OPTICKS:

Stamford OR, A 1712

TREATISE

OF THE

REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

SPECIES and MAGNITUDE

OF

Curvilinear Figures.

LONDON,

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PROP. II. Theor. II.

The Light of the Sun consists of Rays differently Refrangible.

The Proof by Experiments.

Exper. 3. IN a very dark Chamber at a round hole about one third part of an Inch broad made in the Shut of a Window I placed a Glass Prism, whereby the beam of the Sun's Light which came in at that hole might be refracted upwards toward the opposite Wall of the Chamber, and there form a coloured Image of the Sun. The Axis of the Prism (that is the Line passing through the middle of the Prism from one end of it to the other end Parallel to the edge of the Refracting Angle) was in this and the following Experiments perpendicular to the incident Rays. About this Axis I turned the Prism slowly, and saw the refracted Light on the Wall or coloured Image of the Sun first to descend and then to ascend. Between the Descent and Ascent when the Image seemed Stationary, I stopt the Prism, and fixt it in that Posture, that it should be moved no more. For in that posture the Refractions of the Light at the two sides of the Refracting Angle, that is at the entrance of the Rays into the Prism and at their going out of it, were equal to one another. So also in other Experiments as often as I would have the Refractions on both sides the Prism to be equal to one another, I noted the place where the Image of the Sun formed by the refracted Light stood still between its two contrary Motions, in the common Period of its progress and egress; and when the Image fell upon that place, I made fast the Prism. And in this posture, as the

the moſt convenient, it is to be underſtood that all the Priſms are placed in the following Experiments, unleſs where ſome other poſture is deſcribed. The Priſm therefore being placed in this poſture, I let the refracted Light fall perpendicularly upon a Sheet of white Paper at the oppoſite Wall of the Chamber, and obſerved the Figure and Dimenſions of the Solar Image formed on the Paper by that Light. This Image was Oblong and not Oval, but terminated with two Rectilinear and Parallel Sides, and two Semicircular Ends. On its Sides it was bounded pretty diſtinctly, but on its Ends very confuſedly and indiſtinctly, the Light there decaying and vaniſhing by degrees. The breadth of this Image anſwered to the Sun's Diameter, and was about two Inches and the eighth part of an Inch, including the Penumbra. For the Image was eighteen Feet and an half diſtant from the Priſm, and at this diſtance that breadth if diminiſhed by the Diameter of the hole in the Window-ſhut, that is by a quarter of an Inch, ſubtended an Angle at the Priſm of about half a Degree, which is the Sun's apparent Diameter. But the length of the Image was about ten Inches and a quarter, and the length of the Rectilinear Sides about eight Inches; And the refracting Angle of the Priſm whereby ſo great a length was made, was 64 degr. With a leſs Angle the length of the Image was leſs, the breadth remaining the ſame. If the Priſm was turned about its Axis that way which made the Rays emerge more obliquely out of the ſecond refracting Surface of the Priſm, the Image ſoon became an Inch or two longer, or more; and if the Priſm was turned about the contrary way, ſo as to make the Rays fall more obliquely on the firſt refracting Surface, the Image ſoon became an Inch or two ſhorter. And therefore in trying this Experiment, I was as curious as I could be in placing the Priſm by the above-mentioned Rule exactly in

ſuch a poſture that the Refractions of the Rays at their emergence out of the Priſm might be equal to that at their incidence on it. This Priſm had ſome Veins running along within the Glaſs from one end to the other, which ſcattered ſome of the Sun's Light irregularly, but had no ſenſible effect in encreaſing the length of the coloured Spectrum. For I tried the ſame Experiment with other Priſms with the ſame Succeſs. And particularly with a Priſm which ſeemed free from ſuch Veins, and whoſe refracting Angle was $62\frac{1}{2}$ Degrees, I found the length of the Image $9\frac{3}{4}$ or 10 Inches at the diſtance of $18\frac{1}{2}$ Feet from the Priſm, the breadth of the hole in the Window-ſhut being $\frac{1}{4}$ of an Inch as before. And becauſe it is eaſie to commit a miſtake in placing the Priſm in its due poſture, I repeated the Experiment four or five times, and always found the length of the Image that which is ſet down above. With another Priſm of clearer Glaſs and better Polliſh, which ſeemed free from Veins and whoſe refracting Angle was $63\frac{1}{2}$ Degrees, the length of this Image at the ſame diſtance of $18\frac{1}{2}$ Feet was alſo about 10 Inches, or $10\frac{1}{8}$. Beyond theſe Meaſures for about $\frac{1}{4}$ or $\frac{1}{3}$ of an Inch at either end of the Spectrum the Light of the Clouds ſeemed to be a little tinged with red and violet, but ſo very faintly that I ſuſpected that tincture might either wholly or in great meaſure ariſe from ſome Rays of the Spectrum ſcattered irregularly by ſome inequalities in the Subſtance and Poliſh of the Glaſs, and therefore I did not include it in theſe Meaſures. Now the different Magnitude of the hole in the Window-ſhut, and different thickneſs of the Priſm where the Rays paſſed through it, and different inclinations of the Priſm to the Horizon, made no ſenſible changes in the length of the Image. Neither did the different matter of the

the Prisms make any: for in a Vessel made of polished Plates of Glass cemented together in the shape of a Prism and filled with Water, there is the like Success of the Experiment according to the quantity of the Refraction. It is further to be observed, that the Rays went on in right Lines from the Prism to the Image, and therefore at their very going out of the Prism had all that Inclination to one another from which the length of the Image proceeded, that is the Inclination of more than two Degrees and an half. And yet according to the Laws of Opticks vulgarly received, they could not possibly be so much inclined to one another. For let EG represent the Window-shut, F the hole made therein through which a beam of the Sun's Light was transmitted into the darkned Chamber, and ABC a Triangular Imaginary Plane whereby the Prism is feigned to be cut transversly through the middle of the Light. Or if you please, let ABC represent the Prism it self, looking directly towards the Spectator's Eye with its nearer end: And let XY be the Sun, MN the Paper upon which the Solar Image or Spectrum is cast, and PT the Image it self whose sides tovvards V and W are Rectilinear and Parallel, and ends tovvards P and T Semicircular. YKHP and XLJT are two Rays, the first of which comes from the lower part of the Sun to the higher part of the Image, and is refracted in the Prism at K and H, and the latter comes from the higher part of the Sun to the lower part of the Image, and is refracted at L and J. Since the Refractions on both sides the Prism are equal to one another, that is the Refraction at K equal to the Refraction at J, and the Refraction at L equal to the Refraction at H, so that the Refractions of the incident Rays at K and L taken together are equal to the Refractions of the emergent Rays at H and J taken together:

