Draft of the 'Hypothesis Concerning Light and Colors'

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<475r>

Sir

I have sent you the papers I mentioned, by Iohn Stiles. Vpon reviewing them I find some things so obscure as to need a further explication by figures, & some other things I guess will not be new to to you though almost all was new to me when I wrote them: but **{**as**}** they are I hope you will accept of them though not worth the ample thanks you sent. I remember in some discourse with M^{r} Hook I happend to say that I thought light was reflected not by the parts of glass water air or other sensible bodies, but by that same superficies of the æthereal Mediums which refracts it , the rays finding some difficulty to break through it in passing out of denser æther into rarer & a greater difficulty in passing out of the rarer into the denser, & so being either reflected or refracted by the superficies as the circumstances they happen to be in at their incidence make 'em unable or able to break through it. And for confirmation of this I said further that I thought the reflexion of the light at its tending out of glass into air would not be diminisht or weakend by drawing away the air in an air Pump as it ought to be if they were the parts of the air that reflected it: And added that I had not tryed this experiment; but thought he was not unacquainted with notions of this kind. To which he replied that the notion was new & that he would the first opportunity try the experiment I propounded. But upon reviewing the papers I send you, I found it there set down for tryed; which makes me recollect that some years ago I had occasionally observed in an Air Pump here at Christs College that I could not perceive the reflexion of the inside of the glass diminished by drawing out the air. This I thought fit to mention least my former forgetfulness should make me seem to have set down for certain what I never tryed.

Sir I had formerly purposed never to write any Hypothesis of light & colours, fearing it might be a means to ingage me in vain disputes: but I hope I need not fear that if it proceed no further then to the ears of the Society. Considering therefore that such an Hypothesis will much illustrate the papers I send you; I shall not scruple to describe one so far as it may be done in this cursory letter: not concerning my self whether it shall be thought probable or improbable so it do but render the papers I send you more intellegible

<475v>

First then in this Hypothesis it is to be supposed that there is an æthereal Medium much of the same constitution with air but only far more rare more subtile & more strongly elastic: And of the existence of this Medium the motion of a pendulum in a glass exhasted of air almost as quickly as in the open air is no inconsiderable argument.

.2. I suppose this æther a vibrating Medium like air, only the vibrations far more swift & minute; those of air made by a man's ordinary voice succeeding one another at more then a foot distance, but those of æther at a less distance then the hundred thousandth part of an inch. And as in air the vibrations are some larger then others, but yet all equally swift (for in a ring of bells the sound of every tone is heard at 3 or 4 miles distance, in the same order that the bells are stroke:) so I suppose the æthereal vibrations differ in bignes but not in swiftness.

3 As the air can pervade the bores of small glass pipes but yet not so easily as if they were wider, & therefore stands at greater degree of rarity then in the free aereal spaces, & at so much a greater degree of rarity as the pipe is smaller, as is known by the rising of water in such pipesto a much greater height then the surface of the stagnating water into which they are dipt: so I suppose æther, though it pervades the pores of crystal, glass, water & other natural bodies, yet it stands at a greater degree of rarity in those pores then in the free æthereal spaces & at so much a greater degree of rarity as the pores of the body are smaller. Whence it may be that ☿ for instance though a lighter body yet having subtiler parts & consequently smaller pores then water is the more strongly refracting liquor. This also may be the principall cause of the cohesion of the parts of solids & fluids, & of the standing of the ☿ in the Torricellian experiment at a much greater height then 29 inches: For the denser æther which surrounds these bodies must croud & press their parts together much after the same manner that the air surrounding two marbles presses them together if there be little or no air between them.

4 I suppose light is neither this æther not its vibrating motion, but something of a different kind propagated from lucid bodies, whether it be an aggregate of peripatetic qualities or of unimaginably small & swift corpuscles from luminous bodies at great distances from one another or any other corporeal emanation, or some motion of the æther of a differing kind from its vibrations if any such can be imagind proper for this purpose, or an impuls or motion of some other medium dispersed through the æther For the air, vapors – , exhalations electric & magnetic effluvia are all instances that there may be a corporeal emanation or an impuls or motion of some other medium dispersed through æther like the magnetic or electric effluvia, or some motion of the æther of a differing kind from its vibrations if any such can be imagin'd proper for this purpose, or a peripatetic quality. To avoyd dispute & make this Hypothesis general let every man here take his fancy. Only whatever light be I would suppose it consists of successive rays differing from one another in contingent circumstances, as bignes form or vigour; like as the sands on the shore the waves of the sea the faces of men & all other natural things of the same kind differ, it being almost impossible for any sort of things to be found without some contingent variety. And further I would suppose it divers from the æthereal vibrations becaus

[5 As there is a certain tenacity in the superficies of water more then in the inwards parts of either water or air so that dust or even the filings of a metal which readily fall in either water or air will swim if thrown upon their common superficies: so I suppose there is a greater tenacity in the common superficies of a rarer & denser æther then in other places, so that the rays of light find some difficulty in passing through that superficies & are refracted or reflected accordingly as they can or cannot overcome the difficulty. Yet this superficies I suppose to be not a mathematical one like that of water, but of some breadth, the æther therein being of all intermediate degrees of rarity between the rarer & denser Mediums.

