containing objects for examination are placed; small spring clips moveable up and down in sockets in the stage may be pressed over the slider to secure it from falling, when the instrument is used in an inclined or horizontal position; beneath the stage-plate is the diaphragm, which is a plate of brass perforated with four or more holes of different sizes; this revolves on a pivot so as to bring each hole in succession under the object-glass, and is used in modifying the light in examining minute transparent objects. There is a hole in the stage-plate for receiving the spring forceps, and a socket for the condenser. The mirror consists of a circular brass frame, in which are set two silvered glasses, one concave and the other plane, and two inches in diameter; the former reflects the light in converging, and the latter in parallel rays; for facility of adjustment the frame carrying the glasses is made to turn in every direction, by means of joints, and adapted to a tube fitting the brass column, which may be slid either up or down by pressing two small handles projecting from the sides; by this movement, the rays reflected from the concave mirror may be

Fig. 789.


A
BENJ. PIKE Jr. OPTICIAN
294 BROADWAY, NEW-YORK.
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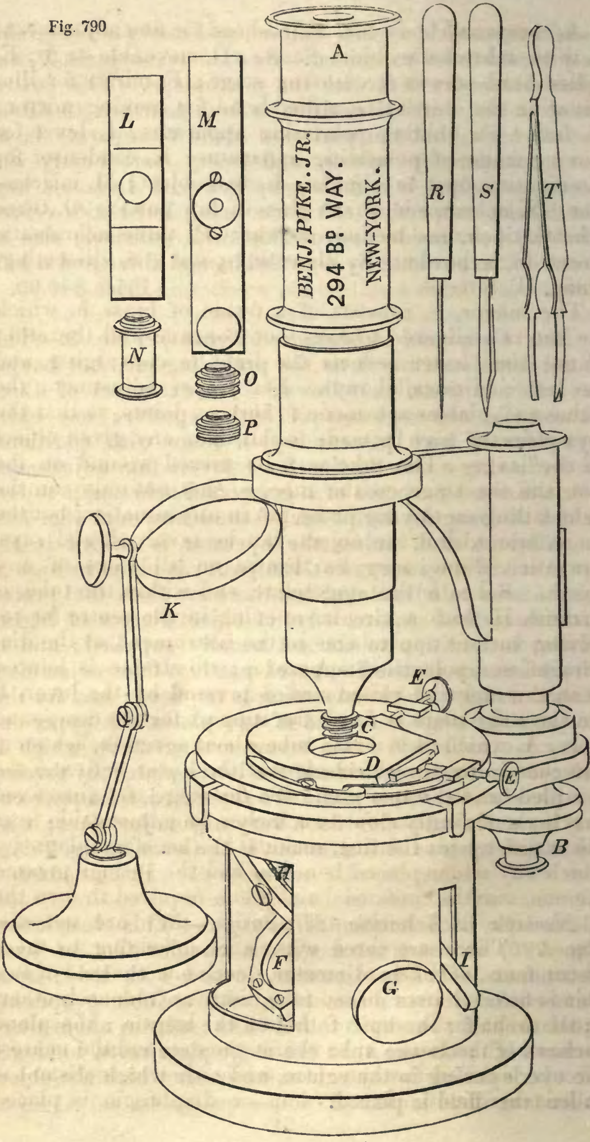
G

brought to a focus or not, as required upon any given object on the stage. The compound body is a tube of brass about seven inches long, and one and a quarter inches diameter. It contains the eye-piece at the upper end, and the object-glasses at the other, screwed to an arm having a square bar which is fitted to move by tooth and pinion motion within the round brass column; to its upper end the eye-pieces are adapted, to its lower the object-glasses. As the latter are of different magnifying powers, and also the objects to be examined rarely of the same thickness, it is required that there should be a focal adjustment; this is effected by a tooth and pinion arrangement in connection with the square bar sliding within the round column E, and motion given by turning the milled head, D, by which the whole tube carrying the eye-piece and object-glasses is made to approach or recede from the object. The eye-piece consists of two plano-convex lenses; the smaller one is called the eye-glass, and the larger the field-glass; they are set in brass cells, and mounted in a tube whose length is about equal to half of the sum of their focus. Between the lenses is placed a stop, or diaphragm, for diminishing the spherical abberration. The inside of these tubes, and also of all other parts through which the light passes, is blackened, so that no other rays than those from the mirror should interfere with the illumination. The achromatic object-glasses are three in number, and screw together, being so arranged that one, two, or three may be used according to the magnifying power required. There is also a double convex lens in a cell, useful where a low power is required. The condenser, H, or illuminating lens for opaque objects, is a plano-convex lens of short focus set in a brass frame, and supported by one of its arms in a socket attached to the stage-plate; the arms are jointed, and the lens may be set in any position required to receive the light and condense it on the object to be examined. The steel forceps, I, for holding small objects, are formed at the end of a small wire, and made to slide in a small tube having a pin projecting to fix it in a hole in the stage; the forceps are opened by pressing small studs between the thumb and finger. The dissecting-knife, M, and point, N, are convenient for separating parts of objects, and the brass forceps, O, for taking up small objects. The fluid-box, R, is of brass, with a glass bottom, and used for containing any liquid to be examined. Several test-objects, P, and glass sliders are sent with the microscope. This instrument in the vertical position is from fourteen to fifteen inches high; but the parts are made to separate in an easy manner by screws, and every part neatly and securely packed in a mahogany box with lock and key, the blocks supporting the parts being lined with velvet, and the box, inside and outside, well polished; size of box, ten inches long by eight wide, and three and a half deep. Price $40.00.

Ross Compound Achromatic Microscope, No. 3.—This is the same instrument as the preceding one, but having several additions, as follows: One extra set of three achromatic object-glasses of higher power; one extra eye-piece of high power; and a stage with additional plate, having a slow motion for extreme fine adjustment. For the usual purposes of a compound achromatic microscope, the magnifying power of the instrument (fig. 789) is sufficient, and, unless the operator is skilled in the operation of the instrument, the power is about as high as can be used to advantage; but there are those that prefer, and others that require, a set of object-glasses of higher power, in addition to the set usually supplied; and to give efficiency to the increased power a finer adjustment than the rack and pinion motion is required; and for this purpose the stage is formed of two plates, the upper one being moveable by a fine screw arrangement, which is attached to the under side of the lower plate; by turning a milled-head the two plates are separated, the upper one moving sufficiently slow for a very nice adjustment; with these differences the instrument is the same as fig. 789. Price $55.00.

Nachet's Achromatic Microscope.—This instrument (fig. 790) is constructed with a circular foot or base, about four inches in diameter, loaded with lead; upon this is fitted a stout brass tube, with an oblong opening in the front for the light to fall on the mirror, about three inches high; on the tube the stage-plate rests, having a circular opening in the centre, and over which the object to be magnified is placed.

Fig. 790



A, compound body; B, milled-head for fine adjustment; C, three achromatic object-glasses; D, moveable stage; E, milled-head screws for moving stage; F, mirror for illuminating the object; G, milled-head for moving mirror; H, frame for holding polarizing apparatus; I, lever for moving frame of polarizing apparatus; K, condenser for illuminating opaque objects; L, test-object; M, micrometer; N, achromatic object-glass of low power; O, three achromatic lenses medium power; P, three achromatic lenses high power; R, dissecting-point; S, dissecting-knife; T, forceps.

