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| --- |
| 1st vertex to 2d = 0∙70 mm. flint glass, |
| 3d „ ,, 4th= 3∙50 „ crown glass, |
| 4th ,, ,, 5th = 19∙51 „ air, |
| 5th ,, „ 6th= 0∙61 ,, flint glass, |
| 7th ,, ,, 8th= 2∙45 „ crown glass. |

The distance between the plane surfaces is 22∙57 mm. This form of eye-piece has been employed by Schönfeld in his southern “Durch­musterung,” and Dr Schroder has made one for the present writer which gives a perfect field 4¼o in diameter on the telescope of 18 inches focal length and 3 ¼ inches aperture already referred to.

*Reflecting Telescope.*

The following are the various forms of reflecting telescopes. The Gregorian telescope is represented in fig. 12. AA and BB are concave mirrors having a common axis and their concavities facing each other. The focus of A for parallel rays is at F, that of B for parallel rays at *f—*between B and F. Parallel rays falling on AA converge at F, where an image is formed ; the rays are then re­flected from B and converge at P, where a second and more enlarged image is formed. Gregory himself showed that, if the large mirror were a segment of a paraboloid of revolution whose focus is F, and the small mirror an ellipsoid of revolution whose foci are F and P respectively, the resulting image will be plane and undistorted. The image formed at P is viewed through the eye-piece at E, which may be of the Huygenian or Ramsden type. The focal adjustment is accomplished by the screw S, which acts on a slide carrying an arm to which the mirror B is attached. The practical difficulty of constructing Gregorian telescopes of good defining quality is very considerable, because if spherical mirrors are employed their aberrations tend to increase each other, and it is extremely difficult to give a true elliptic figure to the necessarily deep concavity of the small speculum. Short appears to have systematically con­quered this difficulty, and his Gregorian telescopes attained great celebrity. The use of the Gregorian form is, however, practically abandoned in the present day. The magnifying power of the

telescope is = (F+*f*)/(*e+x*), where F and /are respectively the focal lengths of the large and the small mirror, *e* the focal length of the eye-piece, and *x* the distance between the principal foci of the two mirrors ( = F*f* in the diagram) when the instrument is in adjustment for viewing distant objects. The images are erect.

The Cassegrain telescope differs from the Gregorian only in the substitution of a convex hyperbolic mirror for a concave elliptical mirror as the small speculum. This form has two distinct advan­tages : (1) if spherical mirrors are employed their aberrations have a tendency to correct each other ; (2) the instrument is shorter than the Gregorian, *cæteris paribus,* by twice the focal length of the small mirror. Fewer telescopes have been made of this than perhaps of any other form of reflector ; but in comparatively recent years the Cassegrain has acquired importance from the fact of its adoption for the great Melbourne telescope. The magnifying power is com­puted by the same formula as in the case of the Gregorian telescope.

The Newtonian telescope is represented in fig. 13. AA is a con­cave mirror whose axis is *aa.* Parallel rays falling on AA converge on the plane mirror BB, and are thence re­flected at right angles to the axis, forming an image in the focus of the eye-piece E.

The surface of the large mirror should be a paraboloid of revolution, that of the small mirror a true optical plane.

The magnifying power i*s=F∣e.* This form is employed in the con­struction of most modern reflecting telescopes. A glass prism of total reflexion is sometimes substituted for the plane mirror.

The Herschelian or front view reflector is represented in fig. 14. AA is a concave parabolic mirror, whose axis *ac* is inclined to the axis of the tube *ab* so that the image of an object in the focus of the mirror may be viewed by an eye-piece at E, the angle *bac* being equal to the angle *caE.* This form was adopted by the elder

Herschel to avoid the loss of light from reflexion in the small mirror of the Newtonian telescope. It has several disadvantages. (1) The upper part of the observer’s head must necessarily obstruct some of the rays which would otherwise fall on the large mirror ; but when a telescope of very large aperture is employed the loss of light thus occasioned is comparatively insignificant. Moreover, disturbance of the air in front of the telescope is created by heat from the observer’s head and body, and this is fatal to the best definition. To avoid the latter drawback Sir John Herschel (*Ency. Brit.,* 8th ed., art. “Telescope,” vol. xxi. p. 128) suggested the employment of a small right-angled prism of total reflexion placed close to the eye­lens of the eye-piece, to permit the observer to view the image by looking in a direction at right angles to the eye-piece, and therefore at right angles to the tube. (2) In consequence of the tilting of the mirror aberration is created, and this increases rapidly with increased tilting. The construction is thus limited to telescopes in which the proportion of aperture to focal length is not too great. In Herschel’s 40-feet telescope the proportion was 1 to 10, and the construction would hardly be applicable to modern telescopes, in w’hich the proportion often rises to 1 to 5 or 6. Yet, when exceed­ingly faint objects have to be observed, this form of telescope has great advantages. Herschel found that some objects which he dis­covered with such an instrument could not even be seen when the same telescope was used in the Newtonian form. The front view telescope, however, has hardly been at all employed except by the Herschels. But at the same time none but the Herschels have swept the whole sky for the discovery of faint nebulæ ; and probably no other astronomers have worked for so many hours on end for so many nights as they did, and they emphasize the easy position of the observer in using this form of instrument.

*Construction of Object-Glasses.*

The first point is the selection of glass disks of suitable quality. The requisites are (1) general transparency and freedom from mechanical defects, such as specks, air-bubbles, &c.; (2) homogeneity; (3) freedom from internal strain. The disk being roughly polished on the sides, faults of the first class are easily detected by inspection. In order to secure the maximum of light grasp for aperture it is desirable that the glass should be as colourless as possible ; if the roughly polished disk is laid upon white paper the amount of dis­coloration can be readily estimated by comparing the colour of the sheet as seen directly with that seen through the glass. Fraun­hofer’s glass was far from colourless, Dollond’s more coloured still ; and we have shown that, for purposes when extreme light grasp is not an object, the less transparency of such glass to the blue rays of the spectrum affords advantages for a better correction of the chromatic aberration of rays in the brighter part of the spectrum. The amount of light excluded by specks, air-bubbles, or even scratches is quite insignificant ; but these blemishes create diffrac­tion phenomena and scattered light in the field, which are very injurious to the performance of the instrument, especially when faint objects are searched for in the neighbourhood of brighter ones. It is essential for a telescope lens that the glass should be perfectly homogeneous ; that is, the refractive index must be identical for every part of the disk. This can be tested with extreme delicacy by grinding the disk into the form of a lens and testing it by Töppler’s method,@@1 described under Optics (vol. xvii. p. 805). If the disk is intended for a concave lens and is already so thin that it becomes undesirable to make it thinner at the edges by convert­ing it, in the first place, into a convex lens, it may be tested by placing one of its surfaces in contact with and at right angles to the axis of a crown lens of known perfection, and testing the com­bination by Töppler’s method. If a glass disk is not properly annealed—that is, if it has been too quickly cooled, so that the outer shell has hardened before the inner portion—the finally solidified mass must be in a state of tension, like that of “Rupert’s drops. ” Unless cooled very gradually an optical disk would fly to pieces, but a very much smaller defect in the annealing process would be fatal for refined optical purposes. Changes of temperature would produce changes of curvature, and the lens would also change its form when successive portions of the strained outer shell were removed in the process of grinding and polishing. Fortunately

@@@1 *Pogg. Annal.,* cxxxi., 1867.