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HINTS

ON

Reflecting & Refracting Telescopes

AND

THEIR ACCESSORIES,

BY

W. H. THORNTHWAITE, F.R.A.S.

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*THIRD EDITION. Much Enlar*ged.

HORNE & THORNT WAITE,

Opticians to the Queen, Royal Observ..ory, &c.,

416, STRAND, LONDON,

FOUR DOORS WEST OF THE ADELPHI THEATRE.

Removed from Newgate Street and Holborn Viaduct.

1878.

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PREFACE TO THE THIRD EDITION.

SINCE the publication of the last edition of "HINTS," it has been deemed advisable not to confine the remarks therein made to Reflectors with *silvered-glass* mirrors, but to add information about the other kinds of Telescopes in general use.

I have therefore added a few remarks on Refractors, and on the various kinds of Reflecting Telescopes.

It is the writer's earnest wish that these additional H INTS" may not only prove of use to the fortunate possessor of any kind of Telescope, but may also help the expectant tyro in the selection of a Telescope most suitable to his ways and means.

MARCH, 1878.

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Introduction.

THE Telescope, one of the noblest instruments devised by man for the enlargement of his natural faculties, is an indispensable aid to the student of Astronomy. The wonders and beauties of the heavens are indeed in a measure revealed to the unaided vision of the observer: he may gaze upon the stars which stud the firmament, lost in the effort to conceive their number or their magnitude, and admiring their fantastic groupings and varied splendours: he may survey the Milky Way, that glorious zone which, like the flying robes of infinite space, spans the heavens; and he may in the study of the motions of the Sun, the Moon, and the brighter planets, find ample scope for wonder and admiration.

But, armed with the "magic tube" of the Astronomer, a new power has been granted to him, and, like a modern Columbus, he sails through the ether of space, while regions hitherto unknown are revealed to his enlarged vision. The glittering points shown by the Telescope are found to be a thousand-fold more numerous than those visible to the naked eye; and where a single star was apparent, a binary or trinary system is often disclosed, with all its beauties of contrasted colours and orbital motion. In the far distant realms of space nebulæ are discovered, and resolved into clouds of stars, or found to consist of glowing gas; our knowledge of these strange world nuclei would be exceedingly small without the assistance of the Telescope. The shining zone of the Milky Way, when investigated with telescopic aid, is found to consist of innumerable stars aggregated together; and we gaze with delight upon its brilliant fields, in which the bright points shine like gorgeous jewels upon the canopy of heaven. The planets, wanderers across the celestial vault, are full of interest; attendant Moons are discerned, circulating around their primaries, suspended in space as lovely miniatures of the solar system of which they form a part. Transported to the neighbourhood of the Sun, we examine his surface, and detect, in the very heart of his intense brightness, strange groups of spots, by the motions of which we are led to the discovery of the Solar rotation. Travelling to the Moon by the help of our wondrous glass, we find in the varied appearance of its surface a charming object of study—the lunar mountains, valleys, and craters being watched under the rays of the rising and setting sun.

In short, the firmament of heaven, with all its wondrous detail of suns, star-groups, planets, and nebulæ, is spread before the student of astronomy as an open page of the great book of nature, each gleaming point and blazing sun sending, from the depths of space, messages of light to earth; it is the Telescope which unfolds to us the mysteries of this revealed page, and therein we read of the power and wisdom of God. The glories of the skies are in part visible to us, but untold wonders are hidden from our eyes; it is the province of the Telescope, leading us through the infinite regions of space, to unveil these marvels, of which we had hitherto no conception, to our admiring gaze.

It is but natural that an observer, while contemplating the glorious orbs which by their radiance fill the midnight sky with splendour, should desire to possess some means of viewing more closely and minutely the beauties of those worlds which circle around him. The brilliant planet, the erratic comet, the changing moon, all fill his mind with a desire to investigate further the structure of the heavens. The records of other observers are eagerly perused, and the student rises from the interesting works of Herschel, or the delightful volumes of Proctor, with an ardent desire to view the beautiful objects described therein, and to possess a telescope by means of which they may be observed.

The telescopes of the ancients, unwieldy and imperfect though they were, yet revealed to the astronomers of the time much information as to the heavenly bodies, and afforded conclusive confirmation of the true theory of the universe, while those systems which did not accord with observed facts were rudely shaken to their downfall. Each advancing age has improved upon the primitive glass of Galileo and his followers, and in the present day the finest mechanism and accurate workmanship are pressed into the service of Astronomy; and telescopes, beside which that of Galileo would seem clumsy and imperfect indeed, are to be found in the possession of every amateur student, while our observatories contain the finest and most accurate instruments that modern science can produce.

The Various Forms of Telescopes.

THEIR CONSTRUCTION AND ADVANTAGES.

FROM the time of Galileo the art of constructing telescopes has made great progress, each improvement marking an epoch in modern astronomical history. Besides inventing the telescopes which bear their names, the great Italian Astronomer and his successors did all they could to improve the forms already in use. For example, that form of the telescope, which in the hands of Galileo startled the world by the discovery of other worlds than ours, is at the present day represented by the very convenient and portable, though not powerful, instrument called the opera-glass. Powerful refracting telescopes differ from the Galilean in having a convex eye lens instead of a concave. If we look through a convex lens, or upon a concave reflecting surface, we shall see, if the eye is within the focus, an erect picture of surrounding objects which will enlarge as the eye is withdrawn until the focal point is reached: past this point the picture will appear inverted, and will now diminish as the eye is removed. It will therefore be obvious that if our eye-piece is without the focus we shall see an inverted picture. As it is necessary that a convex eye lens *should be* without the focus of the object-glass, in order to obtain distinct vision, the inverted picture must be re-inverted by extra lenses when we desire to view terrestrial objects, but this will be of no consequence in celestial observation. Before the invention of achromatic object-glasses, telescopes had to be made of most extravagant focal lengths, in order that the aberrations of the object-glass should be minimized. With these lengthy telescopes Huyghens was associated, and the eye-piece bearing his name was then first used. He thus discovered how to correct an eye-piece, but failed to improve the object-glass. The introduction of achromatic glasses composed of lenses of different densities brings us down to modern times, and the names of Brewster, Dollond and Ramsden.

It was early noticed that these very long focus object-glasses were not only very awkward instruments to manage, but also that no length could ensure a colourless image, and therefore scientific men of those days turned their attention to reflecting telescopes which with the Huyghenian eye-piece showed objects free from colour.

Of reflecting telescopes, the earliest form was that devised by Gregory, but he does not appear to have ever made one. In this form the focal point is passed before the rays from the concave speculum fall upon a small concave mirror from which they are reflected to the eye-piece.

M. Cassegrain substituted for the concave mirror a convex one, and placed it *within* the focus, thereby shortening the telescope by twice the focal length of the small mirror. The Cassegrainian is therefore the most compact form of reflecting telescope. Both the Gregorian and Cassegrainian give fair definition with spherical mirrors, and are therefore easy instruments to manufacture. They are generally focussed by shifting the position of the small mirror.

Sir I. Newton was struck with the difficulty of viewing objects near the zenith, and therefore devised the telescope which bears his name, and in which the small mirror is flat, and being placed at an angle of 45°, reflects the rays at right angles to an eye-piece placed in the side of the tube.

Sir W. Herschel discarded the small mirror, and by tilting his large speculum, formed the image close by the side of the tube, where it could be viewed by the eye-piece.

The principal defect of reflecting telescopes is that they cannot be used as instruments of precision, for instance, as part of a transit-circle. The cause of this is that a mirror does not admit of being so firmly held as an object glass. The less strain there is on a mirror, the better it will perform. It will therefore sometimes happen that an object will not be found exactly in the centre of the field, however correctly the circles of an equatorially-mounted reflector may be set. Unless it be desired to ascertain the *exact* position of a celestial object by the circle readings, a slight error is of no consequence, as the object is certain to be in the field of a moderately high power with careful setting.

To a certain extent an acknowledged superiority of refractors over reflectors is the greater light-giving power of the former, aperture for aperture. An amount of light, very variously estimated by different observers, is lost by the several reflections; as the aperture of the telescope is increased this disparity diminishes, the larger object-glasses, being of necessity thicker, absorb a greater amount of light, whereas the light from a mirror has no absorbing medium to diminish its intensity. It may therefore be confidently asserted that the light-giving power of a very large reflector may equal if not exceed that of an object glass of equal aperture. While, however, a smaller object-glass is equal to a larger reflector in the above respect, it will be inferior in definition and penetrating power. An example of this is seen in the beautiful definition given by an unsilvered glass mirror on bright objects, as the Moon and Venus.

An important defect attributed to reflectors is their unsteady definition. The end of the telescope tube being open, air currents are often very troublesome, especially under certain atmospheric conditions. It used to be often necessary to leave the telescope for nearly half-an hour before the best definition was obtained. The effect of air currents can be obviated by making the tube considerably larger than the speculum, for it was found that the currents do not revolve in the centre of the tube but just within its circumference.

We have lately made all our large reflectors with open ventilated tubes, for if the temperature of the air is the same inside and outside the tube, no air currents occur, and instead of having to wait half-an-hour, steady definition is at once obtained, and is not affected by change of temperature.

There are several advantages possessed by reflectors over refractors. In respect to definition, a more perfect mirror can be worked than an object-glass, it being impossible to quite correct chromatic aberration. A well figured speculum will therefore give the finest possible definition of those celestial objects which appear coloured; such beautiful double stars as β Cygni, γ Andromedæ, η Cassiopeæ, α Herculis, &c., and the delicate tints on Mars, Jupiter, and Saturn being perfectly shown. A most important superiority of reflecting telescopes is their cheapness. In the construction of an object-glass many difficulties arise never experienced by the maker of a mirror. Each glass must be of perfectly uniform density and ascertained refractive index; from these data an elaborate mathematical process shows what curves are necessary, and then comes the grinding and polishing of at least four surfaces, and lastly, the edging and correct centering of the worked lenses. It is quite true that only spherical curves have to be worked, but the final correction often necessitates re-working one or more surfaces several times.

A great advantage of the Newtonian, and especially of the Cassegrainian form as modified by Nasmyth, consists in the easy position of the observer. When viewing zenith objects with a refractor, the observer's head must be thrown so far back that continuous observation is most unpleasant, unless a diagonal be employed, and this is often uncomfortable to work with, and occasions loss of light. But with the above-mentioned reflectors the eye-piece can be always horizontal, and therefore the head and neck are always comfortable.

The last advantage of reflectors that need be mentioned is their very compact nature, ensuring thereby great steadiness and facility of employment, and requiring a smaller observatory.

Until quite lately, all varieties of reflecting telescopes were fitted with metallic mirrors. These were open to very serious objections, amongst them being the extreme difficulty of forming a metallic alloy capable of being highly polished, and remaining brilliant in spite of atmospheric and other influences. Should the surface of a metallic mirror once become tarnished, it must be repolished—an operation of the greatest difficulty, on account of the extreme danger of the speculum losing its original parabolic curve; and thus many a well corrected mirror may be rendered perfectly useless in attempting to remove a stain. This difficulty has been entirely overcome in glass mirrors—by coating the parabolic surface with a very thin film of pure silver about the same thickness as gold leaf.

This film will assume the curve beneath it, and may be repolished many times, it being obviously impossible to touch the glass surface without having rubbed through the silver; but this need never occur, as when the film becomes thin or scratched away, it may be renewed at a trifling expense. It is, of course, very important that the glass surface itself be not much rubbed, as so exact is the method by which these mirrors are tested during their manufacture, that the very spot where this has been done for a few seconds could, on examination, be immediately pointed out. Another great advantage of a glass mirror over one of metal is the inferior weight of the former. In supporting a heavy metallic mirror, excessive care is required, not to have the slightest strain upon it; thus, with large instruments, the mirror often rests on an elaborate system of levers. It was found, with large metallic mirrors, that the presence of a single thread between the mirror and its supports very sensibly interfered with good definition. A glass mirror of the same diameter and thickness as one of metal will be found to weigh far less, and thus its mounting need not be so elaborate, and consequently not so expensive.

A further advantage will be at once discovered by an observer who, after working with a metal, turns his attention to a glass speculum of equal aperture; and that is the extra amount of light reflected from the silver. This is stated to be, on the authority of Sir J. Herschel, for Newtonian telescopes, as ·824 to ·436. The light-grasping power of a glass speculum can be well ascertained by its performance on very faint stars, especially when they are close companions to brighter ones.

Since the introduction of silvered-glass mirrors they have been largely employed in physical observation, and where a large amount of light-grasping power is required, as in spectroscopic work.

Having already briefly described the various forms of telescopes, I will now consider each more fully and with special reference to the stands on which they are mounted, and to which they are individually or collectively suitable. To facilitate the description of the stands it will be useful to class all telescopes under two heads, which may be called, in respect to the position of the observer, Direct and Indirect. The former class includes all varieties of refracting telescopes; and of reflecting telescopes, the Gregorian and original form of Cassegrainian. The latter—Nasmyth's form of the Cassegrainian, the Herschelian, and Newtonian reflecting telescopes. It will be as well, therefore, to follow the above order, describing the suitable stands after each class.

REFRACTING TELESCOPES.

It has been already mentioned that the principal difference between various refracting telescopes consists in the form of the eye-piece. If the latter is concave, and placed within the focus of the object-glass, erect vision will be obtained: but if convex, and without the focus, vision will be inverted, and therefore additional lenses must be employed when viewing terrestrial objects. The simplest form of achromatic telescope for terrestrial purposes, in which an erect image is of course necessary, will therefore consist of a convex object-glass and a concave eye-piece, and these glasses constitute what is known as the Galilean telescope.

THE GALILEAN TELESCOPE.

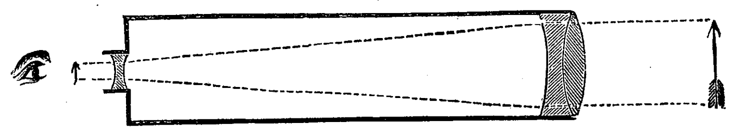


Fig. 1.

This was the earliest telescope devised, and therefore some of the grandest astronomical discoveries have been made with it. But it possesses several defects which it is not possible to perfectly remedy, the principal being, that the full illuminating power of the object-glass is not used, and that any defect in the material of which the object-glass is made, such as air bubbles, scratches, &c., are rendered visible in the field of view. Proctor has well compared the illumination of the Galilean telescope to that of a view seen through the larger end of a cone of paper held in one position. If an observer *move* his eye round the inner edge of the larger end of the cone, he will see the confines of the same extent of view he would at once see should he look through the small end. The latter view is that seen in the ordinary refracting telescope, as in it the extent of the field depends on the eye-piece, but in the Galilean, on the aperture of the object-glass. A stop placed in front of the object-glass of the former occasions loss of light, but it diminishes the field of the latter. The centre of this field will also always be brighter than the edge, a most serious defect, and one that is prejudicial to the use of the Galilean telescope as an astronomical instrument.

THE PERSPECTIVE AND OPERA-GLASSES.

A perspective glass is a short focus Galilean telescope with achromatic lenses; it is now seldom used singly, but in pairs, these forming what are known as opera, race, marine, and field-glasses. Should it be desired to view as large a space as possible at one time an opera-glass should be used. But when magnifying power is required, as in the identification of a small distant object, a race, field, or marine-glass should be employed, the power of a race-glass being greater than that of an opera-glass, and so on : a marine glass being the most powerful Galilean telescope now in common use. Glasses are now often made with revolving eye-pieces of different powers. Those intended for out-door use should always be provided with sliding shades to protect the object-glass from damp or to shield it from the sun's glare. Glasses mounted in aluminium are only about one-third the weight of those in the ordinary metal, and are therefore much more portable, but are more expensive.

There are two important adjustments to be attended to before the best effect is obtained, the first is, of course, the correct focussing; and the second, adjustment to the width between the eyes. People who are obliged to wear powerful spectacles, often find they cannot focus an opera-glass :—a slight alteration in the curves of the eye-pieces will enable any sight to be suited, or if only one eye is defective, only one eye-piece will require alteration. As opera-glasses are usually made to fit an average face, the eye-lenses are large enough to allow a majority of persons to see the two fields of view coincide. Should, however, the width between the pupils of the eyes be much over or under the average, a pair of glasses should be selected of suitable width, or one capable of adjustment to various faces.

The lenses will require no adjustment, having been carefully set by their maker. They will require cleaning, which should be done by wiping them carefully with a soft clean piece of wash-leather or a silk handkerchief. If at any time it should be necessary to remove the lenses from their mounts or cells, care should be taken that they are replaced as they were originally. All the above remarks on the opera-glass equally refer to similar instruments. The focussing screw sometimes gets out of order, but can be re-tightened to the frame with ease ; a screw has lately been invented which does not become so readily unloosed.

THE ORDINARY REFRACTING TELESCOPE.

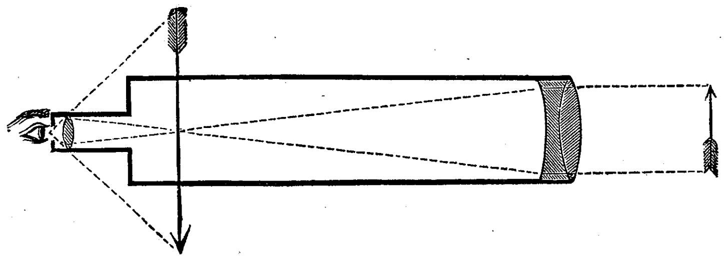


Fig. 2.

The ordinary form of the refracting telescope differs from the Galilean in possessing a convex eye-piece. Should the use of this instrument be limited to celestial observation, in which an inverted image is of no consequence, the telescope will consist of a convex achromatic object-glass and some form of achromatic eye-piece whose power is equal to a single convex lens. In order to show an erect view for landscape observation additional lenses must be introduced between the object-glass and eye-piece, and these are generally combined with the eye-piece in one tube, and form what is called a terrestrial or day eye-piece. A day eye-piece should not be employed for celestial observation, as the extra lenses may occasion defective vision, and are certain to cause loss of light.

Very few adjustments are necessary with refracting telescopes, all that is necessary being to point the telescope to the object by means of the finder or otherwise, roughly focus by means of the sliding draw-tube, and finally sharply focus with the circular milled head which acts on the rack-tube. The object-glass and eye-pieces are truly centered and placed in correct adjustment by their maker, and nothing but violent usage can alter their position. The amateur should not attempt to alter or repair his eye-pieces, as only the very best brass turners and glass workers are employed on their manufacture, and should be entrusted with their repair. It may sometimes happen that when an observer has to carry his telescope from place to place, he will accidentally knock the cell of the object-glass and destroy its correct position at right angles to the tube. The effect of this will be that a star is not uniformly surrounded with diffraction rings of equal brightness, but there is a great concentration of light at one part. This defect can, with great care, be rectified as follows:—Slightly loosen the screws which hold the object-glass end to the tube, and with a piece of soft wood tap gently that part of the cell directly in front of the greatest brightness, or, *in a contrary direction*, that part of the cell exactly opposite; continue to tap until the diffraction rings are perfectly even, and when this is so, screw up the screws. When thus adjusting, keep the object, which should be a bright star, always central in the field of view, and notice the even brightness of the rings both at and out of focus. Large object-glasses are provided with pull and push adjusting screws.

Should an object-glass, when first tried, appear defective in any way, carefully note every particular, as thereby the defect *may* be remedied. First see that the fault does not rest with the eye-pieces: endeavour to try them on other telescopes, and notice if the results are similar. Being sure that the lenses of the object-glass and eye-pieces are quite free from dust and damp, revolve the draw tube holding the eye-piece, and if any defect revolves too, it will be evident that the eye-piece is imperfect, and it should be returned to the maker for correction. If the defect does not revolve with the eye-piece, but remain in one position, the fault most likely rests with the object-glass. First unscrew and remove the object-glass with its cell; now, on looking through the telescope tube from the open end of the draw tube, notice that the tube is free from spider's web or other obstruction, and that the stops are in their proper place. If all is correct, notice that a very slight rattle is just perceptible when the object-glass is gently shaken in its cell, and that a slight pressure with the points of the fingers will cause the object-glass to revolve. If this is not the case, slightly unscrew the counter-cell (a term given to the ring screwed in the cell against the object-glass); and turn the telescope towards a bright star, and focus with an eye-piece whose good quality is known. If the defect apparent in the image of a star was a flare on *each* side of the stellar point, the object-glass was too tightly held and when the counter-cell is slackened, the undue pressure will be removed and the flares will now not be seen. But if the flare is still on one side of the star, remove the eye-piece and place the eye in the focus of the object-glass, when the whole surface of the glass will appear illuminated, and any defect in its material at once rendered visible. As a rule small scratches, or air-holes and bubbles, will only occasion a minute loss of light and are not likely to give rise to a flare. But should any of these defects appear very obvious on the illuminated glass and cannot be removed by wiping, affix pieces of sticking-plaster over them, one by one, until that which gave rise to the flare is covered. If these small coverings do not benefit, the glass is of uneven refraction, and stops of various shapes should be tried in front of the object-glass. Cut these stops of various circular, triangular, and oval openings and coverings, out of cardboard. Do not cover any more of the object-glass than is absolutely necessary to secure perfect vision, in order to preserve as much light as possible. If the edge of the object-glass bends back from having been worked too nearly its completed size, or worked after edging, a circular stop slightly smaller than the glass will render vision much more distinct. Revolve the object-glass by unscrewing the cell, and notice if the flare revolves too; if it does, and no stop can remove it, nothing can be done but to send the glass to a practical optician for his opinion. But if the flare or flares remain in one place and there is one spot in the diffraction rings brighter than the remainder, either the eye-tube does not point exactly to the centre of the object-glass, or the glass itself is not at right angles to the body-tube. The former defect can be identified by cutting out of card one circle the size of the object-glass, and two circles to fit in the draw tube, all having central holes $\frac{1}{2}$-inch in diameter. Place the large circle in front of the object-glass and the two smaller ones in the draw-tube. If the tube is in correct position, on looking through the one nearest the eye, the hole in the extreme circle will be seen exactly in the centre of the hole in the middle card. If it is *not*, alter the direction of the eye-piece end of the telescope, loosening the screws which hold it, to allow of the same being done. But the flare will most likely be caused by the incorrect position of the object-glass, and can be corrected in the way before described, the cell most likely having received an accidental blow. In fact, several of the before-mentioned defects will never be found in the work of a careful optician, but will result from an accidental circumstance.

The lenses of a telescope should never be cleaned, unless it is absolutely necessary. If dust has settled, first brush it off with a clean dry camel's hair pencil, and then very gently wipe clean with a piece of very fine wash-leather, or a soft silk or cambric handkerchief. Any material thus employed should be specially kept for this purpose alone, and when not in use carefully protected from dust. Should the lenses require to be removed from their mounts for cleaning, or otherwise, take care that they are correctly replaced. The edges of an object-glass generally have marks which should be placed together. It will hardly require notice that the convex glass always is next the object viewed. Before screwing in any cell or mount, give half a turn in a contrary direction, when the first thread will generally drop home, thus ensuring truth, and avoiding the risk of the threads of the screw being spoiled.

As it is impossible, with our present knowledge, to perfectly correct the secondary spectrum of an object-glass, a slightly coloured image of a bright object is unavoidable. A good glass should give a very slight tinge of bluish purple at focus, and rather more purple within and green without the focal point. Should, however, the object have a red or an orange colour at the focus, and *within* the focus the expanded disc show a purple centre and red margin, and *without* a red centre and purple margin, the marginal colours being the most apparent, the object glass is under-corrected for colour. A slight separation of the lenses may tend to diminish this. In an over-corrected lens the colours will be exactly in the reverse order, but nothing can be done by the amateur to correct them.

I have now mentioned all the principal defects of a telescope that an amateur *may* attempt to remedy, but it will be far better policy for him to ask a practical optician to attempt the correction than to try it himself, as he may do irreparable damage. None of the remedies here mentioned can do the slightest damage if carefully applied.

An optician can generally remove any error except irregular density, by repolishing one or more of the glasses, but as they have been edged from worked discs considerably larger than the object-glass itself, there is a risk of injuring the centering and figure of the lenses if they are worked after being edged. It will therefore be better for the possessor of an inferior object-glass to procure a new one of similar size and focus, or if the imperfect glass is of large size, and it is necessary to have it re-worked, let it also be re-edged to a smaller cell.

STANDS FOR REFRACTING TELESCOPES.

These stands may be divided into two general classes—the Alt-azimuth and the Equatorial. But there are several varieties of each class, a few of which demand attention as being those most generally employed.

The simplest form of Alt-azimuth stand is called, from the shape of the foot, the pillar and claw stand. The claws are generally hinged, so as to close together and pack into a smaller space (Fig. 3).

The additions capable of improving this stand are, firstly, screw movements in altitude and azimuth, thereby allowing much more even motions to be applied than is possible by the hand alone, and, secondly, sliding steadying rods with universal joints, one end fixed to the telescope and the other to the stand. All the stands just described are intended to be used upon a table or other elevated place, the next form obviates this, and is generally known as the tripod, or garden stand. The claw feet of some stands

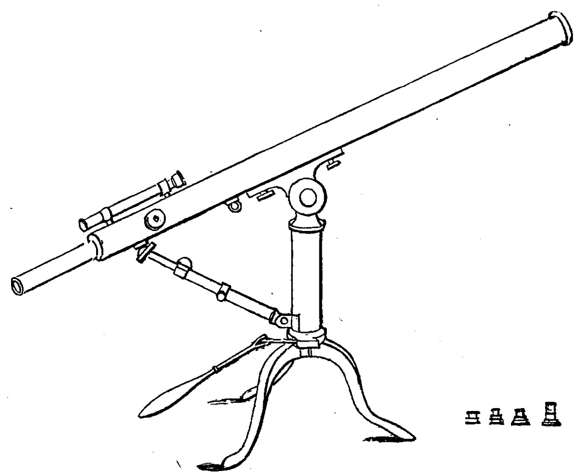


Fig. 3.
THE PILLAR AND CLAW STAND.

sometimes take off, and the pillar can then be screwed to a stout metal pin forming part of a casting, jointed to which are three wooden legs. The pillar is often discarded as well as the claws, and then the movements are brought nearer the casting, thereby ensuring greater steadiness. The above are the principal forms of Alt-azimuth stands for refractors, but an Equatorial costs very little more than an elaborate Alt-azimuth and is greatly to be preferred.

Of Equatorial stands for refracting telescopes there are several kinds, but a very large majority of them are of the German form (Fig. 4).