The mirror, F, consists of a frame of brass, in which are set two silvered glasses, one concave and the other plane; the former reflects the light in converging, and the latter in parallel rays. For proper adjustment the frame and glasses are made to turn on joints, so that the rays reflected may be made to fall upon any given object on the stage. The tube may be turned around on the foot, and the stage on the tube, so that not only can the light falling on the mirror be put in any situation, but the stage, and with it the object, can be revolved, and rays, however oblique, may be thrown on all sides of any object. Beneath the stage-plate, and within the tube, is a frame, H, with a circular opening in the centre for receiving various appendages to the instrument, as the diaphragm, and polarizing apparatus; this frame is jointed so that it may be raised and depressed by the lever, I. To the stage-plate is fixed the support for the compound body, A, which is a brass tube about seven inches long, and containing the object-glass at the lower end, and the eye-piece at the upper end. To the stage-plate are fixed two brass springs, about two inches long, moveable from the stage by pins fitting sockets in the stage-plate, by which any slider placed beneath, and the springs pressed thereon, may be confined; and when required to turn the microscope in a horizontal position, they are not displaced. There are three eye-pieces belonging to these instruments, of different powers; each one consists of two plano-convex lenses placed at a distance from each other, equal to half the sum of their focal lengths; the plane surfaces of the lenses are towards the eye, and the nearest the eye is called the eye-glass, while that more distant is called the field-glass. A stop or diaphragm is placed half way between the two lenses, for the purpose of diminishing the spherical abberration. Each of these eye-pieces fit within the upper end of the compound body, and may be used as occasion requires. To the lower end of the compound body, which is somewhat conical, are fitted, by fine screws, the object-glasses. With this instrument there are usually three sets, having magnifying powers of 100, 300, and 500 diameters, the first being a combination of two achromatic lenses, and the two others combinations of three achromatic lenses; these can be used either singly or in combination, the latter having the best effect. The coarse adjustment of the object-glasses is made by sliding the compound body, A, up or down, in a nicely-fitting tube fixed to its support, while the fine adjustment is effected by the screw at the milled-head, B, by which the support and the compound body also are raised or depressed; the compound body can not only be moved up and down in the tube, but taken away for changing the powers or cleaning the lenses. The condenser, K, or illuminating lens, for opaque objects, is a plano-convex lens of short focus, set in a brass frame, and supported by arms with moveable joints to a brass foot; by this arrangement the lens may be set in any position required to receive the light, and condense it on the object to be examined. There are three diaphragms with this instrument; they are blackened brass cells of about half an inch in diameter, one having an aperture of a quarter of an inch, the others an eighth and sixteenth; they fit in the frame, H, from the upper side of the stage-plate; their use is to modify the rays reflected from the mirror, when required for the object under examination, and to limit the pencil of light allowed to fall thereon. The fluid cell is an oblong brass frame, about an inch and a half long, and a quarter of an inch deep, having a glass bottom cemented within; it is used for holding various fluids in their examination. With the addition of a few test-objects, P, dissecting-knife, R, point, S, and forceps, T, we have described the usual parts and accompaniments of a good achromatic microscope, in which great steadiness, accuracy of adjustment, portability, and other valuable requisites, have been successfully carried out.

There remain several important appendages which accompany more expensive instruments, which we proceed to describe.

A Moveable Stage, D, composed of a sliding-plate, which is made to move over another plate by means of two screws placed diagonally, a curved spring keeping the plate in contact with the screws. By this contrivance an object, when laid on the stage, is capable of being moved in any horizontal direction, so that every part of it can be successively brought into view; the lower plate has three pieces of brass projecting from its circumference, to fit over the edge of the stage-plate.

The Stage Micrometer, M, for measuring the size of small objects, consists of a glass about a quarter of an inch in diameter, set in a brass frame about two and a half inches long, and one third wide. On the surface of the glass is ruled with the point of a fine diamond, a scale occupying one twenty-fifth part of an inch, within which are accurately divided one hundred equal parts; each division is therefore one twenty-five hundredth of an inch apart. These minute divisions are clearly discerned, and have each a visible length, even under the low powers of the microscope; and by laying a small object, as a fibre of silk, or a hair, across this scale, its dimensions can be accurately determined, as the object and the lines on the glass can be seen at one and the same time; if the breadth of the object occupies twenty-five divisions of the scale, its breadth is one hundredth of an inch; if it covers ten only, its breadth is one two-hundred-and-fiftieth of an inch.

The *Camera Lucida* is a valuable addition to a microscope; it consists of a four-sided prism of glass, set in a brass frame or case, and by means of a short tube, or spring clip, applied to the tube of either of the eye-pieces, so that the prism may be directly in front of the eye-glass. To use conveniently, the microscope should be laid in a horizontal position, and supported at a proper distance from the table for convenient use, say from one to two feet, and a sheet of white paper laid on the table beneath the prism; if now the light be reflected through the compound body, an eye placed over the small hole in the frame of the prism, with the sight directed toward the paper, will see the image of any object on the stage, if in the focus, on the sheet of white paper. Should the whole of the field of view be not well illuminated, the prism may be adjusted by turning on its pivots, or a slight movement round the eye-piece, the observer will now bring his eye so near the edge of the prism, that he may be able to see at one and the same time, the image of the object, and the point of a pencil. When he has accomplished this, the pencil may be moved along the outline of the image so as to trace it on the paper; however easy this may appear in description, it will be found somewhat difficult in practice, and the observer should not be foiled in his first attempts, but persevere until he accomplishes his purposes; he may find that he can see the pencil-point, and all at once it disappears; this happens from the movement of the axis of the eye. The pencil should be kept on the paper, and the eye moved about until the pencil is seen again, when the eye is to be kept steadily fixed in the same position, until the entire outline is traced. The operation may be conducted by lamplight, or the diffused light of day. If, after the drawing is made, the object on the stage be removed, and the micrometer fixed thereon in its place, and an image of its magnified divisions drawn, which being compared with that made of the magnified object, the dimensions of the latter are readily ascertained. The size of the picture drawn on the paper, will like all others made by the camera, depend on the relative distance between the object and the paper.

Polarizing Apparatus.—For the purposes of polarizing light, various substances have been employed; sometimes a crystalline mineral, called tourmaline, in the form of a thin plate, confined between two thin glasses, and set in a brass cell; but the most useful for the microscope is a crystal of Iceland spar, called Nicol's prism, consisting of a romb of the spar divided into two equal portions, in a plane passing through the acute lateral angles, and nearly touching the obtuse solid angles, the cut surfaces having been carefully polished, are then cemented together with Canada balsam, so as to form a romb of nearly the same shape as it was before cutting, and capable of transmitting a single image only. As adapted to the microscope, one of these prisms is fitted in a brass cell by means of a piece of cork, so constructed that it may be placed in the circular opening in the frame, H, beneath the stage-plate, and is moved up and down by the lever, I; this lower prism is called the polarizer. Another prism is adapted to the compound body, called the analyzer, of the same construction as the lower one; the conical end to which the object-glasses are usually screwed, is taken away, and another similar piece, having the same screw for the object-glasses, but having a tube entering the compound body in which is contained the prism; on passing rays from the mirror through the instrument, as arranged with these prisms, and revolving either of the prisms, by turning the stage or the compound body; it will be found that there are two positions in each revolution in which no light will pass through the prisms, but be completely darkened; if now a plate of sellenite, or other refracting crystal, be placed on the stage, and be brought into the focus of the object-glass, and the light be brought to pass through the prisms, the sellenite will produce a color according to its thickness; if one of the prisms be now revolved slowly, we shall find more and more light will be transmitted, but the intensity of the color will be diminished; and when a quarter of a revolution has been accomplished, the brilliancy of the color will reappear, but what was originally red will become green, and the green will become red at a second quarter revolution; if the sellenite be removed and some very thin crystals of sulphate of copper, tartaric acid, or many other crystalline substances be substituted for it, a most gorgeous set of colors will be seen; and as the prism is being revolved, the same alternations of color will take place as in the sellenite; every color and every tint of each primary color may be produced by variations of the doubly refracting substances, and the thickness of the same through which the polarized light passes. The uses of polarized light in microscopic examinations, to their full extent, have not yet been fully developed; but they are many, and objects that are far too delicate to exhibit any structure under ordinary illumination, will often be well seen under polarized light. All structures belonging either to the animal, vegetable, or mineral kingdom, in which the power of unequal or double refraction is suspected to be present, are those that should especially be investigated by polarized light.

Microscope, having 3-inch foot or base, 3-inch stage-plate, compound body 8 inches long, fine adjustment attached to an extra stage-plate, one set of three achromatic object-glasses, condenser with arms to support from stage-plate, fluid-cell, dissecting instruments, pair of forceps, and three test-objects. Price $25.00.

Microscope, same as above, but having $3\frac{1}{2}$ inch base, 3 inch stage-plate, and one extra eye-piece of greater power. Price $35.00.

