PHILOSOPHICAL TRANSACTIONS.

February 19. $16\frac{71}{72}$.

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A Letter of Mr. Isaac Newton, *Professor of the Mathematicks in the University of Cambridge; containing his New Theory about* Light *and* Colors: *sent by the Author to the Publisher from Cambridge, Febr.* 6. $16\frac{71}{72}$; *in order to be communicated to the* R. Society.

SIR,

TO perform my late promise to you, I shall without further ceremony acquaint you, that in the beginning of the Year 1666 (at which time I applyed my self to the grinding of Optick glasses of other figures than *Spherical,*) I procured me a Triangular glass-Prisme, to try therewith the celebrated *Phænomena* of

Colours. And in order thereto having darkened my chamber, and made a ſmall hole in my window-ſhuts, to let in a convenient quantity of the Suns light, I placed my Priſme at his entrance, that it might be thereby refracted to the oppoſite wall. It was at firſt a very pleaſing divertiſement, to view the vivid and intenſe colours produced thereby; but after a while applying my ſelf to conſider them more circumſpectly, I became ſurpriſed to ſee them in an *oblong* form; which, according to the received laws of Refraction, I expected ſhould have been *circular*.

They were terminated at the ſides with ſtreight lines, but at the ends, the decay of light was ſo gradual, that it was difficult to determine juſtly, what was their figure; yet they ſeemed *ſemicircular*.

Comparing the length of this coloured *Spectrum* with its breadth, I found it about five times greater; a diſproportion ſo extravagant, that it excited me to a more then ordinary curioſity of examining, from whence it might proceed. I could ſcarce think, that the various *Thickneſs* of the glaſs, or the termination with ſhadow or darkneſs, could have any Influence on light to produce ſuch an effect; yet I thought it not amiſs, firſt to examine thoſe circumſtances, and ſo tryed, what would happen by tranſmitting light through parts of the glaſs of divers thickneſſes, or through holes in the window of divers bigneſſes, or by ſetting the Priſme without ſo, that the light might paſs through it, and be refracted before it was terminated by the hole: But I found none of thoſe circumſtances material The faſhion of the colours was in all theſe caſes the ſame.

Then I ſuſpected, whether by any *unevenneſs* in the glaſs, or other contingent irregularity, theſe colours might be thus dilated. And to try this, I took another Priſme like the former, and ſo placed it, that the light, paſſing through them both, might be refracted contrary ways, and ſo by the latter returned into that courſe, from which the former had diverted it. For, by this means I thought, the *regular* effects of the firſt Priſme would be deſtroyed by the ſecond Priſme, but the *irregular* ones more augmented, by the multiplicity of refractions. The event was, that the light, which by the firſt Priſme was diffuſed into an *oblong* form, was by the ſecond reduced into an *orbicular* one with as much regularity, as when it did not at all paſs through them. So that, what ever was the cauſe of that length, 'twas not any contingent irregularity.

I then proceeded to examin more critically, what might be effected by the difference of the incidence of Rays coming from divers parts of the Sun; and to that end, meaſured the ſeveral lines and angles, belonging to the Image. Its diſtance from the hole or Priſme was 22 foot; its utmoſt length $13\frac{1}{4}$ inches; its breadth $2\frac{1}{8}$; the diameter of the hole $\frac{1}{4}$ of an inch; the angle, with the Rays, tending towards the middle of the image, made with thoſe lines, in which they would have proceeded without refraction, was 44 deg. 56′. And the vertical Angle of the Priſme, 63 deg. 12′. Alſo the Refractions on both ſides the Priſme, that is, of the Incident, and Emergent Rays, were as near, as I could make them, equal, and conſequently about 54 deg. 4′. And the Rays fell perpendicularly upon the wall. Now ſubducting the diameter of the hole from the length and breadth of the Image, there remains 13 Inches the length, and $2\frac{1}{8}$ the breadth, comprehended by thoſe Rays, which paſſed through the center of the ſaid hole, and conſequently the angle of the hole, which that breadth ſubtended, was about 31′, anſwerable to the Suns Diameter; but the angle, which its length ſubtended, was more then five ſuch diameters, namely 2 deg. 49′.

Having made theſe obſervations, I firſt computed from them the refractive power of that glaſs, and found it meaſured by the *ratio* of the ſines, 20 to 31. And then, by that *ratio*, I computed the Refractions of two Rays flowing from oppoſite parts of the Sun's *diſcus*, ſo as to differ 31′ in their obliquity of Incidence, and found, that the emergent Rays ſhould have comprehended an angle of about 31′, as they did, before they were incident.

