Fig. 5.

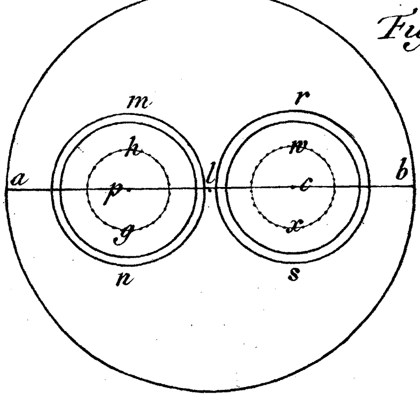


Fig. 6.

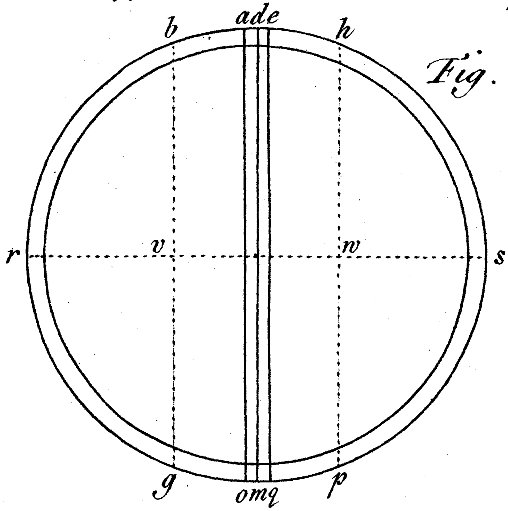


Fig. 7.

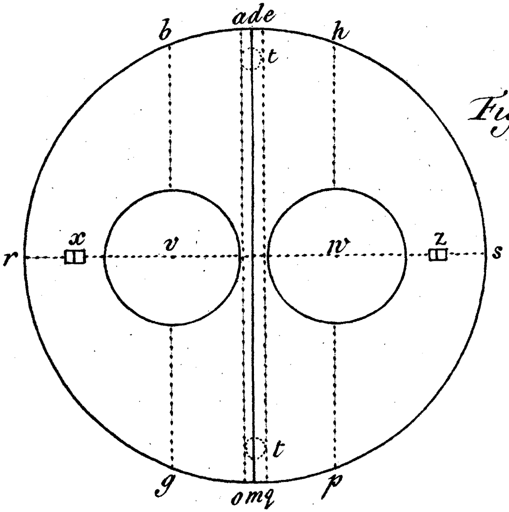
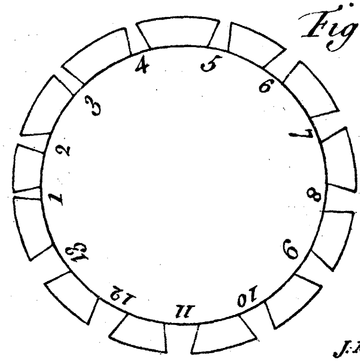


Fig. 8.