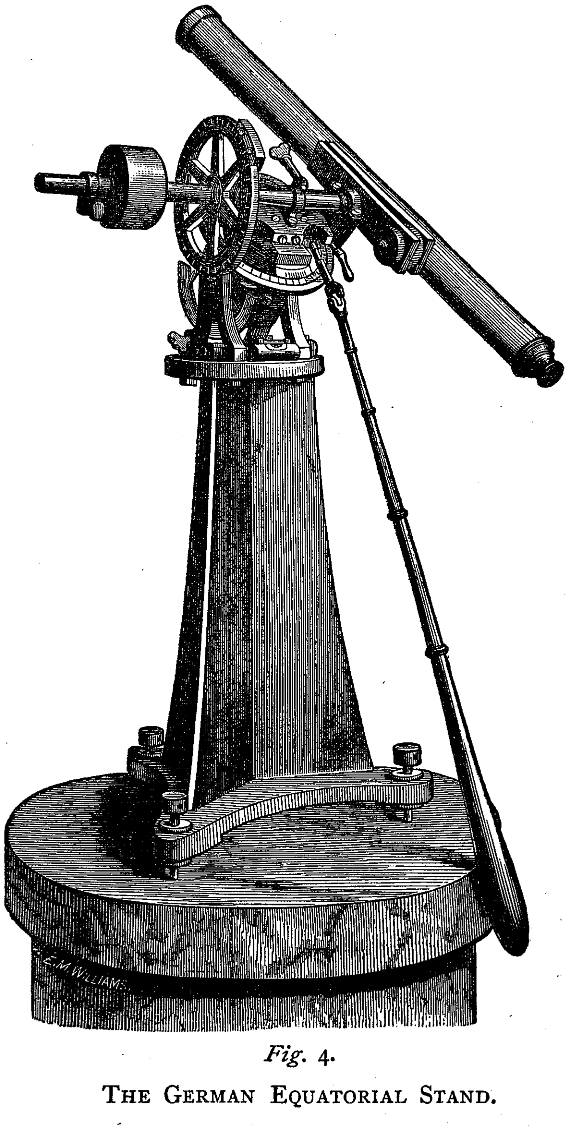


Fig. 4.

THE GERMAN EQUATORIAL STAND.

It would take too much space to describe all the varieties of the German Equatorial, but its general construction may be briefly noted.

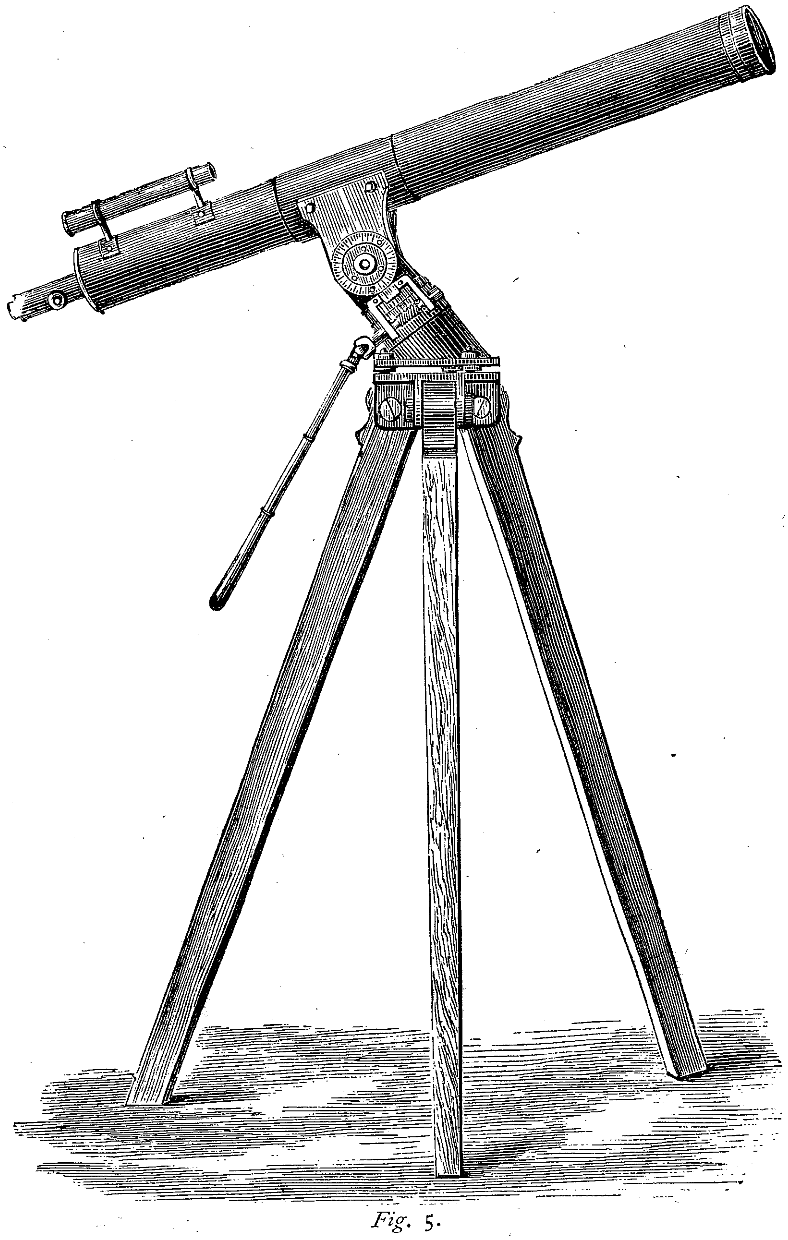


Fig. 5.
THE VICTORIA EQUATORIAL.

An axis which points to the pole carries at right angles another axis, on one end of which is the telescope and on the other a counterpoise. The first axis is revolved in the opposite direction to which the earth rotates, by means of an endless screw, turned by a hand movement or driving clock. In the cheaper forms of Equatorials this screw can be thrown in and out of its bearing by an eccentric, but in the better class of instruments, the screw is always in action, and various other means are provided by means of which the telescope can be *rapidly* moved from one object to another. The second axis merely serves to elevate the telescope to any point below or above the equator, and when following a star is clamped in one position. The two axes give two movements, the first in right ascension and the second in declination. A mount with these movements is called an Angle-block, or Parallactic stand, and when divided circles and reading verniers are added, an Equatorial stand. All Equatorial stands should be provided with adjusting screws, as without them they can only be used at places of exactly the same latitude. When an Equatorial is intended for use at places many degrees distant it should be of the form called universal, in which the polar-axis can be given any altitude between the zenith and horizon.

Mr. Berthon has introduced a modified form of his patent Equatorial specially adapted for refractors and especially useful for those between two and four inches in aperture, and for portable stands. Being without counterpoises it is exceedingly light, and being made with large hollow bearings is very steady (Fig. 5).

Equatorial stands are mounted in two ways, either on an iron pedestal or on long wooden legs. The former is called the fixed Equatorial and the latter the portable. We have lately made some collapsible legs to a four inch telescope on a portable stand which pack altogether into a comparatively very small box.

REFLECTING TELESCOPES.

The different kinds of reflecting telescopes having already been briefly described, a few remarks on each form, more especially in reference to the necessary adjustments, may be useful. The form of reflector may be at once known by the curves of the small mirrors. In the Gregorian the small mirror is concave, in the Cassegrainian convex, in the Newtonian flat, in the Herschelian the small mirror is omitted, and in Nasmyth's modification of the Cassegrainian there are two, convex and flat respectively. The large and small mirrors of all these forms can be made of Speculum metal or glass. The two first are direct and the others indirect vision reflectors.

DIRECT VISION REFLECTORS.

THE GREGORIAN TELESCOPE.

This instrument consists of a large concave mirror which reflects the rays falling upon it to a small concave mirror placed without the focal point at a distance from the large mirror of rather more than the respective foci added together: the latter reflects the rays

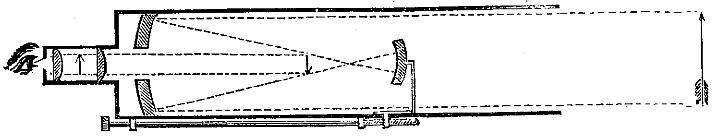


Fig. 6.

through a hole cut or cast in the centre of the large mirror to the eye-piece. The inner lens of the eye-piece hastens the rays to a focal point before they reach the front lens, the rays therefore cross a second time, thereby insuring an erect picture of objects viewed.

Some few years ago the Gregorian telescope was commonly met with, but it has lately been superseded by the other forms. Its principal advantage for terrestrial purposes is the erect image.

The speculum is generally fixed in position, but adjustments are provided to the small mirror and eye-piece. To adjust these, first, unscrew the eye-piece and remove its lenses. In front of the eye-piece is a disc with a small hole, unloose the two screws which hold the disc in position and set the small hole central with the surrounding metal. Having clamped it there, look through the hole and adjust the small speculum by means of the small screws working against it until a complete picture of the large speculum is seen in its centre. Fig. 15. Now replace the lenses and notice if the field of view is equally illuminated. If it is so, all is sufficiently correct for general observation. But if the field appears brighter in one part, slightly alter the position of the eye-hole by shifting the little disc.

The focussing of a Gregorian telescope is generally effected by means of a long screw which when revolved alters the distance between the mirrors.

THE CASSEGRAINIAN TELESCOPE.

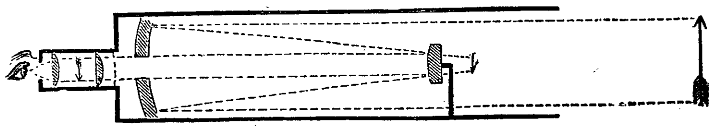


Fig. 7.

In the ordinary form of this instrument, the rays of light from the speculum fall upon a convex small mirror before they come to a focus, and from the convex mirror are returned through the centre of the large mirror to the eye-piece. It is difficult to say why this form has been so seldom made, as it possesses several important advantages, one of the chief being that a Cassegrainian mirror can be mounted in a shorter tube than any other kind of equal power. Should it be desired to have the most powerful telescope in the smallest space, this form should, therefore, be chosen. The length of focus secures a flatness of field and obviates the use of deep eye-pieces.

The adjustments of the ordinary form of Cassegrainian are precisely similar to those of the Gregorian, and it is generally focussed in the same way.

STANDS FOR DIRECT VISION REFLECTORS.

As a rule *any* stand which will carry a refractor will be found suitable for a direct-vision reflector, and therefore it will be unnecessary to describe them again, especially as the first form of reflector just described is seldom used at the present time, except of a very small size, and for terrestrial purposes. The stands for these small reflectors are, however, generally rather more solid in their construction.

INDIRECT-VISION REFLECTORS.

NASMYTH'S MODIFICATION OF THE CASSEGRAINIAN TELESCOPE.

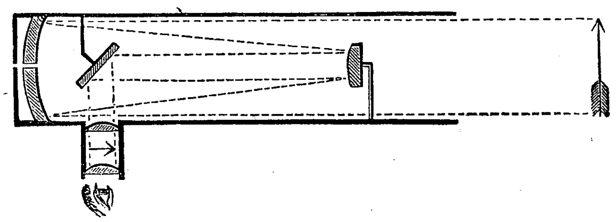
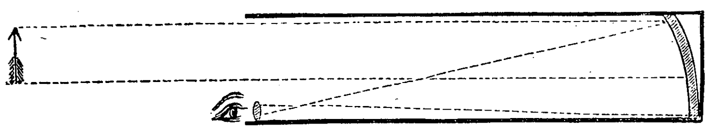


Fig. 8.

The great objection to the ordinary form of the Cassegrainian telescope for astronomical purposes is the uneasy position of the observer when viewing zenith objects; but this defect has been entirely removed by Mr. Nasmyth, at the expense of a slight loss of light. Instead of allowing the rays from the small convex mirror to pass through the large speculum, he interposes a flat mirror which diverts them at right angles to an eye-piece, placed in the side of the body-tube. In his Alt-azimuth the eye-piece was *in* the vertical axis of the telescope, and therefore was always in one position; but as this would be rather inconvenient with an equatorial stand, the eye-piece is placed *close to* the axis, and revolves with the body-tube: it can, therefore, be always brought to a horizontal position, and at such an altitude as to be accessible without the necessity of mounting a high pair of steps. With a further slight modification two persons can view the same object at once.

The adjustments of a modified Cassegrainian are rather more difficult than those of the ordinary form, on account of additional reflective surface. A Cassegrainian mirror should always have a central hole, if made of speculum metal; or if glass, a central spot may be cleaned off the silver film. First adjust the convex mirror by altering the three screws and central clamping screw-pin. To do this properly, remove the flat mirror from the tube, and looking through the central hole in the large mirror, alter the screws until as much as possible of the reflective surface of the large mirror is seen in the centre of the small. If this reflection cannot be procured as an entire circle, adjust the three screws which move the large speculum until it resembles Fig. 15. The adjustments of the convex and great specula must be perfect before the flat should be replaced. When everything appears correct, place the flat in position and adjust it through the door or opening in the same way as the flat is adjusted in the Newtonian telescope. If preferable, the flat can be adjusted at the outset. Tó do this correctly, cover the entire surface of the large mirror with a sheet of white paper, and place the flat so that it reflects to the adjusting-piece, the open end of the tube with the central disc. Next adjust the convex mirror so that it appears as a *complete white* disc when viewed on the flat. When these two adjustments are perfect, remove the paper, and so adjust the large speculum that its complete reflection is seen on the convex mirror, with the dark spot exactly in the centre. If the latter plan be employed, the effects of all the adjustments are to be viewed from the adjusting-piece, instead of from the centre of the large mirror. All the adjustments of a Cassegrainian must be very exact, in order that good definition may be obtained.

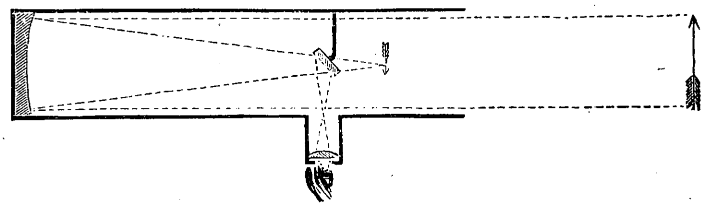
THE HERSCHELIAN TELESCOPE.



No small mirror being required in this form, the whole of the central rays are employed, whereas in all other forms of reflectors they are intercepted by the small mirrors. But it seldom happens that a concave mirror can be tilted, and therefore receive *incidental* rays without affecting its definition. The diffraction rings round a star would be oval, and any object viewed would be slightly distorted. It will be obvious that the distortion will increase as the focus is shortened, and therefore the focus of a Herschelian telescope should be as long as possible. It sometimes happens that a mirror is accidentally worked very slightly cylindrical, and if so, it may be comparatively useless for a Newtonian telescope, but perhaps exactly suitable for a Herschelian, as it will show the best image of a star when the optical axis is not exactly at right angles to the surface of the mirror; the nearer to the side of the tube the best image is formed the better the performance will be. The adjustments of a Herschelian telescope are very simple. Remove the eye-piece and adjust the screws, which act on the cell of the mirror, until the entire surface of the latter is seen illuminated by the sky end of the tube, Fig. 15 (without the black centre spot). Turn the telescope on a star, and, if necessary, alter the direction of the eye tube till a star presents nearly a circular disc inside and outside the focal point. If the mirror is slightly cylindrical, first adjust as far as possible, and finally revolve the mirror in its cell, a few degrees at a time, until a circular disc is obtained.

THE NEWTONIAN TELESCOPE.

A large majority of reflecting telescopes now used are of the Newtonian form, and therefore careful study of the principles and adjustments of it are required, in order that the amateur may not only be able to rectify any accidental adjustment, but also may perfectly grasp the principle on which it is made. A large amount of such knowledge can be applied to the adjustments of all other forms of reflecting telescopes.



Principles of the Newtonian Reflector.—The parallel rays of light from a star or other celestial object, passing down the open telescope tube, are received upon a concave parabolic speculum, and returned as convergent towards a point just outside the end of the tube, and also in the centre or axis of it. The rays of light are not allowed to focus without the tube, but are intercepted and bent, at right angles, to an eye-piece placed in the side of the body-tube, by a small flat mirror, placed at an angle of 45°. This small mirror is in shape an oval, but appears circular when viewed either from the eye-piece, or from the centre of the mirror, were it possible.

ADJUSTMENTS OF A NEWTONIAN TELESCOPE.

The necessary conditions of correct adjustment are as follows :—

A. The flat mirror must be so *placed* that it receives all the rays of light reflected from the speculum, and so *adjusted* that it bends them at an angle of 45° to the eye-piece.
B. The speculum must be so *adjusted* that it reflects all the light it receives to the flat mirror.
C. The eye-piece must be so *placed* exactly opposite the flat mirror that it receives all the light reflected from it.

The correctness of these three adjustments is of the greatest importance; in fact, a telescope cannot perform satisfactorily unless they are perfect. The reader will notice that the terms *placed* and *adjusted* are both employed, the former comprehends what may be called *primary*, and the latter *ordinary* adjustments.

Primary Adjustments.

It is the duty of the optician to see that these adjustments are perfectly correct in a telescope before it passes into the possession of the amateur, who however should ascertain that they are so, and be able to correct any defect in them that may be discovered arising from accident or otherwise.

The primary adjustments may be tabulated thus :—

A^1. To centre the flat in the body-tube.
A^2. To place the flat at an angle of 45° exactly opposite the eye-piece.
C^1. To set the rack and draw tubes at right angles to the body-tube, so that the eye-piece they hold is exactly opposite the flat.

A^1. To centre the Flat in the Body-Tube.

Cut out in cardboard two discs that will fit tightly in the body-tube, one with a central hole of about ¼ of an inch, the other with a hole of about an inch larger in diameter than the flat; place the latter at the open end of the tube, and the disc with the small hole to occupy the space from which the speculum in its cell has been removed. Now on looking through this small hole towards the other, if the flat is central it will stop out the centre of the larger hole, and have a ring of light equally all round it; should this not be the case, but the bright ring be wider at one side than at the other, notice which of the three screw nuts (which stretch the springs supporting the flat mount) is nearest the wider part of the ring, and screw it up slightly, of course releasing the others as you proceed. When the flat is perfectly central, the nuts should be screwed up tightly, and this adjustment will be complete. Should the wide part be equidistant from two of the nuts, screw both these, releasing the third. Care should be taken that the springs obstruct as little light as possible; they should, therefore, oppose their edges to the mirror end of the tube, and not to the sides.

A². To centre the "Flat" to the Rack and Draw Tubes.

In order to correctly centre the eye to these tubes, resource should be had to the adjusting-piece supplied with each instrument: this consists of a brass disc with a very small central hole, and is placed in the same position as an eye-piece. The flat mount and counterpoise having been removed from their ordinary position, set the face of the flat as nearly as possible at an angle of 45°, which may be effected thus. Draw on cardboard a square figure with sides of 3 or 4 inches, join either of the corners, and the diagonal line will be exactly on an angle of 45° to all the sides. Use this diagonal to set the face of the flat at an angle of 45° to a line drawn as a continuation of the axial pin of the flat mount. When the angle of the flat is correct, replace it in the tube, and, looking through the adjusting-piece, revolve the flat till as much as possible of the open speculum end of the tube is seen reflected in it. Should, however, it be found impossible to show the complete end of the tube, slightly loosen the brass screw nuts and shift the springs carrying the flat mount, backwards or forwards, till the complete end is seen reflected in the centre of the flat, and the flat itself is exactly concentric to the circular edge of the draw tube. When this is so, screw up the nuts as equally as possible, so as not to disturb the centering of the flat which formed the last adjustment.

C¹. To set the Rack and Draw Tube in position.

Cut out a piece of white card or thick paper 3 or 4 inches in diameter, and punch a half-inch hole in the centre of it. Having removed the adjusting piece, hold the card in front of the eye, looking through the small hole. Now let the eye and card be removed from the draw-tube until its circular opening illuminated by the white card is seen reflected in the centre of the flat, the margin appearing apparently dull. If the flat be at 45°, and the rack-tube at right angles to the body, the reflected white circle will remain in precisely the same position when the draw-tube is pushed as far in as possible as at its greatest extension. Should the white circle alter its position on moving the rack and draw-tubes, they are not at right angles to the body-tube, and the direction the circle moved should be noticed, and the rack-tubes altered accordingly by fixing thin washers between their plate and the tube: often slightly loosening one of the attaching screws will even suffice. During this adjustment the speculum must be in the tube and also in ordinary adjustment, which may be effected as described on page 28, or adjustment C[1] can be performed last of all.

Ordinary Adjustments.

The correctness of the primary adjustments having been verified, the observer should particularly notice the compound reflections of the speculum and flat seen through the adjusting-piece, as by a thorough knowledge of these he will be enabled at once to identify any irregularity, and then quickly correct it. The flat having been placed in the centre of the tube will prevent an equal area of parallel rays from falling on the mirror, therefore there is a central spot on the mirror, from which no rays are reflected, and this spot, which will of course appear dark when the mirror is illuminated, is of the greatest assistance in the ordinary adjustments.

To place the Mirror into its Cell.

The back of the mirror and the face of the metal ring on which it rests having both been carefully worked flat, and when practicable ground together, many mirrors will be found to perform admirably resting on the metal alone; should, however, a thick piece of felt or flannel be interposed, definition may sometimes be greatly improved. If there should be any mark on the mirror to indicate that it should rest on a certain part of its edge, be careful to place the mirror as indicated. Should it be necessary to elevate the speculum end of the tube, in order to view terrestrial objects, the speculum should be prevented from falling forward out of its cell by a brass ring or some clips; care should be taken that these do not quite touch the surface of the mirror, but are about the thickness of an ordinary sheet of writing paper from it. The mirror being in its cell, and perfectly free from strain on any part of its surface, it may be placed in the tube.

To place the Speculum in the Body Tube.

There are two kinds of speculum cell fittings usually employed, one of which is only applicable to Alt-azimuth instruments, but the other to any construction, and therefore, being more important, is described first. Attached to the end of the body tube are three screw-pins, each of which passes through a corresponding hole in the frame which supports the speculum cell. Screwing on each pin are a couple of brass nuts—one on each side of the frame—by means of which the frame can be delicately moved or firmly kept in any position. By detaching the outer nuts the speculum and cell can be easily removed and replaced without altering their adjustment.

The other form of cell fittings is seldom employed, but it may be useful to describe it. Attached to the iron framework of the speculum cell are three pins, in each of which a groove has been filed. The upper pin, which can be easily distinguished by its groove pointing to the centre of the mirror, should be passed through the upper hole in the frame attached to the tube, the two other pins will then pass through corresponding holes. When the pins are in their holes the grooves will fall home from the weight of the cell and other fittings. Care should be taken that they are well down each time the speculum is replaced, as thereby permanency of adjustment is insured. The cell can be adjusted by three large screws working against it, and three smaller screws passing through these and screwing into it, thus acting as clamps to the large ones. By means of these six screws any part of the cell, and therefore the speculum resting on it, can be either pushed forward or drawn backward.

Appearance of the reflections when all the Adjustments are perfect.

Turn the telescope towards a bright part of the sky, and, if all the adjustments are perfect, the following appearances will present themselves on looking through the adjusting-piece :—

An entire bright disc will be seen with a dark circular spot (this being, as has been before described, the portion of light stopped out by the flat); surrounding the bright disc should be an even dark ring, being that part of the flat not illuminated by the speculum: these circles should all be perfectly concentrical with the circular outline of the end of the draw-tube at any position (Fig. 11).

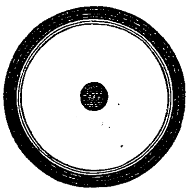


Fig. 11.

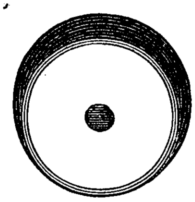


Fig. 12.

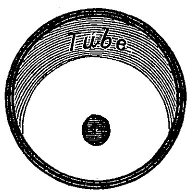


Fig. 13.

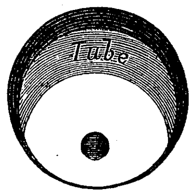


Fig. 14.

Should the appearances differ from these, one or more of the adjustments are not perfect, and the error must be identified and corrected.

To identify any imperfection.

If the bright reflection of the large mirror be seen as a perfect circle, but not exactly in the centre of the flat, and the ring surrounding it is wider at one place than another (Fig. 12), the flat alone requires adjusting, which may be called Adjustment A^3.

If the dark ring is perfectly equal in width, but the bright disc is *not* completely circular (Fig. 13), the mirror alone requires adjusting, which may be called B.

If the bright reflection of the large mirror is *not* seen as a perfect circle, and the small dark spot *not* in the centre, neither is the dull ring perfectly equal (Fig. 14), both the mirror and flat require adjusting. Adjustment AB.

A^3. To adjust the flat or small diagonal Mirror.

Should the wider part of the dark ring be towards the speculum, slightly *unscrew* the small screw at the side of the counterpoise, which will appear to move the bright disc, until it is central in an horizontal direction: but if towards the open end of the tube, screw it up. Should the wider part of the dark ring be towards one side of the tube, slightly loosen the counterpoise and revolve the mount on its axial pin in the direction of the opposite side, this will apparently move the bright disc till it is central in a vertical direction. Perhaps both the horizontal and vertical movements will be requisite. When the ring is perfectly even and the bright disc central (Fig. 11), this adjustment is perfect, and the counterpoise should be firmly screwed up to keep it so.

B. To adjust the large Mirror or Speculum.

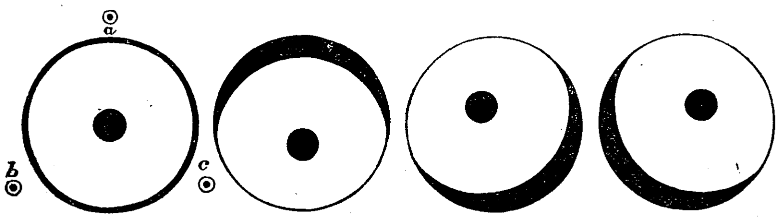


Fig. 15. Fig. 16. Fig. 17. Fig. 18.

It will be easily seen from the above cut that, should the mirror be out of adjustment, it will reflect part of the inside of the tube; in Fig. 16 the upper part of the mirror leans too far back, and consequently the upper part of the tube is reflected, and the under portion of the reflected mirror is not seen. The correction of this imperfection will be obvious, the top screw wants turning in; as this is done the bright circle will appear to rise, and the reflected tube disappear until Fig. 15 is reached. Should on the contrary the lower part of the tube be seen (Fig. 16 *inverted*) the reverse holds good, the bottom of the mirror requires pushing forward; but as there is no screw by which this can be directly effected, the top screw must be therefore unscrewed. Should the reflection of any other part of the tube be shown (such as Figs. 17 and 18), it can be easily identified by moving the hand in front of the open end of the tube until it covers the dark crescent, and wherever this crescent is seen, it shows that that part of the mirror leans too far back, and therefore the screw behind it requires turning in, or the screw opposite to it unscrewed, in order to render the adjustment correct. In the Alt-azimuth cell it will be found necessary to slightly release the small clamping screws before shifting the large screws, but afterwards they should be firmly clamped, as on this greatly depends the stability of the adjustment. Take care that the adjustments continue perfect after the screws are all clamped.

A B. To rectify a Compound Error.

