chance goodness of the object-glass, because he found others equally good which were constructed on similar proportions. This has therefore been adopted as a standard.

It does not at first appear how there can be any difficulty in this matter, because we can always diminish the aperture of the object-glass or speculum, till the circle of aberra­tion is as small as we please. But by diminishing this aper­ture, we diminish the light in the duplicate ratio of the aperture. Whatever be the aperture, the brightness is diminished by the magnifying power, which spreads the light over a greater surface in the bottom of the eye. The apparent brightness must be as the square of the aperture of the telescope directly, and the square of the amplifica­tion of the diameter of an object inversely. Objects there­fore will be seen equally bright if the apertures of the tele­scopes be as the focal distances of the object-glasses di­rectly, and the focal distances of the single eye-glass (or eye-glass equivalent to the eye-piece) inversely. There­fore, to have telescopes equally distinct and equally bright, we must combine these proportions with the former. It is needless to go farther into this subject, because the con­struction of refracting telescopes has been so materially changed by the correction of the chromatic aberration, that there can hardly be given any proportion between the ob­ject-glass and eye-glasses. Every thing now depends on the degree in which we can correct the aberrations of the object-glass. We have been able so far to diminish the chromatic aberration, that we can give very great apertures without its becoming sensible. But this is attended with so great an increase of the aberration of figure, that this last becomes a sensible quality. A lens which has 30° for its semi-aperture, has a circle of aberration equal to its chromatic aberration. Fortunately we can derive from the very method of contrary refractions, which we employ for removing the chromatic aberrations, a correction of the other. For this contrivance we are also indebted to the illustrious Newton.

We call this Newton’s contrivance, because he was the first who proposed a construction of an object-glass in which the aberration was corrected by the contrary aberrations of glass and water.

Huyghens had indeed supposed, that our all-wise Crea­tor had employed in the eyes of animals many refractions in place of one, in order to make the vision more distinct ; and the invidious detractors from Newton’s fame have catched at this vague conjecture as an indication of his knowledge of the possibility of destroying the aberration of figure by contrary refractions. But this is very ill found­ed. Huyghens has acquired sufficient reputation by his theory of aberrations. The scope of his writing in the passage alluded to, is to show that, by dividing any intend­ed refraction into parts, and producing a certain conver­gence to or divergence from the axis of an optical instru­ment, by means of two or three lenses instead of one, we diminish the aberrations four or nine times. This conjec­ture about the eye was therefore in the natural train of his thoughts. But he did not think of destroying the aberra­tion altogether by opposite refractions. Newton, in 1669, says that opticians need not trouble themselves about giv­ing figures to their glasses other than spherical. If this figure were all the obstacle to the improvement of tele­scopes, he could show them a construction of an object-glass having spherical surfaces where the aberration is de­stroyed ; and accordingly he gives the construction of one composed of glass and water, in which this is done com­pletely by means of contrary refractions.

The general principle is this. When the radiant point R (fig. 7), or focus of incident rays, and its conjugate focus F of refracted central rays, are on opposite sides of the re­fracting surface or lens V, the conjugate focus *f* of marginal rays is nearer to R than F is. But when the focus of in­cident rays R, lies on the same side with its conjugate fo­cus F' for central rays, R' is greater than R' F'.

Now fig. 8 represents the contrivance for destroying the colour produced at F, the principal focus of the convex lens V, of crown glass, by means of the contrary refraction of the concave lens *v* of flint glass. The incident parallel rays are made to converge to F by the first lens. This convergence is diminished, but not entirely destroyed, by the concave lens *v,* and the focus is formed in F'. F and F' therefore are conjugate foci of the concave lens. If F be the focus of V for central rays, the marginal rays will be collected at some point *f* nearer to the lens. If F be now considered as the focus of light incident on the centre of *v*, and F' be the conjugate focus, the marginal ray *p F'* would be refracted to some point *f*' lying beyond F'. Therefore the marginal ray *p f* may be refracted to F, if the aberra­tion of the concave be properly adjusted to that of the con­vex.

This brings us to the most difficult part of our subject, the compounded aberrations of different surfaces. Our limits will not admit of our treating this in the same elemen­tary and perspicuous manner that we employed for a single surface. We must try to do it in a compendious way, which will admit at once the different surfaces, and the dif­ferent refractive powers of different substances. This must naturally render the process more complicated ; but we hope to treat the subject in a way easily comprehended by any person moderately acquainted with common algebra.

*Lemma* 1. In the right-angled triangle MXS (fig. 9), of which one side MX is very small in comparison of either of the others, the excess of the hypothenuse MS above the side XS is very nearly equal to ,jyp\*\*\* or to jγg∙ For if about the centre S, with the radius SM, we describe the semicircle AMO, we have AX ∙ XO = MX2. Now AX = MS — SX, and XO is nearly equal to 2MS or 2XS ; on

MX2 the other hand, MS is nearly equal to XS +J- ~ - ; and in like manner MG is nearly equal to 4- XG, and MH is

1 1 MX2 . v,,

nearly equal to -⅞. ,-√ -∣- XH.

2λπ

Prop. I. Let the ray *m*M, incident on the spherical sur­face AM, converge to G ; that is, let G be the focus of in­cident rays. It is required to find the locus H of refract­ed rays.

Let *m* express the ratio of the sine of incidence and re­fraction ; that is, let *m* be to 1 as the sine of incidence to the sine of refraction in the substance of the sphere.