J. Mynde sc.

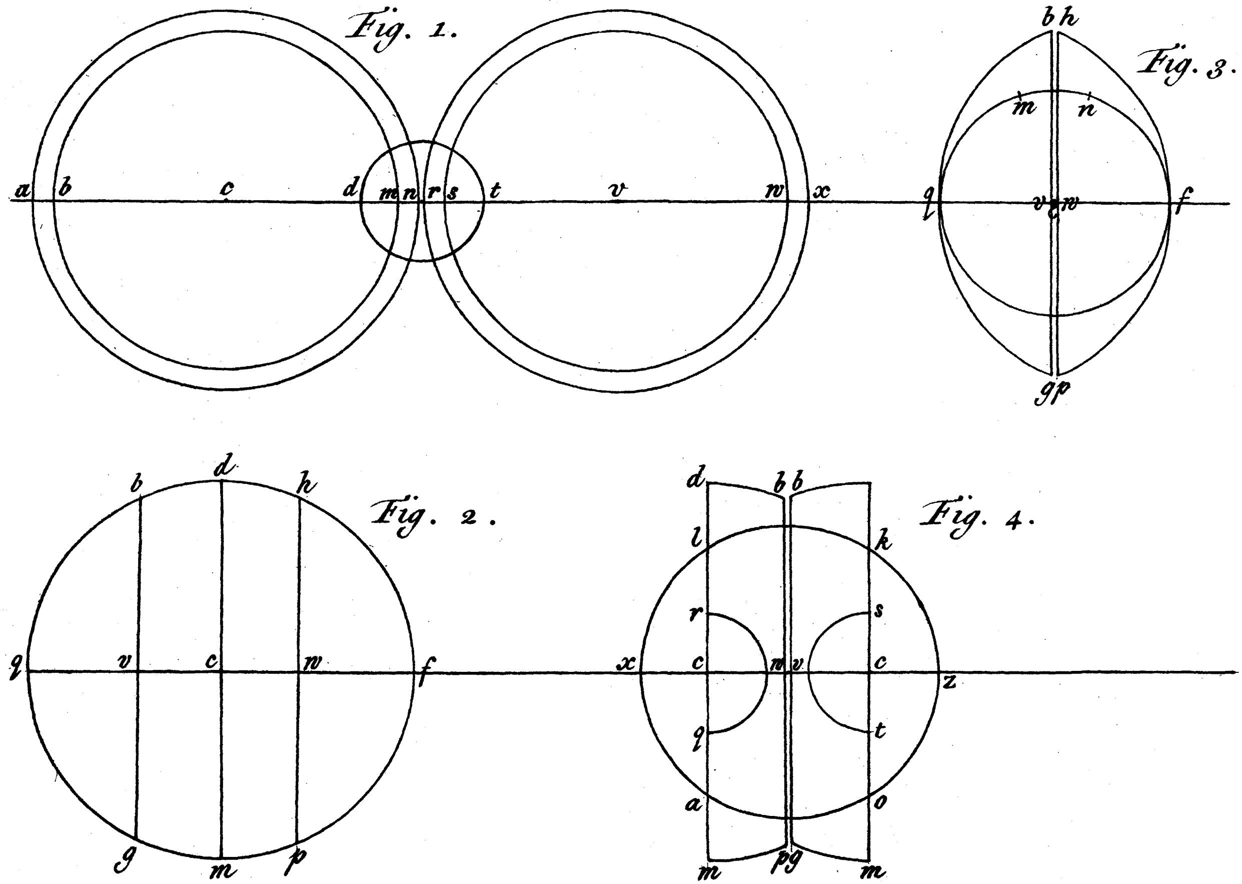


Fig. 1.
a b c d m n r s t v w x
Fig. 3.
b h
m n
q v c w f
g p
Fig. 2.
b d h
q v c w f
g m p
Fig. 4.
d b b
l k
r s
x c w v c z
q t
a o
m p g m

J. Mynde sc.

XXVI. *A Letter from Mr.* James Short, *F. R. S. to the right honourable the Earl of* Macclesfield, *President, concerning a Paper of the late* Servington Savery, *Esq; relating to his Invention of a new* Micrometer.

My Lord,

Read May 10, 1753.

IT is now above a year since I received a letter from the Rev. F. Pezenas, professor of hydrography to the French King at Marseilles, in which he informed me, that M. Bouguer had read, before the Royal Academy of Sciences at Paris, in the year 1748, a memoir, in which he describes an heliometer; which is an instrument, consisting of two objective glasses, for measuring the diameters of the planets. He said also, that this memoir was actually in the hands of M. de Fouchy, Perpetual Secretary of the Academy, or at the Royal Printing-house; and that it was register'd in the minutes of the Academy for the year 1748.

Immediately after reading this letter, I recollected to have heard a paper upon the same subject from the late Servington Savery, of Exeter, Esq; read before the Royal Society, about the year 1743. I therefore had recourse to the minute-book of the Society for that year, where I found the following minute, which I copied in the presence of the right honourable the Lord Charles Cavendish, then Vice-President:

" A

"A paper communicated from Mr. Savery at
"Exon, containing a new method for meaſur-
"ing the difference between the apogeal and
"perigeal diameters of the ſun, was ſhewn; and
"thanks being ordered, Dr. Bradley was de-
"ſired to oblige the Society with an account of
"its contents.

"Octob. 27, 1743."

Upon mentioning laſt year the whole of what I have now repeated to you, your lordſhip was pleaſed to promiſe to ſpeak to Dr. Bradley, who was then in Oxfordſhire, concerning this paper of Mr. Savery; in conſequence of which, I, about the end of laſt May, received the original paper of Mr. Savery from the Doctor's hands.

The volume of the Royal Academy for the year 1748 being now publiſhed, I have found, that F. Pezenas's information was juſt, and therefore I have ſent incloſed to your lordſhip, as Preſident of the Royal Society, the original paper of Mr. Savery, which, if your lordſhip thinks proper, may be returned to the Society.