Should it happen that both speculum and flat require adjustment the latter had better be adjusted with the mirror removed from the tube. A sheet of white paper spread on the ground will serve to illuminate the end of the tube from which the speculum has been taken. The flat can then be adjusted to the illuminated speculum end, as in adjustment A^3, and the mirror, when replaced, as in adjustment B. When the observer has learnt to distinguish between the non-adjustment of the mirror and flat, it is very easy to adjust the latter with the former in the tube, and even considerably out of adjustment. It is even possible to adjust at night on a lamp or other bright object.

To perfect the Adjustments.

When a star is viewed it should appear at focus, as a mere dot with one or two diffraction rings, its disc inside and outside the focal point should be perfectly similar, and when the expanded disc is in the centre of the field it should be seen, even when as small as possible, with the black dot perfectly central.

If, after the greatest care has been taken in adjustment, a flare should appear on looking at a star (say of the second magnitude) with an eye-piece of a high power, and the diffraction rings are not quite concentric, it can generally be rectified by turning the large mirror round in its cell a little at a time. If this does not remove the flare, the adjustment of the flat is not sufficiently correct, and must be altered by means of the screws at its back. If the flare is at the top or bottom of the star the flat must be very slightly revolved by the hand, after unloosing the counterpoise, and when correct, reclamping it. If at either side, namely, in the direction of the major axis of the flat and in a line with the tube, the flat must be altered by the long screw. It is always advisable to leave the telescope for a short time undisturbed, especially if, on first looking at a star, a flare should appear, as these appendages often vanish when the instrument has been for a short time in the air.

A test as to the correctness of the adjustments A and C may be obtained thus: Place a very low power eye-piece in position and notice if the field appears uniformly brilliant; should one edge be shaded it shows that the adjustments are not perfect, and they should be tested and made correct. Should, however, the eye-piece have a very large field, an even marginal shade may be seen, showing that the flat is not quite large enough for the illumination of that large field; this would not interfere with good definition, the only disadvantage would be a slight loss of light with that power. On the other hand, a too large flat would also always occasion loss of light. In trying these experiments the telescope should be directed to a bright part of the sky.

The bulb of a thermometer illuminated by the sun, or on a dull day by any bright light, forms what is known as an "artificial star," and may be used during the day for delicate adjustments in place of a true star.

The cell mount of the large mirror can be removed from the tube and replaced without disturbing its adjustments, but it is very advantageous if the entire instrument can always be left undisturbed when not in use in an observatory of light construction, having a skeleton revolving dome, covered with well oiled canvas or calico, and made with a wide opening and large shutters, as described on page 66. Both the large and small mirrors should be protected by their covers (with which they are provided), when not in use, especially if left in the open air. The larger sized tubes have a door large enough to admit the cover, and so allow of its being put on the large mirror without the necessity of the speculum being removed from the body of the telescope. We have lately introduced a screw movement for delicately revolving the flat mount.

STANDS FOR INDIRECT-VISION REFLECTORS.

THE ALT-AZIMUTH STAND.

Fig. 19.

The word Alt-azimuth is a contraction of Altitude and Azimuth. These terms refer to the two movements which must be given to a telescope mounted on this plan, to enable the apparent motion of celestial objects, due to the revolution of the earth, to be followed, and thus retained in the field of view for continuous observation. When a star is due south, or, as it is technically called, "on the meridian," it has attained its greatest "altitude," or height, from the horizon. The motion preceding this meridian passage is, from the rising of the star—an ascending one—and that immediately succeeding—a descending one—till the star has set. To follow this ascending and descending motion, the telescope must therefore have a Vertical or *Altitude* Movement, which is thus applied:—The Telescope being balanced on trunnions, can be moved from an elevation approaching the Zenith to a horizontal position. In order that it may be secured anywhere between these extremes, attached to the upper part of the telescope is an iron rod, which, sliding through the end of the arm of the stand, can be there clamped. The telescope will now be clamped in *Altitude.* As the progression of celestial objects will apparently be very slow, resource must be had to the smoothness of motion obtained by a screw. The upper end of the Altitude rod is therefore tapped to receive a long screw with a large milled head, jointed to the telescope body; by revolving this head, the telescope is raised or depressed accordingly as the screw is unscrewed, or the reverse. It is necessary that the screw should be withdrawn some way from the rod before clamping it, preparatory to following an object which has passed the meridian, or is setting; as, perhaps, just when the clearest vision is obtained, the observer may be annoyed by the screw action being suddenly stopped by the milled head coming in contact with the top of the rod.

When viewing objects near the zenith, the handle attached to the clamp will be found useful, as it can thereby be reached without leaving the finder. The handle may be so placed that a downward push should clamp, and an upward pull release.

We have lately introduced a great improvement on this handle, substituting for it a long rod shaped as an eccentric, and passing through

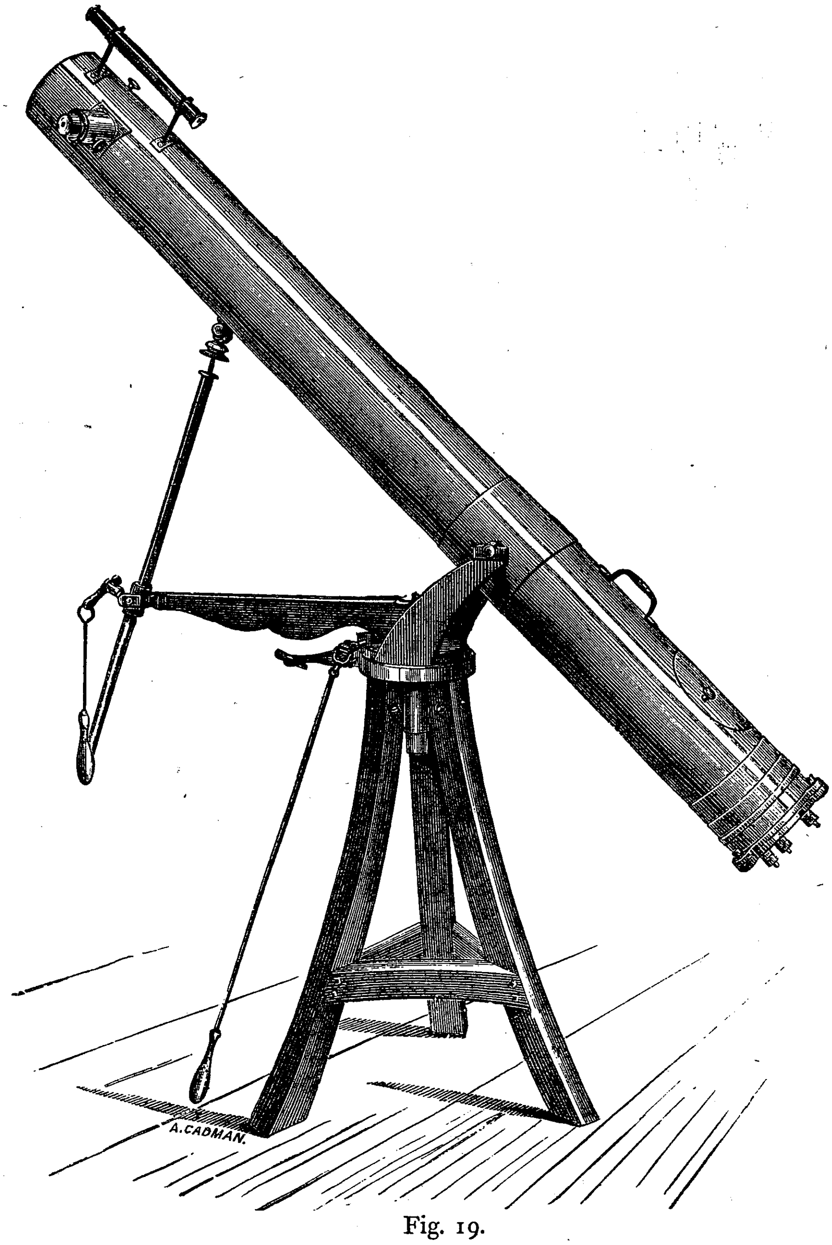


Fig. 19.

THE ALT-AZIMUTH STAND.

a hole just in front of the bearing, of the altitude rod. These holes are connected by a hollow bearing in which a clamping piece slides. When the eccentric is revolved, it presses the clamping piece against the altitude rod, fixing it in any required position. The handle by means of which the eccentrical clamping rod can be revolved works in a bearing fixed to the upper end of the altitude rod, and therefore easily accessible at any elevation.

The second motion in the Alt-azimuth Stand will be indicated by the latter portion of the word, namely, *Azimuth*, and is obtained as follows:—The strong iron disc which forms the upper fitting of the legs has its surface accurately turned. On this revolves an iron disc, rather less in diameter, to which the bearings which support the trunnions of the telescope are attached. The main axis of this disc passes through the centre of the lower disc, and then through a hollow bearing tube, a continuation of it. All these fittings having been most carefully turned and ground together, great steadiness, combined with facility of horizontal movement, is ensured. In order that this motion may be communicated as evenly as possible, resource must be again had to a screw which is thus applied:— The circumference of the lower disc has an endless screw cut on it, in which works a tangent screw, which can be easily thrown in and out of action. The advantages of this plan are many, the most important being the rapidity and ease with which the telescope can be shifted from one object to another, even to those in contrary directions; all that is necessary being to release the clamp and turn the telescope to the object required. The clamp, being carried round with the upper disc, can be fixed directly the desired position is obtained, when the screw is at once in action. Motion is applied to the screw by means of a Hook's joint, named thus from its inventor. This joint being furnished with a long handle, enables the observer, by means of it, to move the Telescope in *Azimuth* without removing his eye from the eye-piece.

It will be seen from the preceding remarks that, by the means of the vertical and horizontal screw motions the telescope can be moved in any direction with the greatest facility, permitting a celestial object to be observed with high powers for a considerable time, and with the greatest pleasure and comfort to the observer.

This stand can be taken to pieces in a few minutes, and thus carried indoors after the observer has finished his evening's work. The operation is best performed as follows: the speculum in its cell having been first removed and covered up, release all the clamps and detach the altitude rod and eccentric from the tube. Resting the tube on the left arm, and grasping the handle with the right hand, it can be lifted from the trunnion-bearings and carried to its destination. The altitude rod and Hook's joint should be next taken, and then the upper disc, with its fittings, can be lifted from its bearings and removed, leaving the legs for a final load.

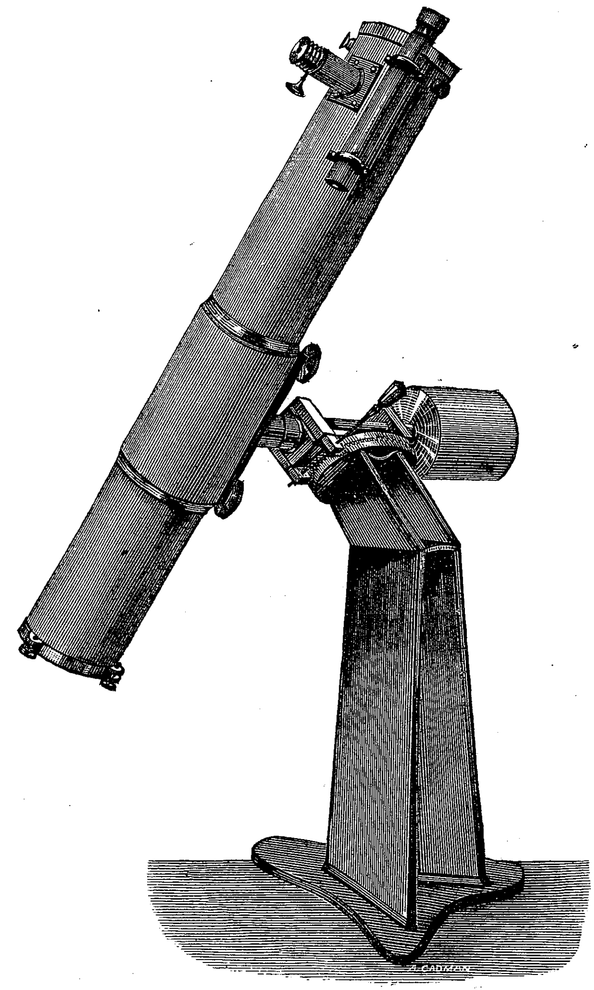


Fig. 20.

Horne and Thornthwaite's Equatorial Reflector.

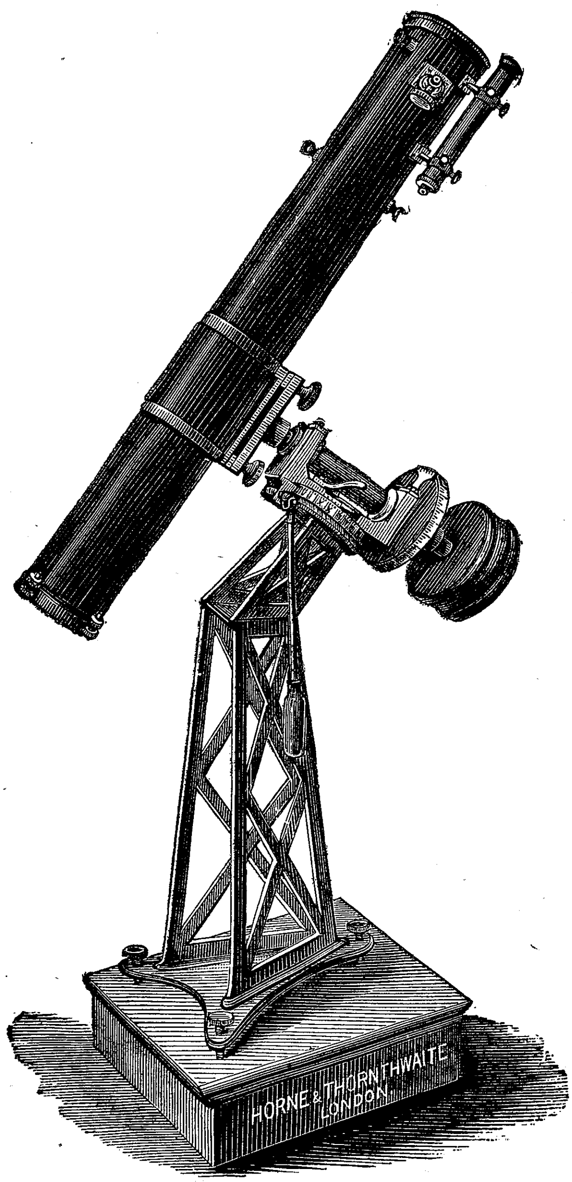


Fig. 21.

Horne and Thornthwaite's Portable Equatorial Reflector.

EQUATORIAL STANDS.

Reflecting telescopes are mounted on several forms of equatorials, a few of which require description. The first is the cheapest form which can be made, and is suitable for telescopes up to 6 or 8 inches in aperture, especially those of a portable nature. The second is on Mr. Berthon's plan, and is suitable either for fixed or portable instruments of 6 to 8 inches aperture; its great advantage is its remarkable steadiness. The last to be noticed is that known as the Berthon equatorial, and is specially suitable for large telescopes, and when clockwork motion is to be applied. The possessor of a 10 or 12 inch mirror on a stand of this form, with a driving clock, will rival in instrumental power some of the best observatories.

HORNE AND THORNTHWAITE'S PORTABLE EQUATORIAL. (Fig. 21.)

Until lately, equatorials of even very moderate aperture were only in the possession of few observers; being of a costly nature they were confined to the observatories of gentlemen whose means equalled their love for scientific pursuits. It was therefore thought that the introduction of a telescope of considerable power on a portable stand, and at a very moderate price, would be a great boon to those observers who have not the space or means to erect an expensive observatory. In order to supply this want, the above-mentioned instrument is manufactured.

The optical parts consist of a 6 inch silvered-glass mirror of about 46 inches focus, guaranteed to divide stars 1″ apart, on favourable occasions, or even closer; two achromatic eye-pieces and a Barlow's lens, or if desired an extra eye-piece in place of the Barlow's. The stand is so constructed that it combines steadiness and portability. There is a tangent screw movement in right ascension. The right-ascension and declination circles are fully divided, with verniers. We have lately introduced a new method of clamping these equatorials which possesses several advantages. Every necessary adjustment is provided for both the optical portions and stand. The entire body can be revolved so that the eye-piece can always be brought to an easy position for observation; it can also be readily separated from the stand. If the body-tube is removed and taken indoors, the counterpoise may be at the north of the foot, and a waterproof cover thrown over the entire stand; it can thus be left out of doors, and a considerable amount of such exposure will not injure the movements. This will of course be a great advantage over setting an instrument in equatorial position on every occasion of observing with it. This equatorial can be made to suit any latitude, and can also be obtained without divided circles, at a reduced price (Fig. 20). Larger forms of this equatorial are made to suit telescopes of 6 or 8 inches in aperture and longer foci.

BERTHON'S PATENT EQUATORIALS.

The great increase in the number of amateur astronomers during the last few years, and the immense improvements in the optical parts of the instruments used by them, demand corresponding improvements in the mounting of Equatorial Telescopes.

Hitherto nearly all Equatorials belong to one of two types—the German and the English. The former is suitable for telescopes of moderate aperture; but with large sizes becomes expensive on account of the necessity of very perfect workmanship—the latter may be produced at less cost, but it is inconvenient, and has several disadvantages, though when expense is no object the defects may be reduced to a minimum by sundry elaborate contrivances, as in the large Achromatic in Greenwich Observatory.

The Equatorial Telescope Stands now to be described combine effectiveness with convenience at a very reduced expense. They are called the "EQUESTRIAN, OR DOUBLE COUNTERPOISED EQUATORIAL STANDS," and though adapted for all kinds of telescopes, they are particularly convenient for Newtonian reflectors.

The first form of these stands is shown in Fig. 22, and is suitable for telescopes of all sizes, but especially for those of about 6 or 8 in. in aperture. Its great peculiarity is the double counterpoises, one on each side of the polar axis. The body tube of the telescope revolves in a cradle, to which are attached two almost circular plates, whose centres have been turned to fit on the wide declination bearings 4 or 5 inches in diameter, which are attached to a hollow cylinder which revolves on a long polar axis attached to the firm iron foot. On each plate a counterpoise is screwed, and on the edge of one plate is a tangent screw by which a slow movement in declination can be applied. An endless screw gives a slow motion in right ascension, and can be worked with a tangent screw and Hook's joint. The declination arc is fixed to one of the plates, and the right ascension circle revolves on the cylinder. The great advantage of this form of stand is its great steadiness, all the bearings being several inches in diameter. The lower end of the body tube can be taken off and packed alongside the upper part, the whole of the working parts of the telescope can, therefore, be packed in a comparatively small case, and the heavy pedestal carried alone. As it will not suffer from exposure, the pedestal can be left in equatorial position out of doors, and the whole of the telescope, counterpoise, movements, &c., can be carried to a safe place in *one* piece.

The principle of the other equatorial devised by Mr. Berthon is the same as that just described, but its construction is different. It is represented in Fig. 23. A well-turned disc of iron, 16 or more inches in diameter, is attached to an iron pedestal at an angle equal to that of the co-latitude of the place for which the telescope is intended, and upon this another disc revolves, being kept from sliding off by a central pivot, or polar axis. This upper disc carries the telescope,

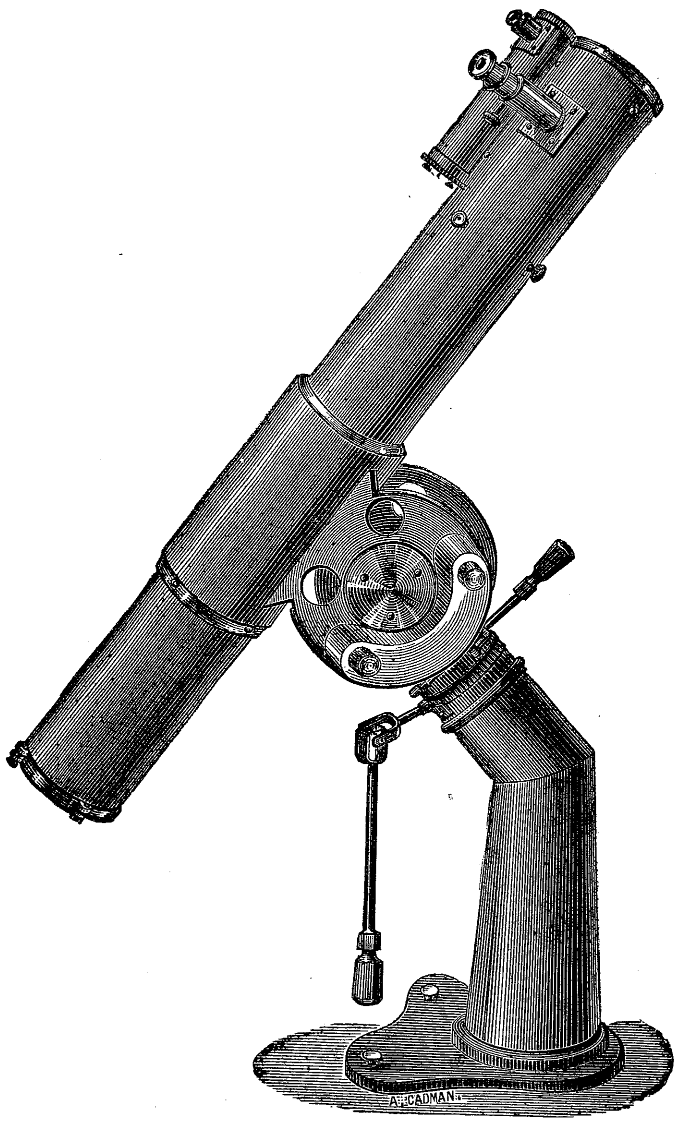


Fig. 22.

THE BERTHON EQUATORIAL.

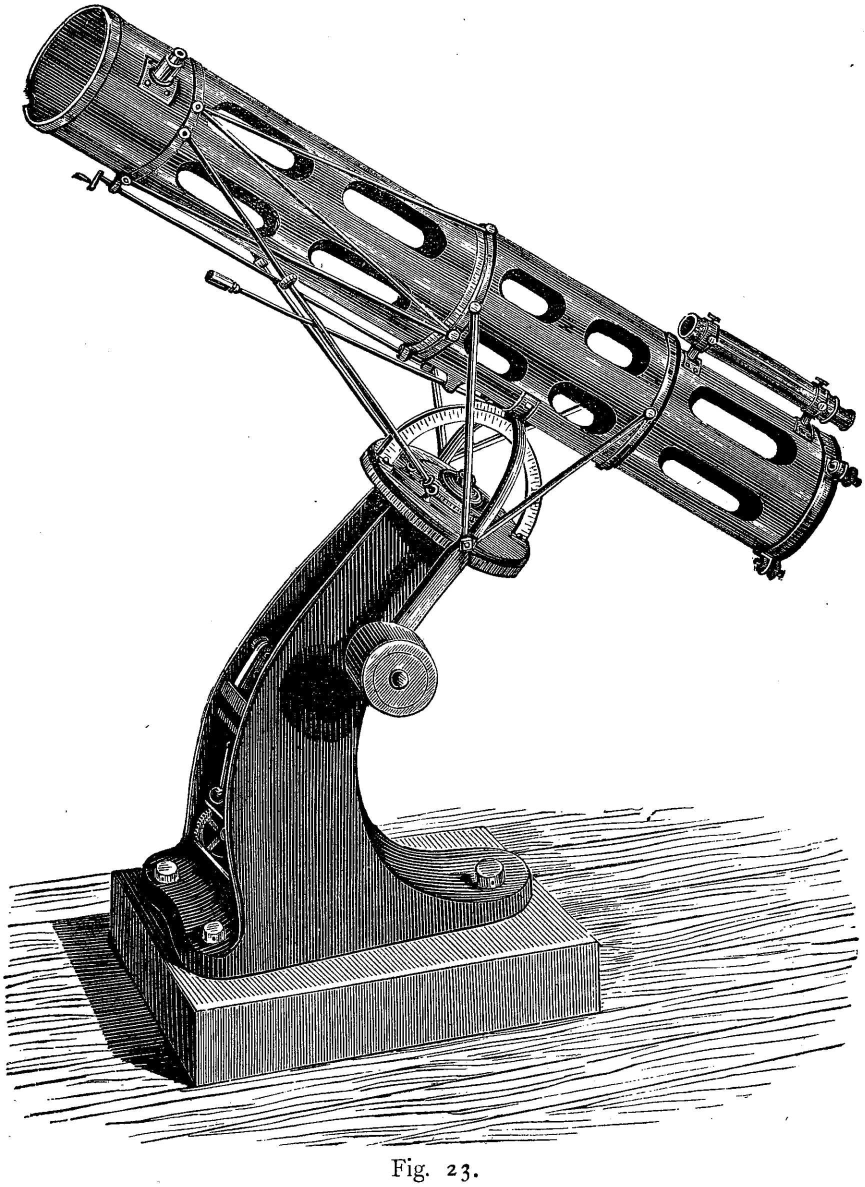


Fig. 23.

THE BERTHON EQUATORIAL.

which is supported by two strong arms working on trunnions, and four oblique rods—two on each side. The two arms extend 10 or 12 inches beyond the trunnions, and each carries a counterpoise half the weight of the telescope. It will be observed that these weights project on the opposite sides of the declination axis, and, when properly adjusted, exactly balance the telescope, *so that the centre of the upper disc becomes absolutely the centre of gravity of the whole mass.* Now at this point an enormous improvement is effected by the simplest possible means, consisting merely of a small plate and two differential screws so arranged as to throw the entire weight of the telescope and upper plate upon the end of the pivot. By this contrivance friction is reduced to a minimum, and movement by hand or by a clock becomes extremely easy.

Spanning the upper disc at right angles to the axial line is a semicircular arch, having the same diameter. Upon this arch the divided declination scale is fixed, and the vernier is attached to the cradle of the telescope. The slow movement in declination is produced by a tangent screw rod, which can be clamped to any part of the abovenamed arch. That in right ascension is as follows :—Passing through the polar axis is a strong rod on the lower end of which the driving wheel acted upon by the clock may be attached, if such a power is employed. The upper end of the rod is fixed to a disc on the edge of which an endless screw is cut, and working in this is a tangent screw, the end bearings of which are fixed to the upper main disc. If the rod and disc are clamped together a direct motion is communicated from the clock to the telescope, and any independent movement can be given by revolving the tangent screw. Should it be requisite to move the telescope rapidly through a large space, either the clamp can be released, or the tangent screw thrown out of action without interfering with the driving clock.

The slow movements and clamps in right ascension and declination are worked by handles placed close by the eye-piece, and therefore very accessible. The circles can be read from the eyepiece end of the telescope. The right ascension circle can be connected to the driving clock so that when once set it will show sidereal time as long as the clock is in motion, thus greatly facilitating right ascension readings. The driving clock is made with firm, large wheels, regulated by governors. It can be readily stopped without risk of injury ; the time it will work without being re-wound depends on the length of the drop allowed for the weight, 3 to 4 hours is the usual duration. The entire clock is protected from injury and dust by enclosure between the sides of the stand and a removable glass front. The stand is so constructed that the telescope can be turned throughout the 24 hours when pointing to the pole. The above description, in its entirety, only refers to specification C in the catalogue. A and B are modified.