Microscope, same as last, with the addition of the moveable stage, D. Price $45.00.

Microscope, with $3\frac{1}{2}$-inch base, $2\frac{3}{4}$-inch stage-plate, 8-inch compound body, 3 eye-pieces of different powers, 2 sets of achromatic object-glasses, condenser with arms to support from stage-plate, fluid-cell, dissecting instruments, forceps, 3 test-objects, moveable frame below stage-plate, camera lucida, and polarizing apparatus. Price $75.00.

Microscope, with 4-inch base, 3-inch stage-plate, 8-inch compound body, 3 eye-pieces, 3 sets of object-glasses, condenser on brass foot, fluid-cell, dissecting instruments, forceps, 6 test-objects, micrometer, moveable frame, H, below stage-plate, and moveable stage-plates, D. Price $85.00.

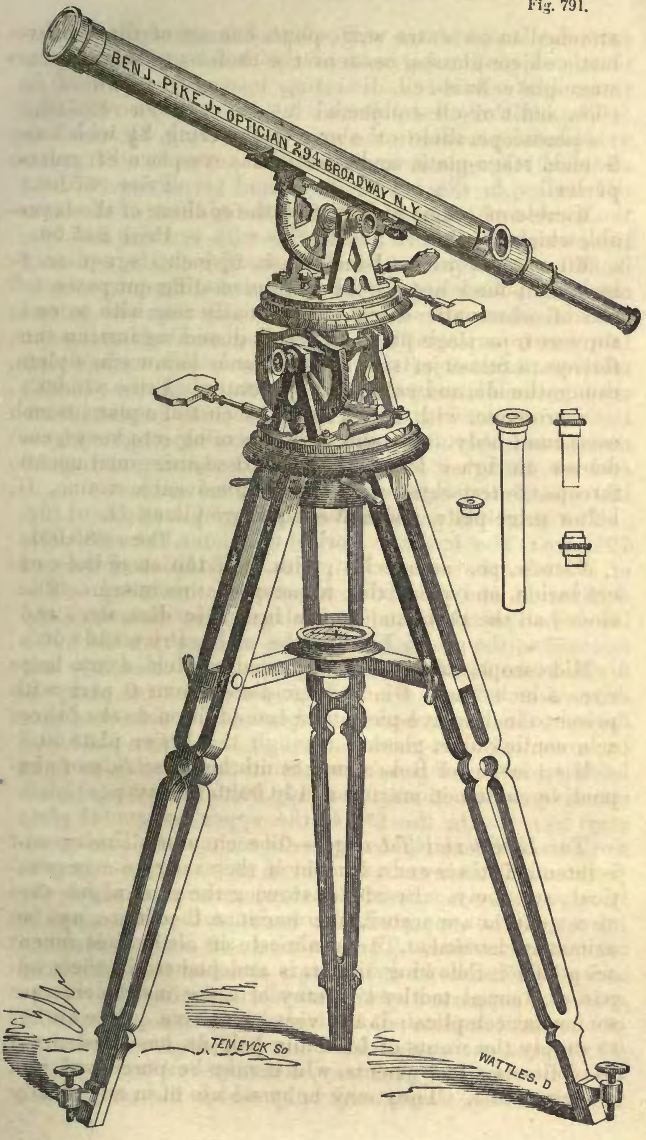
Microscope, same as last, with the addition of the camera lucida, and polarizing apparatus; this instrument includes all the parts and appendages described, fig. 790. Price $105.00.

Microscope, same as the preceding, but extra large size, 5-inch base, 4-inch stage-plate; extra part with prism to incline eye-piece, and one additional set of three achromatic object-glasses. Price $135.00.

Microscopes of Ross's, and Smith and Beck's, more expensive constructions, from $150.00 to $200.00.

The Equatorial Telescope.—The equatorial instrument is intended to answer a number of useful purposes in practical astronomy. Besides answering the general purposes of a quadrant, a transit instrument, a theodolite, and an azimuth instrument, it is almost the only instrument adapted for following the stars and planets in their apparent diurnal motions. Many of these instruments are somewhat complicated, and very expensive. The author to supply the wants of his many patrons, has constructed the following instruments, which may be purchased at a moderate cost. They may be made use of in any steady

Fig. 791.



room or place, and are well adapted for general observations, and performing most of the useful problems in astronomical science.

The basis of all equatorial instruments is a revolving axis placed parallel to the axis of the earth, by which an attached telescope is made to follow a star, or other celestial bodies, in the arc of its diurnal revolution, without the trouble of repeated adjustments for changes of elevation, which quadrants and circles with vertical and horizontal axes require. Such an instrument is not only convenient for many useful and interesting purposes in celestial observations, but is essentially requisite in certain cases, particularly in examining and measuring the relative positions of two contiguous bodies, or in determining the diameters of the planets when the spider's line micrometer is used. The great cost of these instruments has hitherto prevented their coming into very general use, though it is one of the most pleasing and useful instruments connected with astronomical science.

The principal parts of the equatorial instrument (fig. 791) are: The lower or horizontal plates, the semicircle of altitude, the equatorial plates, and the semicircle of declination on which the telescope is mounted. The lower horizontal plate is nine inches in diameter, and fastened to the round head of the mahogany stand; it is divided into 360 degrees, which are subdivided into half degrees or 30 minutes, and numbered from 0 every 10 degrees, the upper horizontal plate is fitted to the lower by a conical axis, passing through the lower plate and having a large winged-screw nut on the inner side of the stand, by which it may be firmly held in any position it may be set. On the top of the upper horizontal plate are two levels at right angles to each other, having adjustments at their ends, by which they may be accurately set, and by means of the three screws on which the instrument is supported, the horizontal plates may be accurately leveled. The semicircle of altitude is seven and a half inches in diameter, is attached to a horizontal axis, and supported by two standards fastened to the upper horizontal plate; it is divided into two quadrants of 90 degrees each, subdivided into half degrees, and numbered from 0 to 90 each way, a vernier reading to single minutes, and a tangent-screw, by which the vertical arc is moved up or down; the centre part of the axis of this arc is enlarged, and has an opening for receiving the axis of the equatorial circles, to which they are firmly secured. The equatorial circles are eight inches in diameter, and consist of two brass plates with shampered edges, the upper or vernier-plate turning freely on the lower or graduated circle, having a horizontal motion by means of a vertical axis; this axis consists of two parts, external and internal, the former secured to the graduated hour-circle, and the latter to the vernier-plate. Their form is conical, nicely fitted and ground into each other, having an easy and steady motion when turned. The equatorial hour-circle is divided into 720 parts, and numbered into degrees and half degrees, from 0 to 360; also into twice twelve hours, with the subdivisions reading to two minutes; these are subdivided by the vernier into single minutes for the half degrees, and into four seconds for the hour circle. In the upper edge of the vernier-plate is cut, in its entire circumference, a thread, into which works an endless screw, by which a slow and steady motion may be given to the upper plate for any number of revolutions.

The semicircle of declination, $7\frac{1}{2}$ inches in diameter, is attached to an axis, and by two standards supported and fixed on the upper equatorial plate; it is divided into two quadrants of 90 degrees each, subdivided to thirty minutes, and having a nonius by which it may be read to single minutes; it has also a slow-motion endless screw, by which it may be elevated or depressed; on the upper edge of this semicircle there is screwed a broad plate, about twelve inches long, to which the telescope is attached, by means of two milled-head screws; the body of the telescope is about four feet long, and the terrestrial or long eye-piece about one foot long; the diameter of the object-glass is three inches; the power of the terrestrial eye-piece is 50 times; two celestial eye-pieces also accompany the instrument, having powers of 120, and 180 to 200 times. Extra eye-pieces of intermediate powers of 80 and 150 times may be had at an additional cost. The adjustment of the eye-pieces to the focus of the object-glass, is made first by sliding into a closely fitting tube, as near as convenient for distinct observation; and then for fine adjustment, the eye-piece is moved in or out by a tooth-and-pinion arrangement, moved by turning a milled-head at the side of the main tube. Two brass cells, with screws fitting the ends of the celestial eye-pieces, containing dark glasses for solar observations, are sent with the instrument.