Fig. 13.

it follows by adding equal things to equal things, that the Refractions at K and H taken together, are equal to the Refractions at J and L taken together, and therefore the two Rays being equally refracted have the same Inclination to one another after Refraction which they had before, that is the Inclination of half a Degree answering to the Sun's Diameter. For so great was the Inclination of the Rays to one another before Refraction. So then, the length of the Image PT would by the Rules of Vulgar Opticks subtend an Angle of half a Degree at the Prism, and by consequence be equal to the breadth *vw*; and therefore the Image would be round. Thus it would be were the two Rays XLJT and YKHP and all the rest which form the Image P*w*T*v*, alike Refrangible. And therefore seeing by Experience it is found that the Image is not round but about five times longer than broad, the Rays which going to the upper end P of the Image suffer the greatest Refraction, must be more Refrangible than those which go to the lower end T, unless the inequality of Refraction be casual.

This Image or Spectrum PT was coloured, being red at its least refracted end T, and violet at its most refracted end P, and yellow green and blew in the intermediate spaces. Which agrees with the first Proposition, that Lights which differ in Colour do also differ in Refrangibility. The length of the Image in the foregoing Experiments I measured from the faintest and outmost red at one end, to the faintest and outmost blew at the other end.

Exper. 4. In the Sun's beam which was propagated into the Room through the hole in the Window-shut, at the distance of some Feet from the hole, I held the Prism in such a posture that its Axis might be perpendicular to that beam. Then I looked through the Prism upon the hole,

hole, and turning the Priſm to and fro about its Axis to make the Image of the hole aſcend and deſcend, when between its two contrary Motions it ſeemed ſtationary, I ſtopt the Priſm that the Refractions on both ſides of the refracting Angle might be equal to each other as in the former Experiment. In this Situation of the Priſm viewing through it the ſaid hole, I obſerved the length of its refracted Image to be many times greater than its breadth, and that the moſt refracted part thereof appeared violet, the leaſt refracted red, the middle parts blew green and yellow in order. The ſame thing happened when I removed the Priſm out of the Sun's Light, and looked through it upon the hole ſhining by the Light of the Clouds beyond it. And yet if the Refraction were done regularly according to one certain Proportion of the Sines of Incidence and Refraction as is vulgarly ſuppoſed, the refracted Image ought to have appeared round.

So then, by theſe two Experiments it appears that in equal Incidences there is a conſiderable inequality of Refractions: But whence this inequality ariſes, whether it be that ſome of the incident Rays are refracted more and others leſs, conſtantly or by chance, or that one and the ſame Ray is by Refraction diſturbed, ſhattered, dilated, and as it were ſplit and ſpread into many diverging Rays, as *Grimaldo* ſuppoſes, does not yet appear by theſe Experiments, but will appear by thoſe that follow.

Exper. 5. Conſidering therefore, that if in the third Experiment the Image of the Sun ſhould be drawn out into an oblong form, either by a Dilatation of every Ray, or by any other caſual inequality of the Refractions, the ſame oblong Image would by a ſecond Refraction made Sideways be drawn out as much in breadth by the like Dilatation of the Rays or other caſual inequality of the Refractions

fractions Sideways, I tried what would be the Effects of ſuch a ſecond Refraction. For this end I ordered all things as in the third Experiment, and then placed a ſecond Priſm immediately after the firſt in a croſs Poſition to it, that it might again refract the beam of the Sun's Light which came to it through the firſt Priſm. In the firſt Priſm this beam was refracted upwards, and in the ſecond Sideways. And I found that by the Refraction of the ſecond Priſm the breadth of the Image was not increaſed, but its ſuperior part which in the firſt Priſm ſuffered the greater Refraction and appeared violet and blew, did again in the ſecond Priſm ſuffer a greater Refraction than its inferior part, which appeared red and yellow, and this without any Dilation of the Image in breadth.

Fig. 14. *Illuſtration.* Let S repreſent the Sun, F the hole in the Window, A B C the firſt Priſm, D H the ſecond Priſm, Y the round Image of the Sun made by a direct beam of Light when the Priſms are taken away, P T the oblong Image of the Sun made by that beam paſſing through the firſt Priſm alone when the ſecond Priſm is taken away, and *pt* the Image made by the croſs Refractions of both Priſms together. Now if the Rays which tend towards the ſeveral Points of the round Image Y were dilated and ſpread by the Refraction of the firſt Priſm, ſo that they ſhould not any longer go in ſingle Lines to ſingle Points, but that every Ray being ſplit, ſhattered, and changed from a Linear Ray to a Superficies of Rays diverging from the Point of Refraction, and lying in the Plane of the Angles of Incidence and Refraction, they ſhould go in thoſe Planes to ſo many Lines reaching almoſt from one end of the Image P T to the other, and if that Image ſhould thence become oblong: thoſe Rays and their ſeveral parts tending towards the ſeveral Points of the

the Image P T ought to be again dilated and ſpread Sideways by the tranſverſe Refraction of the ſecond Priſm, ſo as to compoſe a fourſquare Image, ſuch as is repreſented at πτ. For the better underſtanding of which, let the Image P T be diſtinguiſhed into five equal Parts P Q K, K Q R L, L R S M, M S V N, N V T. And by the ſame irregularity that the Orbicular Light Y is by the Refraction of the firſt Priſm dilated and drawn out into a long Image P T, the the Light P Q K which takes up a ſpace of the ſame length and breadth with the Light Y ought to be by the Refraction of the ſecond Priſm dilated and drawn out into the long Image π q k p, and the Light K Q R L into the long Image k q r l, and the Lights L R S M, M S V N, N V T into ſo many other long Images l r s m, m s ν n, n ν t τ; and all theſe long Images would compoſe the fourſquare Image πτ. Thus it ought to be were every Ray dilated by Refraction, and ſpread into a triangular Superficies of Rays diverging from the Point of Refraction. For the ſecond Refraction would ſpread the Rays one way as much as the firſt doth another, and ſo dilate the Image in breadth as much as the firſt doth in length. And the ſame thing ought to happen, were ſome Rays caſually refracted more than others. But the Event is otherwiſe. The Image P T was not made broader by the Refraction of the ſecond Priſm, but only became oblique, as 'tis repreſented at *p t*, its upper end P being by the Refraction tranſlated to a greater diſtance than its lower end T. So then the Light which went towards the upper end P of the Image, was (at equal Incidences) more refracted in the ſecond Priſm than the Light which tended towards the lower end T, that is the blew and violet, than the red and yellow; and therefore was more Refrangible. The ſame Light was by the Refraction of the firſt Priſm tranſlated further from the