Your lordſhip will obſerve, upon the back of the original paper of Mr. Savery, a memorandum in the hand-writing of our late worthy Preſident, Martin Folkes, Eſq; as a further proof of its authenticity, which runs in theſe words,

"Delivered to me by Mr. Graham, ſealed up
"by the author, and then broke open in his
"preſence ☿ 26 Oct. 1743.

"M. Folkes."

I have likewiſe, my lord, in my hands, an original letter of Mr. Savery to the late Mr. Geo. Graham upon the ſame ſubject, dated Nov. 30, 1743; and a copy of this letter ſhall be delivered, if commanded by the Society, as a farther proof of the authenticity of Mr. Savery's paper. I am,

My Lord,

Your Lordſhip's moſt obedient,

Surrey-ſtreet, May 10, 1753.

and moſt humble ſervant,

James Short.

A new Way of meaſuring the Difference between the apparent Diameter of the Sun at the Times of the Earth's Perihelion and Aphelion, or when the Sun is nearer to or farther from the Earth, with a Micrometer placed in a Teleſcope invented for that Purpoſe; tho' the Charge or magnifying Power of the Teleſcope is ſo great, that the whole Sun's Diameter does not appear therein at one View: By Servington Savery, *of* Exeter, *Eſq; mention'd in Mr.* Short's *preceding Letter.*

Read Oct. 27, 1743.

THIS, I doubt not, will, at firſt ſight, ſeem impoſſible; ſince only a part of the diameter appears, and no viſible mark or point therein, from which ſuch meaſure can be taken: and indeed it is ſo by obſervations with our common teleſcopes, whether dioptric or reflecting ones.

I have

I have therefore contrived ſome dioptric teleſcopes, and a reflecting one; either of which (by repreſenting the object double) will, if well made, anſwer the deſign.

Fig. 1.

Repreſents the whole body of the ſun, as it appears double, and magnified in the teleſcope. Let *an* be the diameter of the one, and *rx* of the other image of the ſun *in perigæo*; ſo ſhall *nr* be the diſtance between the two images at that time; which meaſured with the micrometer is equal to (ſuppoſe) 10 ſeconds.

Let *bm* be the diameter of the one ſolar image, and *sw* of the other, when *in apogæo*: ſo ſhall *ms* be the then diſtance of the ſolar images, meaſuring with the micrometer (ſuppoſe) 1 minute 10 ſeconds. The difference of theſe two obſervations, 1 minute, is the apparent diminution of the ſun's diameter.

The little circle, whoſe diameter is *dt*, is the whole area viſible at once in the teleſcope, which is not one third part of the magnified diameter of the ſun: but ſince both *nr* at one time, and *ms* at another time, are viſible within the teleſcope's area, (if good inſtruments are procured) I can ſee no difficulty in performing what I have propoſed above more accurately than it has ever yet been done, except this one (which ſome time ſince Mr. Graham in a letter to me mention'd) *viz.* that of defining the ſun's diſk truly: and I think to do that to good perfection, is beyond human art. A teleſcope for this uſe may be made to magnify the ſun's diameter to any degree whatſoever, not exceeding ſuch degree, as will make any part of the line *ms* fall without the area of the teleſcope: and I think it will be very difficult to make one with

a charge

a charge ſo great, as not to have more than a geometrical minute of the ſun's apparent diameter viſible at once.

Since the ſun is an object ſo very remote, the pencil of rays flowing from the center of its diſk, and incident all over an object-lens (tho' it ſhould be a foot broad) would not differ ſenſibly from a perfect cylinder within the diſtance of above 100 miles from its baſis at the lens; tho' in reality the whole pencil is an acute cone, whoſe angle at the vertex is almoſt evaneſcent.

Hence it follows:

That if the two poles of two equal object-glaſſes are placed at the diſtance (ſuppoſe) of a foot from one another, the two centers, *c*, *v*, of the two ſolar images muſt, as to ſenſe, remain always at that very ſame diſtance (*viz.* 1 foot) from one another, tho' the ſun ſhould be placed ten times as far off as it now is: but ſince the ſun's greater diſtance would diminiſh the diameters of both of the ſolar images; *m n*, added to *r s*, muſt be the true difference of the apparent diameters of the images (and alſo of the ſun) at different times.