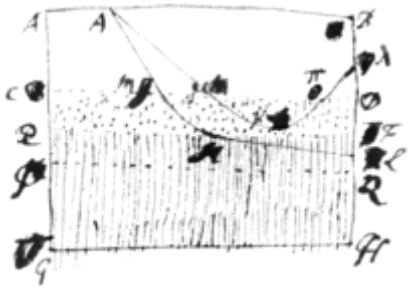
6 When the rays impinge upon this superficies I suppose they cause vibrations in it as stones thrown into water do in its surface, & that these vibrations are propagated every way into both the rarer & denser Mediums as the vibrations of air which cause sound, are from a stroke but yet continue strongest where they began, & alternately contract & dilate the æther in that physical superficies: ♀ which superficies being thus continually agitated by vibration & the æther therein continually expanded & comprest by turns; if a ray of <476r> light impinge upon it while it is much comprest, I suppose it is then too dense & stiffe to let the ray pass through & so it reflects it, but the rays that impinge on it at other times, go through & are refracted.

To explain this a little further you may consider how fluids when formed into thin shells or plates grow much more tenacious & tough then otherwise. Thus things which readily fall in water if let fall upon a bubble of water they do not easily break through it but are apt to slide down by the sides of it if they be not too bigg & heavy. So if two well polished convex glasses grownd on very large spheres be laid one upon another, the air between them easily recedes till they almost touch but then begins to resist so much that the weight of the upper glasse is too little to bring together so as to make the black spot mentioned in these papers appeare in the midst of the rings of colours; & if the glasses be plain though no broader then a two pence, a man with his whole strength is not able to press all the air out from between them so as to make 'em fully touch. You may observe also that Insects will walk upon water without wetting their feet, the thin skin or shell between their feet & the water bearing them up & so motes falling upon water will often lye long upon it without being wetted. And in like manner I suppose a ray in passing out of denser æther into rarer, when there remains between the ray of the rarer æther so little distance to be part through that the denser æther between them may be compared to a thin skin or shell, it finds some difficulty to get through this skin: & the æther where this

skin is being alternately expanded & comprest by the vibrations wherewith 'tis continually agitated, the skin is sometimes weakned by the expansion sometimes strengthend & stifned by the compression & accordingly transmits or reflects the ray.

When a ray finds the refracting superficies so much condensed that it cannot get through, so soon as the ray has spent its force upon the superficies in endeavouring to pierce it, the superficies by its elasticity returns back upon the ray as a racket upon a tennis ball, all the force it received & so reflects it at an angle equal to that of incidence. But if the superficies at the arrival of the ray be in a state of expansion, or not so much condensed but that the ray can pierce it, then I suppose upon the rays departing into the next Medium the superficies acts upon it & adds more or less celerity to it according to the rarity of that Medium; for the rarer the medium is which the ray enters, the more easily does the ray yeild to the action of the superficies. To use a gross similitude you may conceive the action of the superficies upon the departing ray, to be something like that of a man's fingers darting a plumb-stone or other slippery body from between them by compressing it; for] When a ray therefore moves through æther of uneaven density, I suppose it is most prest, urged or otherwise acted upon by the æther on that side towards the denser æther & receives a continual impulsor ply from that side to recede towards the rarer, & so is accelerated if it move that way or retarded if the contrary. On this ground if a ray move obliquely through such an uneavenly dense medium (that is obliquely to those imaginary superficies which run through the equally dens parts of y^{e} medium & may be called the refracting superficies,) it must be incurved, as it is found to be by observation in water when lower parts were gradually made more salt & so more dense then the upper [1]. And this may be the ground of all refraction & reflexion: for as the rarer air with a small glas pipe & the denser air without are not disterminated by a mathematical superficies but the air between at the orifice of the pipe runs through all intermediate degrees of density so I suppose the refracting superficies of æther between unequally dense Mediums to be not a mathematical one but of some breadth the æther therein being of all intermediate degrees of rarity between the rarer & denser æthereal mediums, & refraction I conceive to proceed from the continual incurvation of the ray all the while it is passing this physical superficies. Now if the motion of the ray be supposed in this passage to be incurved or diminished in a certain proportion according to the difference of the densities of the æthereal mediums, & the addition or detraction of the motion be reccond in the perpendicular from the refracting superficies, the sines <476v> of incidence & refraction will be proportional according to what Cartes has demonstrated.

The ray therefore in passing out of the rarer medium into the denser inclines continually more & more towards the refracting superficies & if the differing densities of the mediums be not so great nor the incidence of the ray so obli as to make it ‖ to that superficies before it gets through, then it goes through & & is refracted, but if through the aforesaid causes the ray become ‖ to that superficies before it can get through, then it must turn back & be reflected. Thus for instance it may be observed in triangular glas prism OEF that y^{e} rays AN that tend out of the refr. sup glass into air, do by inclining y^{n} more & more to them, emerge more & more obliquely as at NL till they be infinitely oblique that is in a manner ‖ to the refracting superficies which happens when the angle of incidence is about 60 or 61 gr. & then if they be a little more inclined they become all reflected, as at Avλ becoming I suppose ‖ to the superficies before they can get thrugh it. let ABCD represent the rarer Medium, EFHG the denser CDFE the space between them or refracting physicall superficies in which the æther is of all intermediate degrees of density from the rarest æther at CD to the densest at EF. AL a ray, AN its incident part MN its incurvation by the refracting superficies, & NL its emergent part. Now if the ray AM be so much incurved as to become at its emergence N, as nearely as may be ‖ to CD , its plain that if that ray had been incident a little more obliquely it must have become parallel to CD before it had arrived at EF & so could never have got to the outside of the refracting superficies EF but must have turnd back & been reflected as it is represented at Aμνλ. And the like would have happend if the density of the æther had further increased from EF to PQ so that PQHG might be a denser medium then EFHG was supposed, for then the ray in passing from m to n being so much incurved as at n to become ‖ to CD or PQ, its impossible it should ever get nearer to PQ but must at N begin by further incurvation to turn back & so be reflected. *○

