of the logarithm ſine of half that arc, rejecting the indices.

But, as theſe differences give the diviſions to the ſupplements of the real verſed ſines; therefore the arithmetical complement of the logarithm ſine of any arc being doubled, will give the diſtance of the diviſion for the ſupplement of twice that arc on the line of verſed ſines.

Thus, for 70°, the logarithm ſine is 9,97299
The arithmetical complement is 0,02701
Its double is 0,05402

Which is the number in the foregoing table ſtanding againſt 140°, and is the ſupplement verſed ſine of twice 70 degrees.

Now, as the arithmetical complement of the log. ſines of arcs, are the diſtances on the line of ſines between 90°, and the diviſions to thoſe arcs; therefore the diſtances between 90° and any arc, being twice repeated, will give the diviſion of the ſupplemental verſed ſine to twice the co-ſine of that arc.

XIV. *A Letter from Mr.* John Dollond *to Mr.* James Short, *F. R. S. concerning an Improvement of* refracting Teleſcopes.

SIR.

Read March 1, 1753. IT is well known, that the perfection of refracting teleſcopes is very much limited by the aberration of the rays of light from the geometrical focus; which ariſes from two very different cauſes; that is, from different degrees

grees of refrangibility of light, and from the figure of the ſphere, which is not of a proper curvature for collecting the rays in a ſingle point. The object-glaſs is chiefly affected by the firſt of theſe; nor has there been yet any method diſcover'd for rectifying that aberration ſo, as in the leaſt to remove the indiſtinctneſs of the image ariſing from it. We are therefore reduced to the neceſſity of contracting their apertures, which renders it impoſſible to magnify much without very long glaſſes.

But the caſe is widely different with regard to the eye-glaſſes; for, tho they are very much affected by both the aberrations before-mention'd, yet, by a proper combination of ſeveral together, their errors may be in a great meaſure corrected. If any one, for inſtance, would have the viſual angle of a teleſcope to contain 20 degrees, the extreme pencils of the field muſt be bent or refracted in an angle of 10 degrees; which, if it be performed by one eye-glaſs, will cauſe an aberration from the figure, in proportion to the cube of that angle: but if two glaſſes are ſo proportioned and ſituated, as that the refraction may be equally divided between them, they will each of them produce a refraction equal to half the required angle: and therefore the aberration being in proportion to the cube of half the angle taken twice over, will be but a fourth part of that, which is in proportion to the cube of the whole angle; becauſe twice the cube of one is but $\frac{1}{4}$ of the cube of two; ſo the aberration from the figure, where two eye glaſſes are rightly proportion'd, is but a fourth of what muſt unavoidably be, where the whole is performed by a ſingle eye-glaſs. By the ſame way of reaſoning, when the refraction is divided

divided between three glaſſes, the aberration will be found to be but the ninth part of what would be produced from a ſingle glaſs; becauſe three times the cube of one is but one ninth of the cube of 3. Whence it appears, that, by increaſing the number of eye-glaſſes, the indiſtinctneſs, which is obſerved near the borders of the field of a teleſcope, may be very much diminiſhed, tho' not intirely taken away.

The method of correcting the errors ariſing from the different refrangibility of light is of a different conſideration from the former; for, whereas the errors from the figure can only be diminiſhed in a certain proportion to the number of glaſſes, in this they may be intirely corrected, by the addition of only one glaſs; as we find in the aſtronomical teleſcope, that two eye-glaſſes, rightly proportion'd, will cauſe the edges of objects to appear free from colours quite to the borders of the field. Alſo in the day-teleſcope, where no more than two eye-glaſſes are abſolutely neceſſary for erecting the object, we find, by the addition of a third rightly ſituated, that the colours, which would otherwiſe confuſe the image, are intirely removed: I ſay intirely removed; but this is to be underſtood with ſome limitation; for tho' the different colours, which the extreme pencils muſt neceſſarily be divided into by the edges of the eye-glaſſes, may in this manner be brought to the eye in a direction parallel to each other, ſo as, by the humours thereof, to be converg'd to a point in the retina; yet, if the glaſſes exceed a certain length, the colours may be ſpread too wide to be capable of being admitted thro' the pupil or aperture of the eye; which is the reaſon, that, in long teleſcopes, con-

ſtructed in the common manner, with three eye-glaſſes, the field is always very much contracted.

Theſe conſiderations, Sir, firſt ſet me on contriving, how to enlarge the field by increaſing the number of eye-glaſſes, without any hindrance to the diſtinctneſs or brightneſs of the image: And tho' others had been about the ſame work before, yet obſerving, that the five-glaſs teleſcopes, ſold in the ſhops, would admit of farther improvement, I endeavour'd to conſtruct one with the ſame number of glaſſes in a better manner; which ſo far anſwer'd my expectations, as to be allow'd by ſuch perſons, as are the beſt judges, to be a conſiderable improvement on the former.

Encouraged by this ſucceſs, I reſolved to try, if poſſibly I might gain ſome farther enlargement of the field by the addition of another glaſs: and by placing and proportioning the glaſſes in ſuch a manner, as to correct the aberrations as much as poſſible, without any detriment to the diſtinctneſs, I have obtained as large a field, as is convenient or neceſſary, and that even in the longeſt teleſcopes, that can be made.

Theſe teleſcopes with ſix glaſſes having been well received, and ſome of them being gone to foreign parts, it ſeems a proper time to ſettle the account of its origin; which is one of the motives, that has induced me to trouble you with this ſhort ſketch of the conſiderations, that gradually led me to its conſtruction; and I am emboldened, Sir, to write thus much, from the many favours I have already received at your hands, as well as from a ſenſe of your being a proper perſon to judge in ſuch caſes. And tho' I am ſenſible, that you are not unacquainted with the theory contain'd in this letter, yet toraf-

much

much as the ſubject has never been fully treated by any author, I ſhall endeavour, as ſoon as may be, to draw up a more particular explanation of the aberrations of light by refraction; but ſhall add no more at preſent, only beg leave to take this opportunity of ſubſcribing myſelf

Vine-Court, Feb. 21, 1753.

Your much obliged and moſt humble ſervant,

John Dollond.