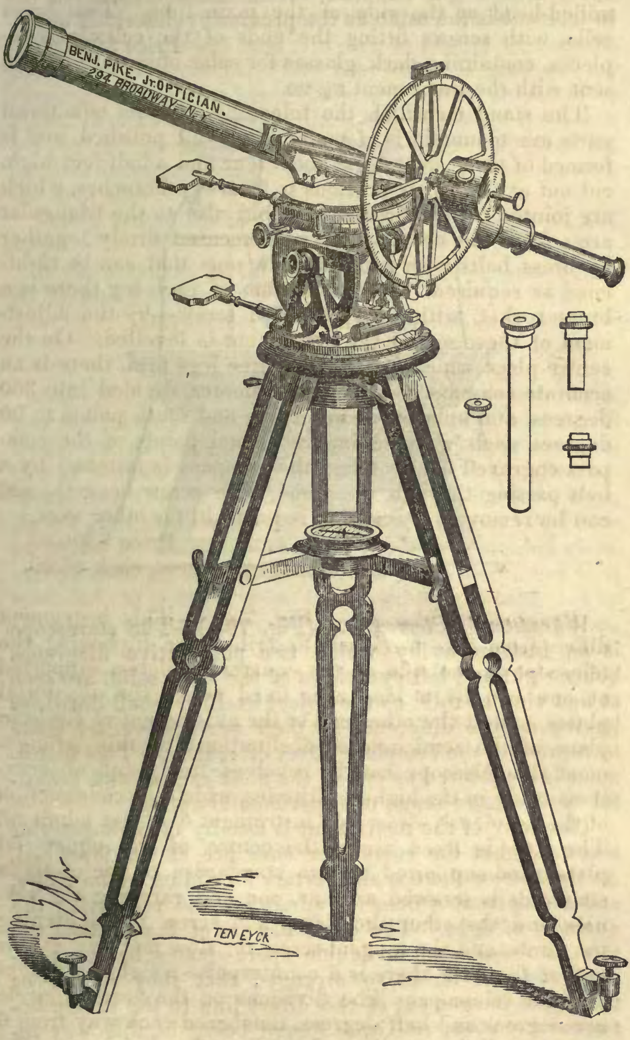
The stand on which the telescope with its equatorial parts are mounted, is of mahogany, well polished, and is formed of three stout legs, about four and a half feet high, cut out at the upper portions to form two branches, which are jointed to the circular top, and also to the triangular arms from the centre-piece, and secured firmly together by brass bolts with winged-screw nuts that can be tightened as required. At the bottom of each leg there is a brass socket, with a large milled screw—by the adjustment of these screws the instrument is levelled. On the centre-piece which braces the three legs firm, there is an accurate compass, 4 inches in diameter, divided into 360 degrees, and numbered from north and south points to 90 degrees each way, having the usual points of the compass engraved on its face; the compass is fastened by a bolt passing through the wood, with screw beneath, and can be removed, if occasion requires it, for other uses.

Price $300.00.

Additional eye-pieces, each $5.00.

Equatorial Telescope.—(Fig. 792.)—This instrument differs from the previously-described one in having the telescope at the side of the equatorial plates, supported at one end by a long axis fixed across the equatorial plates, and at the other end of the axis an entire circle in place of the semicircle of declination; by this arrangement the telescope can be revolved freely and observations made in the highest altitudes, which the construction of the previously-described instrument does not admit of. The axis is fixed across the centre of the equatorial plates, and supported by two standards; to one of these standards is screwed a frame, one end carrying the vernier, and the other the clamp and screw for tightening the circle, and the tangent-screw for slow motion; at this end of the axle there is a counterpoise-weight for balancing the telescope. The divisions on the vertical circle are degrees and half degrees, numbered each way from 0 to 180, and the vernier subdividing the divisions on the

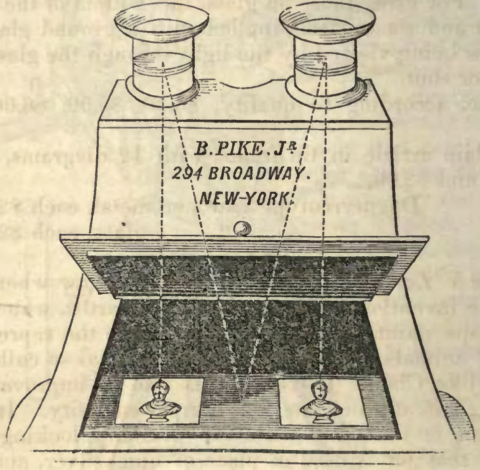
Fig. 792.



circle into single minutes. With these differences the instrument is the same as the previously-described one.

Price $350.00.

Fig. 793.



Wheatstone's Sterescope.—(Fig. 793.)—The sterescope is an instrument by which two perspective diagrams, being right and left eye-views of the same solid, are seen at one view as solid as the object itself, or small drawings having a little difference in their perspective, are made to represent the complete effect of reality. This instrument is considered as one of the most curious and beautiful in the entire range of experimental optics.

The body of the instrument is usually of mahogany or rosewood, but the commoner ones are of tin, japanned. At the bottom there is an aperture for sliding in the views, and at the front a door for admitting and regulating the quantity of light. The eye-tubes are of brass, about the form of those used in double opera-glasses, having prismatic convex lenses so arranged that they refract or throw the images out of the direct line to the centre between the eyes, and each image being in this way removed in a direction toward each other, so as to combine in one, and produce the effect of solidity. The diagrams are usually on cardboard, and about three inches wide, by six or seven inches long; twelve to twenty-five accompany each instrument. The best effect is produced by viewing daguerreotypes; these are either on metal or glass. For using those on glass, the bottom of the box is cut out and sometimes supplied with a ground glass, the pictures being viewed by the light through the glass with the door shut.

Price, according to quality, \$3.50, \$5.00, \$6.00, and \$7.00.

A plain article in tin frame, with 12 diagrams, \$2.00, \$2.50, and \$3.00.

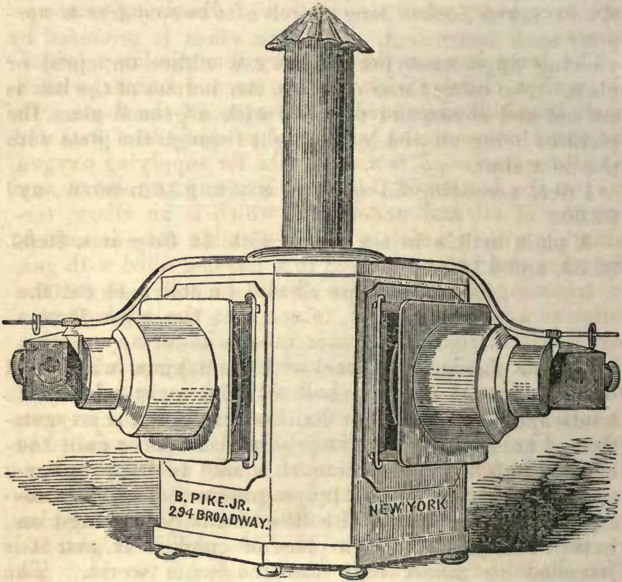
Daguerreotype views on metal, each \$2.00.
" " glass, each \$2.00.

Claude Lorraine Mirror.—"I don't know whether it was the invention of the famous Italian artist, who was in landscape paintings what Landseer is in the representation of animals; or whether the mirror was so called because, like Claude Lorraine, it is said to improve upon nature; but, at all events, it is a great curiosity. Its construction is the same with the ordinary looking-glass, except that jet is used in place of quicksilver, and it is intended to reflect only the inanimate world. The Claude Lorraine mirror derives its value from the principle that all objects are more beautiful in miniature, which renders their defects less apparent; for the unsightly strikes the eye with immediate pain, while that which is perfect grows upon us more gradually. With this mirror, you frame for yourself, as it were, little landscapes at every turn, in which the sky is softer, the grass richer, and the foliage more graceful, than anything you can see without it."

These mirrors are mounted in neat embossed morocco cases.
4 by $5\frac{3}{4}$ inches, price \$2.50.
5 by 6 inches, price \$4.50.
6 by 7 inches, price \$6.00.