place Y to which it tended before Refraction; and therefore ſuffered as well in the firſt Priſm as in the ſecond a greater Refraction than the reſt of the Light, and by conſequence was more Refrangible than the reſt, even before its incidence on the firſt Priſm.

Sometimes I placed a third Priſm after the ſecond, and ſometimes alſo a fourth after the third, by all which the Image might be often refracted ſideways: but the Rays which were more refracted than the reſt in the firſt Priſm were alſo more refracted in all the reſt, and that without any Dilatation of the Image ſideways: and therefore thoſe Rays for their conſtancy of a greater Refraction are deſervedly reputed more Refrangible.

Fig. 15. But that the meaning of this Experiment may more clearly appear, it is to be conſidered that the Rays which are equally Refrangible do fall upon a circle anſwering to the Sun's Diſque. For this was proved in the third Experiment. By a circle I underſtand not here a perfect Geometrical Circle, but any Orbicular Figure whoſe length is equal to its breadth, and which, as to ſenſe, may ſeem circular. Let therefore A G repreſent the circle which all the moſt Refrangible Rays propagated from the whole Diſque of the Sun, would illuminate and paint upon the oppoſite Wall if they were alone; E L the circle which all the leaſt Refrangible Rays would in like manner illuminate and paint if they were alone; B H, C J, D K, the circles which ſo many intermediate ſorts of Rays would ſucceſſively paint upon the Wall, if they were ſingly propagated from the Sun in ſucceſſive Order, the reſt being always intercepted; And conceive that there are other intermediate Circles without number which innumerable other intermediate ſorts of Rays would ſucceſſively paint upon the Wall if the Sun ſhould ſucceſſively emit every ſort apart.

And seeing the Sun emits all these sorts at once, they must all together illuminate and paint innumerable equal circles, of all which, being according to their degrees of Refrangibility placed in order in a continual series, that oblong Spectrum P T is composed which I described in the third Experiment. Now if the Sun's circular Image Y which is made by an unrefracted beam of Light was by any dilatation of the single Rays, or by any other irregularity in the Refraction of the first Prism, converted into the Oblong Spectrum, P T : then ought every circle A G, B H, C J, *&c.* in that Spectrum, by the cross Refraction of the second Prism again dilating or otherwise scattering the Rays as before, to be in like manner drawn out and transformed into an Oblong Figure, and thereby the breadth of the Image P T would be now as much augmented as the length of the Image Y was before by the Refraction of the first Prism ; and thus by the Refractions of both Prisms together would be formed a foursquare Figure $p \pi t \tau$ as I described above. Wherefore since the breadth of the Spectrum P T is not increased by the Refraction sideways, it is certain that the Rays are not split or dilated, or otherways irregularly scattered by that Refraction, but that every circle is by a regular and uniform Refraction translated entire into another place, as the circle A G by the greatest Refraction into the place *ag*, the circle B H by a less Refraction into the place *bh*, the circle C J by a Refraction still less into the place *ci*, and so of the rest ; by which means a new Spectrum *pt* inclined to the former P T is in like manner composed of circles lying in a right Line ; and these circles must be of the same bigness with the former, because the breadths of all the Spectrums Y, P T and *pt* at equal distances from the Prisms are equal.

Fig. 14 & 15

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I considered further that by the breadth of the hole F through which the Light enters into the Dark Chamber, there is a Penumbra made in the circuit of the Spectrum Y, and that Penumbra remains in the rectilinear Sides of the Spectrums P T and *pt*. I placed therefore at that hole a Lens or Object-glass of a Telescope which might cast the Image of the Sun distinctly on Y without any Penumbra at all, and found that the Penumbra of the Rectilinear Sides of the oblong Spectrums P T and *pt* was also thereby taken away, so that those Sides appeared as distinctly defined as did the Circumference of the first Image Y. Thus it happens if the Glass of the Prisms be free from veins, atd their Sides be accurately plane and well polished without those numberless waves or curles which usually arise from Sand-holes a little smoothed in polishing with Putty. If the Glass be only well polished and free from veins and the Sides not accurately plane but a little Convex or Concave, as it frequently happens ; yet may the three Spectrums Y, P T and *pt* want Penumbras, but not in equal distances from the Prisms. Now from this want of Penumbras, I knew more certainly that every one of the circles was refracted according to some most regular, uniform, and constant law. For if there were any irregularity in the Refraction, the right Lines A E and G L which all the circles in the Spectrum P T do touch, could not by that Refraction be translated into the Lines *ae* and *gl* as distinct and straight as they were before, but there would arise in those translated Lines some Penumbra or crookedness or undulation, or other sensible Perturbation contrary to what is found by Experience. Whatsoever Penumbra or Perturbation should be made in the circles by the cross Refraction of the second Prism, all that Penumbra or Perturbation would be conspicuous in

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the right Lines *a e* and *g l* which touch thoſe circles. And therefore ſince there is no ſuch Penumbra or Perturbation in thoſe right Lines there muſt be none in the circles. Since the diſtance between thoſe Tangents or breadth of the Spectrum is not increaſed by the Refractions, the Diameters of the circles are not increaſed thereby. Since thoſe Tangents continue to be right Lines, every circle which in the firſt Priſm is more or leſs refracted, is exactly in the ſame Proportion more or leſs refracted in the ſecond. And ſeeing all theſe things continue to ſucceed after the ſame manner when the Rays are again in a third Priſm, and again in a fourth refracted Sideways, it is evident that the Rays of one and the ſame circle as to their degree of Refrangibility continue always Uniform and Homogeneal to one another, and that thoſe of ſeveral circles do differ in degree of Refrangibility, and that in ſome certain and conſtant Proportion. Which is the thing I was to prove.