EQUATORIAL ADJUSTMENTS.

A traveller who journeys in a southerly direction will notice as he proceeds that stars, which in England appeared close to the southern horizon, gradually increase their altitude, whereas the polar star will appear to get lower and lower, until at last, as he crosses the equator, it will disappear from view. If the traveller were to take an equatorial stand with him, he would have to gradually lower the elevation of the polar axis to keep his instrument in correct adjustment. It will thus be seen that the correct elevation of the polar axis to the latitude of the place of observation is a most important adjustment. As a rule large equatorial stands are set by their makers to the latitude of London 51°, 28′, 38″, and afterwards adjusted by a strong foot screw as required. But when one of this kind of telescope is ordered, the maker would be apprised of its destination, in order that he may be able to set the instrument as nearly as he can to the latitude of the place.

An equatorial stand should be placed on the firmest foundation obtainable; any neglect of this precaution will be the cause of constant errors of observation and vibration of image. The pillar on which the instrument stands should be let some distance into the ground, and, when practicable, rest there on a bed of concrete. The upper surface of the pillar should be as level as possible.

I.—To place the Polar Axis in the Meridian.

The polar axis being approximately directed to the pole, find out from an almanac the time any bright star of some altitude is on the meridian, due south.

Revolve the upper disc till the bubble of the level is perfectly central, and when this is done firmly clamp the telescope in that position, leaving the declination movement free. A few minutes before the time of transit point the telescope to the star as nearly as possible without unclamping, and shift the iron foot until the star is exactly in the centre of the field, using a low power. Now, in order to follow the apparent motion, gently continue to push the iron foot until the moment of transit, when immediately stop. An assistant should keep his eye at the eye-piece to regulate by word of mouth the imparted motion, and so keep the star perfectly central in the field, The mean time of transit may be obtained from an accurate watch, but it is far better to take the time from a sidereal clock on all occasions.

II.—To correct the Declination Vernier.

In a Berthon equatorial this has been originally done thus :—The upper disc and all it carries having been removed, the lower disc was accurately levelled, the stand being tilted to allow of this being done. The upper disc having been replaced, a stride level was placed on the top of the body tube, and it was turned throughout the twenty-four hours, gently altering the declination by means of the tangent screw until the bubble remained central throughout the circuit. When this was so the index of the vernier was set to 0° on the declination circle. As the above described operation is of too heavy a nature to be effected by an amateur, the following is a very good plan to mechanically adjust all the verniers, and may be used with with any form of equatorial :—Clamp the telescope to 0° in declination, and by means of a level placed on the body of the telescope alter the right ascension movement *alone* until the telescope is perfectly level, pointing E. Now revolve the hour-circle until XXIV is read by the vernier. Shift the telescope through 12 hours, and *without altering* the declination or hour-circle, level the body as before described, but of course this time pointing W. If the vernier now reads XII whilst the declination is still 0°, all the verniers are in correct position. But if the W reading is not at XII when the bubble is central, alter the right ascension until the reading is exact, and then correct the level by slightly shifting the declination. When the bubble is again central, alter the position of the declination vernier one half the ascertained error of reading. If the telescope be now moved through exactly twelve hours it will be exactly horizontal at each extreme when the declination is 0°. All that will be requisite, if this is the case, will be to notice that the index of the second right ascension vernier reads exactly half way between the extremes. If it does not, correct its position.

But in a German equatorial (Figs. 4 and 21) in which a declination *circle* is on *one side* of the polar axis, instead of being over it as in the Berthon, the correct position of the vernier can be astronomically ascertained before proceeding further. Read the declination of any star within 30 minutes of its meridian passage with the circle facing E. Now revolve the instrument till the circle faces W. and re-direc the telescope to the same star and again note its declination. If the declination circle has been moved through *exactly* 180°, and therefore the two readings are precisely alike, the declination vernier is correctly placed. But if the two readings are not the same, alter the vernier half the difference between them. With a refracting telescope this operation may be repeated several times in order to secure the greatest exactness, but with some reflectors a persistent small error cannot be well avoided, it should not exceed 1 or 2 minutes of arc. This remark applies to all adjustments.

Example:—The declination reading of γ^1 Andromedæ was 40° 34′ with the circle E. and 40° 10′ when W.; half the difference 24′ is 12′, and therefore the vernier must be altered that amount. To do this, fix the telescope on the star, and alter the vernier till it reads

$$40^\circ\ 22' = \begin{cases} 40^\circ\ 34' - 12' & \text{E.} \\ \quad\text{or} & \\ 40^\circ\ 10' + 12' & \text{W.} \end{cases}$$

III.—To adjust the Polar Axis to the Latitude of Observation.

Read the declination of a star as nearly as possible on the meridian; if this is the same as the declination given in the *Nautical Almanac* or a star catalogue, the position of the polar axis is correct. If the two amounts do not agree, set the vernier to the correct catalogue declination, and bring the star into the centre of the field of view by altering the latitude screw in the iron foot, moving the telescope in right ascension as requisite.

Example:—The declination of α Leonis was read as 13° 4′ N., the catalogue showed that it ought to have read 12° 36′, the telescope was lowered so that the vernier read 12° 36′, and the latitude screw was altered until the star was central.

IV.—To test the accuracy in position of the Telescope.

A.—Should the declination of a star six hours from the meridian, that is, due east or west, read correctly in both positions, as well as at transit, the position of the telescope is correct.

B.—Should meridian declinations read correctly, while at equal distances from that position there are *equal* errors of a *contrary* nature (that is, one + and the opposite —), the vernier is correctly set, but the meridian position of the instrument is wrong.

C.—Should meridian declinations read correctly, while at equal distances from that position there are *equal* errors of the *same* nature (that is, both + or both —), the vernier is not correctly set, but the meridian position is right.

D.—Should meridian declinations read correctly, while at equal distances from that position, there are *unequal* errors of *any* nature, both the setting of the vernier and the meridian position are incorrect.

A plus error (+) means that the vernier reading is higher than the catalogue position ; for example, the reading is 10° N. and the catalogue gives 8° 30′ N., or if of south declination 5° S. to catalogue 10° S. A minus error (—) of course means exactly the contrary. But for all adjustments, stars of *north* declination should be selected: for meridian positions a moderate altitude will suffice, but for observations at six hours from the meridian only stars that are above 25° N. declination should be used. The reason why stars are observed at or about *six hours' distance* is that an *horizontal* movement given to the foot of the equatorial will cause the telescope, if pointed in that direction, to move in *declination;* such stars may, for brevity, be called *six hour* stars.

The method by which the vernier of a German equatorial can be accurately set having been already described and presumably acted on, its position will not require correction. But its correct position is assured if the conditions under B are fulfilled. These conditions should, however, *always* be applied to a *Berthon* equatorial, as if the mechanical setting of the vernier has not been sufficiently exact, the conditions under B will *not* be fulfilled.

With either form of instrument if B is realized, and therefore the setting of the vernier is correct, the meridian position can be obtained as follows :—Select a six hour star, and having noted its declination error by comparing its vernier reading with the catalogue amount, firmly clamp the vernier to the *catalogue declination*. As the telescope must be moved to do this, the star will have shifted from the centre of the field, it must be brought back to that position without shifting the declination setting. If there is an azimuth motion it must be employed in addition to that in right ascension, but if there is none, the foot must be moved. The direction of this movement will depend on the nature of the ascertained error. If the star is six hours W. and the vernier reading is + (or if E. —) the upper end of the polar axis or the north foot must be moved towards the E. If the star is W. and the reading is — (or E. and +) the upper end of the polar axis or the north foot must be moved towards the W. The foregoing adjustments will most likely ensure the correct conditions of A.

With the Berthon equatorial the E. and W. declinations may not fulfil the conditions of B, but do so with C. In that case the vernier may be corrected as follows :—If the vernier readings are +, the vernier must be moved towards the south of the circle, the amount of the error; if —, the reverse. The vernier can be best altered by meridian observations, and afterwards the latitude must be re-adjusted as before described (III).

But as it is not likely that the preliminary setting of the meridian position was sufficiently exact to allow of C being fulfilled, D is most likely to be the condition of a Berthon equatorial when it is first placed in rough adjustment; and therefore the following plan may be employed to accurately adjust one of those instruments, even when it is placed on a stone whose upper surface is not level.

Having approximately placed the instrument facing the south, and adjusted the polar axis as before described (III), read the declinations of a six hour E. star and a six hour W. star, and compare each result with the position as given in a catalogue. Subtract the smaller from the larger amount in each case, and add the remainders together. Half this will be the vernier error, which may be corrected, and the telescope placed in the meridian as just described. If the ordinary rule for indices be followed, the nature of an error will easily be identified. Examples 1 and 2.

Another plan may be employed, though perhaps it is inferior to that just described. It is as follows :—Observe an E. or W. six hour star, and having set the vernier to the catalogue declination, centre the star by shifting the foot and the right ascension movement. When the star is exactly central in the field of view, turn the telescope to another star twelve hours distant, and observe the declination error Half this will be the vernier error. The vernier can be altered this amount, and the star refound by again shifting the foot. All that now will be requisite will be to re-adjust the polar axis on a meridian star. Example 3.

EXAMPLE 1.

Meridian ...	α Tauri ...	16° 15′	read as	16° 15′	Error	0
East	α Ursæ Majoris	62° 25′	,,	54° 20′	—	8° 5′
West	α Andromedæ	28° 24′	,,	26° 9′	—	2° 15′
				2	—	10° 20′
			Vernier error		—	5° 10′

EXAMPLE 2.

Meridian ...	i Cancri ...	29° 14′	read as	29° 14′	Error	0
East	κ Bootis ...	52° 24′	,,	50° 40′	—	1° 44′
West	γ Andromedæ	41° 42′	,,	42° 56′	+	1° 14′
				2	—	30′
			Vernier error		—	15′

EXAMPLE 3.

Meridian ...	α Leonis ...	12° 36′	read as	12° 36′	Error	0
East	η Draconis ...	61° 48′	,,	61° 48′	,,	0
West	ϵ Pegasi ...	39° 38′	,,	41° 24′	+	1° 46′
	Vernier error	53′		2	+	1° 46′
	Set vernier to	40° 31′			+	53′

The foot was shifted until ϵ Pegasi was in the centre of the field, the vernier altered so that it read 39° 38′, and finally the latitude screw re-corrected.

To set the Right Ascension Vernier.

The right ascension and hour-circle of an equatorial should always be movable, for, if not, a distinct calculation must be made before each observation. A movable hour-circle is fitted with two verniers, one reading time, and the other right ascension, and one of these can be shifted for preliminary adjustment. Two data are requisite before this can be done. Greenwich time can generally be obtained at the nearest Postal Telegraph Office, but as this will be only correct for places of the same longitude, the longitude of the place of observation can be easily determined from an ordnance map, and the distance converted to time (15′ longitude = 1^m time). If the place is east of Greenwich, this amount must be added; if west, the contrary. Accurate mean local time having been thus ascertained, look in an almanac opposite the date of observation for the mean time of transit of a convenient star or planet, which is given for every day of the year.

The accurate position of the foot of equatorial being known, a few minutes before the time of transit find the desired object and keep it central in the field of view, by means of the hand following movement, until the instant of transit. Now firmly clamp the telescope, as it will be exactly in the meridian, and alter the indices of the verniers until they are exactly opposite. Finally, adjust the level until the bubble is central.

If there are more adjusting screws than that in latitude, by their means the foot of the pillar should be brought level and parallel with the stone, before *any* adjustment is effected. An alteration in the east or west screws may be used to delicately alter the meridian position of the entire instrument. Raising the west foot will move the vernier towards the west.

To find a Celestial Object by means of the Declination and Hour Circles.

A movable hour-circle is now invariably used with equatorials, as by its use a considerable amount of calculation is avoided. The right ascension and time setting depend on the way this circle is figured. This will be easily understood if the circle is compared to a clock face and the time vernier to a hand. If the face revolved and the hand was a fixture the hours would have to be figured in an opposite direction to those usually marked on a clock face. In some forms of equatorials this plan is adopted, and therefore there are two ways of finding a celestial object.

If the circle is figured from W. to E.:

A.—Clamp the telescope to the declination given in an almanac, allowing the error of refraction if the object is near the horizon.

B.—Revolve the hour-circle until it reads to the vernier with which it turns the right ascension of the object sought.

In some forms of the Berthon equatorial the hour-circle can be connected with the clock; if this is the case, after the circle has been set to sidereal time on the lower vernier, it should be clamped to the clock axis, and no further time setting will be necessary.

C.—Turn the telescope until the lower fixed vernier reads on the lower half of circle the sidereal time of the observation.

If the circle is figured from E. to W.:

A.—Clamp the telescope to the declination.

B.—Revolve the movable hour-circle till it reads (to the lower vernier attached to the pier) the right ascension of the object.

C.—Turn the telescope until the movable vernier reads (on the hour-circle) the sidereal time of the observation.

Example: To find α Virginis (Spica) at 11 o'clock mean time on June 30th, 1875, or at XVII. 35m. 25s. as shown by the sidereal clock.

A.—The declination of Spica on June 30th was 10° 30′ 43″, and the vernier was set to this position.

B.—The hour-circle which read from W. to E. was revolved till it read to the upper vernier, the right ascension of Spica XIII. 18m. 38s.

C.—The telescope was turned, so that the lower vernier read XVII. 35m. 25s. and the star was in the field of view.

If the circle had read from E. to W. the right ascension setting could have been effected thus:—

B.—The hour-circle is revolved till it reads XIII. 18m. 38s. to the lower vernier.

C.—The telescope is turned till the movable vernier reads XVII. 35m. 25s., and the star is in the field.

Twenty-four hours of sidereal time may be roughly estimated as four minutes shorter than twenty-four hours of mean time, or a gain of ten seconds every hour; a watch thus regulated will keep fairly correct sidereal time. If time is not accurately known a slight movement in right ascension will often bring the object into the field. The correctness of the local time of any place may be easily ascertained by setting one vernier to the right ascension of a known star in the field, when the other vernier will show correct sidereal time. If this operation is quickly performed, a clock or watch may be accurately set at the commencement of the evening's work. Time however can be most accurately ascertained by a meridian passage.

Example: Spica being brought in the centre of the field, and the right ascension circle set to XIII. 18m. 38s., the time shown by the other vernier was XVIII. 3m.

To convert Mean into Sidereal Time.

Mean time can be easily converted into sidereal; but data must be obtained from an almanac. Example:—To convert VII 50m. Greenwich mean time to sidereal time on July 10th, 1875:—

Sidereal time at mean noon, July 10th ...	VII.	12m.	1s.
Add sidereal interval for 7h. 50m. ...	VII.	51m.	17s.
Sidereal time	XV.	3m.	18s.

Table of Refractions (Bessel).

Altitude.	Refraction.	Altitude.	Refraction.	Altitude.	Refraction.	Altitude	Refraction.
0°	34′ 54″	6°	8′ 23″	14°	3′ 47″	35°	1′ 22″
1°	24′ 24″	7°	7′ 19″	16°	3′ 18″	40°	1′ 8″
2°	18′ 8″	8°	6′ 29″	18°	2′ 56″	50°	48″
3°	14′ 14″	9°	5′ 49″	20°	2′ 37″	60°	33″
4°	11′ 39″	10°	5′ 16″	25°	2′ 3″	70°	21″
5°	9′ 46″	12°	4′ 25″	30°	1′ 39″	80°	10″

Thus a star which really was *on* the horizon would appear 34′ 54″ *above* it.

When an object is some distance from the meridian, refraction influences right ascension as well as declination. The observer need not make any allowance for refraction except when finding objects with high powers on an achromatic telescope, or in ascertaining their exact position. With a low power the object sought is sure to be in the field without allowing for any refraction.

To adjust the "Finder."

Direct the Telescope to any bright star (the Pole-star being by far the best, as it has very little apparent motion), and bring this star into the centre of the field of a low-power eye-piece. Now adjust the "finder" by means of the three screws bearing on it, till the star is bisected by the cross wires seen in the focus of the eye-lens of the "finder." Change the low eye-piece to a high one, and perfect the adjustment in the same way. Any well defined terrestrial object at a distance can be employed, in the day time, to roughly adjust the "finder," leaving the final adjustments to be made on a star. If a small Newtonian is used as a "finder," its line of sight may be regulated by slightly altering the adjustment of the speculum of the "finder," by means of the three screws.

With reflectors the finder is often made of sufficient power to act as an equatorial telescope. After the optical adjustments of a reflector have been perfected the finder is accurately adjusted, and then the setting of the equatorial is done with the finder alone. The great advantage of this plan is that the finder can be firmly fixed, and the mirrors removed, for silvering or otherwise, and afterwards replaced and adjusted to the finder, thereby running no risk of disturbing either the optical or equatorial adjustments of the instrument.

To Silver and Polish Glass Specula.

The cost of silvering is trifling, and with cleanliness and ordinary care, very little difficulty will be experienced in the operation. The apparatus and chemicals required consist of the following articles :—

APPARATUS.

A Silvering Vessel.—This should be a circular porcelain or glass dish, 1 inch or more larger in diameter than the speculum to be silvered, and sufficiently deep to allow of about half-an-inch stratum of fluid between the face of the mirror and the bottom of the dish, which should be flat.

A Box of Scales and Weights.
A Glass funnel and filtering paper.
Two Glass Rods for stirring.
A Five-ounce Glass Measure.
A 20-oz. Glass Flask, and a 40-oz. ditto.
A Retort Stand for supporting the same.
A Spirit Lamp.
A Sand Bath.
A test tube, ¾ or 1-inch in diameter.
Some clean Cotton Wool.
A piece of very fine Wash-leather.
A support of Wood, on which to cement the Speculum, described further on.

A Mixing Vessel.—The larger flask will answer well, or a 40-oz. glass measure, which will also prove useful for other purposes. The mixing vessel should always be transparent, in order that the action of the ammonia can be easily seen. If a flask be used the mixture can be shaken; if a measure, it may be stirred, but care must be taken not to touch the glass with the point of the rod, as it may scratch, and cause a crack.

CHEMICALS.

	Nitrate of Silver in Crystals.
M.	Nitrate of Ammonia.
M.S.	Pure Potash, prepared by Alcohol.
M.	White Sugar Candy.
M.	Tartaric Acid.
	Alcohol.
D.S.	Liquor Ammoniæ.
S.	Sugar of Milk.
D.	Tartrate of Soda and Potash (Rochelle Salts).
	Distilled Water.
	Nitric Acid.
	Pitch.
	Fine Rouge.
	Turpentine.

All the above chemicals should be as pure as possible, especially the potash. They are not all required in each process to be described, those specially used are therefore marked, M., D., S. These letters indicate the three processes, called respectively, Martin's, Draper's, and the Sugar of Milk. The method of preparing, cleansing, and immersing the mirror, and polishing the silver film, is the same in all processes.

To support the Mirror in the Silvering Vessel.

There are several ways of doing this, dependent on the depth of the vessel. Should the back of the mirror be level with the edge of the dish, when its face is the requisite distance, (about ½-inch) from the bottom, it may be secured as follows :—Procure a strip of wood, about three inches wide, and of sufficient length to rest securely on the opposite sides of the vessel. Pour on the centre of this piece of wood some melted pitch, and whilst it is still hot, place it on the back of the mirror, previously smeared very slightly with turpentine, which should be allowed nearly to evaporate. The turpentine will secure the adhesion of the hot pitch to the glass, and care should be taken that, when cold, the mirror and its support are firmly cemented together before commencing the silvering process. Should the dish be so deep that there would be more than the requisite distance between the bottom of it and the face of the mirror, a block of wood of sufficient thickness must be screwed to the suspending strip, and the speculum cemented to it, instead of directly to the strip itself. On the contrary, should the dish be very shallow, the mirror may be raised, by placing thin pieces of wood between the strip and the edges of the dish; or the strip need not rest on the edges of dish, but have an independent support at each end. When the speculum is found to be firmly cemented to its support, place it in the dish, and pour in water until it reaches a quarter of an inch up the side of the mirror (Fig. 25). Measure this quantity, as it will show the amount of silvering solution required to be prepared. Now proceed—

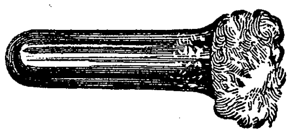


Fig 24.

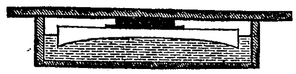


Fig. 25.

To Clean the Mirror.

To do this fill the end of the test tube with cotton wool, leaving plenty outside the tube (Fig. 24), and having poured a small quantity of strong nitric acid on the front of the mirror, rub the acid well all over the front and sides with the cotton wool brush. Now pour on the surface a little water to dilute the acid, and again well rub the front and sides. Place the speculum under a water-tap for a few minutes, until the acid is washed away, and finally well rinse with distilled water; then place it in the silvering vessel (previously thoroughly cleansed) and pour in distilled water until it touches the entire face of the speculum.

The water will appear to cleave to the entire surface when it is perfectly clean. If the operator fails to completely clean the mirror with the acid, he should, after the acid is entirely washed away, dry the surface with a perfectly clean linen cloth, and then apply a mixture of equal parts of a solution of potash (1 oz. in 10 oz. distilled water) and alcohol, well distributed with a clean cotton wool pad; this mixture is then diluted by adding a little water, and again rubbed; finally the surface is plentifully rinsed with distilled water, and the mirror is then supported face downwards in a vessel of distilled water, as before described. In very cold weather it may be found advantageous to have the mirror slightly warmer than the bath, and both these warmer than the silvering vessel, which should be kept cool. The mirror may be warmed by standing it in distilled water at a temperature of about 90°, any dish except the silvering vessel being employed to hold it.

To Immerse the Mirror.

Remove the mirror from the distilled water, and wipe the back and edge with some clean cotton wool if there is any water thereon, taking care not to touch its surface. If this precaution be not taken the water is liable to drain down the sides of the mirror whilst silvering, and cause streaks at the edge of the film. Having poured away the distilled water, pour into the silvering vessel Solution A, and then add slowly B, stirring well together meanwhile with a glass rod; directly the solution begins to change colour gently immerse one edge of the mirror, and then the whole surface, taking care that no air bubbles or specks of any kind remain between the surface of the mirror and the solution. Gently agitate the silvering vessel, so that the solution may be kept in motion for the first few minutes, until the film begins to form; or the mirror suspended in the fluid may have a gentle rotatory motion imparted to it; but in any case this motion is a most important element towards obtaining a silver film of uniform thickness, and free from stains, especially if the back of the mirror be not dry. Care must be taken not to lift the surface of the mirror out of the solution during the motion, as this may cause a streaky film. When the deposition of silver commences let the mirror remain undisturbed until nearly all the silver in solution has been thrown down. To ascertain this, break through the stratum of silver formed on the surface of the ring of fluid surrounding the mirror, and should the fluid below be perfectly clear the deposition of silver is complete. The time the deposition will occupy will depend on the temperature of the solution and the process employed. In summer it will be completed much more rapidly than in colder weather, during which period the operation can be more satisfactorily performed in a warm room. Do not leave the mirror too long in the solution, for directly the silver is all thrown down, there is a tendency to cover the brilliant silver film with a white deposit, which is not readily polished off; to avoid the risk of this occurring it will be found preferable to take the mirror out of the solution before the silver is quite exhausted.

To prepare the Silvered Surface for Polishing.

If the solution is still warm, immediately the mirror is removed, pour over its silvered surface a little warm distilled water, several times, until about a pint has been used. But if the solution from which the speculum has been removed is perfectly cool, cold water may be allowed to flow on the surface for five minutes or more, from an ordinary tap, finally rinsing with distilled water. When clean, the film may be dried, by placing the mirror with its silvered surface resting on some filtering paper (Fig. 26), but it is far better to rapidly dry off the superficial water by means of a good draught of air, and soak off the water as it comes to the edge with some absorbent paper. After the water has disappeared from the surface, the film, being still damp, may be allowed to gradually dry, leaving it unpolished for a few hours; or the mirror may be held at some distance from a fire, so as to quickly drive off any remaining moisture, care being taken not to over-warm the mirror itself; the film can then be immediately polished. In damp weather it will *always* be better to slightly warm the film before polishing it.

To Polish the Silvered Surface.

Make a couple of polishing pads by filling two pieces of very soft wash-leather about six inches square loosely with cotton wool, and tying them into balls (Fig. 27). Gently remove any dust that may have settled on the film with some loose cotton wool, and then go over it with one of the pads in small circular strokes for about 5 minutes or more (Figs. 28 and 29). This will consolidate the film and fit it for polishing. Spread a little of the finest rouge on a sheet of writing paper, and impregnate the other pad with it. Go over the film with

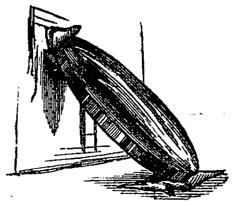


Fig. 26.

Fig. 27.

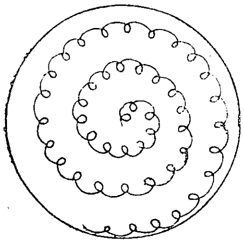


Fig. 28.

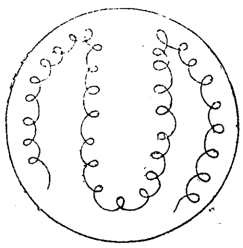


Fig. 29.

the rouged rubber, using the same circular strokes until it is perfectly polished. Never commence with the rouged pad, as the surface may be injured. When once the film has been consolidated it will remain so, and can be repolished many times with the rouged pad should it get tarnished. The pads should be kept from dust in wide-mouthed bottles for future use. With care the film will last for a long time, especially if it is not allowed to get damp, and consequently the mirrors should never be brought uncovered from the cold air into a warmer temperature.

A small box or bag containing some quick-lime, kept in the tube of the telescope when not in use, will help to absorb all extraneous moisture.

A lens may be supported in the solution by twisting a piece of copper wire round its circumference, and then silvered and polished in the same way as the speculum.

To Separate the Mirror from the Wooden Support.

Should the mirror be attached directly to its support, insert a chisel between them, when one or two gentle blows will cause them to separate; but, should the mirror be cemented to a block, Fig. 25, stand the mirror on edge, when a slight tap on the block will detach it. Scrape off any pitch that remains on the back of the mirror, finally using some turpentine to wipe it perfectly clean. Great care should be taken not to finger the film.

MARTIN'S PROCESS OF SILVERING.

Prepare the following four solutions, which are only to be mixed together at the time of using, and when kept *separately* are said to undergo no change by keeping.