The Dioptric Lantern.—(Fig. 794.)—The Improved Prismatic Dioptric Dissolving Apparatus, invented by the Rev. St. Vincent Beechey, possesses, within less compass than a single lantern of the ordinary description, all

Fig. 794.



the powers of two lanterns, with only one small lamp of intense brightness, free from the objectionable smell and great heat of ordinary lamps, whereby a disc of twenty feet for each tube may be obtained; each disc is capable of being darkened to any required extent, without the least shadow on any particular portion of the picture; and, from the superiority in the optical arrangements of the apparatus, each picture is perfectly flat and well defined to the extreme edge. As the two discs may be thrown either together on one circle, or two united at various distances in length upon the screen, the number of effects which may be produced may be easily imagined; they present a succession of dissolving views, so accurately and gradually dissolving, that the most experienced eye can not perceive the process going on. The portability of the apparatus is also of importance; the whole can be packed, viz., the lantern, gas-bag, retort, purifier,

&c., with several dozen slides, in a case, two feet long, twenty inches wide, and fifteen deep—a decided advantage over every other description of dissolving-view apparatus.

The lamp is upon the ordinary fountain-lamp principle, with a circular wick like an argand burner, with a small lime-ball suspended in the apex of the flame. In the exact *centre* of the wick, *and precisely level with the top of it when raised*, is a small tube for supplying oxygen gas; at the bottom of this tube is a cup to receive any overflow of oil, and underneath which is an elbow, terminating with a union, where a flexible tube is united, the other end being attached to a gas-bag filled with gas. In trimming the lamp, care should be taken to cut the cotton to a uniform height, to see that the edges form a regular circle round the inner tube, without any portion of the wick coming in contact with the oxygen tube; and the under part of the lime-ball should be suspended half an inch from, and exactly over, the centre of the oxygen tube. The wick of the lamp should not be raised too high, but just to produce as much smoke as will be entirely absorbed by the gas. Apply a pressure of about twenty pounds on the bag, and sufficient gas only turned on by the small stop-cock to produce perfect brightness. This should be particularly attended to; if too much gas is turned on, the lime-ball is cooled, and gas wasted. The advantages of this mode of illumination, and its applicability to dissolving views, are: first, its intense brightness, being of sufficient illuminating power, with condensers of only three and three quarters inches diameter, to throw a sharp and well-defined disc of *twenty feet* diameter; secondly, its maintaining a uniform brightness for two or three hours consecutively, and, in this respect, superior to the oxy-hydrogen light; thirdly, the simplicity of arrangement, and facility of management; fourthly, the economy, the consumption of gas being very little more than one cubic foot, and one ounce and a half of oil, per hour.

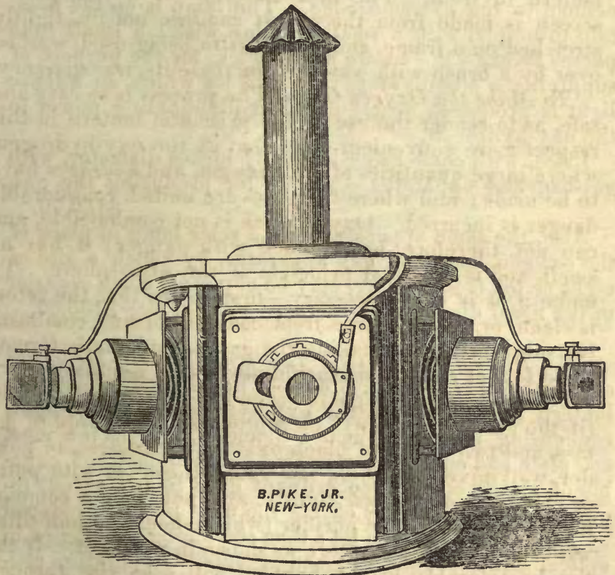
Directions for Use.—The lantern should be placed from twelve to fifteen feet from the screen, by which a disc of these dimensions will be obtained; and as the distance is increased between the lantern and the screen, so in the same ratio will the size of the disc be increased; but if this extends beyond twenty feet, it will be necessary to change one of the object-lenses in each tube for those of longer foci; this is easily effected, by drawing out the tube containing the lenses, removing the one loose in the cell, and substituting one of longer focus. Perfect coincidence of discs is obtained, laterally, by moving the prism on its hinged joint, and perpendicularly, by moving round the tube containing the shutter. The lenses and prisms should be examined, to see that they are clean and free from dust, and carefully placed in their right position. A very little experience will enable those using the instrument to manage the levers and prisms, and, with facility, to produce all the effects desired. When practicable, an opaque screen should be used, by having the lantern in front. The best material for a transparent screen is made from the widest cambric muslin, tightly stretched on a frame, and, previous to being used, washed over by a brush with water, to increase its transparency.

To Make the Oxygen Gas.—The process is so easy and safe, as to render the use of the prismatic lantern in this respect more convenient than that of the oxy-hydrogen, where large quantities of both oxygen and *hydrogen* have to be made; and where the gases are united, considerable danger is incurred. Oxygen gas is not combustible, and can not, therefore, be attended with danger; it has no smell, and is the vital principle of the atmosphere. To make it, it is only necessary—first, to see that the retort is clean, or, at least, free from coal, oil, or any combustible substance (after making the gas, a residuum is formed at bottom of retort, this should always be removed previous to making fresh gas); secondly, put into the retort (if the gas-bag is empty) eleven ounces of chlorate of potass, and two ounces of black oxide of manganese, in powder, well mixed together; lute round the cover with putty or clay; screw it down tightly, and put it on a common fire; and connect the purifier (which should be half filled with water) with the retort, as shown in wood-cut. If the fire be tolerably bright, bubbles will soon rise through the water in the purifier; when they come fast and regularly, without intermission, allowing all atmospheric air to be expelled, connect the purifier with the gas-bag by the flexible tube, and in about ten minutes you will have three feet of the purest oxygen gas; when the bubbles cease, or when the bag is full, *turn* the stop-cock, to prevent gas escaping, unscrew the tube from the purifier, and take the retort off the fire. When required for use, attach the tube from the gas-bag to the lamp, having previously removed any moisture that may have collected in the aperture of the stop-cock in the process of making the gas, which is easily done by passing a narrow strip of linen, or piece of string, through the orifice.

Price, with apparatus for producing the gas, $135.00.

Also, the same lantern with a solar lamp in place of the oxygen lamp and gas apparatus, by which a brilliant disc of eight or ten feet may be made much superior to the ordinary form of dissolving lanterns. Price $120.00.

Fig. 795.



The Trinoptric Lantern.—(Fig. 795.)—This differs from the Dioptric Lantern by having in addition to the two tubes with lenses and prisms placed at the sides, one without a prism placed directly in front of the lantern, combining the powers of three lanterns in one, with only one lamp. With the oxygen lamp a disk of twenty feet may be obtained for each tube, and each disc capable of being darkened to any required extent, without the least shadow on any particular portion of the picture. The three discs, by means of prisms, may be thrown, either altogether on one circle, or united, at various distances in length, on the screen, to form one panoramic picture. All the various effects that can be produced by the employment of two or three distinct lanterns, of the usual form, each requiring a light, are obtained far more effectively, and with much more facility, by the trinoptric lantern, which, exclusive of always securing uniform illumination, from the superiority in the optical arrangement of the apparatus, each picture is perfectly flat, and well defined to the extreme edge. The lamp is on the fountain principle, with a small circular wick; a small tube passes through the centre of the wick, for the purpose of supplying a stream of oxygen gas, by which an intense light is produced, nearly equal in illuminating power to the oxy-hydrogen.