According to Mr Azout (*Harris*'s *Lexic. Techn. Vol.* I. *ſee* SUN), the apparent diameter of the ſun never exceeds 32′ 45″; whence its radius never exceeds 16′ 22″ 30‴; the tangent whereof is about 476,328 (if I miſtake not) to the radius 100,000,000.

As the ſaid tangent : to the ſaid radius : : ſo half an inch : to 04.96 inches, and decimal parts.

According to this,

If the focal length of a lens is 104.96 inches and parts, it cannot collect the ſun's rays to a leſs focus at the time of his perigee than one inch in diameter, or half an inch radius.

Fig. 2.

The whole circle reprefents a well-center'd object-lens, whofe focal length is (as above calculated) 104.96 inches and parts (rather a little lefs, that the two images may be fure not to touch one another.) Let the two diameters *d m*, *qf*, divide it into four quadrants, but the diameter *q f* muft be occult, or delible. Let *c w* be half an inch, and *c v* equal to it. Through *v* (and alfo thro' *w*) let a chord-line be drawn parallel to the diameter *d m*, viz. *b g*, *h p*. Thro' the faid chord-lines *b g*, and *h p*, and alfo thro' the diameter *d m*, divide the lens into four parts.

Fig. 3.

Let the ftrait edge of the fruftum *b v g q* in the preceding figure be cemented faft to that of the fimilar fruftum *h w p f* of the fame lens, as they appear in this prefent Fig. 3. wherein, for the eafier underftanding the placing them, I have noted each fruftum with the fame letters it was noted withal in the preceding Fig. 2. Having then with barm faftened a white paper all over both fides of the lens I made for trial (which I did, not only to fecure the cemented joint from breaking, but to prevent the injury which the polifh might receive in cutting and grinding the edges) I defcribed a circle *q m n f* on the center *c*, fit for the tube I had to put in it; and having made it round, and wafh'd it clean, after the edges were ground true, that nothing fandy might hurt the polifh, I foak'd it in clean water, till I could eafily take off the

the paper. I alſo, before I took off the paper, mark'd one end of each fruſtum in the edge at *m* and *n*, that if they fell aſunder, they might be cemented together again the ſame way. This model (made of a ſpectacle-glaſs about 12 or 13 inches focus) gave me encouragement to try the following one, which I thought better.

Fig. 4.

I made my ſecond model of the two middle fruſtums *m c d h w p*, *m c d b v g*, of the lens Fig. 2. by cementing their edges, *h w p*, *b v g*, together, as they are placed in the preſent Fig. 4. ſo the pole *c* of each part muſt conſequently be half an inch (ſuppoſing its focal length is about 104 inches) from the middle where *c* ſtood in Fig. 2. *viz.* the pole of one fruſtum where *v*, and of the other where *w* now ſtands. I left open at each pole a ſemicircular aperture *r w q*, *s v t*, about two thirds of an inch diameter, and cover'd all the reſt of the circle *a x l k z o*, to which I had cut it fit for the tube. The focus of the lens I made it of was about 3 feet.

Note, The rays of red light in the two ſolar images will be next to one another in both theſe models, which, I take it, will render the ſun's diſk more eaſy to be obſerved than the violet ones. This I mention, becauſe the glaſſes in theſe two ſorts are ſomewhat priſmatical, but moſtly thoſe of my firſt model, which could therefore bear no great charge. Alſo the fruſtum on the right-hand of my firſt model renders the ſolar image at the focus on the left, and that on the left-hand renders it on the right: but it is not ſo with the ſecond model, or with the next contrivance, which is the beſt, if well made.

Fig. 5.

In this the greateſt difficulty conſiſts in getting two well-center'd object-glaſſes, whoſe focal lengths are equal; for it is neceſſary they ſhould be ſo, becauſe they are to be combined with the ſame convex eye-lens (common to them) at the ſame diſtance. *a b* is the diameter of a plain braſs plate, which may be two inches and a half broad, or ſomewhat leſs; two ſhort equal cylindric braſs tubes, *m n*, *r s*, muſt be faſtened thereon, with their centers *p c*, equidiſtant from the center *l* of the plate, and diſtant one inch from one another in the diameter *a b*, as the figure ſheweth. In the tubes muſt be put two equal object glaſſes of the focal length of $104\frac{9}{10}$ inches, or rather ſomewhat leſs, as aforeſaid. Through the plate there muſt be made in the middle of each tube a round aperture, *viz. h g*, *w x*, whoſe diameters muſt be proportion'd to the focal length of the eye-lens, and not exceed the third part thereof, leſt the object appear confuſed.