There is yet another Circumſtance or two of this Experiment by which it becomes ſtill more plain and convincing. Let the ſecond Priſm D H be placed not immeately after after the firſt, but at ſome diſtance from it; Suppoſe in the mid-way between it and the Wall on which the oblong Spectrum P T is caſt, ſo that the Light from the firſt Priſm may fall upon it in the form of an oblong Spectrum, $\pi\tau$ Parallel to this ſecond Priſm, and be refracted Sideways to form the oblong Spectrum *p t* upon the Wall. And you will find as before, that this Spectrum *p t* is inclined to that Spectrum P T, which the firſt Priſm forms alone without the ſecond; the blew ends P and *p* being further diſtant from one another than the red ones T and *t*; and by conſequence that the Rays which go to the blew end π of the Image $\pi\tau$ and which therefore ſuffer the greateſt Refraction in the firſt Priſm, are again in the ſecond Priſm more refracted than the reſt. *Fig.* 16.

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Fig. 17. The ſame thing I try'd alſo by letting the Sun's Light into a dark Room through two little round holes F and φ made in the Window, and with two Parallel Priſms ABC and $\alpha\beta\gamma$ placed at thoſe holes (one at each) refracting thoſe two beams of Light to the oppoſite Wall of the Chamber, in ſuch manner that the two colour'd Images P T and MN which they there painted were joyned end to end and lay in one ſtraight Line, the red end T of the one touching the blew end M of the other. For if theſe two refracted beams were again by a third Priſm D H placed croſt to the two firſt, refracted Sideways, and the Spectrums thereby tranſlated to ſome other part of the Wall of the Chamber, ſuppoſe the Spectrum P T to *p t* and the Spectrum M N to *m n*, theſe tranſlated Spectrums *p t* and *m n* would not lie in one ſtraight Line with their ends contiguous as before, but be broken off from one another and become Parallel, the blew end of the Image *m n* being by a greater Refraction tranſlated farther from its former place M T, than the red end *t* of the other Image *p t* from the ſame place M T which puts the Propoſition paſt diſpute. And this happens whether the third Priſm D H be placed immediately after the two firſt or at a great diſtance from them, ſo that the Light refracted in the two firſt Priſms be either white and circular, or coloured and oblong when it falls on the third.

Exper. 6. In the middle of two thin Boards I made round holes a third part of an Inch in Diameter, and in the Window-ſhut a much broader hole, being made to let into my darkned Chamber a large beam of the Sun's Light; I placed a Priſm behind the Shut in that beam to refract it towards the oppoſite Wall, and cloſe behind the Priſm I fixed one of the Boards, in ſuch manner that the middle of the refracted Light might paſs through the hole

made

made in it, and the rest be intercepted by the Board. Then at the distance of about twelve Feet from the first Board I fixed the other Board, in such manner that the middle of the refracted Light which came through the hole in the first Board and fell upon the opposite Wall might pass through the hole in this other Board, and the rest being intercepted by the Board might paint upon it the coloured Spectrum of the Sun. And close behind this Board I fixed another Prism to refract the Light which came through the hole. Then I returned speedily to the first Prism, and by turning it slowly to and fro about its Axis, I caused the Image which fell upon the second Board to move up and down upon that Board, that all its parts might successively pass through the hole in that Board and fall upon the Prism behind it. And in the mean time, I noted the places on the opposite Wall to which that Light after its Refraction in the second Prism did pass; and by the difference of the places I found that the Light which being most refracted in the first Prism did go to the blew end of the Image, was again more refracted in the second Prism than the Light which went to the red end of that Image, which proves as well the first Proposition as the second. And this happened whether the Axis of the two Prisms were parallel, or inclined to one another and to the Horizon in any given Angles.

Illustration. Let F be the wide hole in the Window-shut, *Fig.* 18.
through which the Sun shines upon the first Prism A B C, and let the refracted Light fall upon the middle of the Board D E, and the middle part of that Light upon the hole G made in the middle of that Board. Let this trajected part of the Light fall again upon the middle of the second Board *d e* and there paint such an oblong coloured Image of the Sun as was described in the third Experiment. By

By turning the Prism A B C slowly to and fro about its Axis this Image will be made to move up and down the Board *d e*, and by this means all its parts from one end to the other may be made to pass successively through the hole *g* which is made in the middle of that Board. In the mean while another Prism *a b c* is to be fixed next after that hole *g* to refract the trajected Light a second time. And these things being thus ordered, I marked the places M and N of the opposite Wall upon which the refracted Light fell, and found that whilst the two Boards and second Prism remained unmoved, those places by turning the first Prism about its Axis were changed perpetually. For when the lower part of the Light which fell upon the second Board *d e* was cast through the hole *g* it went to a lower place M on the Wall, and when the higher part of that Light was cast through the same hole *g*, it went to a higher place N on the Wall, and when any intermediate part of the Light was cast through that hole it went to some place on the Wall between M and N. The unchanged Position of the holes in the Boards, made the Incidence of the Rays upon the second Prism to be the same in all cases. And yet in that common Incidence some of the Rays were more refracted and others less. And those were more refracted in this Prism which by a greater Refraction in the first Prism were more turned out of the way, and therefore for their constancy of being more refracted are deservedly called more Refrangible.

Exper. 7. At two holes made near one another in my Window-shut I placed two Prisms, one at each, which might cast upon the opposite Wall (after the manner of the third Experiment) two oblong coloured Images of the Sun. And at a little distance from the Wall I placed a long slender Paper with straight and parallel edges, and ordered

ordered the Prisms and Paper so, that the red Colour of one Image might fall directly upon one half of the Paper, and the violet colour of the other Image upon the other half of the same Paper; so that the Paper appeared of two Colours, red and violet, much after the manner of the painted Paper in the first and second Experiments. Then with a black Cloth I covered the Wall behind the Paper, that no Light might be reflected from it to disturb the Experiment, and viewing the Paper through a third Prism held parallel to it, I saw that half of it which was illuminated by the Violet-light to be divided from the other half by a greater Refraction, especially when I went a good way off from the Paper. For when I viewed it too near at hand, the two halfs of the Paper did not appear fully divided from one another, but seemed contiguous at one of their Angles like the painted Paper in the first Experiment. Which also happened when the Paper was too broad.