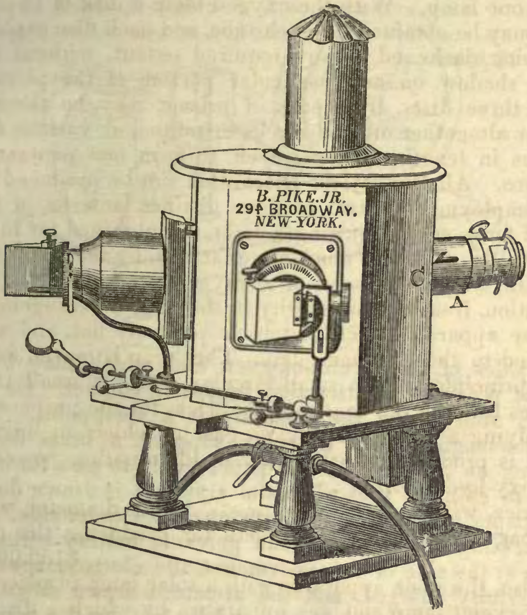
Price, with condensing lenses $3\frac{3}{4}$ inches diameter, with gas-bag and apparatus complete for producing the gas, $150,00.

Also, the same apparatus with a solar lamp in place of the oxygen lamp and gas apparatus, by which a disc of eight or ten feet, or more, may be obtained, much superior to the usual dissolving lanterns. Price $135.00.

The Prismatic Binoptric Lantern, for Oxy-Hydrogen or Lime-Light.—(Fig. 796.)—The prismatic binoptric lantern is adapted for the oxy-hydrogen, or lime-light, condensing lenses $3\frac{3}{4}$ inches diameter, and is the most complete and effective instrument yet manufactured, capable of giving one or two brilliant discs to any extent required, with dissolving effects the most perfect produced by one lantern and one jet: thus combining excellence in optical and mechanical arrangements. Apparatus, consisting of the most improved oxy-hydrogen jet and lime-holder, with clockwork motion, two large gas-bags, with stop-cocks, flexible tubes, pressure-boards, hydrogen generator and purifier, iron retort for oxygen, &c.

Price $265.00.

Fig. 796.

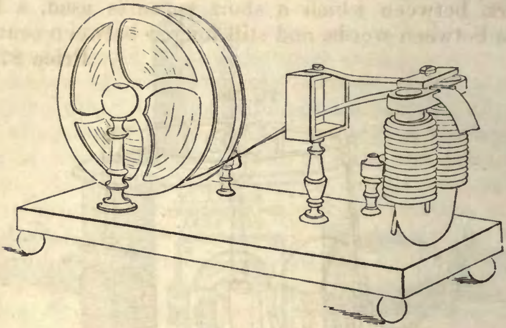


With oxy-hydrogen microscope, having three powers, and several sliders with objects attached, as shown at A, (fig. 796), additional. Price $110.00.

With polariscope, and apparatus additional, $110.00.

Telegraph Model.—(Fig. 797.)—This model represents the essential parts of Professor Morse's telegraph, consisting of an electro-magnet with the poles upward, having the ends of the wires surrounding the magnet connected to two brass cups with binding screws, which are fastened to the base on which the instrument is mounted. A brass roller, or spool, on which the narrow riband of paper is wound, and which may be drawn off as required, passing through an opening or guide in the brass pillar supporting the lever ; to the end of the lever, and just over the poles of the electro-magnet, is an armature, or bar of soft iron, not in contact, but a small distance above

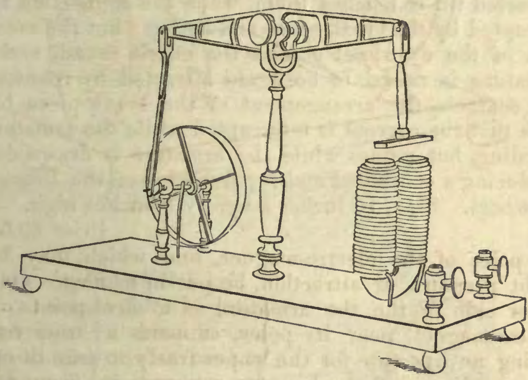
Fig. 797.



the poles of the electro-magnet, and which may by a slight pressure, or attraction, be put in contact. On the under side of the the armature is a steel-point. The electro-magnet, near its poles, supports a brass frame, having an aperture for the paper freely to pass through, and so adjusted that when the armature is drawn down, the paper is indented by the point on the under side. On connecting the wires from a galvanic battery with the cups at the side of the instrument, the electro-magnet is powerfully charged, and the armature drawn down, as often as connection is made, and broken, by the wire in the hand of the operator. This wire may be of great length, communicating as they do, in some cases, between distant cities. The armature with the pen-point being brought down, indenting the paper, which at the same time is being drawn through the aperture in the frame between the poles of the electro-magnet. We can connect and disconnect the wires of the battery as often and as fast as we please, consequently can magnetize the magnet, and draw down the armature and point as quick and as often as we please. If constantly magnetized, the mark would be a long line; if momentary, a dot; a little longer time, a short line; so that we may have dots, spaces and dots, in any number, and lines and spaces of any length, or any combination of any or all of these marks, from which an alphabet has been formed, that may be read with facility by one familiar with its characters; these different combinations of dots, and of short and long lines, with short and long spaces forming the letters, between which a short space is used, a longer space between words, and still longer between sentences.

Price $7.50.

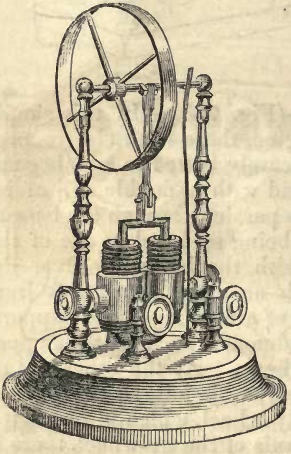
Fig. 798.



Magnetic Beam Engine.—(Fig. 798.)—In this simple arrangement of the beam-engine, there is an electro-magnet with its poles upward, securely bolted to a mahogany base, the magnet being wound with a double coil of insulated copper wire, the ends passing through the base to the under side, one of them being soldered to one of the screw cups for connection with the battery. Over the poles of the electro-magnet is an armature, of soft iron, which is attached to one end of a walking-beam, supported on a stout vertical brass column, branched at the upper part for the reception of the beam. At the other end of the beam, is attached, by a moveable joint, a connecting-rod, working the crank of a fly-wheel, which is supported on two brass pillars; on the axis of the fly-wheel, there is a silver break-piece, by which the battery current may be interrupted, and renewed, alternately, by means of a spring alternately in contact, as the axis moves round, one end of the spring having contact with the break, when the armature is to be brought down, but otherwise free; the other end of the spring passes through the mahogany base, and is soldered to one of the wires from the electro-magnet, the break on the axis having contact by means of a wire beneath the base, with a screw-cup for connection with the battery current. The cylindrical pot battery (Fig. 391) is of sufficient power to work this engine with ease and rapidity, drawing the armature down to the poles of the magnet with considerable power, being attracted till it touches them, when the connection is interrupted by the break-piece and spring; but the momentum of the fly-wheel carries the crank round, and the armature is raised to be again attracted by renewal of the contact—the arrangement of the break-piece being such that the current is interrupted while the armature is receding, but passes while the armature is drawn down, producing a continued and rapid motion of the beam and fly-wheel. Size, 10 inches long, by 8 inches high.

Price $9.00.

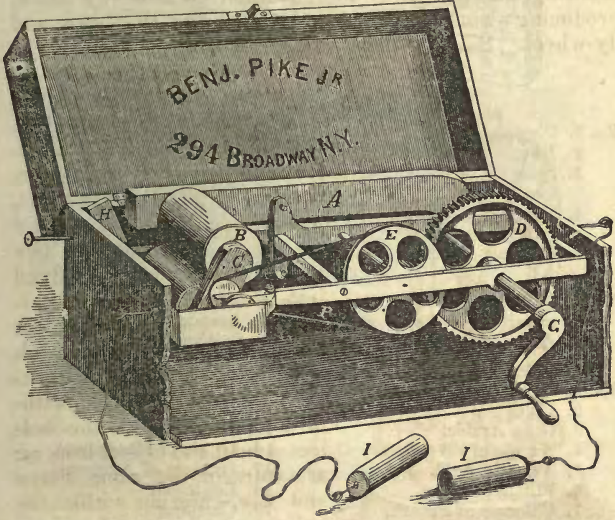
Fig. 799.