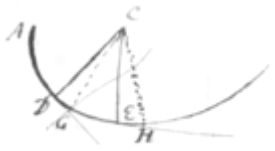


This may be the cause & manner of relexion when light tend from the rarer toward the denser æther, but to know how it should be reflected when it tends from the denser into the rarer you are to consider how fluids neare their superficies are less pliant & yeilding then in their more inward parts, & if formed into a thin plate

or shel they become much more stif & tenacious then otherwise. Thus things let fall —— And so I suppose æther in the confine of two mediums is less pliant & yeilding then in other places & so much the less pliant by how much the mediums differ more in density: so that a ray in passing through this **{**cuticle**}** & so great difficulty where the mediums are of very differing density as to be reflected by incurvation after the manner described above: the parts of the æther on that side where they are less pliant & yeilding acting upon the ray much after the manner that thay would do were they denser there then on the other side And this I suppose **{**may**}** be the cause of the reflexion of Quicksilver & other metalline bodies. It must concur to increase the reflective virtue of the superficies when rays tend out of the rarer into the denser. And in that case therefore the reflexion having a double cause <477r> much; after the same manner as if all the glass between B & D were broken off at B the obtuse angle of the Diamond cut.

Exempl. 2. In machinis mobilibus.

$\mathrm{Ca \cdot ab :: Cd \cdot dg} = \frac{\mathrm{ab,Cd}}{\mathrm{Ca}}$. $\mathrm{AF \cdot CF :: Ab \cdot ba} = \frac{\mathrm{CFAb}}{\mathrm{AF}}$. $\mathrm{Ca \cdot ab :: Cd \cdot dg} = \frac{\mathrm{CF,Ab,Cd}}{\mathrm{Ca,AF}}$.



$\mathrm{Ce \cdot eD :: dg \cdot gD} = \frac{\mathrm{eD,CF,Ab,Cd}}{\mathrm{Ce,Ca,AF}}$. $\mathrm{Ab \cdot Dg :: Ce, CAa, AF \cdot De, CF, Cd}$.

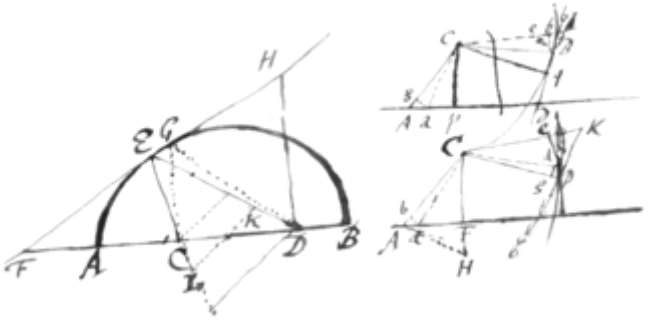
$\ddot{\mathrm{C}}\mathrm{A} \cdot \ddot{\mathrm{C}}\mathrm{D} :: \mathrm{Ce, CA, AF \cdot De, CF, CD}$. $\ddot{\mathrm{F}}\mathrm{A} \cdot \ddot{\mathrm{C}}\mathrm{A} :: \mathrm{CA \cdot AF}$.

$\ddot{\mathrm{F}}\mathrm{A}\ddot{\mathrm{C}}\mathrm{D} :: \mathrm{Ce, CAq \cdot De, CF, CD}$. $\ddot{\mathrm{C}}\mathrm{A} \cdot \ddot{\mathrm{C}}\mathrm{D} :: \frac{\mathrm{CA,AF}}{\mathrm{CF}} = \mathrm{AH}$. $\frac{\mathrm{De,CD}}{\mathrm{Ce}} = \mathrm{DK}$.

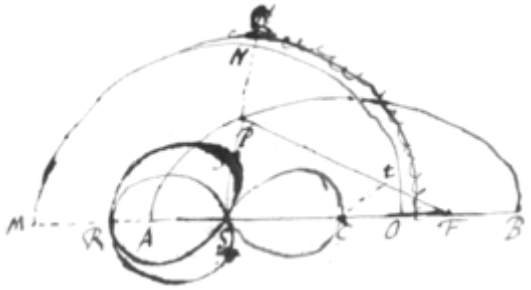
$\mathrm{DF \cdot CF :: \square EDG \square ECG}$. $\square$ECG ut $\frac{\mathrm{CF}}{\mathrm{DF}}\square\mathrm{EDG}$. $\angle$ECG ut $\frac{\square\ \mathrm{ECG}}{\mathrm{ECq}}$ $\angle$ECG ut $\frac{\mathrm{CF} \times \square\mathrm{EDG.}}{\mathrm{DF,ECq}} = \frac{\square\mathrm{EDG}}{\mathrm{ED,EC}} = \frac{\square\mathrm{EDG}}{\mathrm{EKq - KDq}}$.

$\angle$ECG×EKq−KDq ut $\square$EDG.