Sometimes instead of the Paper I used a white Thred, and this appeared through the Prism divided into two Parallel Threds as is represented in the 19th Figure, where *Fig.* 19. D G denotes the Thred illuminated with violet Light from D to E and with red Light from F to G, and *d e f g* are the parts of the Thred seen by Refraction. If one half of the Thred be constantly illuminated with red, and the other half be illuminated with all the Colours successively, (which may be done by causing one of the Prisms to be turned about its Axis whilst the other remains unmoved) this other half in viewing the Thred through the Prism, will appear in a continued right Line with the first half when illuminated with red, and begin to be a little divided from it when illuminated with Orange, and remove further from it when illuminated with Yellow, and still

further when with Green, and further when with Blew, and go yet further off when illuminated with Indigo, and furthest when with deep Violet. Which plainly shews, that the Lights of several Colours are more and more Refrangible one than another, in this order of their Colours, Red, Orange, Yellow, Green, Blew, Indigo, deep Violet; and so proves as well the first Proposition as the second.

Fig. 17. I caused also the coloured Spectrums P T and M N made in a dark Chamber by the Refractions of two Prisms to lye in a right Line end to end, as was described above in the fifth Experiment, and viewing them through a third Prism held Parallel to their length, they appeared no longer in a right Line, but became broken from one another, as they are represented at *p t* and *m n*, the violet end *m* of the Spectrum *m n* being by a greater Refraction translated further from its former place M T than the red end *t* of the other Spectrum *p t*.

Fig. 20. I further caused those two Spectrums P T and M N to become co-incident in an inverted order of their Colours, the red end of each falling on the violet end of the other, as they are represented in the oblong Figure P T M N; and then viewing them through a Prism D H held Parallel to their length, they appeared not co-incident as when viewed with the naked Eye, but in the form of two distinct Spectrums *p t* and *m n* crossing one another in the middle after the manner of the letter X. Which shews that the red of the one Spectrum and violet of the other, which were co-incident at P N and M T, being parted from one another by a greater Refraction of the violet to *p* and *m* than of the red to *n* and *t*, do differ in degrees of Refrangibility.

I illuminated also a little circular piece of white Paper all over with the Lights of both Prisms intermixed, and when it was illuminated with the red of one Spectrum and deep violet of the other, so as by the mixture of those Colours to appear all over purple, I viewed the Paper, first at a less distance, and then at a greater, through a third Prism; and as I went from the Paper, the refracted Image thereof became more and more divided by the unequal Refraction of the two mixed Colours, and at length parted into two distinct Images, a red one and a violet one, whereof the violet was furthest from the Paper, and therefore suffered the greatest Refraction. And when that Prism at the Window which cast the violet on the Paper was taken away, the violet Image disappeared; but when the other Prism was taken away the red vanished: which shews that these two Images were nothing else than the Lights of the two Prisms which had been intermixed on the purple Paper, but were parted again by their unequal Refractions made in the third Prism through which the Paper was viewed. This also was observable that if one of the Prisms at the Window, suppose that which cast the violet on the Paper, was turned about its Axis to make all the Colours in this order, Violet, Indigo, Blew, Green, Yellow, Orange, Red, fall successively on the Paper from that Prism, the violet Image changed Colour accordingly, and in changing Colour came nearer to the red one, until when it was also red they both became fully co-incident.

I placed also two paper circles very near one another, the one in the red Light of one Prism, and the other in the violet Light of the other. The circles were each of them an Inch in Diameter, and behind them the Wall was dark that the Experiment might not be disturbed by any Light coming from thence. These circles thus illuminated, I viewed through a Prism so held that the Refraction might be made towards the red circle, and as I went from them

they came nearer and nearer together, and at length became co-incident; and afterwards when I went still further off, they parted again in a contrary order, the violet by a greater Refraction being carried beyond the red.

Exper. 8. In Summer when the Sun's Light uses to be strongest, I placed a Prism at the hole of the Window-shut, as in the third Experiment, yet so that its Axis might be Parallel to the Axis of the World, and at the opposite Wall in the Sun's refracted Light, I placed an open Book. Then going Six Feet and tvvo Inches from the Book, I placed there the abovementioned Lens, by vvhich the Light reflected from the Book might be made to converge and meet again at the distance of six Feet and tvvo Inches behind the Lens, and there paint the Species of the Book upon a sheet of vvhite Paper much after the manner of the second Experiment. The Book and Lens being made fast, I noted the place vvhere the Paper vvas, vvhen the Letters of the Book, illuminated by the fullest red Light of the Solar Image falling upon it, did cast their Species on that Paper most distinctly; And then I stay'd till by the Motion of the Sun and consequent Motion of his Image on the Book, all the Colours from that red to the middle of the blew pass'd over those Letters; and when those Letters were illuminated by that blew, I noted again the place of the Paper when they cast their Species most distinctly upon it: And I found that this last place of the Paper was nearer to the Lens than its former place by about two Inches and an half, or two and three quarters. So much sooner therefore did the Light in the violet end of the Image by a greater Refraction converge and meet, than the Light in the red end. But in trying this the Chamber was as dark as I could make it. For if these Colours be diluted and weakned by the mixture of any adventitious Light, the distance between the places of the Paper will not be so great. This distance in the second Experiment where the Colours of natural Bodies were made use of, was but an Inch and a half, by reason of the imperfection of those Colours. Here in the Colours of the Prism, which are manifestly more full, intense, and lively than those of natural Bodies, the distance is two Inches and three quarters. And were the Colours still more full, I question not but that the distance would be considerably greater. For the coloured Light of the Prism, by the interfering of the Circles described in the 11th Figure of the fifth Experiment, and also by the Light of the very bright Clouds next the Sun's Body intermixing with these Colours, and by the Light scattered by the inequalities in the polish of the Prism, was so very much compounded, that the Species which those faint and dark Colours, the Indigo and Violet, cast upon the Paper were not distinct enough to be well observed.