And ſince it is ſcarce poſſible to center an object-lens to very good perfection, thoſe in the two cylinders (tho' put in by a good artiſt) may happen to render the two ſolar images at too great a diſtance from, or too near to one another. But this fault, if not too great, may be remedied, by turning one or both of the lens's a little way round; and then their eccentric poles will by that means be brought nearer to, or further from, one another; and when they are once well plac'd, there ſhould be a mark made in each lens, and its cylinder; that if it is taken out to be wiped, it may be put in again the ſame way. There ſhould alſo be a different mark in one of the glasses, that each may know its own cylinder. They must both of them be very close all round to their respective cylinders; otherwise one lens may slide nearer to or further from the other; which if it should in the least degree, between the first and second observation, all the labour would be lost.

Either of these three parts of double lens's may be combined with a convex eye-lens as usual, and have a micrometer placed at the common focus.

Such a double lens, of either sort, may be proved whether it is well composed or not, without the trouble of combining it with its eye-lens; by holding it in the sun's rays, as one would a burning glass, and applying a piece of white paper at its focus, where, I apprehend, the two solar images will appear as distinct as when an eye-lens is applied, tho' not so large; and each of them one inch broad, if the focal length is as above, *i. e.* almost $104\frac{9}{10}$ inches.

After the same manner may the double object-mirror of a reflecting telescope for this use be proved.

Fig. 6.

The circle *bdhpmg* is the circumference of a concave mirror made of black glass: it must be very thick, that it may not spring or bend with any thing that presseth on it to keep it fast; for that may injure the concavity of it.

The circle within it on the same center *c* sheweth, that the concavity thereof must not be continued quite home to the very edge of the mirror, but the little space between the two circles must be ground very true on a plain. The prick'd lines must not be drawn; they are only to indicate where the poles

v w

v w of the two fruſtums muſt be brought, after the mirror is diametrically biſected.

Let the concave ſide be defended, by paſting a paper all over it, and then let it be divided with a ſaw in the diameter *d c m*; taking care that the ſaid diameter be in the middle of the kerf, which may be as broad as the ſpace between the lines *a o*, *e q*. Let the aſperities of the edges of both fruſtums be ground off, that they may be very ſtrait after their being ſawn.

Fig. 7.

Repreſents a thick round plate of braſs very plain, and equally thick all over, having lines drawn on it, as on Fig. 2. alſo one line on each ſide of the diameter *dm*, equidiſtant from it, and parallel thereto. The diſtance of theſe two lines *a o*, *e q*, from one another equal to the kerf of the ſaw, which divided the mirror. The diameter of this plate muſt be equal to that of the mirror before it was divided.

On the under ſide of the plate muſt be two pins faſtened thereto, *t t*, their diameters equal to the kerf of the ſaw, that they may keep the two fruſtums of the mirror at the ſame diſtance from each other that they were before their diviſion; ſo ſhall their circular edges be extended as far as the circumference of the plate, and their ſtrait edges touch the ſaid pins in the lines *a o*, *e q*.

The end of the tube muſt be turn'd on the inſide exactly to fit the plate and mirror, that they may not ſlide any way, for that would ſpoil the obſervations.

In the diameter of the plate *r s*, on the points *v*, *w*, diſtant half an inch from *c*, the center of the plate, and

and a whole inch from each other, let a circle for the aperture of each fruſtum, of a proper ſize, according to the intended charge of the teleſcope, be deſcribed, and cut out. Alſo in the ſaid diameter, equidiſtant from the center *c*, *viz.* at *x* and *z*, let there be a ſcrew for each fruſtum, to elevate it a little from the plate, as ſhall be needful.

Let there be a ſpring contrived to preſs on the backſide of the one fruſtum *o r a* againſt the point *v*, being the middle between the edge *a o*, and the ſcrew *x*, to keep the fruſtum cloſe to the plate at the points *a o*, and alſo cloſe to the ſcrew *x*, when it is ſcrew'd in. Let the like be alſo done on the back of the other fruſtum *e s q*.

I ſay then,

1. That before the two ſcrews are put in at *x*, *z*, the two fruſtums of the mirror will lie plain on the plate of braſs, and have one pole at *c* common to them, and, conſequently, will collect all rays, which, during their incidence, are parallel to the axis of the tube to one common focus in the ſaid axis of the tube, juſt as they would have done before the mirror was divided.