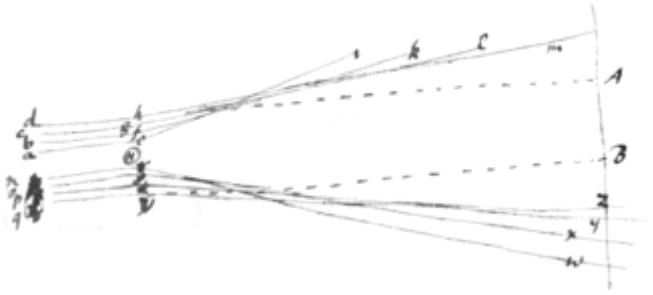
Let AB, CD represent the ‖ planes of a lookinglass



BD the plane of the Diamond cut making at B a very obtuse angle with the plane AB. And let all the light between the rays **{illeg}**[Editorial Note 1] FBM pass perpendicularly through the parallel planes of the glass & fall upon the paper between I **{illeg}** & M & all the light between the rays GO et HD be refracted by the oblique plane of the diamond cut BD & fall upon the paper between K & L: and the light which passes perpendicularly thorough the ‖ planes of the glass & falls upon the paper between I and M will be bordered with three or more fringes of colours at M If Plates of Looking glass sloopt off neare the edges with a diamond cut be held in the same beam of light, the light which passes through the parallel planes of the glass, within [& falls upon white paper at some distance from the glass] will be bordered with the like fringes of colours although it be bounded only by the diamond cut



Obs. 1. And hence I seem to gather that the rays in passing by the sides of the hair at a little distance are bent & those are most bent which pass by the hair at the leats distance. Let H represent the hair, aei, bfk, cgl, dhm four rays passing by the hair at several distances & bent in e, f, g, h & let them fall on the paper beyond the hair at i, k, l, m. And let nrw, osx, pty, qvz represent four other rays passing by the hair on the other side & bent in r, s, t, v & let them fall on the paper at w, x, y, z. And let mz be the shadow of the hair cast upon the paper. By this bending of the rays the shadow will become broader then it would be if they were not bent, [&] Produce the outmost rays dh & qu in right lines to A & B & if those rays were not bent in passing by the hair the breadth of the shadow of the hair upon the paper would not be greater then AB whereas by experience its found considerably greater.] And if the rays which pass by the hair at the least distance be most bent as is represented in the figure the shadow will be broadest in proportion to the distance of the paper from the hair when the paper is nearest to the hair, as is found true by experience. But if the outmost rays dh & qu be not bent, produce them in right lines & let them fall on the paper at A, B



& the breadth of the shadow will be AB which is less then it is found by experience these rays are therefore bent tho not so much <477v> as the rays which pass by the hair at a less distance.

So then the dark lines above mentioned which run along between the first and second fringes of the shadows of either knife & meet in the middle of the light which passes between the knives at the distance of a fift part of an inch from the concourse of the edges of the knives, are in the passage of the light between the knives distant from the edges of the knives the 320^{th} part of an inch or there abouts.

At another time when the two knives were distant eight feet & five inches from the little hole in the window made with a small pin as above, the point i where the dark line **{illeg}**is & xip meet & cross one another between the first fringes of the shadows of the two knives, fell upon a paper placed at the following distances from the knives when the distances between the edges of the knives were also as follows.

Distances between the edges of the knives in millesimal parts of an inch	Distances of the Paper from the knives in inches
deg	
0'012	. $1\frac{1}{2}$.
0'020**{illeg}**	. $3\frac{1}{3}$.
0'034	. $8\frac{3}{5}$.
0'057	. 32.
0'081	. 96.
0'087	$131\frac{1}{2}$.

And hence I gather that the light which makes the fringes with the shadows between them upon the paper is not the same light at all distances of the paper from the knives, but when the paper is held neare the knives the fringes are made by light which passes by the edges of the knives at a less distance & is more bent then when the paper is held at a greater distance.

When I made these Observations I designed to repeat most of them with more care & exactness & to make some new ones for determining the manner how the rays of light are bent in their passage by bodies for making these fringes of colours with the dark lines between them: but I was then interrupted & cannot now think of taking these things into further consideration. And since I have not finished this part of my designe I shall conclude with proposing some Quæres in order to a further search to be made by others. [who may take these things into consideration]

Quære 1. Do not Bodies act upon light at a distance & by their action bend its rays & is not this action strongest at the least distance.

⊙ 1B. Are not &c < insertion from f 478r > ⊙ 1B. Are not the rays of light in passing by the edges & sides of bodies bent several times backwards & forwards with a motion like that of an Eele.

< text from f 477v resumes >

2 Do not the rays which differ in refrangibility differ also in flexibility& are they not by their different inflexions separated from one another so as after separation to make the colours in the three fringes above described. And after what manner are they inflected to make those fringes.

3 Do not the rays of light which fall upon bodies & are reflected or refracted begin to bend before they arive at the bodies, & are they not reflected refracted & inflected by one & the same Principle acting variously in

various circumstances.

4 Do not light & bodies act mutually upon one another, that is to say bodies upon light in emitting reflecting refracting & inflecting it, & light make <478r> ally upon bodies for heating them & pulling their parts into a vibrating motion wherein heat consists. And do not black bodies conceive heat more easily from light then those ‡ < insertion from lower down f 478r > ‡ **{**Ad**}** 4. **{**Ad**}** Do not black bodies conceive heat more easily from light then those of other colours do by reason that the light falling on them is not reflected back but enters the bodies & is often reflected & refracted within them before it is shifted & lost. And is not the greatness or vigour of the action between light & sulphureous bodies observed above one reason why sulphureous bodies take fire more readily & burn more vehemently then other bodies do?