Exper. 9. A Prism, whose two Angles at its Base were equal to one another and half right ones, and the third a right one, I placed in a beam of the Sun's Light let into a dark Chamber through a hole in the Window-shut as in the third Experiment. And turning the Prism slowly about its Axis until all the Light which went through one of its Angles and was refracted by it began to be reflected by its Base, at which till then it went out of the Glass, I observed that those Rays which had suffered the greatest Refraction were sooner reflected than the rest. I conceived therefore that those Rays of the reflected Light, which were most Refrangible, did first of all by a total Reflexion become more copious in that Light than the rest, and that afterwards the rest also, by a total Reflexion, became as copious as these. To try this, I made the reflected Light pass through another Prism, and being refracted

by it to fall afterwards upon a sheet of white Paper placed at some distance behind it, and there by that Refraction to paint the usual Colours of the Prism. And then causing the first Prism to be turned about its Axis as above, I observed that when those Rays which in this Prism had suffered the greatest Refraction and appeared of a blew and violet Colour began to be totally reflected, the blew and violet Light on the Paper which was most refracted in the second Prism received a sensible increase above that of the red and yellow, which was least refracted; and afterwards when the rest of the Light which was green, yellow and red began to be totally reflected in the first Prism, the light of those Colours on the Paper received as great an increase as the violet and blew had done before. Whence 'tis manifest, that the beam of Light reflected by the Base of the Prism, being augmented first by the more Refrangible Rays and afterwards by the less Refrangible ones, is compounded of Rays differently Refrangible. And that all such reflected Light is of the same Nature with the Sun's Light, before its Incidence on the Base of the Prism, no Man ever doubted: it being generally allowed, that Light by such Reflexions suffers no Alteration in its Modifications and Properties. I do not here take notice of any Refractions made in the Sides of the first Prism, because the Light enters it perpendicularly at the first Side, and goes out perpendicularly at the second Side, and therefore suffers none. So then, the Sun's incident Light being of the same temper and constitution with his emergent Light, and the last being compounded of Rays differently Refrangible, the first must be in like manner compounded.

Fig. 21. *Illustration.* In the 21th Figure, A B C is the first Prism, B C its Base, B and C its equal Angles at the Base, each of

of 45 degrees, A its Rectangular Vertex, F M a beam of the Sun's Light let into a dark Room through a hole F one third part of an Inch broad, M its Incidence on the Base of the Prism, M G a less refracted Ray, M H a more refracted Ray, M N the beam of Light reflected from the Base, V X Y the second Prism by which this beam in passing through it is refracted, N *t* the less refracted Light of this beam, and N *p* the more refracted part thereof. When the first Prism A B C is turned about its Axis according to the order of the Letters A B C, the Rays M H emerge more and more obliquely out of that Prism, and at length after their most oblique Emergence are reflected towards N, and going on to *p* do increase the number of the Rays N *p*. Aftervvards by continuing the motion of the first Prism, the Rays M G are also reflected to N and increase the number of the Rays N *t*. And therefore the Light M N admits into its Composition, first the more Refrangible Rays, and then the less Refrangible Rays, and yet after this Composition is of the same Nature vvith the Sun's immediate Light F M, the Reflexion of the specular Base B C causing no Alteration therein.

Exper. 10. Two Prisms, which were alike in shape, I tied so together, that their Axes and opposite Sides being Parallel, they composed a Parallelopiped. And, the Sun shining into my dark Chamber through a little hole in the Window-shut, I placed that Parallelopiped in his beam at some distance from the hole, in such a posture that the Axes of the Prisms might be perpendicular to the incident Rays, and that those Rays being incident upon the first Side of one Prism, might go on through the two contiguous Sides of both Prisms, and emerge out of the last Side of the second Prism. This Side being Parallel to the first Side of the first Prism, caused the emerging Light to be Parallel to

to the Incident. Then, beyond these two Prisms I placed a third, which might refract that emergent Light, and by that Refraction cast the usual Colours of the Prism upon the opposite Wall, or upon a sheet of white Paper held at a convenient distance behind the Prism for that refracted Light to fall upon it. After this I turned the Parallelopiped about its Axis, and found that when the contiguous Sides of the two Prisms beeame so oblique to the incident Rays that those Rays began all of them to be reflected, those Rays which in the third Prism had suffered the greatest Refraction and painted the Paper with violet and blew, were first of all by a total Reflexion taken out of the transmitted Light, the rest remaining and on the Paper painting their Colours of Green, Yellow, Orange, and Red as before; and afterwards by continuing the motion of the two Prisms, the rest of the Rays also by a total Reflexion vanished in order, according to their degrees of Refrangibility. The Light therefore which emerged out of the two Prisms is compounded of Rays differently Refrangible, seeing the more Refrangible Rays may be taken out of it while the less Refrangible remain. But this Light being trajected only through the Parallel Superficies of the two Prisms, if it suffered any change by the Refraction of one Superficies it lost that impression by the contrary Refraction of the other Superficies, and so being restored to its pristine constitution became of the same nature and condition as at first before its Incidence on those Prisms; and therefore, before its Incidence, was as much compounded of Rays differently Refrangible as afterwards.

Fig. 22. *Illustration.* In the 22th Figure A B C and B C D are the the two Prisms tied together in the form of a Parallelopiped, their Sides B C and C B being contiguous, and their Sides A B and C D Parallel. And H J K is the third Prism,