A:

- Solution *a* is made by dissolving 175 grains of pure crystallized nitrate of silver in 10 ounces of distilled water.
- Solution *b* is made by dissolving 262 grains of pure nitrate of ammonia in 10 ounces of distilled water.

B:

- Solution *c* is made by dissolving one ounce (avoirdupois) of pure potash (prepared by alcohol) in 10 ounces of distilled water.
- Solution *d*.—Dissolve half an ounce (avoirdupois) of pure sugar candy in 5 ounces of distilled water, then add 52 grains of tartaric acid and boil in a glass flask for ten minutes. When cool add one ounce of alcohol, and then dilute with distilled water so as to make up the volume of the solution to 10 ounces for use in winter, or to about 12 ounces for summer use.

Having previously estimated the amount of solution that will be required, which, in order to render the description clear, shall be assumed as 16 ounces.

Into a graduated measure first pour 4 ounces of solution *a*, and then to it add 4 ounces of solution *b*, and call the mixture A.

Into a second measure pour 4 ounces of solution *c*, and then add to it 4 ounces of solution *d*, and call the mixture B.

The contents of the vessel containing the mixed solution A is to be first poured into the silvering vessel, and then the mixed solution B is to be added to it and stirred together. The effect of the mixing shows whether the solutions are properly prepared. The solutions should not at once lose transparency on being mixed together, but should change in colour in about 30 seconds, first to a pinkish yellow, then brownish, and finally to an inky black; prior to this inky black state being arrived at, the mirror should be immersed face downwards in the solution.

The above process is exceedingly effective when the strength of the ammonia is correct. But as this salt has a tendency to largely absorb moisture, its strength cannot be relied upon. If the solutions turn too quickly, or if a brown precipitate is immediately formed, the ammonia is not sufficiently strong, and the result will be a very thin coating of silver, as the deposition will be in the solution and not on the mirror. This result will also take place if B is too strong, and therefore B should not be added too rapidly, in order that if a rapid change of colour seems imminent the addition may be at once stopped. I have adopted two methods of avoiding an excess or deficit of ammonia. With the proportions just given, take $3\frac{1}{2}$ ounces of solution *a*, and add 4 ounces of solution *b*, and then $3\frac{1}{2}$ ounces of solution *c*; if there is a precipitate add some more *b* until it is re-dissolved, and then proceed as if there had been no precipitate in the first instance. Add a few drops alternately of solutions *a* and *c* until a precipitate is just formed. If, however, all the remaining half ounces of *a* and *c* can be added without any change taking place, a few more drops of *a* are sure to produce the required precipitate.

The precipitate, when formed, can be removed by filtration, straining through cotton wool, or by allowing it to settle, and pouring off the clear solution. If this plan is followed out, 4 ounces of solution *d* must be added to the mixed solutions when they are in the dish. The second modification of this process has been devised by Mr. ACKLAND, and in it, also, the strength of the Nitrate of Ammonia salt need not be exact.

Solution A.—Dissolve 100 grains of nitrate of silver and 180 grains of nitrate of ammonia together in 8 ounces of distilled water, and then add 240 grains of pure potash previously dissolved in 4 ounces of distilled water. Shake or stir well together.

Solution B.—Dissolve 150 grains of sugar candy and 20 grains of tartaric acid in 12 ounces of distilled water and boil for ten minutes, and allow the solution to become quite cold, and then add one ounce of alcohol.

Solution C.—Dissolve 20 grains of nitrate of silver in one ounce of distilled water.

These three solutions should be kept in closely stoppered bottles in a cool dark place.

For use, measure out equal amounts of solutions A and B, but before mixing add solution C, drop by drop, to solution A, stirring or shaking briskly after each drop. A brown precipitate will soon be produced, which should be, if possible, re-dissolved by stirring. Directly there is a precipitate of sufficient density to cloud the solution, and on which stirring has no effect, allow it to settle for several minutes. When this is done pour off the clear or very slightly clouded solution into another vessel, leaving the precipitate behind. The solutions A and B may now be mixed together either in the silvering dish or mixing vessel, therefore gradually add B to A, stirring well all the time.

With Martin's process the time occupied with cold solutions seldom takes more than fifteen minutes, and in summer often much less. In fact, I have often effected the entire process, from cleaning to polishing, in less than half-an-hour.

DR. HENRY DRAPER'S FORMULA FOR SILVERING.

Solution B.—Dissolve 560 grains of Rochelle salt in 2 or 3 ounces of water and filter.

Solution A.—Dissolve 800 grains of nitrate of silver in 4 ounces of water; take an ounce of strong ammonia of commerce, and add the nitrate solution to it until a brown precipitate remains undissolved, then add more ammonia and again some nitrate of silver solution. This alternate addition is to be carefully continued until the silver solution is exhausted, when some of the brown precipitate should remain in suspension. The mixture then contains an undissolved excess of oxide of silver. Filter. Just before using, mix with the Rochelle salt solution, and add water enough to make 22 ounces.

A modification of this process has lately been tried with a fair amount of success In its employment the same chemicals are required, but in a different proportion; it is as follows:—

A.—Dissolve 2 scruples of nitrate of silver in 5 ounces of water and ammoniate, leaving an excess of silver. To this solution add B:—1 dram of Rochelle salt in 5 ounces of water, and the deposition of silver will soon commence. Both solutions may be filtered, or allowed to drain through a little cotton wool lightly stuffed into the neck of a funnel.

THE SUGAR OF MILK PROCESS FOR SILVERING.

The chief difference between this formula and that described at length consists in the substitution of sugar of milk for the sugar candy.

A.—Dissolve 2 drams of nitrate of silver, 1½ drams of pure potash; and B:—2 drams of sugar of milk, in equal amounts of distilled water. Pour two-thirds of the solution of silver into the mixing vessel, and add liquor ammoniæ until the precipitate first formed is just re-dissolved; now add all the solution of potash, and re-dissolve the precipitate. Directly the solution becomes clear add the remaining silver, drop by drop, until a *slight* precipitate is formed, which will not dissolve, even if stirred for several minutes. When ready for silvering add to the ammoniated solutions, freed from precipitate by subsidence or straining, solution B, which should be previously filtered, and may be also warmed if the weather is cold.

Both Draper's and the Sugar of Milk processes take about three times as long as Martin's.

The quantities of silver, etc., here given are sufficient for any amount of silvering solution up to 30 ounces; but it must be noted that the solutions need not be *over* strong; it will therefore be better to keep to a standard strength, such as the above quantities of chemicals to 20 ounces of solution, and roughly estimate the amount of each substance that will be wanted when the quantity of solution required has been ascertained.

GENERAL HINTS ON SILVERING.

Be very careful not to employ too much ammonia in preparing solution A. Do not mind an inky colour so long as there is no visible precipitate undissolved.

Be very careful to clean the superficial edges, as stains are more likely to appear there than anywhere else.

Never leave the mirror too long in its bath, as the film is sure to tarnish directly all the silver is thrown down; and the polishing may then prove a tedious process.

Keep the back of the mirror dry during the entire operation, but especially at its commencement.

Be very careful the film is perfectly dry before any attempt is made to polish it.

As pitch is soluble in ammonio-nitrate of silver, great care must be taken not to let any particles fall into the solution, or come in contact therewith, otherwise a thin silver film will be the certain result.

All thin articles to be silvered should be cemented to their supports with pure gutta percha and not with pitch.

Never attempt, except with Martin's process, to silver a mirror or "flat" in a room where the temperature is below 60° F., as the film produced will be thin, uneven, of a blue tint, and incapable of bearing a high polish.

ACCESSORIES TO THE TELESCOPE.

EYE-PIECES.

In order to successfully observe, it is of the greatest importance that a suitable eye-piece is employed. To an inexperienced observer the use of very high powers will be both disappointing and useless; he must remember that as the magnifying power of the instrument increases, so, apparently, does any tremor or vibration in the stand, and any unfavourable condition of the atmosphere. He will also lose much of the pleasure felt by those who possess instruments unprovided with clockwork motion, when they allow an object to slowly pass across the field of view, as with high powers this will be small. As experience increases, high powers may be used on favourable occasions and suitable objects.

The lowest power should have the largest field possible, as it will be employed for the observation of nebulæ, clusters, and comets, many of which occupy a comparatively large space in the heavens. No. 1 in the list of Aplanatic eye-pieces at the end of this book, magnifying 60 diameters on a 6 feet focus, exactly answers this requirement, and the observer cannot do better than select it as the lowest of his series. This power also gives a very beautiful view of the moon, the whole disc being contained in the field; but when the study of individual craters is desired, higher powers must be employed, say from 120 to 250. These latter eye-pieces will also be generally useful for planetary and stellar work. It will thus be seen that the three eye-pieces most suitable for a beginner are 60, 120 and 250. As the eye becomes trained to delicate observation, one or two of the highest powers should be added to the foregoing series—their use will be for splitting the closest double stars, and observing the minute craters on the moon.

The eye-pieces in the list are classed under the following heads: Huyghenian, Ramsden's, Aplanatic, and Kellner's. The first named is that most generally employed, as it is slightly more achromatic than the second form; but the Ramsden has the great advantage of giving a flatter field, and when each of its lenses is corrected for colour, no better eye-piece can be desired, especially on planets.

The Aplanatic construction is a modification of the Kellner, and possesses the same advantage—a very large field; they are, therefore, especially useful on nebulæ, &c.

SOLAR EYE PIECES.

The smallest sized speculum mentioned in this book, and any object glass above 2 inches aperture will concentrate sufficient heat to crack the coloured glass of an ordinary sun-cap, and thereby endanger the observer's sight. A specially constructed eye-piece is, therefore, absolutely necessary for continuous solar observation. One of the most simple methods of diminishing the sun's light and heat is the use of a Barlow's lens, silvered as the mirrors. A thin film should be deposited on each surface of the lens in preference to a single thicker film on one surface. These films are so transparent that when held up to the light they appear of an exquisite neutral tint, and when the lens thus coated is placed in its usual position in the draw-tube, and the Sun viewed through them, fine definition will be obtained, without any further protection.

Many observers use a diagonal eye-piece, in which one surface of the reflecting prism reflects sufficient light to secure perfect definition, whilst the excess of light and heat is transmitted through the prism.

We have lately constructed for Mr. Bessemer a solar telescope consisting of a 6-inch glass mirror, the front surface of which is polished to a parabolic curve, but unsilvered, and the back polished concave, so as not to give a second reflection, as it will present a transparent convex surface to the incidental light and will cause it to diverge. The cell is cut away so as to allow a large proportion of the light to pass through. The flat is also unsilvered, and being worked as an ordinary solar prism, also gives a single reflection; the back of the flat mount is also cut away to allow the light and heat to be still further diminished by passing through the transparent prism. With this instrument I have observed the Sun with ease without requiring any sun cap.

The late Mr. Dawes devised a solar eye-piece which bears his name; this consists of a diaphragm pierced with holes of various sizes placed in front of the eye-piece and capable of regulating either the amount of light or diameter of field. A cheap modification of this eye-piece has been lately introduced by Mr. Levander, in which a single aperture can be contracted or enlarged with great facility and exactness. A very good and safe plan of observing the Sun has been employed by Mr. Howlett: it consists in throwing the Sun's image direct from the eye-piece upon a white disc. The further the disc is off, the greater will be the magnified picture. Several observers can thus, together, view the solar disc, the phenomena of which will be the more distinctly seen if the Sun's rays are not allowed to enter the room, except through the telescope.

BARLOW'S LENS.

If in an achromatic object-glass the concave lens has a greater power than the convex, the resultant focus will be *negative*, that is, objects will appear to diminish when viewed through it. But if a small lens of this construction be inserted between the speculum and the eye-piece, the convergent rays falling upon it will be rendered more parallel, and therefore give the same result as if a glass of longer focus was employed, consequently the magnifying power will be thereby increased. (*See Sir J. Herschel on the Telescope, art.* 33).

This lens, when constructed in the usual manner, and placed about 5 inches from any eye-piece, increases the magnifying power by half as much again. It will thus be very easy to double any series of eye-pieces that may be chosen. For instance, suppose the series are 70, 130, and 250, these multiplied by 1·5 will give an extra series of 70, 105, 130, 195, 250, and 375. A variation of each of these powers can be obtained by shifting the position of the lens in the draw-tube.

We have lately placed a Barlow's lens between the flat mirror and the speculum, thereby considerably diminishing the size of the flat and securing a great increase of power and a flat field, without interfering in the least with definition.

THE MICROMETER.

This accessory to the Telescope is useful for many purposes. In the first place, it enables the diameter of any object, or its distance from another, to be accurately measured; and, secondly, when a position circle is applied to it, it determines the angle that a line joining these objects makes with the meridian. One form of this instrument is that called *The Parallel Wire Micrometer;* it consists of a small box within which slide two frames, on each of which are fixed some fine spider's threads, and which can be shifted apart by means of screws with graduated heads. Its mode of employment is as follows :—Suppose it be wished to measure the diameter of a planet, a wire properly focussed by the eye-piece would be brought to each side of the disc, and the distance apart of the wires then ascertained by the number of revolutions of the graduated heads that have been necessary. A notched scale of teeth also placed in the focus of the eye-piece assists in the rough measurement, accuracy being obtained by means of the graduated heads.

In this and in all other forms of micrometer the value of the divisions on the graduated head and of its entire revolution must be ascertained before the result just obtained can be reduced to minutes and seconds of arc. This may be done thus :—Separate the wires by any known number of revolutions of the head and allow an equatorial star to pass from one wire to the other. Accurately determine, by means of a clock or watch, the time this takes, and the amount, reduced to minutes and seconds of arc (page 76), will be the distance between the wires in that position; this can easily be calculated for any position of the threads, and for any number of turns of the heads or fractions of them.

If a position circle be added, the instrument is called *The Position Micrometer*. The box containing the parallel spider's threads and another single thread at right angles to them is attached to a moveable graduated circle. Suppose it be desired to measure the angle and distance apart of a double star, the observer should, as a rule, proceed thus :—Turn the circle till the single thread bisects one of the stars during its passage across the field of view, and make the circle to read at zero. The single line should now be brought to bisect each star, and the reading of the graduated circle will show the position angle of the stars. Their distance apart may be obtained by means of the parallel wires or threads, a wire being brought over each star as before described.

As the spider threads, from their excessive fineness, will be invisible in the field of view, some illumination of them is necessary, and this is generally effected by means of a small ray of light from a lamp.

THE DOUBLE IMAGE MICROMETER.

This instrument generally consists of a lens which has been divided in two semicircles, which can be separated by means of graduated heads, each half then forming a picture of the object viewed. Its method of employment will be thus :—Suppose, for example, it be desired to measure the diameter of the moon, the discs would be separated until the edge of the right limb of one image touches the left limb of the other; the number of revolutions of the graduated heads which have been necessary to do this reduced to their value in arc will give the lunar diameter at the time of measurement. The advantage of this form of the instrument consists principally in its applicability to other telescopes than those driven by clockwork. Other forms of micrometers have been invented, but those just described are in most constant employment.

BERTHON'S DYNAMOMETER.

By the aid of this simple but effective little instrument, the magnifying power of any eye-piece can be accurately ascertained. It can also be used to measure the diameter of wire, the thickness of metal, or indeed any round or flat object whose diameter or thickness does not exceed two-tenths of an inch; and its accuracy is such that its indications are correct to the one-thousandth part of an inch.

If a telescope, when focussed as for viewing a star, is directed to a bright part of the sky, or, better still, where the diameter of the telescope is large, to a distant and moderately well lighted object, and the eye is placed about 10 inches directly behind the eye-piece, a small clearly defined circle will be seen immediately in front of the eye-lens. This small disc is the miniature image of the object-glass and if the diameter of the clear aperture of the object-glass be divided by the diameter of this miniature image, the quotient gives the exact magnifying power of the eye-piece, when used with that particular object-glass. By the aid of the Dynamometer the diameter of the miniature image can be accurately measured, and the power of the eye-piece thence ascertained.

Having arranged the Telescope as above described, the process of measuring the image is performed as follows :—Holding the Dynamometer near the eye-piece, observe the miniature disc by the aid of an ordinary pocket lens of low power, shifting the Dynamometer until the two internal edges exactly touch the circumference of the image, note the division opposite the point of contact; this is the diameter of the image in decimals of an inch. Dividing now the diameter of the clear aperture of the object-glass by this decimal, the quotient is the exact magnifying power of the eye-piece when used with that particular object-glass. Example :—The clear aperture of the object-glass being 6·24 inches, and the diameter of the image, as indicated by the Dynamometer, being ·026, we obtain, by dividing 6·24 by ·026, a quotient of 240, which is the magnifying power.

The diameter of wire, sheet metal, or other suitable object, may be accurately ascertained by sliding it along until the two edges just touch the internal sides of the Dynamometer, when the division exactly opposite the point of contact is equal to the diameter of the article measured. Thus, if a wire passes freely up the wide end of the triangular opening until it is stopped at the first short division beyond ·04, its diameter is ·042 of an inch. The scale is so divided that each long division represents ·01, or the hundredth part of an inch. Each of the first two long divisions from 0 is divided into 10 parts, each of which is equal to ·001, or the thousandth part of an inch. Each of the remaining long divisions is divided into five parts, each equal to ·002, or the two-thousandth part of an inch.

THE ASTRONOMICAL SPECTROSCOPE.

It is not the writer's intention to go into the theory of the spectroscope, as so many admirable works have been written on this subject, but to briefly notice its application to the telescope. The student should consult Schellen's, Roscoe's, or Lockyer's books of the subject, or a most useful little book just issued by Proctor, should he desire further information. The spectroscope has lately been extensively used in the investigation and study of the heavenly bodies, and with wonderful success, fresh discoveries constantly being made.

Two forms of spectroscopes are commonly employed for astronomical purposes. The first consists of one or more prisms, with their apices pointing in the same direction, each prism widening the spectrum received from that next to it. As such a series is limited, on account of repeated deviation bringing the rays to the point from which they started, various arrangements are used to elevate the rays when they reach that point, and either re-transmit them through the same or another series of prisms. In spectroscopes of this construction we get both dispersion and deviation: in order to secure *direct* vision the arrangement of the prisms must be different, and such an instrument is accordingly called a direct vision spectroscope. The direct vision spectroscope is generally constructed on the principle that a flint glass prism will give a much longer spectrum than a crown glass prism whilst causing an equal deviation of light. If we look through a single flint prism we shall see an object considerably displaced; but if we now put in the opposite direction a crown prism of sufficient power to correct the deviation, we shall see the object in its correct place, but it will be tinted with the prismatic spectrum. It is therefore possible to balsam together a series of flint and crown prisms, and thereby obtain a considerable amount of dispersion, that is length of spectrum, without scarcely any deviation. It will be obvious that a number of prisms absorb a large amount of light, and therefore, to a certain extent, the length of the spectrum of an object is limited by its brightness. From the same cause the spectrum of the Sun can be enlarged to comparatively any extent, and, therefore, only a narrow strip of solar light is admitted by a slit. This strip can be taken from a part of the sun's surface crossing a spot, and therefore allowing the spectrum of the spot to be seen; or, if from the sun's limb bringing into view the spectrum of the corona and prominences, and even the prominences themselves. The focal image of a star, being a minute bright point, will illuminate a very small portion of the slit, and will appear in the spectroscope as a coloured line; and therefore a cylindrical lens is used to elongate the spot to a bright line, and give breadth to the spectrum, before the light passes through the slit. It being very difficult to keep the star-line exactly opposite the slit except with a most accurate driving clock; it was soon noticed that the slit was unnecessary, as there was a sufficient line of light formed by the cylindrical lens alone; such a spectroscope can be even used on an alt-azimuth. A spectroscope can therefore be used for stellar purposes, with or without a slit, a remark also applicable to the observation of nebulæ, comets, and other objects. Both convex and concave cylindrical lenses have been used.

The method of using all forms of spectroscopes being nearly similar, the following hints on observing different phenomena may prove useful to the possessor of *any* spectroscope, though, in respect to solar details, they are specially applicable to powerful instruments.

In order to properly observe the solar prominences a powerful spectroscope, applied to an equatorially mounted telescope, driven by clockwork, is necessary. But as they have been glimpsed by a comparatively small spectroscope on an alt-azimuth, the observer should not despair of seeing them with moderate means.

The prominences are examined with an equatorial, driven by clock-work, as follows:—Having discovered the exact focus of the telescope, by receiving the solar image on a card in place of the eye-piece, place the slit exactly at this spot. Now revolve the spectroscope till the slit is at right angles to the sun's limb. Notice that the sharp edge of the sun is seen across the slit, which at first may be narrow. Two spectra will be seen, the limb of the Sun giving a bright band of colour with dark lines, and side by side with this is a faint spectrum from the earth's atmosphere. If the slit be carried round the edge of the Sun, by the independent movements of the telescope, coloured lines will be seen on the faint spectrum directly the slit is over a prominence. These lines, which correspond to the solar lines, C, F, and D^3, will vary in length as the slit is carried across the prominence; and this variation will enable the exact shape to be ascertained. One end of the line being against the bright spectrum, will enable the *vertical* shape to be indicated by the variations of the other end. If the slit be now carried across the prominence at right angles to the former direction the *horizontal* shape can be ascertained in the same way. Should the line appear separate from the solar spectrum, that part of the prominence will be detached from the Sun.

If there is sufficient dispersion to nearly obliterate the fainter spectrum, the slit can be opened as widely as the light of the bright spectrum will allow, or this may be toned down by coloured glasses, and the entire prominence then seen at once, instead of in sectional lines. There will be an image of the prominence where each bright line was before situated. Either of these images can be seen in the field accordingly as the red, yellow, or bluish-green part of the spectrum is brought into view.

The method of viewing other celestial objects depends on the employment of a slit. If a slit is used it should first be sharply focussed by the eye-piece. The star having been found, is focussed to a line by the cylindrical lens, and the slit is placed over and upon this line. The spectrum can then be sharply focussed by means of the separate adjustments of the spectroscope and telescope. When once the correct position of the spectroscope has been ascertained, the above adjustment need not be repeated, but the object may be found through the prisms, and delicately focussed as usual.

If there is no slit, remove the tube containing the prism, and focus the star to a line by the cylindrical lens, either with or without an inner eye-piece, the eye being placed exactly where it would be if the prism was being employed. Having replaced the prism the spectrum can be delicately focussed to a sharp edged band, with the dark lines clearly visible, by means of the rack of the telescope. The method of viewing any other celestial object is similar in all respects, except that when the object cannot be focussed to a line, it should be elongated by the lens as much as possible.

The width of the slit should be regulated to the brightness of the subject and the sharpness of the lines: when using a cylindrical lens it may be opened very widely, in order to admit as much light as possible.

In viewing objects with a reflecting telescope the small mirror sometimes forms a dusky horizontal band across the centre of the spectrum. We have lately found that by the introduction of a Barlow's lens, very much under or over corrected, an image on one side of the focal point will be formed free from this band. On the other side it will of course be increased.

To view the combustion of a salt in a gas flame or spirit lamp :— Make a saturated solution of the salt, and into it dip a platinum wire bent to the loop, and introduce the wire and the solution which clings to it into the flame. If preferable a small piece of the salt or crystal can be fused whilst supported on the loop. Focus the slit by means of the sliding eye-piece, and direct the spectroscope to the flame. A slight alteration of focus and of the width of the slit may be necessary to distinctly show the bright lines. The same plan can be followed in viewing the Sun without a telescope, only the lines will be dark instead of light.

The small spectroscope about to be described forms a very convenient method of observing the spectra of meteors; for this purpose the spectroscope should be used by itself, and should consist of the prism and cylindrical lens alone.

A small right-angled prism is sometimes placed over part of the slit, in order that the spectrum of a known substance can be seen in the field, for comparison.

We have lately introduced a small direct vision spectroscope, which can be adapted to all varieties of spectroscopic investigation. A short description of this instrument may be useful.

HORNE & THORNTHWAITE'S MINIATURE UNIVERSAL SPECTROSCOPE.

This instrument consists of a series of direct vision prisms, a cylindrical lens, an adjustable slit, an achromatic lens to focus the slit; all enclosed in brass tubes, which, for astronomical purposes, can be affixed a low power eye-piece.

The instrument can be used in three forms; with the focussing lens and slit, for general purposes; with the cylindrical lens alone, for examining the stars, nebulæ, &c., with the aid of a telescope, and for viewing meteors, the Aurora Borealis, without such aid; and with the cylindrical lens and low power eye-piece for general observations of all astronomical phenomena, excepting those connected with the sun; the prism being, of course, always required. The second form cannot, perhaps, be used, unless there is a considerable amount of focal adjustment to the telescope, or a Barlow's lens be employed; but the third will focus at the same position as the eye-piece would be if used by itself.

OBSERVATORIES.

THE degree of perfection already reached by optical instruments demands a more careful study of their surroundings, including the question of all influences that may affect their free and perfect performance. Of these influences—after the almost inscrutable differences of atmospheric disturbance in different places—the effects of our buildings upon the definition of our telescopes is the most important consideration.

With the large apertures now in the hands of so many amateurs, the disturbance of the visual rays is so great and annoying, and so large a part of it is manifestly due to the observatory itself, that some of the most enthusiastic observers prefer the open canopy of the skies to the comfort and shelter of a revolving roof, when it is purchased at such a price. But it is now confidently hoped that these observatories, based upon the experience of years, will go far to dispel an error, which tends not only to destroy that perfect personal comfort so necessary to the free exercise of the delicate senses of an observer, but the due protection which a good telescope deserves.

It may be boldly asserted that the construction of observatories has proceeded, hitherto, upon a wrong principle. The instruments are generally, so to speak, smothered in the nests built for them, and almost "killed by kindness." Where expense is no object, solid structures of brick or stone are reared, with more or less massive domes, at a great expenditure of money and materials; herein lies the mistake, for it is now capable of abundant proof that the optical efficiency of observatories is in the inverse ratio of their solidity, and, provided the structure be capable of resisting all the storms that may beat upon it, the thinner it is the better it will fulfil its functions.

The two great desiderata in an observatory are—1, freedom from damp; 2, non-interference with heavenly rays. Both of these are entirely dependent upon temperature. (1) Damp is the condensation of moisture from the surrounding air upon any surface colder than itself—witness a glass of very cold water brought into a warm room; but more than this, a chief source of damp is the condensation of moisture from a portion of ground inclosed by solid walls, and covered over; and as artificial heat is manifestly inadmissible in an observatory, such a building, especially if it consists only of a ground floor, is simply a condensing chamber, and when any considerable rise of temperature occurs, as in a thaw, the walls run down with moisture, and the instruments are coated with dew, all of which is plainly attributable to the fact that the walls, &c., do not rapidly accommodate their temperature to that of the air, and they keep the instruments within them colder than they would otherwise be, and that for a considerable time. Again (2) as to the non-interference with rays from stars, &c., this also is entirely a question of temperature. Experiments with our large Newtonians, which seem to be peculiarly susceptible to these disturbances, have proved that their performance is seriously affected by a difference of one degree Fahr. between the temperature inside the building and out of doors. Especially is this felt in summer time, when walls and roof have been raised to a high temperature during the day, and keep on radiating heat far into the night. The question, then, is this: can an observatory be built absolutely and entirely free from those evils, and securing to perfection the desiderata named above? To this it is replied that it can, and that in a manner which secures every advantage at a price that places it within the reach of all who can afford the delights of a telescope.