< text from higher up f 478r resumes >

5 Do not all fixt bodies when heated beyond a certain degree emit light by the vibrating motion of their parts.

6 Is not fire a body heated so hot as to emit light copiously. For what else is a red hot iron or a red hot stone then fire & what else is a burning coale then red hot wood [whose heat is preserved by the actions of an acid spirit in the air acting upon & dissolving the wood.

7 Is not the flame a vapour fume or exhalation heated red hot that is so hot as to shine For bodies do not flame which do not emit a copious fume.

8 Are not the sun & fixt stars great earths vehemently hot whose heat is conserved by the mutual action & reaction between them & the light which they emit & whose parts are kept from fuming away by the vast weight of the Atmospheres incumbent upon them.

9 Do not the rays of light in falling upon the bottom of the eye, excite vibrations in the Tunica retina which vibrations being propagated along the solid fibres of the Optick Nerves into the brain cause the sense of seeing. * < insertion from lower down f 478r > * For since dense bodies conserve their heat a long time & the densest bodies conserve their heat the longest, the vibrations of their parts are of a lasting nature & therefore may be propagated along solid fibres of uniform dense matter to a great distance for conveying into the brain the impressions made upon all the Organs of sense. For that motion which can continue long in **{illeg}** & the same part of a body can be propagated a long way from one part to another supposing the body homogeneal so that the motion may not be reflected refracted & interrupted or disordered by any uneavenness of the body. < text from higher up f 478r resumes > 10 Do not several sorts of rays make vibrations of several bignesses, which according to their bignesses excite sensations of several colours much after the manner that the vibrations of the air according to their several bignesses exite sensation of several sounds? And particularly do not the most refrangible rays excite the shortest vibrations for making a sensation of deep violet, the least refrangible the largest for making a sensation of deep red & the several intermediate sorts of rays vibrations of several intermediate bignesses to make sensations of the several intermediate colours?

11 May not the harmony & discord of colours arise from the proportions of the vibrations propagated through the optic nerves into the brain as the harmony & discord of sounds arises from the proportions of the vibrations of the air. For some colours are agreable as those of gold & Indigo & others disagree.

12 Are not the species of objects seen with both eyes united when the Optick nerves meet before they come into the brain: the fibres on the right side of both Nerves uniting there & after unison going thence into the brain in the nerve which is on the right side of the head & the fibres on the left side of both nerves uniting in the same place & after union going into the brain in the nerve which is on the left side of the head & these two nerves meeting in the brain in such a manner thet their fibres make but one intire species half of which on the right side of the sensorium comes from the right side of both eyes & the other half of which on the left side of the sensorium comes from the left side of both eyes? For the optic nerves of such animals as look the same way with both eyes (as of Men, Doggs, Sheep, Oxen) meet before they go into the brain, but the Optic nerves of such animals as do not look the same way with both eyes (as of Fishes & the Chameleon) do not meet if I am rightly informed.

7B.

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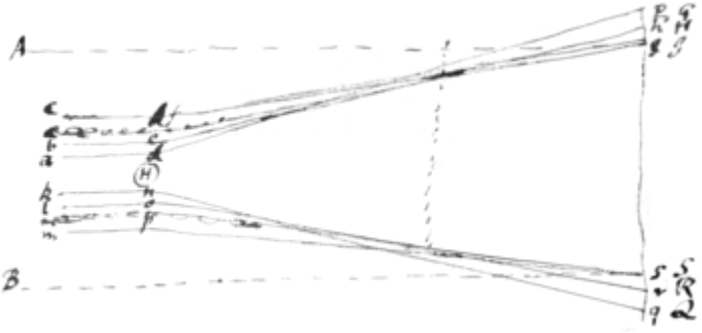

Obs.1. | Let X represent one end of the Hair, adg, beh, cfi three rays passing by one side of the hair at several distances, kng, lor, mps three other rays passing by the other side of the hair at the like distances; d, e, f & n, o, p the places where these">the rays are bent in their passage by the hair; g, h, i, q, r, s the places where these rays fall on paper si the breadth of the shadow of the hair cast on the paper & Ai & Bs two rays passing to the points i & s without bending when the hair is taken away. And it is manifest that all the light between the lines Ai & Bs is bent in passing by the hair & turned aside from the shadow: for if any part of this light were not bent it would fall on the paper within the shadow si & there illuminate it contrary to experience. Bodies therefore act upon the light at a considerable distance in its passing by them; but the action is strongest on the rays which pass by at the least distances & grows weaker & weaker accordingly as the rays pass by them at distances greater & greater, as is represented in the scheme For thence it comes to pass that the shadow of the hair is much broader in proportion to the distance of the paper from the hair when the paper is neare the hair then when it is at a great distance from it.

Ad Obs. 6. And hence the light which is least bent & goes to the inward ends of the streams passes by the edges of the knives at the greatest distance, & this distance when the shadow begins to appear between the streams is about the eight hundredth part of an inch. And the light which passes by the edges of the knives at distances still less & less is more & more bent & goes to those parts of the streams which are further & further from the direct light, [because as the knives approach one another till they touch, the light at the inward ends of the streams vanishes more and more & the streams grow shorter & shorter at those ends untill they wholy disappear.]