Axial Wheel Engine.—(Fig. 799.)—In this engine two helices of insulated copper-wire, at a convenient distance apart, are clamped and fastened by screws to the sides of two brass pillars, which are fixed in a neat turned wooden base. At the top of these pillars there is an axis, with crank and fly-wheel, the crank working a rod, and supporting within the upper part of the helices a bent rod of soft iron, an armature of the same shape and size, entering within the helices at the lower end, is fastened to the base of the instrument. One end of the wire forming the helices is connected with one of the screw-cups, on the base of the instrument, for receiving the battery-current, the other end, of the wire of the helix, being in connection with a break-piece on the axle of the fly-wheel, and having a spring acting against it, so that the battery-current is alternately made and broken by the spring being in contact, or not; this spring is connected by a wire, beneath the base, to the other cup, for the battery-current. The power of a moderate sized pot-battery, fig. 391, is sufficient for working this engine, the current of which circulating in these helices, induces magnetism in the bent bars, and powerfully attracting them within the helices; when, by the revolution of the axle, the spring is separated from the break-piece, and the current stopped, the momentum of the fly-wheel bringing up the crank, and bent iron rod, again to be attracted and brought up—thus producing a rapid and uniform motion.

Price $10.00.

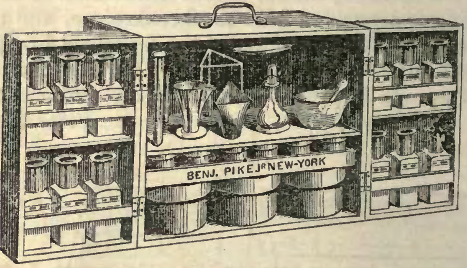
Fig. 799½.



Improved Magnetic Electric Machine for Medical Application.—(Fig. 799½.)—A, horse-shoe magnet; B, wire coil; C, armature; D, driving-wheel; E, pulley-wheel; G, handle; H, regulator; I, conductors. The electrical current is obtained by turning the handle, which by means of cog-wheels and a pulley, revolves an armature with a coil of insulated copper wire on each pole, against a permanent magnet. No *liquids* or *acids* are required. Whatever part of the body is affected, to which electricity is to be applied, the conductors may be moved about each side of the part affected, to distribute the electricity; and if covered with a sponge or flannel, and wet, the effect is more agreeable, and the power increased. They are used in the treatment of paralysis, rheumatism, nervous, and many other diseases, with great success. Price $10 00.

Youth's Chemical Cabinet (fig. 800), containing upward of 62 chemical preparations, tests, and useful apparatus, without any acid or deleterious or dangerous article.

Fig. 800.



12 SQUARE BOTTLES.

No. 1. Phosphorized Oil.
2. Nitrate of Copper.
3. Solution of Acetate of Cobalt.
4. Solution of Nitrate of Silver.
5. Tincture of Galls.
No. 6. Phosphuret of Lime.
7. Sub-carbonate of Potash.
8. Prussiate of Potash.
9. Bichromate of Potash.
10. Sulphate of Iron.
11. Tincture of Litmus.
12. Caustic Potash.

6 LARGE BOXES.

No. 1. Sulphate of Soda.
2. Stourbridge Clay.
3. Alum.
No. 4. Nitrate of Potash.
5. Acetate of Lead.
6. Sulphur.

24 SMALL BOXES.

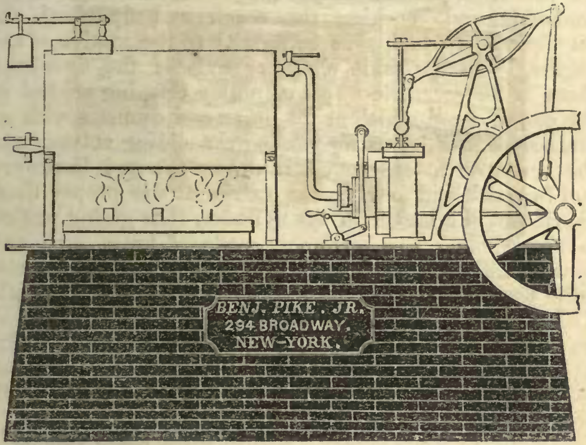
No. 1. Steel Filings.
2. Litharge.
3. Gum Arabic.
4. Nitrate of Strontian.
5. Tartaric Acid.
6. Fluate of Lime.
7. Chlorate of Potash.
8. Red Lead.
9. Carbonate of Magnesia.
10. Lycopodium.
11. Powdered Charcoal.
12. Sulphuret of Antimony.
No. 13. Muriate of Ammonia.
14. Nitrate of Barytes.
15. Benzoic Acid.
16. Oxide of Manganese.
17. Oxalate of Ammonia.
18. Logwood.
19. Camphor.
20. Borax.
21. Nitrate of Mercury.
22. Isinglass.
23. Sulphate of Copper.
24. Resin.

APPARATUS, &c.

Earthenware Mortar and Pestle.
Glass Spirit-Lamp and Cover.
Metallic Capsule.
Glass Stirring-Rod.
Precipitating Glass.
Turmeric Paper.
Litmus Paper.
Filtering Paper.
Funnel.
Tripod Stand.
Two Crucibles.
Tin-Foil.
Glass Tubing.
Lamp Cotton.
Metallic Zinc.
Sheet Ditto.
Bullets.
French Chalk.
Test-Tube.

In cardboard case, price $2.50; cedar case, $3.50; mahogany case, French polished, with lock and key, $5.00. Larger cases of chemicals and apparatus at $10, $15, $20, and $28.

Fig. 801.



Working Model of Steam-Engine.—(Fig. 801.)—The above represents a neat and compact model of this interesting machine, sometimes called the "king of machines," and as an example of a self-regulator is unsurpassed by any other forms of machinery. The boiler for the generation of steam is of strong copper or brass, and is heated by the flame of a spirit-lamp, having a number of wicks. On the top of the boiler is placed the safety-valve, with its lever and weight; this valve opens upward, so that should the elastic force of the steam become too great, the valve opens and the steam escapes. At one end of the boiler is a water-cock, and at the other end, and near the top, a cock and the steam-pipe. This steam-pipe connects with the cylinder of the engine, forcing a steam-tight piston backward and forward by an arrangement of sliding valves, so adjusted as alternately to admit the steam above and below the piston, and also alternately to let it escape in the air. The working beam is supported at its fulcrum by a neat and substantial framework of polished brass, and connects at one end to the piston-rod, working through a steam-tight stuffing-box, and attached by an arrangement giving parallel motion, or so as to move the rod in a right line, although the end of the working beam moves in the arc of a circle. To the other end is attached, by a moveable joint, the connecting-rod, working the crank and fly-wheel, the revolutions of which give uniformity to the motion of the engine. On the main shaft, or axis of the fly-wheel, there is an eccentric-wheel or pulley clasping around it, the end of a rod which at the other end connects with an arrangement of levers for moving the sliding valves. As the eccentric moves round, it draws the rod backward and forward, and moving the valves at the proper time, distributes the steam in the cylinder, thus giving motion to the whole. The engine is made of brass, well and neatly finished, and with the boiler, is mounted on a metallic base, handsomely japanned to represent brick-work. The engine is put in operation by pouring a half pint of water into the boiler, by the opening at the safety-valve, and applying the heat of the alcohol lamp, which, without soiling the brass-work, will cause the engine to work with great rapidity. Size, 22 inches long, 13 inches high.

Price $30.00.
Larger size, $50.00.

Common School Apparatus, consisting of Juvenile Instructor, Numeral Frame, Geometrical Forms, Arithmetical Solids, Geological Cabinet, Globe, Tellurion, Orrery, Thermometer, &c., with directions for using each article.

The above have been greatly improved in style, durability, &c., with many important additions. Out of the many school-superintendents who have recommended the above instruments, are a few whose names are subscribed to the following certificate, who are well known in the state of New York as competent judges:—

"This is to certify, that after a careful examination of the Scientific School Apparatus, we can not refrain from expressing our decided opinion, that its general introduction into our schools is of importance, and would cheerfully recommend it to the community. The different departments being well adapted to most of the branches pursued in our common schools, will greatly facilitate the teachers, as well as the pupils, in the pursuit of those branches it is so eminently calculated to illustrate."