The Romsey Observatory was the first of a great many that have been erected during the last few years, with uniform success. It has stood unscathed the storms of fifteen winters and the heat of fifteen summers, and it is still perfectly good and sound.

In respect to the two great desiderata mentioned above, it may be stated—(1) That the steel pinions of the sidereal clock are as bright after eight winters as when they were first polished. Yet, strange to say—to clear certain trees,—this little observatory stands in the wettest possible position, over the edge of a large extent of water meadows, and water is continually trickling within twelve inches of its boards. (2). As to the other desideratum. Two Newtonians, of the same size, excellence and kind of equatorial mounting have been repeatedly tried against each other on the same stars, &c., and with the very same eye-pieces, one instrument was in the building, the other outside, ten yards distant, at the same height. If there was any difference it was in favour of the observatory, which perhaps arose from the comfort experienced by the observer, and the quietness of a sheltered eye, to say nothing of the advantage of greater darkness in viewing delicate objects.

The advantages of a wide opening in the roof are manifest, and for reflectors (Newtonian), with which vertical views are easiest and best, it extends beyond the middle of the roof, the ridge of which is not central, but farthest from the opening side, so as to command these views with ease.

Finally, the advantages of this light structure are so abundantly proven that it is earnestly presented to the consideration of the very best observational astronomers.

To construct an Observatory on the Romsey model.

Procure ten good straight posts about 4 inches thick and 8 feet long, set them in the ground in a circle, 10 feet 4 inches in diameter, to a depth of 18 inches. Should it be desired to give the building a rustic appearance the posts may be left with the bark on, but they will last longer if it is removed; the lower ends should also be

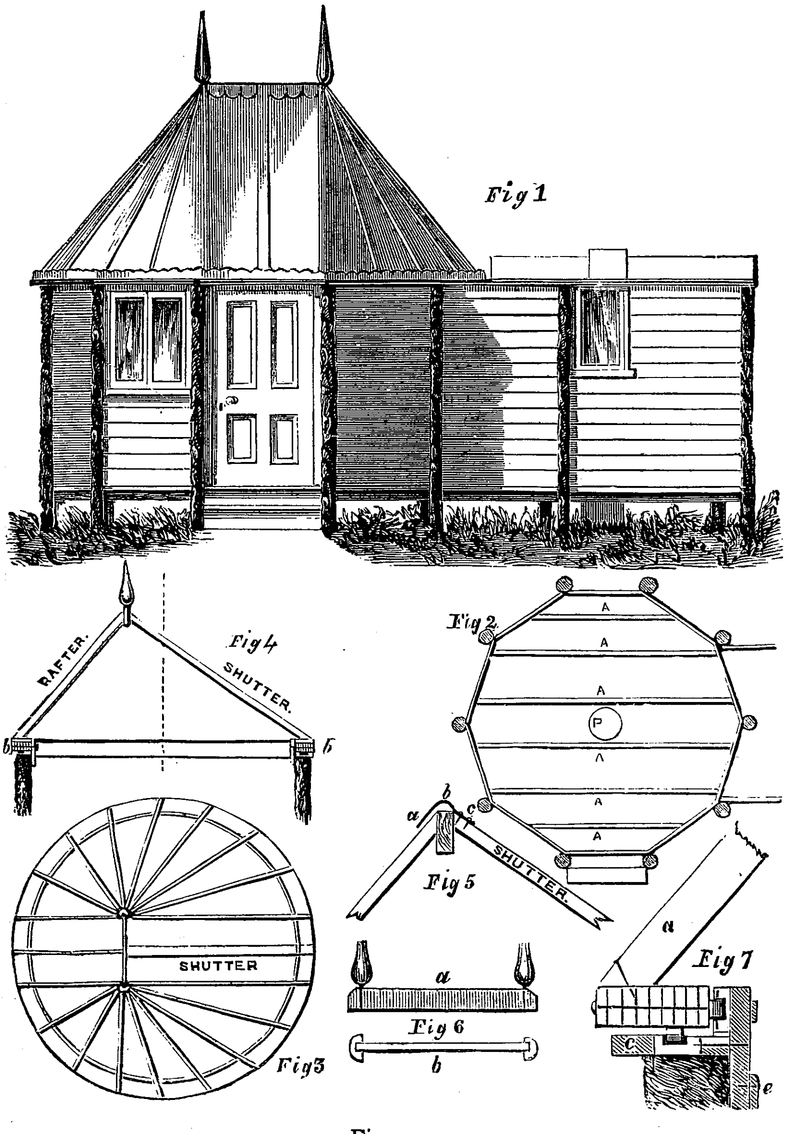


Fig 1
Fig 4
RAFTER.
SHUTTER.
b
b
Fig 2
A
A
A
P
A
A
A
a
b
c
SHUTTER.
Fig 5
SHUTTER
Fig 3
a
Fig 6
b
a
Fig 7
c
e

Fig. 30.

charred. In order to rapidly and accurately place the posts in the ground, first set up a temporary central post of the desired height, in which an iron axial pin is fixed, on which revolves a straight radius bar with spirit level attached. If this bar is marked at 5 feet 2 inches from the central pin it will serve to regulate the distance and height of each post. Nail a piece of inch board, 6 inches wide, so that one end rests on half the top of a post, and the other end on the post next to it. Ten of these will form the plate over which the roof will revolve. The next thing is the floor, which may be laid on joists 5 inches by 2 inches, supported by trimmers between the posts, or by stumps in the ground according to the fancy of the builder; the two middle joists will be placed wide enough for the telescope pedestal to stand between without touching. The walls, of thin weather-board, will be nailed on inside the posts, beginning at the top. The highest board, which may be of stouter wood, should be nailed to the plate also, and stand up 2¼ inches above it. (See Fig. 7.) Windows can be placed facing the best horizontal views, or the upper panels of the door can be of thick glass.

And now the important part is the revolving roof. The ring for this may be constructed in two ways, the latter of which is preferable. Some well-seasoned inch planks of red deal must be cut into segments of a circle, 10 feet 5 inches in diameter inside, 6 inches wide. They should be equal in length and sufficient in number to make two such circles. They must then be laid on the plate in two layers "breaking joint," using the radius-bar to regulate the circle accurately, then all nailed firmly together and the nails clinched. When this is done the ring can be lifted down and have its inner edge planed smooth with a compass plane.

The better plan to construct the ring is somewhat similar to that used to make a child's hoop; it is as follows:—Cut out of a flexible wood a number of lengths as long as possible and all exactly the same width, say about 2 inches or 2½ inches wide. The thickness of these pieces will depend on the flexibility of the wood; should this be softened in a lime kiln or well soaked in water they may be half an inch thick. Set up in the ground a number of short posts round which the ring is to be bent; these should be fixed within a circle slightly smaller than that originally marked by the radius bar, which may therefore be remarked accordingly and employed on a short central pin. A bracket should be fixed on the *outside* of each post at the same level, on which the ring is to rest. All the posts and brackets being prepared, bend a length of wood round the posts and secure each end to the nearest post by a clamp, and complete the circle with one or two more lengths, end to end. If the two or three lengths forming the circle are equal it will be advantageous. Having completed the inner circle, lay the centre of another length over the junction of two inner lengths and clamp all three together. Fix a length over each of the other joints in the same way, taking care that the ends meet but do not overlap. Proceed in the same way, laying ring over ring, removing the clamps when the outer length holds the inner, until a thickness of about 4 inches has been reached. A little care will prevent any joint being exactly over another, as the more evenly the joints are distributed the firmer will the ring be. Bore a number of holes with a small bit, just large enough to admit long French nails, which should be driven through from the inside and clinched on the outside, especial care being taken to firmly secure the ends of the outer lengths. Countersunk screws may be substituted for the nails. If the ring rests evenly on the brackets its upper and lower surfaces may be roughly planed, and will be ready for the rafters. If the ring has been made on the method first described, before the rafters can be affixed it must be supported on wooden stools or trestles, and great care must be taken that it is perfectly level all round; but if made on the better plan, the posts and brackets will hold it securely.

Cut out nineteen rafters from 7 feet to 9 feet long, and 2 inches by 1 inch thick, and two more 9 feet by 2 inches by 2 inches on which to hang the shutters. These will all be attached to the ring at equal distances, meeting together at the ridge, and fixed to the two semi-cylindrical blocks and connecting board, called the "ridge piece." See Figs. 3, 4, 5, and 6.

First set up the ridge piece on a temporary support, one foot out of centre, and to it fix, on one side, the stouter rafters on which the shutters are to be hung, and on the opposite side the rafters corresponding to them. The ends of these having been securely fixed to the ring, the side rafters may next be set up, and joined to the ring and the ridge. The rafters must first be cut to the proper length for their respective positions, and their ends cut to the proper bevels for fixing on to the ring and the ridge. The two stout rafters to carry the shutters will leave an opening—a parallelogram, 3-ft. wide, and about 8-ft. 6-in. long. The shutters, made of the same scantling as the rafters, with tranverse stretchers and diagonal braces, will have three hinges each, and a slip of strong canvas nailed over the joints; a light board 4-in. wide, screwed on over the canvas with which they are covered, is to lap over the middle joint. On their upper ends, where they abut against the ridge, they must each have a piece of zinc or galvanized iron, bent like *a*, *b*, *c*, Fig. 5, and nailed over the canvas. The spaces between the rafters should be filled by stretching good sail-cloth upon them, in gore-shaped pieces, and finally strips of wood, 1-in. wide, nailed over the tacks, and the lower ends of the canvas brought well down over the outer edge of the ring. A strong bar, turning on an axis fixed to the framework of one shutter, and crossing the other, can be used to keep them securely closed. This bar should have a cord fixed to each end, one cord to pull the bar into a horizontal position against a stop, and the other cord to pull it to a vertical position, and thus allow of the shutters being opened. The only remaining consideration is to make this completed roof revolve.

Procure from an ironmonger twenty sash rollers, the larger the better, and let ten of them into the plate, one over each post; these are the bearing rollers: the other ten must do duty as guides to prevent the roof shifting laterally; they must be set into blocks of wood, with their pins vertical, and the blocks nailed to the plate, and also to the upper board. (See Fig. 7.)

Though this roof revolves well when the rollers are oiled, it is better to have a small tackle, consisting of two single blocks, called in the navy a "gun tackle purchase;" the standing block being attached to the shutter frame, and a hook on the other block can be transferred successively to a screw eyebolt near the top of every other post inside, to pull the roof round.

A better but more expensive contrivance to revolve the roof consists of an endless iron rack, screwed to the ring, in which works a toothed wheel, with a strong pinion turned by a handle revolving on an axis fixed to the walls.

During the many years that observatories of this kind have stood, not one has had its roof blown off by a gale of wind. The force seems to act downwards on the conical surface: nevertheless, it is safest to have short lines, about one foot long, to lash it down to the eyebolts in one or two places.

The canvas should be well saturated with boiled linseed oil, and then have about three coats of paint, of the lightest gray colour, and the strips of wood and ornamentation, if any, round the eaves painted green.

The interior of the building will be finished by papering it on the canvas in the usual way; and any kind of light cornice upon the highest board adds to the internal appearance.

REFERENCES TO ILLUSTRATIONS.

Fig. 1.—South elevation.

Fig. 2.—Ground plan. A, A, A, &c., joists; P, pedestal of telescope.

Fig. 3.—Roof details.

Fig. 4.—Section of roof, N and S, showing the eccentricity of the ridge.

Fig. 5.—Section of ridge; ridge *b*; *a*, rafter; *c*, metal cover to ridge, attached to shutters.

Fig. 6.—Ridge, *a*, vertical section; *b*, horizontal section.

Fig. 7.—Upper end of a post; *a*, rafter; *c*, plate; *e*, weather board.

Partly from the *English Mechanic.*

HORNE & THORNTHWAITE'S ASTRONOMICAL CLOCK.

Fig. 31.

An accurate timekeeper is one of the most useful adjuncts to a telescope; in fact, the report of an observation, to be of any astronomical utility, must be always accompanied by the exact sidereal time at which it took place. An instrument of this perfection is generally very expensive, but Messrs. HORNE & THORNTHWAITE have introduced the above in the hope that it will supply a want long felt amongst amateur astronomers of a really reliable clock, fit for astronomical purposes, at a reasonable price.

The Escapement is dead beat, maintaining power to go whilst being wound, the pendulum is compensated so as to be uninfluenced by a rise or fall of temperature—the dial is enamelled, and the outer case is of polished mahogany.

HORNE & THORNTHWAITE have a direct *hourly* signal from Greenwich Observatory to their Strand Establishment, for the purpose of thoroughly and readily testing the qualities of these clocks, and ascertaining their uniformity of rate, and they are thus enabled to speak in high terms of the regularity of their performance.

Clocks of a similar quality, showing MEAN time, can be supplied at the same price.

The compensating Pendulum used is a slightly modified form of that so highly extolled by Captain KATER. It is easily adjusted, the centre of oscillation is low, and, unlike the mercurial form, cannot be put out of adjustment during transport.

The rod *a*, Fig. 32, is of straight white deal which, after two days' baking in a japanner's stove, was thoroughly impregnated with melted SOLID paraffin (this being found the best of all materials to prevent the action of damp). The deal rod passes freely through the pendulum bob *b b*, and is furnished at the lower end with a regulating screw, *c*, a divided nut, *d*, and a clamping nut, *e*; and at the upper part with the spring, *f*, and suspension pin, *g*. A bar of zinc, *h*, bent as shown in the cut, with a hole through which the regulating screw, *c*, passes; and to the top of this bar of zinc the pendulum bob, *b b*, is firmly fixed by screws at *i*.

The mode by which correction for variation of temperature is produced in this pendulum can be readily understood. Assuming that at a given temperature the Clock is keeping correct time—now, it is evident that if the temperature rises that the spring *f*, deal rod *a*, and screw *c*, will be lengthened by that increase, and this lengthening would (unless otherwise prevented) lower the pendulum bob, *b b*, and thus lower the centre of oscillation, causing the Clock to *lose*. To prevent this, the bent zinc bar, *h*, is introduced, to which the pendulum bob is fixed at *i*. This on an increase of temperature can only expand upwards, resting as it does on the upper part of the

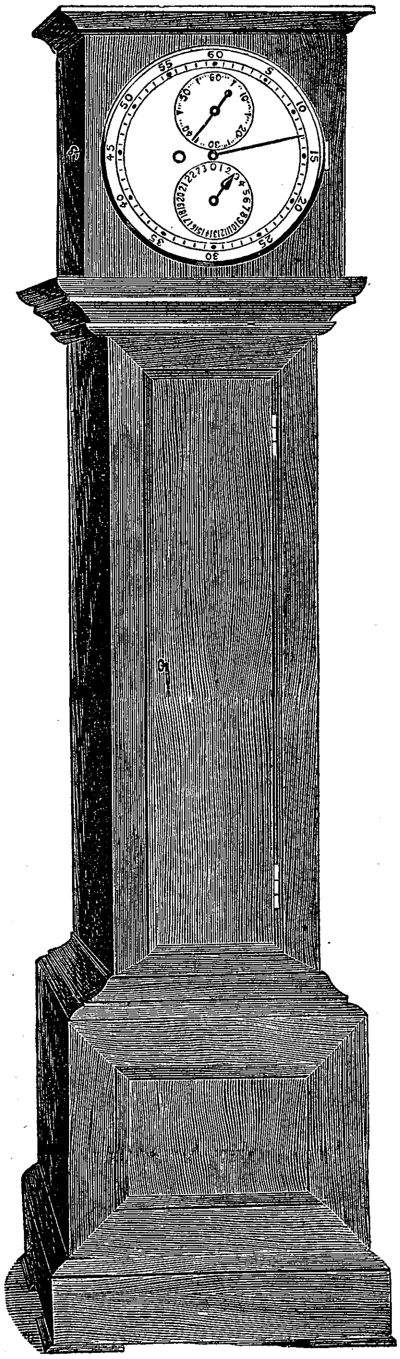


Fig. 31.

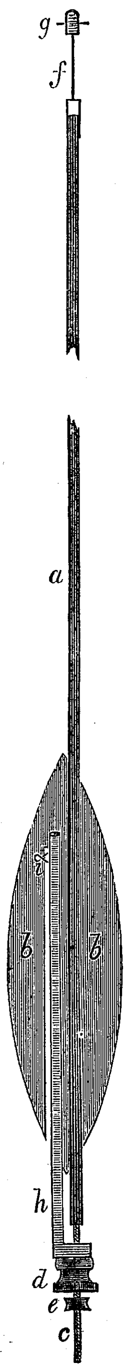


Fig. 32.

divided nut *d*, and when such an expansion does take place, its length has been so arranged that it carries upwards the pendulum ball, *b b*, *exactly* as much as the spring *f*, the rod *a*, and screw *c*, would tend by their united expansion to lower it, and thus, by preserving the centre of oscillation always at the same distance from the suspending pin *g*, the Clock is uninfluenced by changes of temperature; for it need scarcely be mentioned that if a decrease of temperature occurred, the very reverse would take place, the spring *f*, rod *a*, and screw *e*, would contract, tending to carry upward the bob *b b*, but this would be counteracted by the zinc bar, *h*, shortening just as much, and thus preventing any variation of the centre of oscillation.

HINTS ON OBSERVATION.

Always select the time and circumstances most suitable to the particular observation to be made.

A dark night on which the stars appear of great brilliance is generally most suitable for the examination of faint objects.

A night on which there is a slight haze, or when there is either moonlight or twilight will often prove most valuable for viewing bright objects.

The character of the definition depending on atmospheric influences can be generally ascertained by putting a star's image out of focus and noticing if the enlarged disc appears covered with undulating waves or perfectly quiet, the latter state is of course the better. This experiment should not be tried until the telescope has been for a few minutes exposed to the air.

The most important element in obtaining the finest definition is correct focussing. Before observing nebulæ, clusters, or difficult double stars, sharply focus on a moderately bright *single* star.

Should the possessor of a telescope be short or long sighted, and wish to exhibit celestial objects to his friends, it will be his wisest plan to first bring his eye to a normal focus by means of an eye-glass and then to focus with this assistance. For it is best, if possible, not to allow inexperienced friends to focus for themselves unless peculiarity of vision compels them to do so. I have often been amused at a preference shown for *stars* out of focus; an inexperienced eye likes to see celestial objects as *large* as possible, and therefore prefers the larger disc seen inside or outside the focus to the minute spot seen at that point. The focus of the eye shortens with long continued gazing.

Endeavour to cultivate the use of both eyes; it frequently happens that the habit of using only one eye prevents the employment of that most sensitive to light or planetary details.

Never overpress magnifying power. A skilled observer will see far more with a moderately low power than a tyro with the deepest eye-piece ever made. Very faint objects can often be seen when looking at another part of the field, or as it is technically called, "oblique vision." If the eye be kept a few minutes in the dark before observing faint objects, it will be more sensitive to them.

Nearly all the best drawings of planets have been made with powers of from 200 to 300.

It has also been found advantageous to occasionally shift the position of an object in the field when it is being drawn, as the eye will not be so fatigued if various portions of the retina are employed.

Several instruments for ascertaining star magnitudes have been invented, but nothing is better than an adjustable aperture.

The colour of a star can often be best estimated as an out of focus disc, especially with reflectors. Never judge the colour of a star near the horizon.

Never attempt to view the Sun without a special eye-piece. A neglect of this simple precaution may, in an instant, cause the observer the loss of his sight.

When viewing the Moon with powerful telescopes, employ a light blue or neutral tinted glass, to diminish the amount of light, which from a large aperture is perfectly unbearable, especially to observers whose eyes are weak.

Observations of Mercury and Venus are most satisfactory if made during the day; for this purpose an equatorial is almost indispensable, though both planets may be sometimes picked up without that assistance if their right ascension and declination are compared with other objects visible in the daylight. Proctor has well shown how this may be done in one of his most useful "Half Hours."

Of the satellites of Saturn, a telescope of 2-inches aperture should show Titan; one of 3-inches, Titan and Iapetus; 4-inches, both these, Rhea, and Dione; 6-inches, all the former, Tethys, and perhaps Enceladus; the fainter satellites cannot possibly be seen with a less aperture than 10-inches, and that with exceptionally favourable definition.

Stops can be cut out of cardboard, or thin zinc, or tin; and should always be blacked with some lamp-black and gold size.

Stops should be supported a few inches in front of the tube of a reflector, in order that the air may have free egress between the end of the tube and the stop, and not pass *through* the stop.

Stops are seldom required with telescopes of less than 4 inches aperture, unless the edge of the object glass or mirror is imperfect. As a rule specula are worked in discs of the required size, and therefore the extreme edge is often slightly defective. This is the reason why there are $6\frac{1}{2}$, $8\frac{1}{2}$, $10\frac{1}{2}$ and $12\frac{1}{2}$ mirrors, it being supposed that the marginal $\frac{1}{4}$-inch shall be covered with a stop. But many mirrors perform admirably up to the extreme edge, and only require stops from defective atmospheric conditions. With large telescopes a series of stops of various sizes are most useful.

The first stop should be just enough to cover the extreme margin, and then a series, diminishing by inches of diameter. Thus, for a 12-inch mirror or object glass, they should be of the following inches:—$11\frac{1}{2}$, 11, 10, 9, 8, 7, 6, 5, and 4. The latter will probably never be wanted, except for comparison or viewing the Sun. Never employ a smaller stop than *absolutely* necessary.

When there is an easterly wind, the best telescopes may show stars with triangular discs: this defect may be partially remedied with a properly constructed stop. Cut out a circle the size of the telescope tube, and from the same centre draw another circle, of such diameter that, while it is as near as possible the aperture of the telescope, there may be a sufficiently strong ring between the circles to support the segments to be described. Join the circumference of the inner circle with three equidistant chords, of 60°. Now cut away all the surface of the inner circle excepting the three segments enclosed by the chords and the circle, and, therefore, leaving them attached to the ring. This stop should be revolved in front of the aperture until the segments cover the angles of triangular stars.

A very useful stop can be made out of perforated zinc or cardboard; if the entire aperture be covered the definition of bright objects will often be greatly improved.

Many other shaped stops are sometimes employed; eccentrical openings being often used with reflectors, on account of the small mirror. Central stops are sometimes useful, especially with slightly inferior glasses.

The diameter of the field of each eye-piece should be ascertained. To do this, notice the time a star, whose declination is almost nil, takes in passing across the *centre* of the field. This time multiplied by 15 will give the diameter in arc.

To preserve the silver film of a glass mirror, never bring it *uncovered* from a cold to a warmer place, as a deposition of moisture is sure to take place, which will sometimes do more injury than a shower of rain. If an accidental deposition takes place, do not attempt to wipe the moisture dry, but place the mirror at some distance in front of a fire, until it has been driven off.

At sunrise there is often a rapid rise in temperature after a cold night, and therefore there is a chance of moisture being deposited on the specula of a telescope left in a closed observatory. The chance of this taking place is much lessened by the ventilated tubes now employed, and it may be still further obviated by placing a small lamp, with its flame distributed by means of a piece of wire-gauze, at some distance under the speculum during a cold night. The heat should be just sufficient to gently warm the mirror, and the air above it, a few degrees.

Do not polish the silver film more than absolutely necessary, or too often. A few spots will only occasion a small loss of light, and will not materially affect definition.

The best light for an observatory is an ordinary, dark, bull's-eye lantern, burning benzoline spirit.

The best material to clean lacquered brass work is a piece of chamois leather and a little sweet oil.

Always make notes of each observation, showing the power used, the character of the definition, &c.

Amongst the most useful Astronomical books are Proctor's "Half Hours" with the "Telescope" and "Stars," for the tyro; Webb's "Celestial Objects," Proctor's "Star Atlas," and Chambers' "Practical Astronomy," for the student, with the addition of Loomis' "Astronomy," for the practised observer.

Other useful works are Proctor's "Spectroscope," Beckett's "Astronomy without Mathematics," and Darby's "Astronomical Observer." The latter work is, I fear, out of print, but, apart from a few mistakes, it is a very useful work, especially to an observer who does not possess an equatorial.

For theoretical works, Herschel's "Telescope" and "Astronomy" are most useful.

The possessor of a telescope should also subscribe to the "Astronomical Register," the "Observatory," and the "English Mechanic."

DEFINING AND SEPARATING TESTS.