Ad Obs. 7. And hence the light of the first fringe passed by the edge of the knife at a distance greater then the eight hundreth part of an inch & the light of the second fringe passed by the edge of the knife at a greater distance then the light of the first fringe did, & that of the third at a greater distance <479r> Could all the phænomena of nature be [evidently] deduced from only thre or four general suppositions there might be great reason to allow those suppositions to be true: but if for explaining every new Phænomena you make a new Hypothesis if you suppose that the particles of Air are of such a figure size & frame, those of water of such another those of Vinegre of such another , those of sea salt of such another , those of nitre of such another, those of Vitriol of such another, those of Quicksilver of such another, those of flame of such another, those of Magnetick effluvia of such another, If you suppose that light consists in such a motion pression or force, & that its various colours are made by such & such variations of the motion & so of other things: your Philosophy will be nothing else then a systeme of Hypotheses. And what certainty can there be in a Philosophy which consists in as many Hypotheses as there are Phæ nomena to be explained. To explain all nature is too difficult a task for any one man or even for any one age. Tis much better to do a little with certainty & leave the rest for others that come after, then to explain all things by conjecture without making sure of any thing. And there is no other way of doing any thing with certainty then by drawing conclusions from experiments & phænomena untill you come at general Principles & then from those Principles giving an account of Nature. Whatever is certain in Philosophy is owing to this method & nothing can be done without it. I will instance in some particulars.

One principle in Philosophy is the being of a God or spirit infinite eternal omniscient, omnipotent, & the best argument for such a being is the frame of nature & chiefly the contrivance of the bodies of living creatures. All the great land animals have two eyes, in the forehead a nose between them a mouth under the nose, two ears on the sides of the head, two arms or two fore leggs or two wings on the sholders & two leggs behind & this symmetry in the several species could not proceed from chance there being an equal chance for one eye or for three or four eyes as for two, & so of the other members Nothing is more curious & difficult then the frame of the eyes for seeing & of the ears for hearing & yet no sort of creatures has these members to no purpose. What more difficult then to fly? & yet was it by chance that all creatures can fly which have wings? Certainly he that framed the eyes of all creatures understood the nature of light & vision he that framed their ears understood the nature of sounds & hearing, he that framed their noses understood the nature of odours &

smelling, he that framed the wings of flying creatures & the fins of fishes understood the force of air & water & what members were requisite to enable creatures to fly & swim: & therefore the first formation of every species of creatures must be ascribed to an intelligent being These & such like considerations are the most convincing arguments for such a being & have convinced mankind in all ages that the world & all the species of things therein were originally framed by his power & wisdom. And to lay aside this argument is unphilosophical.

Another Principle is that matter is impenitrable by matter. This is usually looked upon as a maxim known to us by the light of nature, altho we **{**know**}** nothing of bodies but by sense. We find by dayly experience that bodies resist one another as often as they come together & cannot by any force be made <479v> to penetrate one anothers dimensions. And this holding true without exception in all bodies here below in which we can come to make observations we conclude it to be the property of all bodies whatsoever. And such observations occurring every day to every man this property of bodies is acknowledged by all men without any dispute & looked upon as an Axiom.

A third principle is that all bodies in the Vniverse have a tendency towards one another proportional to the quantity of matter conteined in them & that this tendency in receding from the body decreases & is reciprocally proportional to the square of the distance from the body: [And all small bodies have the like tendency towards the great ones This tendency towards the earth we find in all bodies here below & call it gravity] Such a tendency towards the earth we find in all bodies here below & call it gravity. & by experiments of the Pendulum & of falling bodies we find it exactly proportional to the quantity of matter in the several bodies We find it also in the Moon, the force which keeps her in her Orb being reciprocally . The like tendency towards proportionall to the square of her distance from the earth Iupiter we find in his four satellites which are thereby kept in their Orbs about him & this tendency by comparing the Orbs & Revolutions of the Satellites together is proportional to the matter in the Satellites reciprocally as the squares of their distances from Iupiter. The like tendency to Saturn we find in his five Satellites, proportional directly to their matter & in reciprocally to the **{**squares**}** of their distances. And all the Planets both primary & secondary & so many Comets as have been well observed appear to have the same tendency towards the Sun proportional directly to the matter in each of them & reciprocally to their distances from the sun. And by the rest or very small motion of the Aphelia of the Planets it appears that this tendency of the Planets towards Iupiter Saturn & the Sun & of the Moon towards the earth decreases in receding

[Editorial Note 2]

$$\frac{\mathrm{ADq,CFq}}{\mathrm{EFq}} = \mathrm{CDq} + \frac{\mathrm{MCq}}{\mathrm{NGq}}\mathrm{CGq}. \frac{\mathrm{CFq+EFq}}{\mathrm{EFq}}\mathrm{ADq} = \mathrm{MCq} \times \frac{\mathrm{NGq+CGq}}{\mathrm{NGq}}. \frac{\mathrm{ACq,ADq}}{\mathrm{EFq}} = \frac{\mathrm{ACq \times MCq}}{\mathrm{NGq}}.$$

A fourth Principle is that all sensible bodies are aggregated of particles laid together with many interstices or pores between them For water soaks into the pores of all animal & vegetable substances & some minerals & quicksilver into the pores of Metall & acid liquors into the pores of all minerals & metals in dissolving them, & light passes through aire, water oyles salt **{**spars**}** sand glass crystal gemms & all other pellucid substances & through the particles of all metals & minerals dissolved in pellucid menstruums or vitrified & through thin pieces of wood, flesh, bone horn stone & vitrified earth. As by the third Principle we gave an account heretofore of the motions of the Planets & of the flux & reflux of the sea, so by this Principle we shall in the following treatise give an acct of the permanent colours of natural bodies, nothing further being requisite for the production of those colours then that the coloured bodies abound with pellucid particles of a certain size & density. This is to be understood of the largest particles or particles of the last composition. For as bodies are composed of these larger particles with larger pores between them so it is to be conceived that these larger particles are composed of smaller particles with smaller pores between them. And when water dissolves salts & acid menstruum or quicksilver dissolves metals it is to be conceived that the liquor enters the larger pores & separates the larger particles of the salt or metal from one another without soaking into the smaller particles