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An exhibition of the above-mentioned apparatus, by its own recommendation, will have more impression upon enlightened minds, than the above certificate which is here presented, for the purpose of securing their attention. Visible motions of revolving planets in miniature, will convince the skeptic that the astronomical department alone is worth the attention of all. The Tellurion makes easy and comprehensive to juveniles, the philosophy and cause of day and night, and their variation in length; the changes of the seasons; phenomena of the moon: its changing, quartering, fulling, ascending and descending, passing its nodes, and its different positions at each change; the eclipses of the sun and moon; variation of the tides; signs of the zodiac, &c. The Orrery represents the eight primary planets, with their nineteen satellites or moons, performing their journeys around their primaries in their flight around the sun. All of which should be illustrated in every school. They are arranged in a suitable case, and offered for $16 per set.

Geological Specimens.—No. 1. Quartz. 2. Quartz. 3. Burrstone. 4. Felspar. 5. Mica. 6. Granite. 7. Granite. 8. Gneiss. 9. Mica Slate. 10. Hornblend. 11. Sienite. 12. Basalt. 13. Lime. 14. Lime. 15. Serpentine. 16. Talc. 17. Soapstone. 18. Gypsum. 19. Sandstone. 20. Puddingstone. 21. Coal. 22. Coal. 23. Organic Remains. 24. Coral. 25. Lava. 26. Calcareous Spar. 27. Fluor Spar. 28. Iron Pyrites. 29. Spe. Oxide of Iron. 30. Bro. Oxide of Iron. 31. Galena. 32. Copper Pyrites.—33. Ponderous Spar. 34. Magnetic Iron.——The last two Numbers are substituted when the whole 32 can not be furnished. In a wooden tray, price $2.00.

Tables arranged for Baumé's Hydrometer, for Syrups, &c., at 60 *degrees of heat, showing the Specific Gravity, and the Quantity of Sugar in Pounds and Ounces in the Wine Gallon of the Syrup.*

Degrees of the Instrument.	Specific Gravity.	Quantity of Sugar per Wine Gallon. lbs.	oz.	Degrees of the Instrument	Specific Gravity.	Quantity of Sugar per Wine Gallon. lbs.	oz.
0	1.000	Water.		25	1.210	4	11
1	1.007	0	2½	26	1.221	4	15
2	1.014	0	5	27	1.231	5	2
3	1.022	0	7½	28	1.242	5	6
4	1.029	0	10	29	1.252	5	10
5	1.036	0	12½	30	1.262	5	14
6	1.044	0	15	31	1.275	6	3
7	1.052	1	2	32	1.286	6	7
8	1.060	1	5	33	1.298	6	12
9	1.067	1	8	34	1.309	7	0
10	1.075	1	10½	35	1.321	Saturated Syrup.	
11	1.083	1	13	36	1.334		
12	1.091	2	0	37	1.346		
13	1.100	2	3	38	1.359		
14	1.108	2	6	39	1.372		
15	1.116	2	9	40	1.384		
16	1.125	2	12	41	1.398		
17	1.134	2	15	42	1.412		
18	1.142	3	2	43	1.426		
19	1.152	3	5	44	1.440		
20	1.161	3	9	45	1.454		
21	1.171	3	12	46	1.470		
22	1.180	4	0	47	1.486		
23	1.190	4	4	48	1.501		
24	1.199	4	7	49	1.516		
25	1.210	4	11	50	1.532		

Baumé's Hydrometer, or Sacrometer for Syrups, is equally adapted for acids, leys, and other liquids heavier than water. This instrument is of all others the one in greatest use; the scale or numbers on the stem however are arbitrary, and formed, as most others, after the ideas of their projectors, and having no particular reference by which they may be understood. The above table is designed to supply this deficiency, and fix the value of the numbers in the scale. Thus at 13° the specific gravity is 1.100 or one tenth heavier than water, and the solution contains 2 pounds 3 ounces of solid matter in the gallon.

Price, in glass, 75 cts.; extra large, $1 50; brass, $4; silver, $6.

Price of Trallis's Hydrometer for Spirits, 10 to 14 inches, $1; 14 to 17 inches, $2 50; the same with thermometer, $3 50. (See p. 389.)

Table corresponding with Trallis's Hydrometer for Spirits, by Volumes, from 0 to 100. Opposite each Volume of Pure Alcohol is affixed its Specific Gravity, and its Commercial Strength, over and under Proof.

Hydrometer Degree in Volumes of Alcohol.	Specific Gravity.	Percentage Over-Proof.	Hydrometer Degree in Volumes of Alcohol.	Specific Gravity.	Percentage Over-Proof.	Hydrometer Degree in Volumes of Alcohol.	Specific Gravity.	Percentage Under Proof.	Hydrometer Degree in Volumes of Alcohol.	Specific Gravity.	Percentage Under Proof.
100	.7940	100	75	.8765	50	50	.9335	0	25	.9700	50
99	.7988	98	74	.8791	48	49	.9354	2	24	.9710	52
98	.8034	96	73	.8817	46	48	.9373	4	23	.9720	54
97	.8077	94	72	.8842	44	47	.9391	6	22	.9731	56
96	.8118	92	71	.8867	42	46	.9409	8	21	.9741	58
95	.8157	90	70	.8892	40	45	.9427	10	20	.9751	60
94	.8194	88	69	.8917	38	44	.9444	12	19	.9761	62
93	.8230	86	68	.8941	36	43	.9461	14	18	.9771	64
92	.8265	84	67	.8965	34	42	.9478	16	17	.9781	66
91	8299	82	66	.8989	32	41	.9494	18	16	.9791	68
90	.8332	80	65	.9013	30	40	.9510	20	15	.9802	70
89	.8365	78	64	.9036	28	39	.9526	22	14	.9812	72
88	.8397	76	63	.9059	26	38	.9541	24	13	.9823	74
87	.8428	74	62	.9082	24	37	.9556	26	12	.9834	76
86	.8458	72	61	.9104	22	36	.9570	28	11	.9845	78
85	.8488	70	60	.9126	20	35	.9583	30	10	.9857	80
84	.8518	68	59	.9148	18	34	.9596	32	9	.9869	82
83	8547	66	58	.9170	16	33	.9609	34	8	.9881	84
82	.8575	64	57	.9192	14	32	.9622	36	7	.9893	86
81	.8603	62	56	.9213	12	31	.9634	38	6	.9906	88
80	.8631	60	55	9234	10	30	.9646	40	5	.9919	90
79	.8658	58	54	.9258	8	29	.9657	42	4	.9933	92
78	.8685	56	53	.9275	6	28	.9668	44	3	.9947	94
77	.8712	54	52	.9295	4	27	.9679	46	2	.9961	96
76	8739	52	51	.9315	2	26	.9689	48	1	.9976	98
75	.8765	50	50	.9335	Proof. 0	25	.9700	50	0	1.0000	water.

Pure alcohol has a specific gravity of .7940, at 60° heat, and is 100 per cent. over-proof.

75 volumes of pure alcohol, and 25 volumes of water, have a specific gravity of .8765, or 50 per cent. over-proof.

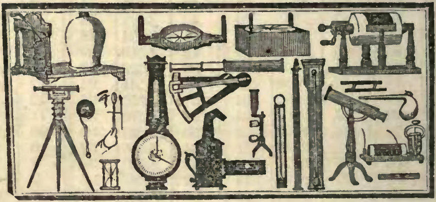
50 volumes of pure alcohol, and 50 volumes of water, have a specific gravity of .9335, or proof spirits.

25 volumes of pure alcohol in 75 volumes of water, have a specific gravity of .9700, or 50 per cent. under proof.

Pure water has a gravity of 1.0000.

At 60 degrees of the thermometer, the above tables are perfectly correct; but when the temperature is below 60°, an addition must be made of one volume for every five degrees of the thermometer; and when above 60°, a like quantity must be deducted, or 2 per cent. on the commercial strength for every 5 degrees of heat—*adding when below, and deducting when above* 60°.

* For the preparation of these tables, the author is indebted to Mr. Robert Bennett, of Cincinnati, Ohio.



INDEX TO VOLUME I.

INDEX TO SUPPLEMENT.