Prism, by which the Sun's Light propagated through the hole F into the dark Chamber, and there passing through th se sides of the Prisms AB, BC, CB and CD, is refracted at O to the white Paper PT, falling there partly upon P by a greater Refraction, partly upon T by a less Refraction, and partly upon R and other intermediate places by intermediate Refractions. By turning the Parallelopiped ACBD about its Axis, according to the order of the Letters A, C, D, B, at length when the contiguous Planes BC and CB become sufficiently oblique to the Rays FM, which are incident upon them at M, there will vanish totally out of the refracted Light OPT, first of all the most refracted Rays OP, (the rest OR and OT remaining as before) then the Rays OR and other intermediate ones, and lastly, the least refracted Rays OT. For when the Plane BC becomes sufficiently oblique to the Rays incident upon it, those Rays will begin to be totally reflected by it towards N; and first the most Refrangible Rays will be totally reflected (as was explained in the preceding experiment) and by consequence must first disappear at P, and afterwards the rest as they are in order totally reflected to N, they must disappear in the same order at R and T. So then the Rays which at O suffer the greatest Refraction, may be taken out of the Light MO whilst the rest of the Rays remain in it, and therefore that Light MO is Compounded of Rays differently Refrangible. And because the Planes AB and CD are parallel, and therefore by equal and contrary Refractions destroy one anothers Effects, the incident Light FM must be of the same kind and nature with the emergent Light MO, and therefore doth also consist of Rays differently Refrangible. These two Lights FM and MO, before the most refrangible Rays are separated out of the emergent Light MO agree in Colour,

lour, and in all other properties so far as my observation reaches, and therefore are deservedly reputed of the same Nature and Constitution, and by consequence the one is compounded as well as the other. But after the most Refrangible Rays begin to be totally reflected, and thereby separated out of the emergent Light MO, that Light changes its Colour from white to a dilute and faint yellow, a pretty good orange, a very full red successively and then totally vanishes. For after the most Refrangible Rays which paint the Paper at P with a Purple Colour, are by a total reflexion taken out of the Beam of light MO, the rest of the Colours which appear on the Paper at R and T being mixed in the light MO compound there a faint yellow, and after the blue and part of the green which appear on the Paper between P and R are taken away, the rest which appear between R and T (that is the Yellow, Orange, Red and a little Green) being mixed in the Beam MO compound there an Orange; and when all the Rays are by reflexion taken out of the Beam MO, except the least Refrangible, which at T appear of a full Red, their Colour is the same in that Beam MO as afterwards at T, the Refraction of the Prism HJK serving only to separate the differently Refrangible Rays, without making any alteration in their Colours, as shall be more fully proved hereafter. All which confirms as well the first Proposition as the second.

Scholium. If this Experiment and the former be conjoyned and made one, by applying a fourth Prism VXY to refract the reflected Beam MN towards *tp*, the conclusion will be clearer. For then the light N*p* which in the 4th Prism is more refracted, will become fuller and stronger when the Light OP, which in the third Prism HJK is more refracted, vanishes at P; and afterwards when the less refracted

Fig. 22.

refracted Light O T vanishes at T, the less refracted Light N*t* will become encreased whilst the more refracted Light at *p* receives no further encrease. And as the trajected Beam M O in vanishing is always of such a Colour as ought to result from the mixture of the Colours which fall upon the Paper P T, so is the reflected Beam MN always of such a Colour as ought to result from the mixture of the Colours which fall upon the Paper *pt*. For when the most refrangible Rays are by a total Reflexion taken out of the Beam MO, and leave that Beam of an Orange Colour, the excess of those Rays in the reflected Light, does not only make the Violet, Indigo and Blue at *p* more full, but also makes the Beam M N change from the yellowish Colour of the Sun's Light, to a pale white inclining to blue, and afterward recover its yellowish Colour again, so soon as all the rest of the transmitted light MOT is reflected.

Now seeing that in all this variety of Experiments, whether the trial be made in Light reflected, and that either from natural Bodies, as in the first and second Experiment, or Specular, as in the Ninth; or in Light refracted, and that either before the unequally refracted Rays are by diverging separated from one another, and losing their whiteness which they have altogether, appear severally of several Colours, as in the fifth Experiment; or after they are separated from one another, and appear Coloured as in the sixth, seventh, and eighth Experiments; or in Light trajected through Parallel superficies, destroying each others Effects as in the 10th Experiment; there are always found Rays, which at equal Incidences on the same Medium suffer unequal Refractions, and that without any splitting or dilating of single Rays, or contingence in the inequality of the Refractions, as is proved in the fifth and sixth Experiments;

and seeing the Rays which differ in Refrangibility may be parted and sorted from one another, and that either by Refraction as in the third Experiment, or by Reflexion as in the tenth, and then the several sorts apart at equal Incidences suffer unequal Refractions, and those sorts are more refracted than others after separation, which were more refracted before it, as in the sixth and following Experiments, and if the Sun's Light be trajected through three or more cross Prisms successively, those Rays which in the first Prism are refracted more than others are in all the following Prisms, refracted more then others in the same rate and proportion, as appears by the fifth Experiment; it's manifest that the Sun's Light is an Heterogeneous mixture of Rays, some of which are constantly more Refrangible then others, as was proposed.

PROP. III. Theor. III.

The Sun's Light consists of Rays differing in Reflexibility, and those Rays are more Reflexible than others which are more Refrangible.

THIS is manifest by the ninth and tenth Experiments: For in the ninth Experiment, by turning the Prism about its Axis, until the Rays within it which in going out into the Air were refracted by its Base, became so oblique to that Base, as to begin to be totally reflected thereby; those Rays became first of all totally reflected, which before at equal Incidences with the rest had suffered the greatest Refraction. And the same thing happens in the Reflexion made by the common Base of the two Prisms in the tenth Experiment.