<480r>

[Editorial Note 3]

$Db \cdot BD :: Mb \cdot MP . BD \cdot CE :: PB \cdot PC . CE \cdot Ec :: PN \cdot Nc \mid Db \cdot Ec :: MB, BP, PN \cdot MP, PC, NC .$
$:: \frac{MB,BP}{MP} \cdot \frac{NC \times PC}{PN} :: \frac{MB,PB}{PM} \cdot \frac{NC,PC}{PN} . // CE \cdot Cc :: PN \cdot Pc . / Db \cdot Cc :: MB, PB, PN \cdot MP, PCq , \frac{MB,PB}{MP} \cdot \frac{PCq}{PN} .$
$/ Db \cdot Ec \cdot Cc \cdot Bb :: \frac{MB,PB}{PM} \cdot \frac{NC,PC}{PN} \cdot \frac{PCq}{PN} \cdot \frac{PBq}{PM}$

Between the sines of incidence & refraction counted from the sine of incidence when the refraction is made out of the Plate of any substance into the surrounding Medium of any other substance, that is in this case out of Glass into Air. Now if the thickness of the Glass be increased by degrees so as to bear to its first thickness (vizt that of a quarter of an inch) the proportions of 34386 to 34385, 34384, 34383, 34382 &c, & the first thickness be divided into 100000000 equal parts the increased thicknesses will be 100002908, 100005816, 100008725, 1000011633 &c and the Angles of which these thicknesses are secants will be 26' 13", 37' 5", 45' 6", 52' 26" the radius being 100000000, and the sines of these Angles are 762, 1079, 1321, 1525 and the proportional sines of refraction 1172, 1659, 2031, 2345 the Radius being 100000. For

<480v>

As Mathematicians have two Methods of doing things which they call Composition and Resolution & in all difficulties have recourse to their method of resolution before they compound so in explaining the Phænomena of nature the like methods are to be used & he that expects success must resolve before he compounds. For the explications of Phænomena are Problems much harder then those in Mathematicks. The method of Resolution consists in trying experiments & considering all the Phænomena of nature relating to the subject in hand & drawing conclusions from them & examining the truth of those conclusions by new experiments & drawing new conclusions (if it may be) from those experiments & so proceeding alternately from experiments to conclusions & from conclusions to experiments untill you come to the general properties of things, [& by experiments & phænomena have established the truth of those properties] Then assuming those properties as Principles of Philosophy you may by them explain the causes of such Phænomena as follow from them: which is the method of Composition. But, if without deriving the properties of things from Phænomena you feign Hypotheses & think by them to explain all nature you may make a plausible systeme of Philosophy for getting your self a name, but your systeme will be little better then a Romance. ‡ To explain all nature is too difficult a task for any one man or even for any one age. Tis much better to do a little with certainty & leave the rest for others that come after you then to explain all things by conjecture without making sure of any thing.

Thus in Mathematical Principles of Philosophy I first shewed from Phænomena that all bodies endeavour by a certain force proportional to their matter to approach ane another, that this force in receding from the body grows less & less in reciprocal proportion to the square of the distance from it & that it is equal to gravity & therefore is one & the same force with gravity. Then using this force as a Principle of Philosophy I derived from it all the motions of the heavenly bodies & the flux & reflux of the sea, shewing by mathematical demonstrations that this force alone was sufficient to produce all those Phænomena, & deriving from it (a priori) some new motions which Astronomers had not then observed but since appeare to be true, as that Saturn & Iupiter draw one another, that the Variation of the Moon is bigger in winter then in summer, that there is an equation of the Moons meane motion amounting to almost 5 minutes which depends upon the position of her Apoge of the Sun.

<481v>

Seign^{r} Rizzetti in the beginning of his paper writes thus. Newtonus cum lumini Solis objecisset Prisma triangulare, agravit spectrum Solis magis produce quam lex vulgata refractionis postulasset: ideo lumen solis in refractione dispergi, ita ut unicus simplex radius in plures discindatur.

But Newton affirms no such thing. He represents that every ray emitted from the Sun or other lucid body, continues one & the same without any dispersion or splitting by refraction or change in repect of refrangibility or colour. For in his first Definition, he calls the Rays of light its least parts, whether successive in the same lines or contemporary in several lines. And in his second Proposition he brings his 5^{t}, 6^{t}, 7th, 8th, 9th & 10th Experiments to prove that one & the same ray is not by refraction disturbed shattered, dilated split or spread into many rays. And his first Proposition is that homogeneal light is refracted regularly without any dilatation splitting or shattering of the Rays.