β Leporis	2″·8	282°	3·5, 14
ρ² Eridani	2″·7	87°	5·5, 10·5
Σ 2941 Serpentis	2″·6	2°	7·5, 11
6 Serpentis	2″·2	13°	5, 12
γ Equulei (A-B)	2″·1	277°	5, 11
κ Leonis	2″	210°	5, 10·5
ν Scorpii (C-D)	1″·9	48°	7, 8
90 Herculis	1″·9	123°	6, 10
52 Orionis	1″·8	200°	6, 8
3 Monocerotis	1″·8	356°	5·5, 10
42 Orionis	1″·8	220°	5, 9
2 Vulpeculæ	1″·8	124°	6, 11·5
33 Orionis	1″·7	26°	5, 6
2 Camelopardi	1″·7	299°	5·5, 7·5
6 Cassiopeiæ	1″·7	197°	6, 8·5
μ Libræ	1″·6	345°	5·5, 6·25
δ Cygni	1″·6	336°	3·5, 9
λ Ophiuchi	1″·5	33°	4, 5
σ² Cancri	1″·5	332°	6, 6·5
P. I. 123 Piscium	1″·5	212°	6·5, 8
Σ 3062 Cassiopeiæ	1″·5	293°	6, 7
36 Andromedæ	1″·4	356°	6, 6
π Aquilæ	1″·4	119°	6, 7
42 Ceti	1″·4	349°	6, 8
τ Cygni	1″·3	172°	5, 7·5
35 Comæ (A-B)	1″·3	58°	5, 8
ζ Herculis	1″·3	147°	3, 7
14 (*i*) Orionis	1″·3	212°	5·5, 7
π Cephei	1″·3	20°	5, 10
191 Virginis	1″·2	216°	7, 7·5
73 Ophiuchi	1″·1	255°	6, 7·5
ο Σ 170 Canis Min.	1″·1	121°	6·5, 6·5
ε Arietis	1″·1	200°	5, 6·5
P. xix. 108 Draconis	1″·0	342°	9, 9
1 Coronæ	1″·0	299°	6, 6
η Orionis	1″·0	82°	4, 5
P. xi. 111 Ursæ Maj. (A-B)	1″·0	344°	6, 6·5
68 Hydræ	1″·0	256°	7, 10
P. xix. 263 Cygni	0″·9	195°	7·5, 8
ζ Boötis	0″·9	300°	3, 3·5
ζ Cancri (A-B)	0″·8	108°	6, 7
P. iii. 46 Arietis	0″·8	91°	8, 9
167 Herculis	0″·8	212°	7, 9
1 Delphini	0″·8	343°	6, 9·5
η Coronæ	0″·7	69°	5·5, 6
μ² Boötis	0″·7	143°	6, 7
λ Cygni (A-B)	0″·7	87°	5, 6
95 Ceti	0″·7	73°	5·5, 10·5
59 Aquilæ	0″·7	137°	7, 8
P. xx. 177 Delphini	0″·6	210°	7·5, 8
φ Draconis	0″·6	63°	4·5, 6
52 Arietis (A-B)	0″·6	269°	6·6
γ² Andromedæ	0″·6	110°	7·5, 8
Σ 749 Tauri	0″·6	23°	7·1, 7·2
P. xi. 9 Leonis	0″·6	286°	7·5, 7·5

ν Scorpii (A-B)	0″·6	1°	4·4, 7
42 Comæ	0″·5	13°	4·5, 5
22 Crateris	0″·5	143°	6·4, 6·9
2 Serpentis	0″·5	119°	6, 6
14 Lyncis	0″·5	63°	4·7, 7·2
λ Cassiopeiæ	0″·5	142°	5·5, 5·5
β Delphini	0″·5	15°	4·5, 7
19 Draconis	0″·4	303°	7, 7·5
7 Tauri	0″·4	232°	6, 6·5
ω Leonis	0″·4	67°	6, 7
4 Aquarii	0″·4	157°	6, 8
o Σ 24 (Burn. 235) Cass. (A-a)	0″·4	65°	7, 8
χ Aquilæ (A-B)	0″·3	70°	6, 6·5

Most of the first forty stars in this list should be divided by a 5-inch speculum or object-glass. The beginner will, however, find some difficulty in seeing the companions to such stars as β Leporis, 6 Serpentis, δ Cygni, &c., with less than six or six-and-a-half inches of aperture. Such pairs as ζ Herculis. δ Cygni. 90 Herculis, &c., are often best seen in bright twilight, some of the best measures indeed of δ Cygni have been made an hour before sunset. ζ Boötis is almost invariably best seen in twilight. Six-and-a-half inches should show the first fifty or so on this list, but the tyro must not expect to see such stars as 95 Ceti or 1 Delphini double with such an aperture except on the very rarest occasions; at least nine inches will be requisite to see these well. An eight-and-a-half or nine inch telescope will exhibit the next ten or twelve stars, and ten inches should show the remainder. The distances under 5″ in these lists are given, where possible, to the nearest tenth of a second, and the position angles to the nearest degree. The measures are mainly from Dunêr, Baron Dembowski, Burnham, Gledhill, Wilson, and Seabroke, &c., and are the latest the writer has been able to obtain ; but as many of the stars are binaries, a few years will of course make a considerable alteration in both the position angles and distances entered in the lists.

LIGHT TESTS.

γ Crateris	3″	102°	4, 11·5
ν Ceti	7″·7	82°	4·5, 12
P. xi. 111 Ursæ Maj. (A-C.)	13″	142°	6, 13
P. xvii. 94 Ophiuchi	4″	67°	7, 13
72 Virginis	30″	16°	7·5, 13
58 Ceti	3″·5	15°	6·5 (var.) 14
15 Monocerotis (A-B, A-C, A-D)	2″·7, 15″, 40″	206°. 15°, 307°	6, 9·5, 15, 14
30 Pegasi	5″, 10″	20°, 220°	5, 14, 14
δ Cancri	45″	121°	4·5 15
η Canis Minoris	5″	30°	6, 15
ε Trianguli	4″	119°	5·5, 15
P. xxiii. 179 Piscium	2″·4	228°	8·5, 15
ω^2 Aquarii	5″·6	89°	5, 15
110 Herculis	55″	110°	5, 16
85 Virginis	30″	320°	6, 16
β Equulei (A-B, B-C, A-D)	35″, 3″, 50″	314°, 14°, 278°	5, 13, 16, 14
55 Andromedæ	25″	350°	5·5, 16
P. xx. 177, 8 Delphini (A-C)	20″	121°	7·5, 16
P. xiv. 212 Libræ	(A-B) 10″, 20″ (A-C)	273°, 320°	6, 8, 16
14 Monocerotis	10″	207°	6, 16
μ Andromedæ	49″	110°	4, 16
γ Equulei (A-C.)	25″	10°	5, 17
τ Boötis	10″	350°	4.5 17
94 Ceti	5″	260°	5.5 17

τ Orionis	(A-B.), (B-C.), (A-D.)	15″, 2″, 20″	250°, 55°, 64°	4, 15, 16, 12
Procyon ...	... ...	42″	312°	1, 17
4 Delphini	... ...	10″	359°	4·5, 17
χ Aquilæ (A-C.)	... ...	1″·7	360°	6, 17
α^2 Capricorni	... (A-BC.)	6″, 1″·5 (B-C)	145°, 250°	3, 14, 16
5 Monocerotis	... ...	35″	30°	4·5, 17
κ Leonis (A-C.)	... ...	45″	30°	5, 18
o Σ 24 (Burn. 235) Cassiop.				
A-B, 44″; A-C, 61″; B-b, 5″; C-c, 8″.			288°. 67°, 80°, 49°	A 7, B 11½, C 11½, b 18, c 17
η Cygni ...	... (A-B.)	20″, 30″ (A-C.)	170° 332°	4·5 (var.), 18, 18
β Aquilæ...	... ...	12″	17°	3½, 18
ζ Aquilæ ...	.. ...	5″	60°	3½, 18
α^2 Cancri...	... ...	10″	320°	4·5, 18
σ Coronæ (A-C.)	... ...	20″±	232°±	6, 20
Regulus ...	... (A-B)	176″, 5″ (B-C.)	307°	1, 8·5, 20
β Lyræ ...	... ...	46″±	270°±	3, 20

The first seven stars should be shown by a five inch telescope.
,, twenty-one or twenty-two ,, six-and-a-half inch telescope.
,, twenty-five ,, eight-and-a-half inch telescope.

The remaining stars on the list will be found good tests for telescopes of from nine to fourteen or fifteen inches aperture.

The magnitudes given are expressed according to Herschel's scale, but those of the smaller stars on the list are necessarily liable to considerable uncertainty.

For the above lists I am indebted to the great kindness of Mr. Herbert Sadler.

CATALOGUE

OF

Reflecting and Refracting Telescopes,

AND THEIR ACCESSORIES.

ACHROMATIC PERSPECTIVE GLASSES.

Page 11.

		£	s.	d.
Perspective Glass, with enamelled or leather-covered body	... ...	0	7	6
,, ,, ivory and gilt draw	... .	0	13	0
,, ,, ,, ,, larger size ...	... ...	0	16	0
More powerful glasses	£1 1s., £1 10s.,	2	2	0

ACHROMATIC OPERA GLASSES.

Page 11.

Opera Glasses, with leather-covered bodies, six lenses in flexible cases,	12s. 6d., 15s., £1 1s., £1 7s. 6d.	£2	2	0
,, ,, ,, ,, twelve lenses	£3 3s.	£4	4	0

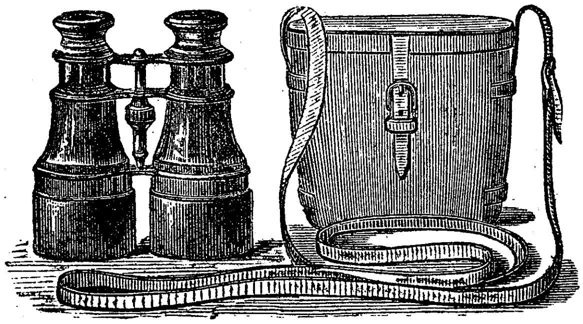


Fig. 33.

ACHROMATIC FIELD GLASSES.

Page 11.

Field Glasses, with leather-covered bodies, sun shades, six lenses, in sling cases (Fig. 33)	£1 1s., £1 10s., £2 2s.,	£2	12	6
,, ,, ,, ,, ,, twelve lenses	£3 3s., £4 4s., £5 5s.,	£6	6	0

In addition to the above, Opera and other glasses can be obtained in many varieties of fancy mountings.

Any of the above in Ivory bodies	20 per cent extra
,, Pearl ,, ...	75 ,,
,, Aluminium mounts	100 ,,

HORNE & THORNTHWAITE beg to direct especial attention to the following glasses, which they have selected from their extensive Stock as being most suitable to the ordinary requirements of their customers.

The "ADELPHI" Opera Glass. This instrument consists of a pair of achromatic object glasses 1¼ inches in *clear* aperture; and eye-pieces; mounted in metal bodies, covered with black leather, with the necessary focussing arrangement. It weighs 8 ounces, and is enclosed in a flexible case. £1 1s.

The "GEM" Opera Glass. This instrument consists of a pair of achromatic object glasses 1 inch in *clear* aperture, and eye pieces; mounted in metal bodies, covered with mother of pearl; with the necessary focussing arrangement. It weighs 6 ounces, and is enclosed in a flexible case. An elegant present. £2 2s.

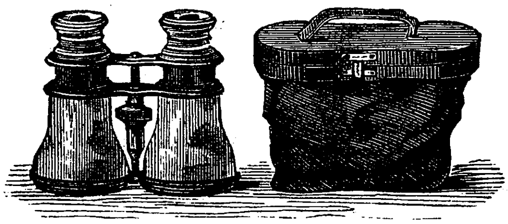


Fig. 34.

The "STRAND" Opera Glass (Fig. 34). This instrument consists of a pair of achromatic object glasses 1½ inches in *clear* aperture, and eye-pieces; mounted in metal bodies, covered with ivory; with the necessary focussing arrangement. It weighs 10 ounces, and is enclosed in a flexible or sling case. Suitable for general use at places of entertainment. £2 5s.

The "TOURIST'S" Glass. This instrument consists of a pair of best achromatic object glasses, 1½ inches in *clear* aperture, and eye pieces; mounted in metal bodies covered in black leather; with the necessary focussing arrangement, and sun shades. It weighs 17 ounces, and is enclosed in a sling case. A useful companion for a traveller. £3 3s.

The "UNIVERSAL" Glass. This instrument consists of a pair of best achromatic object glasses, 1¾ inches in *clear* aperture, and revolving eye pieces of three different powers; mounted in metal bodies covered with black leather; with the necessary focussing arrangement, and sun shades. It weighs 23 ounces, and is enclosed in a sling case. Suitable for all purposes and to all sights. £4 10s.

The "YACHTING" Glass. This instrument consists of a pair of best achromatic object glasses, 1⅞ inches in *clear* aperture, and eye pieces; mounted in metal bodies covered with black leather; with the necessary focussing arrangement, double draw, and sun shades. It weighs 25 ounces, and is enclosed in a sling case. Suitable for pilots, yachtsmen, and general marine purposes, being one of the most powerful glasses made. £6 10s.

ACHROMATIC TELESCOPES,

With Erecting Eye Pieces. Page 12.

NAVAL TELESCOPES, with cylindrical or taper bodies covered with leather, single or double draws, sun and spray shades, £1, £1 10s., £2 2s., £3 3s., £4 4s., £5 5s., £6 6s., £7 7s., £8 8s.

NAVAL TELESCOPE, Admiralty pattern, with 2⅛ object glass, fitted in a leather covered taper body, leather caps and slings, nickel plated fittings and focussing draw tube. £3 15s.

MILITARY TELESCOPES. Double draw in cases, £1 11s. 6d., £3 3s., £4 4s. The smallest size will show a bullet mark at 1,000 yards.

MILITARY TARGET TELESCOPE. Pancratic eye piece, focussed by rack and draw, on portable tripod stand, with registering board affixed, in case complete, £9 10s.

Any of the above telescopes are suitable for deer stalking or similar purposes, but HORNE & THORNTHWAITE manufacture a special telescope, with micrometer eye-piece, by means of which the exact distance of the object aimed at can be ascertained, and the rifle sighted accordingly. This telescope is also very suitable for military purposes, £7 5s.

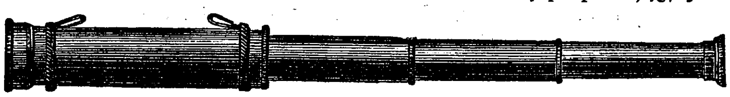


Fig. 35.

TOURISTS' TELESCOPES (Fig. 35). These telescopes are made in several draws, so as to close up into a small case ; all the tubes, &c. are made as light as possible, so as to ensure portability. The smallest size will show bullet marks at 800 yards, and distinguish objects at a distance of 8 miles. 10s. 6d., £1 1s., £1 10s., £2 2s., £2 12s. 6d.

THE ALPINE TELESCOPE. This Telescope, although weighing only four ounces, is capable of showing bullet marks at 800 yards, and windows in houses 8 miles distant. Its extreme portability recommends it strongly to the Alpine Tourist, enabling him to observe, even when travelling on railroads or steamboats, objects in the landscape with perfect ease. This telescope has been thoroughly tested by an experienced Swiss traveller, and found to fulfil all the requirements needed, with such portability as to still further recommend it. £1 1s.

HORNE AND THORNTHWAITE'S BINOCULAR TELESCOPES.

This instrument consists of a pair of precisely similar telescopes, placed side by side at a distance adjustable, by means of a screw, to the width between the observer's eyes A second screw focusses both eyepieces. Though this binocular is not much larger than a field glass, its power is much greater. Price in sling case, £8 8s. Larger sizes, £10 10s., £15 15s. In Aluminium, £16 10s., £18 10s., £24.

MAHOGANY STANDS for any of the above £1 18s. to £2 10s.

TELESCOPE CLIP to fasten to window frame 17s. 6d. to £2 2s.

UNIVERSAL JOINT to fasten into a tree 12s. 6d. to £1 1s.

REFRACTING TELESCOPES FOR ASTRONOMICAL PURPOSES.

Page 12.

HORNE & THORNTHWAITE beg to give notice that all object glasses in the following Lists are worked under their personal superintendence, and with the assistance of their extensive series of optical tools, which they have augmented with the original tools employed by the Dollonds, and recently purchased from that firm. They can, therefore, confidently guarantee their new object glasses to be equal to any yet produced.

TELESCOPE, with polished brass body, rack and draw adjustment to focus. achromatic finder with the necessary adjustments, dew cap, packed complete in mahogany box, and

Object Glass ...	2½-in.	3-in.	3½-in.	4-in.	4½-in.	5-in.	6-in,
	£7 5s.	£11	£15 10s.	£22 10s.	£32	£45	£71

TELESCOPE as above, mounted on tall mahogany garden stand, and

Object Glass ...	2½-in.	3-in.	3½-in.	4-in.	4½-in.
	£14	£18	£25	£34	£45

TELESCOPE as above, mounted on tall mahogany garden stand, with horizontal and vertical screw motions, and

Object Glass ...	2½-in.	3-in.	3½-in.	4-in.	4½-in.
	£18	£2	£30	£40	£52

TELESCOPE as above, mounted on a portable equatorial stand, with a few degrees adjustment in latitude. Hour circle, with double divisions and two verniers, declination circle, tangent screw motions to both circles, which are divided on brass, counterpoise, and requisite levels, and

Object Glass	3-in.	3½-in	4-in.	4½-in.	5-in.	6-in
	£30	£40	£50	£65	£85	£105

Two forms of these instruments are manufactured—the Berthon Portable Stand, page 18, and Fig. 5, and the modified German Equatorial, page 17, and Fig. 4. Either a firm wooden tripod or an iron pillar is included.

TELESCOPE as above, on best fixed equatorial stand, with considerable adjustment in latitude, hour circle with double divisions and verniers, declination circle, both divided on silver with reading microscopes, driving clock and independent hand motions, counterpoise and requisite levels, and

Object Glass	3½-in.	4-in.	4½-in.	5-in.	6-in.
	£68	£80	£92	£110	£140

HORNE AND THORNTHWAITE will furnish special estimates for equatorially mounted telescopes of larger aperture, and for any of the above stands without the telescope. They have also thought it better *not* to include eye pieces, &c., in the above prices : customers can, therefore, select those most suitable to their requirements from the list of accessories.

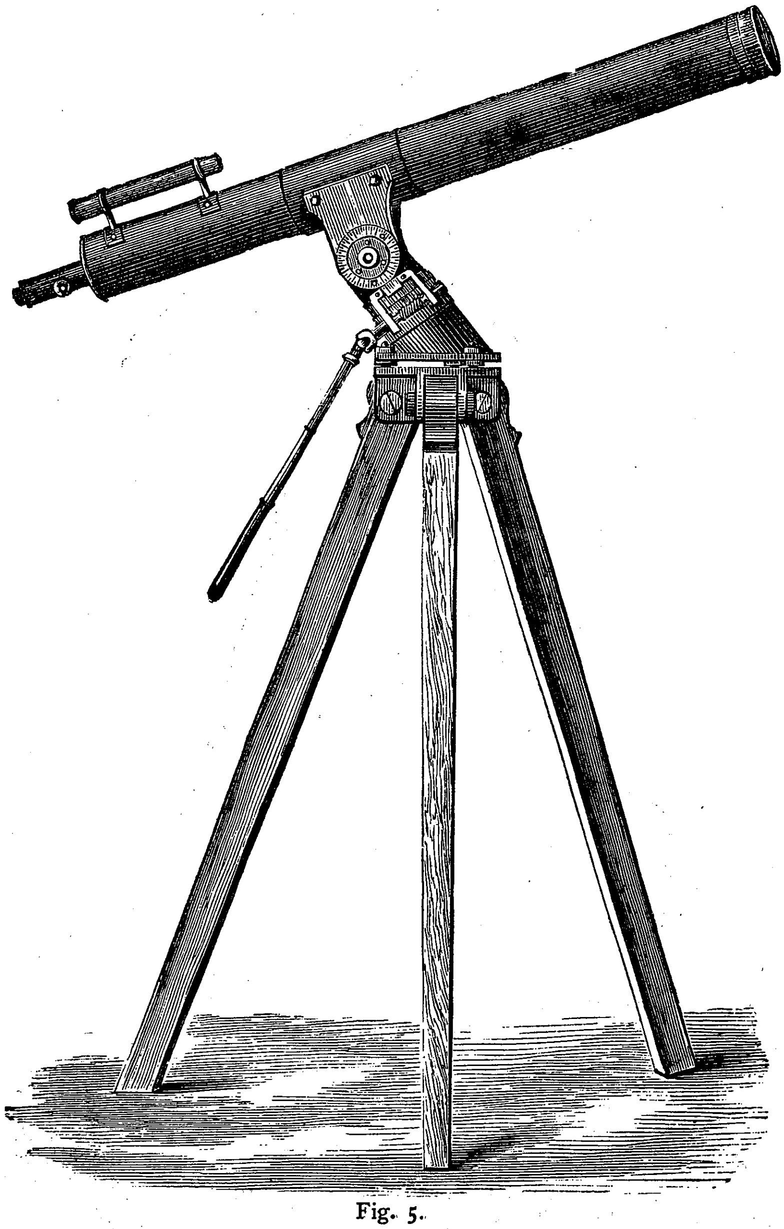


Fig. 5.

THE "VICTORIA" EQUATORIAL TELESCOPE. Page 18, Fig. 5, as supplied to members of that institute; consisting of a "Student's" telescope mounted on a portable "Berthon" equatorial on tripod stand. £25.

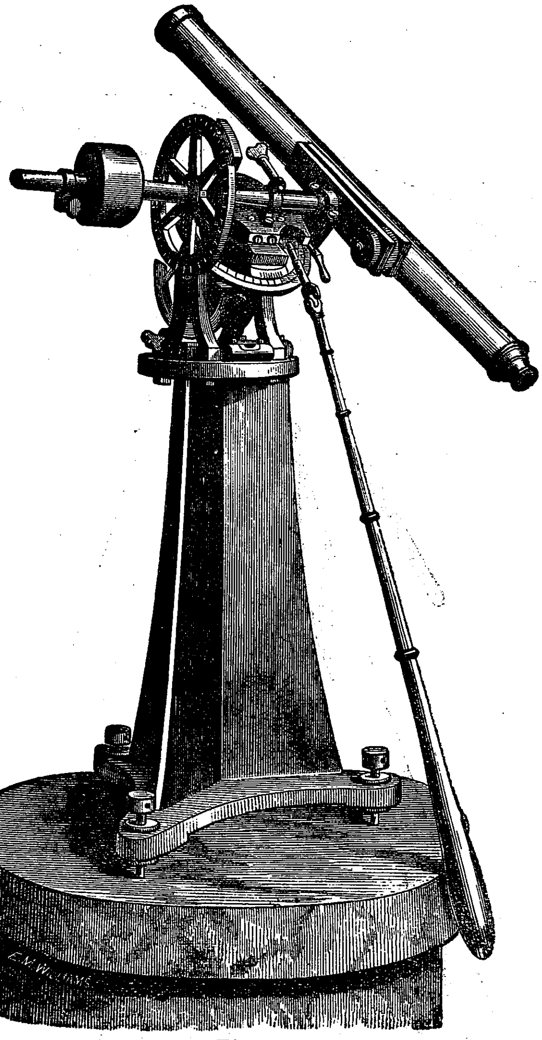


Fig. 4.

HORNE & THORNTHWAITE'S "STUDENT'S" UNIVERSAL EQUATORIAL STAND. Page 17 and Fig. 4. Specially suitable for the "Student's" telescope, but adapted for any of the same size, with 6 inch hour circles, reading to 10 seconds, and 6 inch declination circles reading to 3 minutes, divided on brass, capable of carrying any size telescope up to 3½ feet, £12 12s.; divided on silver, £14 14s. Ditto, large size, capable of carrying a 6 foot telescope, with 8 inch circles, divided on brass, £25; divided on silver, £28.

ASTRONOMICAL OBJECT GLASSES.

Clear aperture...	2½-in.	3-in.	3½-in.	4-in.	4½-in.	5-in.	6-in.
Focal length ...	36-in.	48-in.	48-in.	60-in.	72-in.	80-in.	100-in.
In Brass Cells...	£2 15s.	£5	£8	£12 10s.	£18	£26	£45

The above foci are those usually employed by us; but object-glasses of particular foci or diameter can be made to order at slightly higher prices.

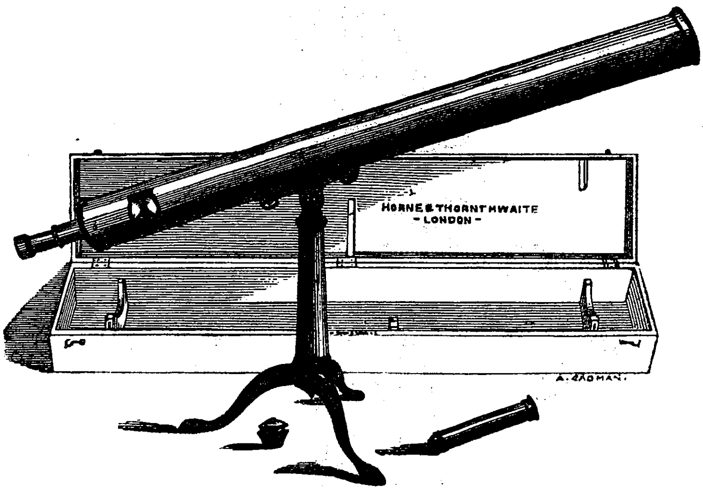


Fig. 36.

HORNE & THORNTHWAITE'S STUDENT'S ASTRONOMICAL REFRACTING TELESCOPE. Page 16. Fig. 3.

This Telescope, although so low in price, is well made in all its parts, and quite equal in its definition to those formerly sold at a much higher cost.

The body of the Telescope is of polished brass, with pillar and claw stand; rackwork adjustment to eye-piece; achromatic object glass, of our own manufacture, 2·85 in *clear* aperture, and 3 feet focus; one astronomical eye-piece with sun cap, and one day eye-piece, and finder. The whole enclosed in a polished pine wood case, with lock and key.

This instrument will, on a fine clear day, show the time by a church clock twelve miles distant, and clearly define the moon and belts of Jupiter, the rings of Saturn, and many of the double stars; and the object glass will bear a magnifying power of 200 diameters.

The eye-pieces supplied with this Telescope, at the above price, are a terrestrial or day power of 40, and a celestial, for observing the stars, &c., of 60; but a celestial of any other power may be substituted for that of 60 without extra cost. £10, or without the finder, £8 8s.

Mahogany Tripod Garden Stand for the above, 5 feet high, firm, steady and portable, £1 11s. 6d.

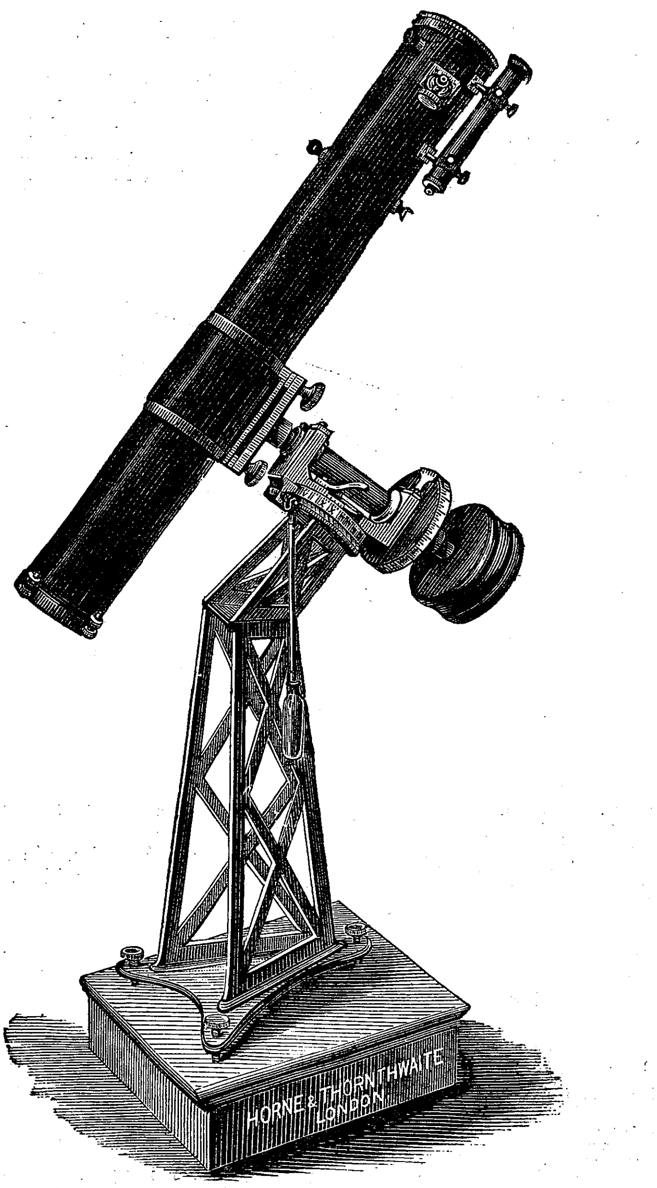


Fig. 21.