But becauſe this computation was founded on the Hypotheſis of the proportionality of the *ſines* of Incidence, and Refraction, which though by my own Experience I could not imagine to be ſo erroneous, as to make that Angle but 31′, which in reality was 2 deg. 49′; yet my curioſity cauſed me again to take my Priſme. And having placed it at my window, as before, I obſerved, that by turning it a little about its *axis* to and fro, ſo as to vary its obliquity to the light, more then an angle of 4 or 5 degrees, the Colours were not thereby ſenſibly tranſlated from their place on the wall, and conſequently by that variation of Incidence, the quantity of Refraction was not ſenſibly varied. By this Experiment therefore, as well as by the former computation, it was evident, that the difference of the Incidence of Rays, flowing from divers

parts of the Sun, could not make them after decuſſation diverge at a ſenſibly greater angle, than that at which they before converged; which being, at moſt, but about 31 or 32 minutes, there ſtill remained ſome other cauſe to be found out, from whence it could be 2 degr. 49'.

Then I began to ſuſpect, whether the Rays, after their trajection through the Priſme, did not move in curve lines, and according to their more or leſs curvity tend to divers parts of the wall. And it increaſed my ſuſpition, when I remembred that I had often ſeen a Tennis-ball, ſtruck with an oblique Racket, deſcribe ſuch a curve line. For, a circular as well as a progreſſive motion being communicated to it by that ſtroak, its parts on that ſide, where the motions conſpire, muſt preſs and beat the contiguous Air more violently than on the other, and there excite a reluctancy and reaction of the Air proportionably greater. And for the ſame reaſon, if the Rays of light ſhould poſſibly be globular bodies, and by their oblique paſſage out of one medium into another acquire a circulating motion, they ought to feel the greater reſiſtance from the ambient Æther, on that ſide, where the motions conſpire, and thence be continually bowed to the other. But notwithſtanding this plauſible ground of ſuſpition, when I came to examine it, I could obſerve no ſuch curvity in them. And beſides (which was enough for my purpoſe) I obſerved, that the difference 'twixt the length of the Image, and diameter of the hole, through which the light was tranſmitted, was proportionable to their diſtance.

The gradual removal of theſe ſuſpitions, at length led me to the *Experimentum Crucis*, which was this: I took two boards, and placed one of them cloſe behind the Priſme at the window, ſo that the light might paſs through a ſmall hole, made in it for the purpoſe, and fall on the other board, which I placed at about 12 feet diſtance, having firſt made a ſmall hole in it alſo, for ſome of that Incident light to paſs through. Then I placed another Priſme behind this ſecond board, ſo that the light, trajected through both the boards, might paſs through that alſo, and be again refracted before it arrived at the wall. This done, I took the firſt Priſme in my hand, and turned it to and fro ſlowly about its *Axis*, ſo much as to make the ſeveral parts of the Image, caſt on the ſecond board, ſucceſſively paſs through the hole in it, that I might obſerve to what places on the wall the ſecond Priſme would refract them.

And

And I ſaw by the variation of thoſe places, that the light, tending to that end of the Image, towards which the refraction of the firſt Priſme was made, did in the ſecond Priſme ſuffer a Refraction conſiderably greater then the light tending to the other end. And ſo the true cauſe of the length of that Image was detected to be no other, then that *Light* conſiſts of *Rays differently refrangible*, which, without any reſpect to a difference in their incidence, were, according to their degrees of refrangibility, tranſmitted towards divers parts of the wall.

When I underſtood this, I left off my aforeſaid Glaſs works; for I ſaw, that the perfection of Teleſcopes was hitherto limited, not ſo much for want of glaſſes truly figured according to the preſcriptions of Optick Authors, (which all men have hitherto imagined,) as becauſe that Light it ſelf is a *Heterogeneous mixture of differently refrangible Rays*. So that, were a glaſs ſo exactly figured, as to collect any one ſort of rays into one point, it could not collect thoſe alſo into the ſame point, which having the ſame Incidence upon the ſame Medium are apt to ſuffer a different refraction. Nay, I wondered, that ſeeing the difference of refrangibility was ſo great, as I found it, Teleſcopes ſhould arrive to that perfection they are now at. For, meaſuring the refractions in one of my Priſmes, I found, that ſuppoſing the common *ſine* of Incidence upon one of its planes was 44 parts, the *ſine* of refraction of the utmoſt Rays on the red end of the Colours, made out of the glaſs into the Air, would be 68 parts, and the *ſine* of refraction of the utmoſt rays on the other end, 69 parts: So that the difference is about a 24*th* or 25*th* part of the whole refraction. And conſequently, the object-glaſs of any Teleſcope cannot collect all the rays, which come from one point of an object, ſo as to make them convene at its *focus* in leſs room then in a circular ſpace, whoſe diameter is the 50*th* part of the Diameter of its Aperture; which is an irregularity, ſome hundreds of times greater, then a circularly figured *Lens*, of ſo ſmall a ſection as the Object-glaſſes of long Teleſcopes are, would cauſe by the unfitneſs of its figure, were Light *uniform*.

This made me take *Reflections* into conſideration, and finding them regular, ſo that the Angle of Reflection of all ſorts of Rays was equal to their Angle of Incidence; I underſtood, that by their mediation Optick inſtruments might be brought to any degree of perfection imaginable, provided a *Reflecting* ſubſtance could be found,