He saith further that if the breadth of the image of a lucid point cast upon the bottom of the eye were about the 55th part of the bread of the pupill of the eye the hair of a mans head could not appear so distinct as it really doth; & then he adds. Cum dixerim in visione capilli locum minima esse aberratio ni Newtonianæ quia minime cernitur, adversus hujusmodi argumentum rationabilior mihi videretur objectio ducta a Propositione VII Autoris: nimirum adeo extenuari lumen aberrans in distantia a suo centro, ut (loquar Newtoni verbis) non sit sensibile nisi in eodem centro aut prope illud. Vt objectioni respondeam, divisa semidiametro luminis aberrantis in undecim partes equales; ejus densitas juxta Newtonianam sententiam, decresit in talam Arithmeticam proportionem, ut cum expressa sit in prima parte a numero 21, exprimatur in secunda a numero 19, & sic deinceps, adeo ut in parte ultima exteriori exprimatur per unitatem. And yet M^{r} Newton affirms no such Arithmetical proportion. His Rule is that the density of the light at any distance from the center is as the distance of that point from the circumference applied to its distance from the center. Let the semidiameter of the erring light be divided into eleven equal parts, & the density of the light in the midle of the part next the center will be to its density in the middle of the part next the circumference not as 21 to 1 but as $\frac{10\frac{1}{2}}{\frac{1}{2}}$ to $\frac{\frac{1}{2}}{10\frac{1}{2}}$ or as 441 to 1

He saith further. Vidit sapientissimus Anglus speciem solarem magis in longum porrectam quam lex vulgaris refractionis postulasset cum illam cerneret diversicolorem, scilicet rubram, mox flavam, deinde viridem, postea cæruleam, & tandem supra violaceam, hoc experimento fretus suum confecit systema luminis at colorum. Omnia experimenta, quibus illud innixum est, renovare curari, & ea (prologu**{illeg}** id licet?) partim falsa, & omnia reliqua inveni propter omissionem —— alicujus circumstantiæ æquivoca ac minime concludentia. Vt unicum [experimentum] allendas obsecro. Then he describes the experiment of painting a chart with red & blue colours & casting the species thereof through a Lens upon which paper as is described above & denies the success. If it did not succeed with him it was because he did not know perfectly well as is described above. He should have told the world that Newton founded his Theory of light & colours upon the experiment which for its demonstrative evidence he calls experimentum crucis. This experiment he could not deny because it hath been tried again & again with full success both in France & in Italy as well as in England: & therefore he passes it by in silence & denies the conclusion drawn from it, & contrary to the <481r> Rules of Logic disputes against the conclusion without taking note of the Premisses.

<482v>

Pag. 2. L. 38 & p. 6 l 16 Theoriam meam non intelligit Radius unus simplex non dispergitur in plures.

Pag. 2. lin. 15. Vult observationem posse corrigi.

Ib. l. 16. Telescopia magis perficientur per reflexionem et p. 10. l. 13.

P. 4. l. 21. Ergo Newtonus Objectionem prævidit.

P 5. l. 12. Imo ducenties densius et amplius, sed Rizzellus calculum ignorat. Sed et Millies densius intra dimitiam latitudinem capillæ & decies millies densius intra septiman partem latitudines capillæ &c.

P. 6. l. 14. Falsum est.

P. 7. l 6 Hinc patet authorem stuidio partium sesibere.

Ib. l. 8 Verum est experimentum, sed Rizellus nescit vere tentare.

P. 6. l. 1 Lux dispergitur quidem transiens per Prisma et non dispergitur transiens per Lentem! Ita Rizzellus, qui et promittit se hoc in libro edendo ostensurum esse.

Titus MS^{ti} est: Christino Martinella Patricio Veneto Iohannes Rizzellus S. D.

The Objector doth not understand the Theory against which he is writing. For he supposes that I make one single principal ray to be by refraction dispersed & spread into many. Pag. 2. lin. 3, 8 & pag. 6 lin 16

2 His Emanuensis knows not how to try the Experiments For the experiment which he denyes the success of (pag. 7. lin. 8) doth succeed if tried with intense colours & with a Lens well made, free from veins & of a sufficient breadth.

3 If he had reasoned right he would have found the light upon the hair not only twenty times denser but above 200 times denser then at the extremity pag. 5 lin. 12.

4 Whence is it that Telescopes by reflexion out do those by refraction, For the Telescope by reflexion made by M^{r} Hadley which is but five feet & a quarter long discovered the four innermost satellites of ♃ when the Moon was up & by reason of the Moonshine the Telescope of Hugenius which is 124 feet long & a very good one discovered only three of them. See Pag. 2 lin 16 & pag. 10. lin. 13.

5 The Objector denies the Conclusion without shewing the flaw of the Premisses, & brings an objection against it. pag. 4. l. 21. Which way of proceeding being once allowed brings every thing to a squabble. & puts an end to experimental Philosophy & even to Mathematicks it self. And the objection is old & sufficiently answered by M^{r} N. in Prop. VII lib. 1. Optices, if M^{r} Rizzell had understood the answer. He should either have showed the flaw in the Premisses, or have granted the Conclusion & enquired how, notwithstanding it, vision can be so distinct as it is.

6 He tells us that light is dispersed in passing through a Prism but not in passing through a Lens, & that he hath written a book to prove this (pag. 6. lin. 1, 3 & pag. 10 l. 2 & pag. 1. lin. 6, 11) & whereas M^{r} Newton had shewn how to mend Object Glasses by putting water between two Glasses he proposes to use instead of water a denser Medium then glass. His Paper is a banter like that of Gorden.

[1] See M^{r} Hooks Micrographia where he speaks of the inflexion of a ray

[Editorial Note 1] The preceding diagram has been written over in the manuscript.

[Editorial Note 2] The following mathematical fragment is written upside down.

[Editorial Note 3] The text on this and the following page is written upside down.