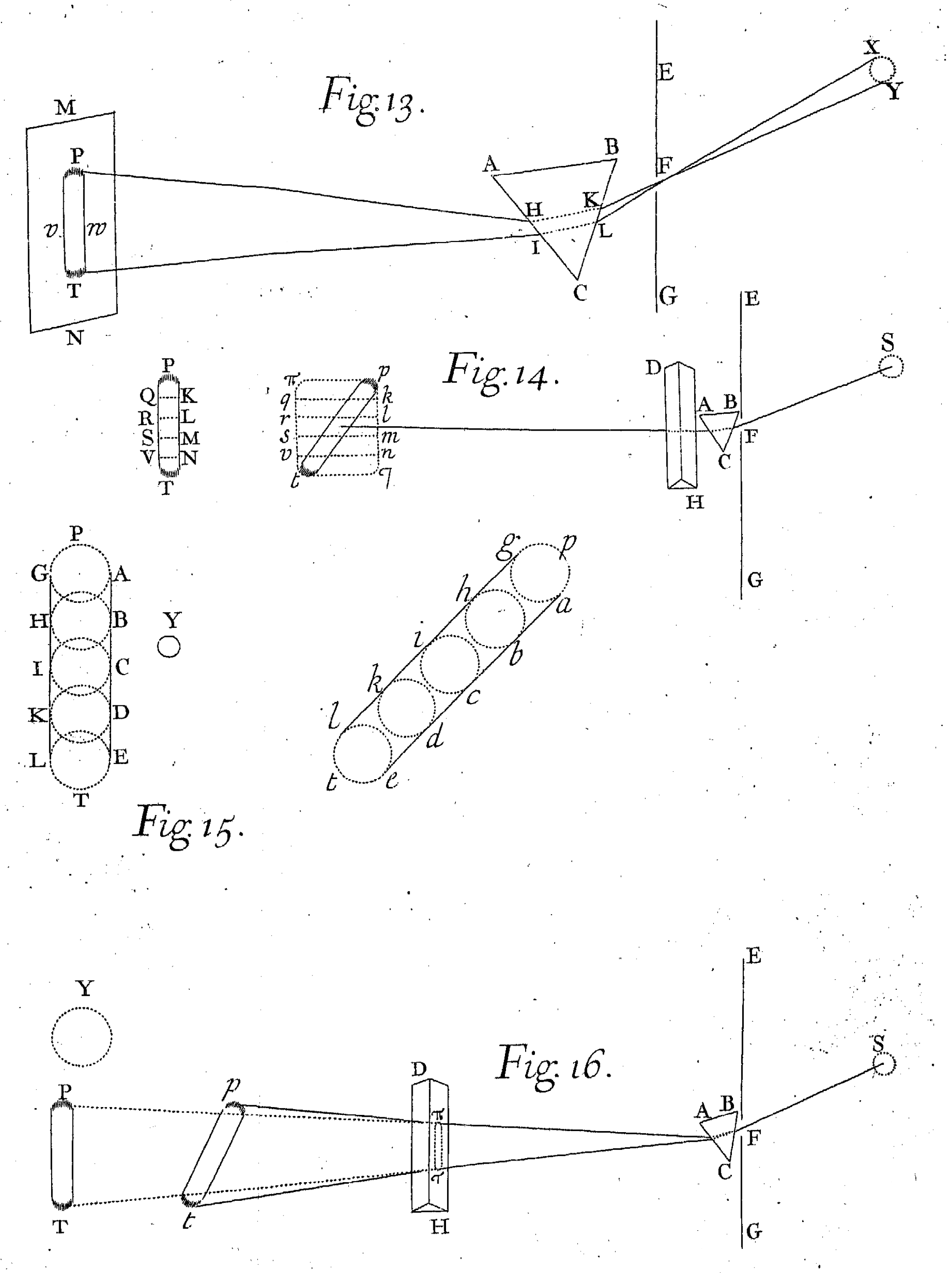
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.

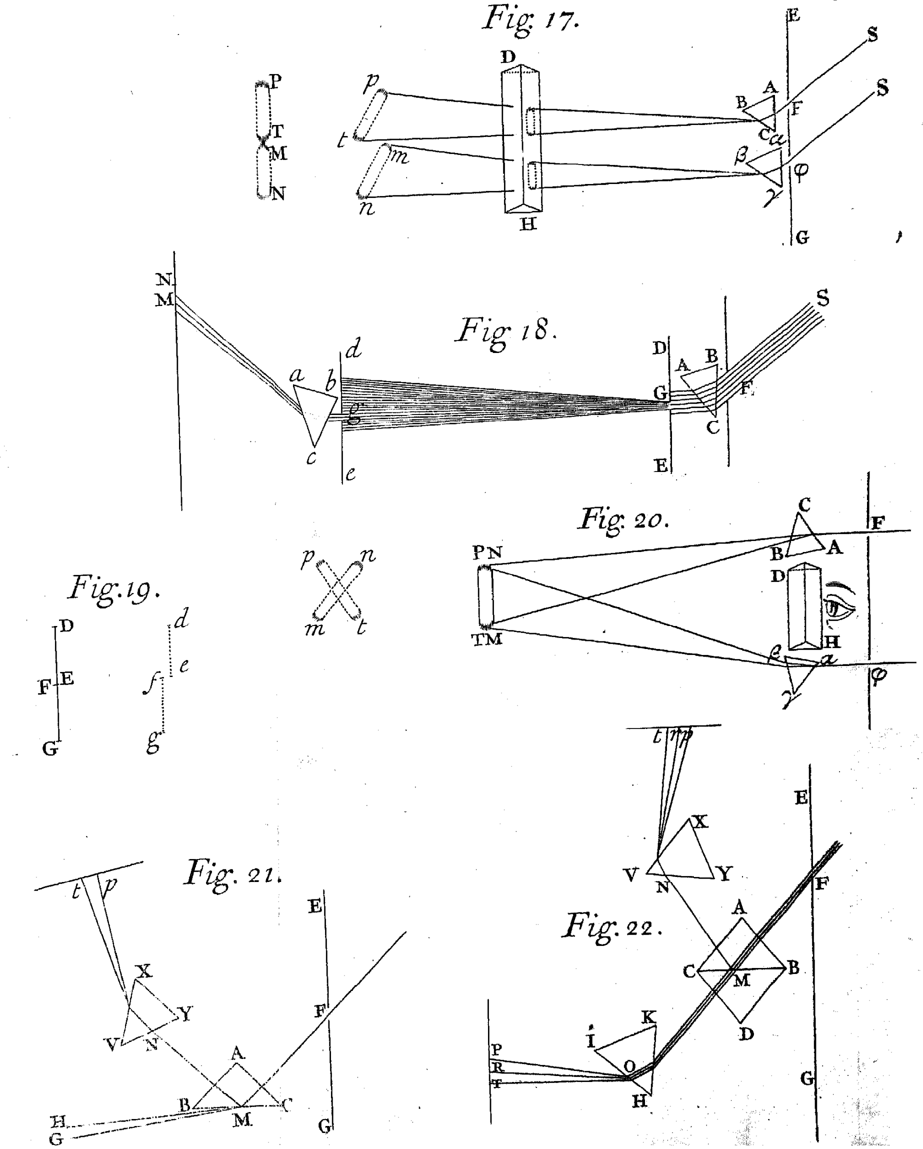
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.