Horne and Thornthwaite's Portable Equatorial Reflector.

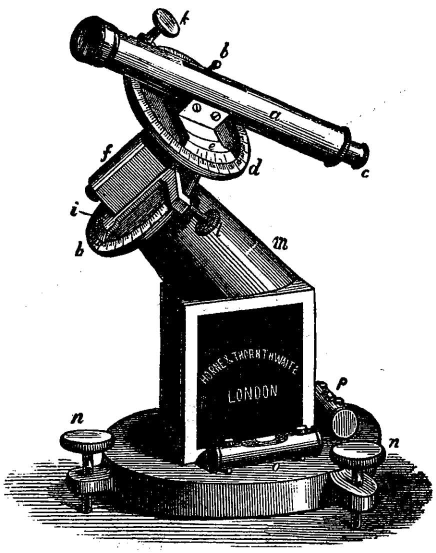


Fig. 37.

HORNE & THORNTHWAITE'S STARFINDER (Fig. 37). This instrument consists of a miniature equatorially-mounted telescope, and two eye-pieces, by means of which any celestial object whose catalogue position is known can be found, and various other sidereal problems solved. Full particulars are sent with the instrument, which may be obtained, set to any latitude, £5 15s. 6d. and £8 8s.

ASTRONOMICAL REFLECTING TELESCOPES.

HORNE & THORNTHWAITE beg to give notice that all specula in the following Lists are manufactured under their immediate supervision, and are personally tested, both optically and on celestial objects; they can, therefore, guarantee their excellence.

HORNE & THORNTHWAITE'S PORTABLE EQUATORIALLY-MOUNTED NEWTONIAN TELESCOPE. Page 36, Figs. 20 and 21.

Telescope with 6-inch silvered-glass mirror, with equatorial motions ...	£20
The same, with divided circles	£24
Telescope as above, with 6½-inch mirror and improved motions in right ascension and declination, divided circles	£35

The iron pillars for these equatorials are made firm and heavy when they are intended to be left *in situ*, but when required for transport from place to place, they are made of a lighter form.

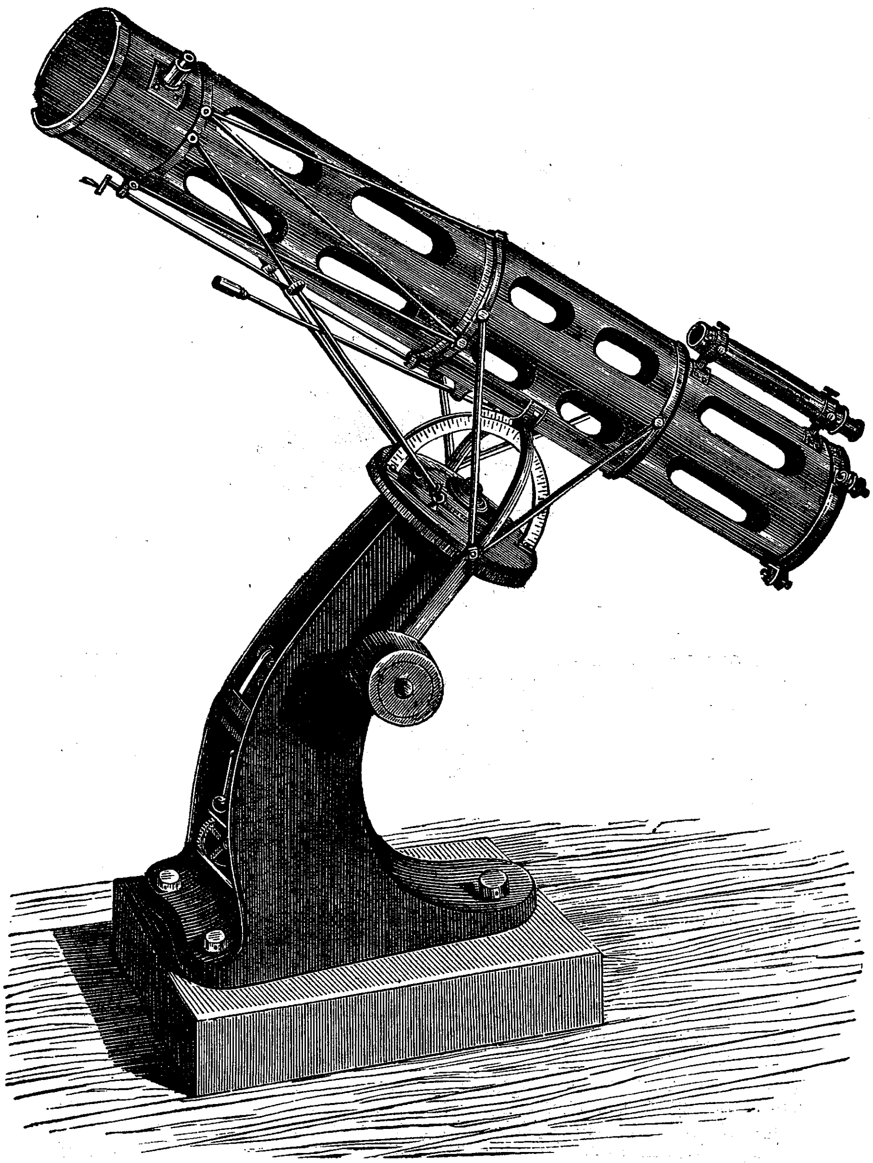


Fig. 23.

BERTHON'S PATENT EQUATORIAL STAND.

NEWTONIAN REFLECTING TELESCOPE ON BERTHON'S PATENT EQUATORIAL STAND. Page 30, Fig. 22.

With silvered-glass mirror, 6½-inch	... ...	£50
" " 8½ "	... ...	£70

This form of stand is exceedingly steady. The lower end of the tube can be removed and packed with the whole of the working portion of the equatorial and the remainder of the tube in a comparatively small case. The circles are fully divided, and the hour circle is movable, with double verniers. Screw movements in right ascension and declination.

NEWTONIAN OR CASSEGRAINIAN REFLECTING TELESCOPE, ON BERTHON'S PATENT EQUATORIAL STAND. Page 39, Fig. 23, with silvered glass mirrors.

	6½-in.	8½-in.	10-in.	12½-in.	15-in.	18-in.	24-in.	36-in.	48-in.
A.	£45	£70	£80	£120	£210	£330	£510	£1600	£3000
B.	70	90	110	150	260	410	620	1800	3400
C.	90	110	140	200	320	500	750	2400	4400

SPECIFICATION A includes a silvered glass Newtonian or Cassegrainian mirror and secondary reflector mounted in an iron body tube. The telescope is supported on an equatorial stand, with screw motions in right ascension and declination. The hour circle can be rotated, and is fully divided and read by two verniers. The declination circle is fully divided with vernier.

SPECIFICATION B includes a telescope and equatorial as in A, with the addition of a driving clock with governor regulator.

SPECIFICATION C includes telescope, equatorial and driving clock, as in B, with all the metal work of the best finish. The tube ventilated, if desired, and is revolved by mechanical means. The right ascension and declination hand movements are so arranged that both can be worked, either at the eye-piece or vernier, with the greatest facility. The hour circle is acted upon by the driving clock, and when once set will read accurate time until the clock stops. The circles can be read from the eye-piece. A novel method of micrometer illumination is affixed. Specification C can be an equatorial of the German form at a slight increase of price. The larger Cassegrainians are made either in the original form or in Nasmyth's modification of the same. The above specifications do *not* include eye-pieces, &c., as HORNE & THORNTHWAITE have thought it preferable to allow their customers to select the accessories most suitable to their requirements; they will, however, be happy to select the necessary adjuncts should they be requested to do so, or customers may select their own from this catalogue.

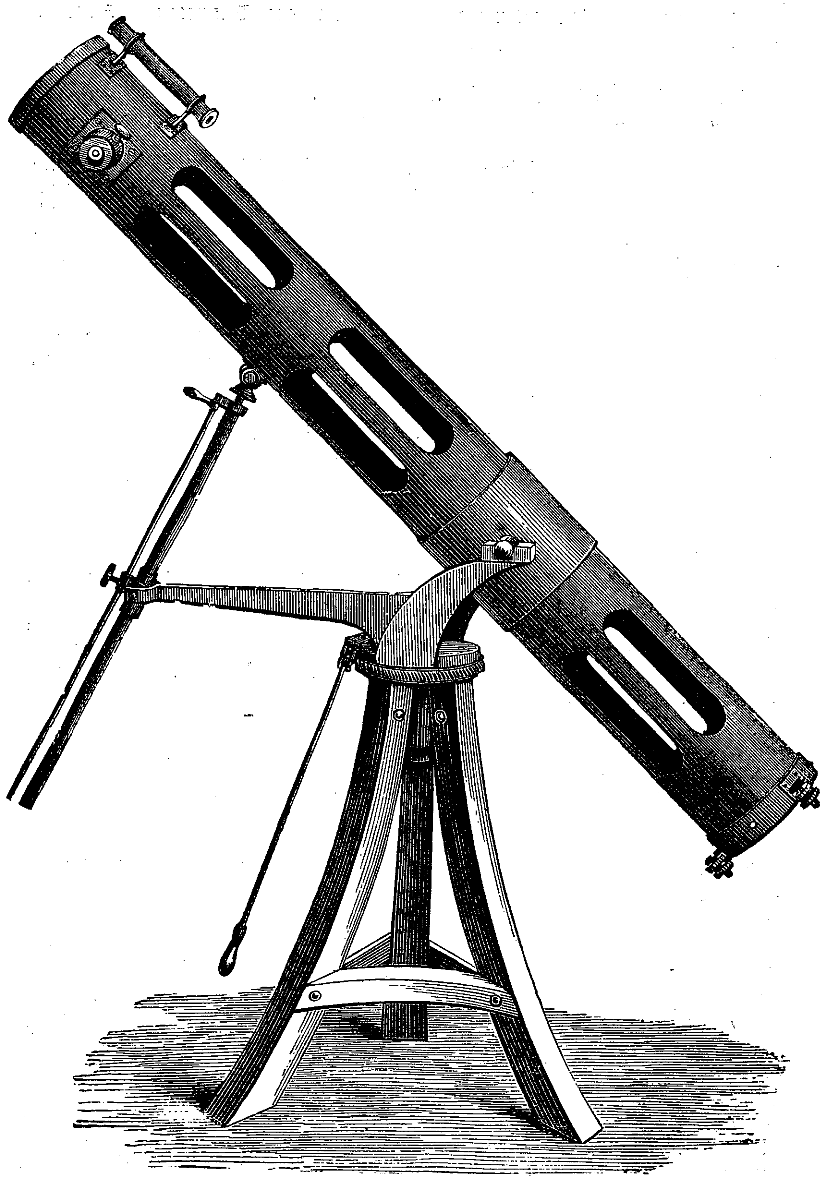


Fig. 38.
THE ALT-AZIMUTH STAND.

NEWTONIAN REFLECTING TELESCOPE on ALT-AZIMUTH STAND, as described at page 33, fitted with a Silvered Glass Speculum. Fig. 19.

	£	s.	d.
6½ inch Speculum, 6½ or 5-feet focus	23	0	0
8½ " " 6½ "	32	0	0
10 " " 7 "	44	0	0
12½ " " 8 "	68	0	0

If with HORNE & THORNTHWAITE'S improved vertical and horizontal motions and ventilated tube, with superior finish to metal work, Fig. 38, 25 per cent. extra.

SILVERED-GLASS SPECULA (*unmounted*).

Newtonian, Cassegrainian, Gregorian, or Herschelian.

PERFORMANCE GUARANTEED.

	£	s.	d.
3 inch diameter, 2 feet focus	3	10	0
4 " 3 "	4	0	0
5 " 4 "	4	10	0
6 " 5 "	5	17	6
6½ " 6½ "	6	5	0
8½ " 6½ "	13	0	0
10 " 7 "	25	0	0
12½ " 8 "	38	10	0
14 " 8 "	55	0	0
16 " 10 "	75	0	0
18 " 12 "	100	0	0
20 " 12 "	130	0	0
22 " 15 "	165	0	0
24 " 18 "	200	0	0
26 " 18 "	250	0	0
30 " 24 "	300	0	0
36 " 30 "	400	0	0
48 " 36 "	700	0	0

SILVERED-GLASS DIAGONAL MIRRORS (*unmounted*).

PERFORMANCE GUARANTEED.

	£	s.	d.
1 inch in the minor axis, or narrowest diameter of the ellipse ...	1	0	0
1½ " " " " ...	1	10	0
2 " " " " ...	2	0	0
2½ " " " " ...	2	10	0
3 " " " " ...	3	3	0
3½ " " " " ...	4	4	0
4 " " " " ...	5	5	0

THE "ROMSEY" OBSERVATORY.

Page 60.

For 5-feet Telescopes	15	0	0
" 6 " "	20	0	0
" 7 " "	28	0	0
" 8 " "	35	0	0

SILVERING AND POLISHING SPECULA.

	£	s.	d.		£	s.	d.
5-inch	0	6	0	10-inch	0	15	0
6½ "	0	8	0	12½ "	1	1	0
8½ "	0	10	6	Diagonal Planes	0	3	0

APPARATUS FOR SILVERING, &c.

Page 49.

SILVERING VESSELS.

	£	s.	d.		£	s.	d.
16½ inch	1	0	0	10-inch	0	6	0
13 "	0	15	0	8½ "	0	4	6
11 "	0	7	6	6½ "	0	3	0

GLASS MEASURES.

	£	s.	d.		£	s.	d.
40-oz.	0	5	0	5-oz.	0	1	3
10 "	0	2	0	2 "	0	0	10

		£	s.	d.
Glass Funnels	6d., 9d., and	0	1	0
Filter Papers, for ditto	per hundred	0	1	0
Polishing Pads, in stoppered bottles	... ...	0	1	6
Glass Rods	... 2d. and	0	0	3
Cotton Wool	... per oz.	0	0	3
Test Tube	... ...	0	0	2
Flask	3d., 6d., and	0	1	0
Boxes of Scales and Weights	... from	0	4	0
Spirit Lamp	... ...	0	2	0
Retort Stands	... from	0	3	6
Sand Bath	... ...	0	0	6

CHEMICALS.

		£	s.	d.
Nitrate of Silver	.. per oz.	0	3	8
Nitrate of Ammonia	... "	0	0	3
Potash, pure, by alcohol (in stoppered bottle)	... "	0	1	4
Best Sugar Candy	... "	0	0	4
Tartaric Acid	... "	0	0	4
Alcohol	... "	0	0	4
Liquor Ammoniæ	... "	0	0	2
Sugar of Milk, powdered	... "	0	0	2
Tartrate of Soda and Potash (Rochelle Salt)	... "	0	0	2
Distilled Water, pure...	per gallon	0	1	0
Nitric Acid, pure	... per oz.	0	0	2
Pitch	... per lb.	0	0	4
Fine Rouge	per bottle	0	1	0
Turpentine	... per pint	0	1	0

SET OF SILVERING APPARATUS.

Including dish and other apparatus, with sufficient chemicals to silver a—

	£	s.	d.
6½-inch Mirror four times	1	1	0
8½ " "	1	5	0
10 " "	1	10	0
12½ " "	1	15	0

ASTRONOMICAL EYE PIECES.

Page 58.

HUYGHENIAN CONSTRUCTION.

Of the following magnifying powers on a 6-feet focus object-glass.

	£	s.	d.
50, 90, 160, 250	0	15	0
370, 500	1	1	0

RAMSDEN'S CONSTRUCTION.

With Achromatic Lenses.

	£	s.	d.
120	1	0	0
250	1	7	6
500	1	12	6

APLANATIC CONSTRUCTION.

	£	s.	d.
60, 120, 250 ... each	1	10	0

KELLNER'S CONSTRUCTION.

	£	s.	d.
30, 60, and 80 ... each	1	10	0

Eye-pieces of any other power or construction made to order.

	£	s.	d.
Erecting Day Eye-piece, page 13	1	5	0
Pancratic ,,	1	12	6
Barlow's Lens, page 5	1	1	0
Adjusting Piece for Reflectors, page 25	0	2	6
Thornthwaite's Binocular Eyepiece	10	10	0

SOLAR EYE PIECES.

Page 59.

	£	s.	d.
Silvered Barlow's Lens	1	10	0
Solar Diagonal	1	12	6
Dawes' Solar Eye-piece	8	0	0
Levander's Diaphragm Eye-piece	3	3	0
Coloured Eye-piece Cap for observing the Moon	0	5	0
Neutral Tint and Smoke-coloured Wedges, for use on the Sun, Moon, and Planets	1	1	0

Other varieties of Solar eye-pieces to order.

MICROMETERS.

Page 60.

		£	s.	d.
Parallel Wire Micrometer		5	5	0
Position Micrometers	£8 8 0 to	15	15	0
Double Image Micrometer		8	8	0
Illuminating Apparatus	from	2	10	0
Extra Ramsden's Eye-pieces	,,	0	15	6
Berthon's Dynamometer (page 61)		0	7	6
Ditto, mounted with eye-piece		1	1	0

ASTRONOMICAL SPECTROSCOPES.

Page 62.

	£	s.	d.
Horne and Thornthwaite's Miniature Universal Spectroscope	2	15	0
Star Spectroscopes £4, £8, £15,	20	0	0
Solar Spectroscopes £14, £20, £26,	40	0	0

TRANSIT INSTRUMENTS

On cast-iron stands, with fully divided circles, reading microscopes, three micrometic and one diagonal eye-pieces, complete in case :—

	£	s.	d.
1½-inch Object-glass, 15-inch focus, portable	20	0	0
1¾ " " 20 " "	22	10	0
2 " " 25 " "	25	0	0
2¼ " " 30 " "	38	0	0
3 " " 36 " fixed	60	0	0
3¼ " " 42 " "	67	0	0

BERTHON'S TRANSIT INSTRUMENT, £15, £20. In this instrument the telescope is firmly fixed in a horizontal position at right angles to the meridian, a reflector revolving *in* the meridian exhibits transit stars in the telescope ; the illumination of the lines is effected on an entirely new principle allowing delicate observations to be most easily made.

TRANSIT EYE-PIECES, for use with Equatorials, £1 1s., £2 2s.

DR. ROYSTER PIGOTT'S FLASHING TRANSIT EYE-PIECE, £1 12s. 6d. and £2 5s. In this instrument a silvered disc, with lines cut through the film, is substituted for the spider threads ; as a star, therefore, passes the lines it flashes. The great advantage of this instrument is that artificial illumination of the lines is rendered unnecessary.

HORNE & THORNTHWAITE'S SIDEREAL, OR MEAN TIME ASTRONOMICAL CLOCK (page 72), £20.

WORKS ON ASTRONOMY.

Page 77.

Proctor's Small Star Atlas	0	5	0
" Half-hours with the Stars...	0	5	0
" Half-hours with the Telescope	0	2	6
Webb's Celestial Objects	0	7	6
Chambers' Descriptive Astronomy	1	8	0

HORNE & THORNTHWAITE,

416, STRAND.

April, 1878.

HORNE & THORNTHWAITE'S

IMPROVED

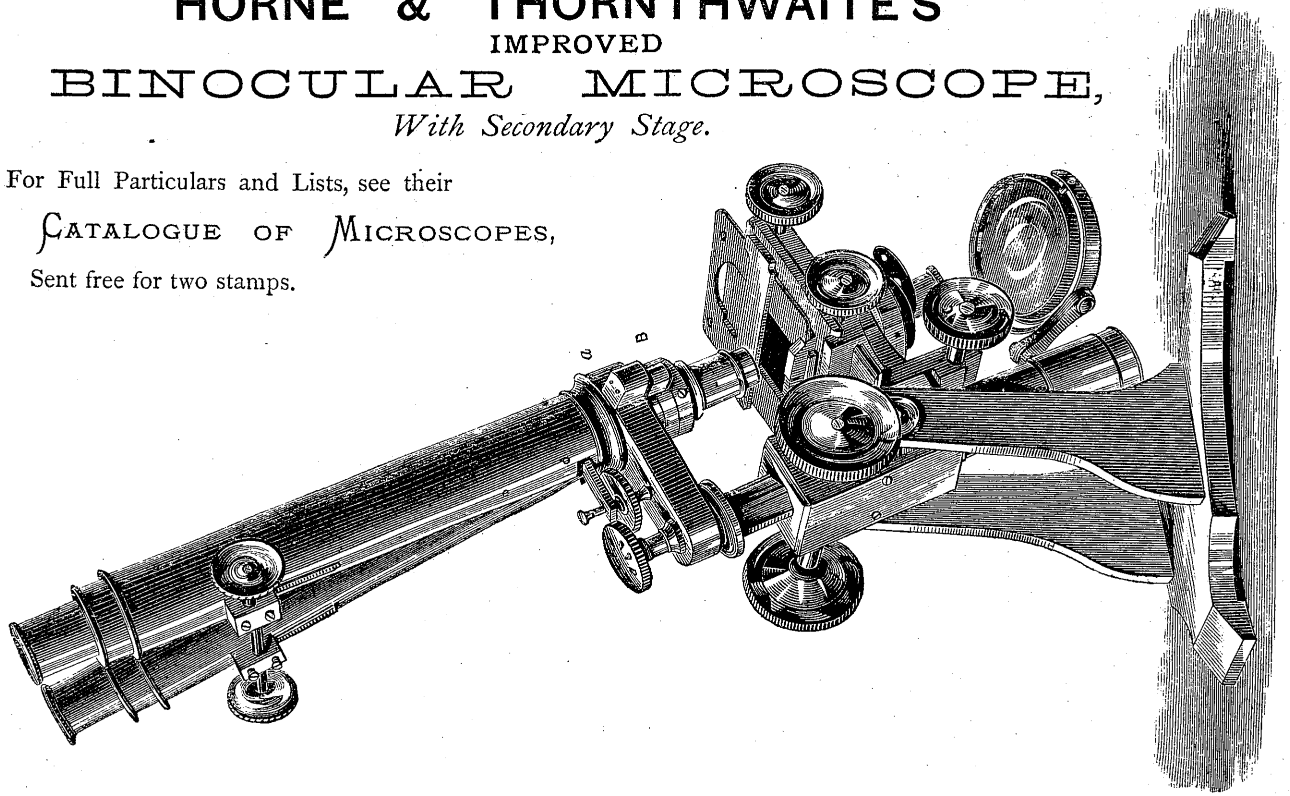
BINOCULAR MICROSCOPE,

With Secondary Stage.

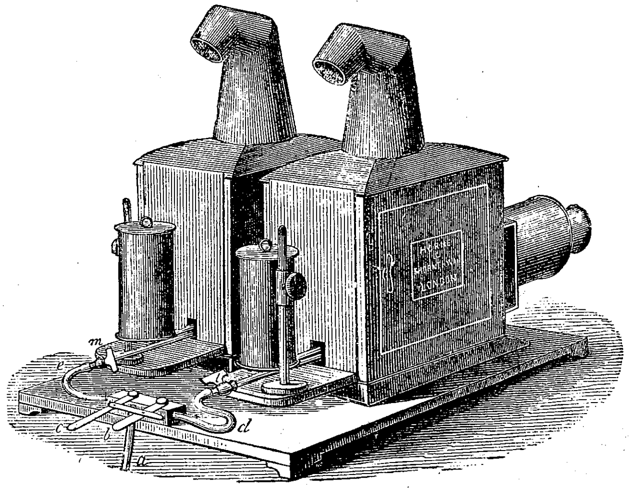
For Full Particulars and Lists, see their

CATALOGUE OF MICROSCOPES,

Sent free for two stamps.



HORNE & THORNTHWAITE'S
DISSOLVING VIEW APPARATUS & SLIDES.



The Lecturer's Set of Oxycalcium Dissolving View Apparatus, of first-class manufacture, mahogany body Lantern, with handsome brass fronts, 4-inch condensers; Fountain Oxycalcium Lamp; Gas Bag, Pressure Boards; Oxygen Retort and Purifier, Conducting Tube; and with supply of Lime Balls and Oxygen Mixture, with full directions for use. £21.

The School Set of Oxycalcium Dissolving View Apparatus, with Lanterns having 3½-inch condensers, and the extra apparatus as above described. £14 14s.

School Set of Dissolving View Apparatus, fitted with Argand Fountain Oil Lamps, 3½-inch condensers. £8 8s.

Phantasmagoria Lantern, 3½-inch condensers, with Argand Fountain Oil Lamp, for showing 3-inch Pictures. £3 3s.; Ditto with rackwork adjustment, £3 10s.

Oxycalcium Apparatus, fitted to ditto, £5 extra.

Microscope attached to any of the foregoing instruments for showing live insects, sections of woods, &c., £2 2s. extra.

An endless variety of Photographs and Hand-Painted Slides can be had to fit any of the above Lanterns.

Photographic and other Slides for the Lantern, as below:—

Continental Photographs, each coloured, 4s. 6d.; uncoloured, 2s.
Scripture, London, and Natural History, each, coloured, 4s.; uncoloured, 1s. 6d.
Lever Slides, 6s. each. **Comic Transformations,** 2s. each.
Chromatropes, 10s. 6d. each. **Natural Phenomena,** 6s. 6d. each.
Pictures for the Dissolving Views, comprising the Holy Land—The Overland Route to India—The Mill at Llanrwst—The Ship—The Seasons—Mount Vesuvius—Mount Etna—Tower of London—The Old and New Royal Exchange—The Arctic Expedition—Patterdale Bridge—Water Mill—Ascent to Mont Blanc—The Turko-Russian War, &c.
Magic Lantern of japanned tin, with brass sliding tube, lamp and reflector, giving a clear picture of 3-feet in diameter, 5s. Set of Slides for ditto, 4s.
Magic Lantern of japanned tin, with brass sliding tube, lamp and reflector, giving a clear picture of 4-feet in diameter, 7s. 6d. Set of Slides for ditto, 7s. 6d.
Magic Lantern of japanned tin, with brass sliding tube, lamp and reflector, giving a clear picture of 6-feet in diameter, 10s. 6d. Set of Slides for ditto, 10s. 6d.
Magic Lantern of japanned tin, with brass sliding tube, lamp and silvered reflector for producing a picture 8-feet in diameter, £1. Set of Slides for ditto, £1.
Improved Magic Lantern of japanned tin, with brass sliding tube, argand lamp, and silvered reflector, for producing a clear picture 9-feet in diameter showing 2½-inch pictures, in case, £1 10s. Set of Slides for the above, £1; ditto Astronomical ditto, £1 15s.; Lever Slides, each, 4s. 6d.; Slipping Comic, each 2s.; Chromatropes, each 10s. 6d.; Natural Phenomena, each 4s. 6d.

Dissolving View Apparatus and Slides sent out on hire, and Demonstrators supplied to manage the Exhibition. Terms on Application.

Further Particulars, see complete Catalogue of Dissolving View Apparatus.

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