2. But when the two ſcrews *x z* are put in their places, and ſcrew'd a little way through the braſs plate, they will lift the two fruſtums free from the plate at their circular edges, *viz.* at *r* and *s*, while their ſtrait edges, *a o*, *e q*, are kept to touch the plate with both their ends (not in the middle, by reaſon of the mirror's concavity) by the preſſure of the ſprings, as was mention'd above. By this means the pole *c* of the fruſtum *o r a* will be removed from *c* toward

toward *r*; and likewise the pole *c* of the other frustum *esq* be removed from *c* towards *s*, more or less according to the quantity of the elevation of each frustum by the screw that raiseth it: so that now there will appear at the focus two solar images; whereas there was but one, before the screws were put in.

By moving the screws, the two solar images may be brought to any distance from one another; but care must be taken not to raise one frustum more than the other, and the two solar images must almost touch one another at the time of the perigee; otherwise it must be better adjusted.

This telescope may be finished with a small elliptical specillum of black glass, ground plain on its reflecting surface, and a convex eye-lens, like that described by J. Hadley, Esq; F. R. S. in *Phil. Trans.* N° 376. A micrometer may be contrived for it at the common focus, near the eye-lens.

Such a double object-speculum would be capable of a vast improvement, by combining it with a concave specillum, which would reflect the images thro' a hole in the center *c* of the said speculum to fall on a convex eye-lens, after the manner of our new sort of reflecting telescopes, was it not for the difficulty of adapting such a micrometer to it as would exactly measure minutes and seconds; for the eye-glasses of such having usually a pretty large focal length, would bear much larger divisions on a micrometer, than Mr. Hadley's with a small eye-glass can do, tho' their charges should be equal, or that of the former did exceed.

I find that large object-glasses for telescopes are not commonly well center'd, with their poles in the very middle

middle of them. I ſent for two to London, both of which were faulty; I therefore return'd them, and had two ſent me again, as eccentric well nigh as the former ones.

Harris's *Lexicon Techn.* Vol. I. (ſee *Optics*) gives a rule for centering optic-glaſſes; but I think the following may be more ſure and handy for a glaſs-grinder's uſe, and ſoon try whether a convex lens is well center'd.

Fig. 8.

Repreſents a round plate of braſs, conveniently thick, and well harden'd by hammering (were it not for the ruſt, harden'd ſteel would be better), having many notches round it, one a little wider than that which is next to it, and number'd 1, 2, 3, *&c.* in their proper order, each of them wider at the bottom than at the entrance. I fitted ſuch a notch to the thickeſt ſide of one of the glaſſes I had from London, ſo as the edge enter'd it but a little way, not half the depth thereof; but, on trying the oppoſite ſide, it went in, the whole depth thereof, and would have gone deeper, if the notch had been ſo cut: I then ground the lens narrower on that ſide which was thinneſt, until I found it was at that place as thick as where I firſt try'd it in the notch. After this manner I reduc'd the glaſs to an equal thickneſs on its four quarters, and then ground off from other places what was needful to bring it circular. I alſo took care, when I tried it in the notch, that the lens ſhould not be warmer on the one ſide than on the other by grinding, but tarried till I thought it thoroughly cold; and was alſo careful not to thruſt it in harder on the one ſide than on the

 oppoſite

opposite side; for I could plainly observe a difference afterward, if I neglected to mind both these circumstances, or indeed either of them *.

XXVII. *A Description of a Contrivance for measuring small* Angles, *by Mr.* John Dollond; *communicated by Mr.* J. Short, *F. R. S.*

Read May 10, 1753.

LET an object-glass, of any convenient focal length (being truly ground and well center'd) be divided into two equal parts or segments, by cutting it strait through the center; and let a piece of machinery be so contriv'd, as to hold these two segments in the same position to each other, as they stood in before they were cut asunder; and to be capable at the same time of drawing them to different distances from that position, in the manner, as is represented in the figure.

Each of these segments will form a distinct image of any object, to which they are directed; differing in nothing from that, which might have been made by the whole glass before it was cut, except in brightness. And while these segments are held in their original position, the images will coincide, and become one single image as at first; but, in proportion as they

* Dr. Smith, in his Complete System of Optics, published in 1738, has described a very accurate and ready method of centering object-glasses, which was always used by the late Mr. George Graham, from whom the doctor had it.