

Fragments on Optics

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<619r>

Qu. 23. By what means do bodies act on one another at a distance. The ancient Philosophers who held Atoms & Vacuum attributed gravity to Atoms without telling us the means unless perhaps in figures: as by calling God Harmony & representing him & matter by the God Pan & his Pipe, or by calling the Sun the prison of Jupiter because he keeps the Planets in their orbs. Whence it seems to have been an ancient opinion that matter depends upon a Deity for its laws of motion as well as for its existence. The Cartesians make God the author of all motion & its as reasonable to make him the author of the laws of motion. Matter is a passive principle & cannot move it self. It continues in its state of moving or resting unless disturbed. It receives motion proportional to the force impressing it. And resists as much as it is resisted. These are passive laws & to affirm that there are no other is to speak against experience. For we find in our selves a power of moving our bodies by our thought Life & will are active Principles by which we move our bodies, & thence arise other laws of motion unknown to us.

And since all matter duly formed is attended with signes of life & all things are framed with perfect art & wisdom & Nature does nothing in vain; if there be an universal life & all space be the sensorium of a thinking being who by immediate presence perceives all things in it as that which thinks in us perceives | ^{see} their pictures in the brain: the laws of motion arising from life or will may be of universal extent.

— those laws. To some such laws the ancient Philosophers seem to have elluded when they called God H{arm}ony, & signified his actuating matter harmonicaly by the God Pan's playing upon a Pipe & attribute musick to the spheres made the distances & motions of the heavenly bodies to be harmonical, & represented the Planets by the seven strings of Apollo's Harp.

——— If you think that the Vis inertia is sufficient for conserving motion, pray tell me the Experiments from whence you gather this conclusion. Do you learn by any experiment that the beating of the heart give no new motion to the blood, that the explosion of Gunpouder gives no new motion to {a} bullet or that a man by his will can give no new motion to his body? Or do you learn by experiment that the beating of the heart takes away as much motion from something else as it gives to the blood or that explosion takes away as much motion rom something else as it gives to a bullet or that a man by his will takes away as much motion from something else as he gives to his body? If so, tell me your experiments {;} if not, your opinion is Reasoning without experience is very slippery. A man may puzzle me by arguments against local{ized} motion but I'le beleive my eyes. A man may may bring plausible arguments against the power of the will but I'le beleive experience. A man may argue plausibly for blind fate against final causes but I find by experience that I am constantly aiming at something. Were it not for experience I should not know that matter is heavy or impenetrable or moveable or that I think or am or that there is matter or any thing else. And therefore to affirm any thing more then I know by experience & good reasoning upon it is precarious. Even arguments for a Being if not taken from Phænomena are slippery & serve only for ostentation. An Atheist will allow that there is a Being absolutely perfect, necessarily existing & the author of mankind & call it Nature: & if you talk of infinite wisdom or of any perfection more then he allows to {say} in {natur} heel recon at a chemæra & tell you that you have the notion of finite or limited wisdom from what you find in your self & are able of your self to {prefin} the word no{t}, or more then to any verb or adjective & without the existence of wisdome

not limited or wisdome more then finite to understand the meaning of the phrase as easily as Mathematicians understand what is meant by an infinite line or an infinite area. And hee may tell you further that the

<620v>

And While these powers are of so large extent, I do not see but that they may be numbred among the general laws of motion. The *Vis inertiae* is a passive principle by which bodies persist in their motion or rest, receive motion in proportion to the force impressing it & resist as much as they are resisted: By this principle alone there could never have been any motion in the world. Thinking is an active principle by which we move our bodies according to our will, & thence arise other laws of motion unknown to us, which if {all} the Universe be the sensorium of a thinking Being, may be of greater extent. Gravity was reckoned among the laws of motion by the ancient Philosophers who attributed gravity to their Atoms in vacuo, & the forces above mentioned by which small bodies act on one another at small distances may have a good title as gravity to be reckoned among those laws.

But while I call those forces attraction & repulse I would not be understood to define the cause or manner of the action. That which I call attraction may be done by impulse or by some other means unknown to me. I only use that word to signify a force by which bodies tend towards one another whatever perfect Art & be the cause duly formed is attended with signs of life: & if since all things are framed with wisdom & Nature does nothing in vain all matter if there be an universal life & all space be the sensorium of a thinking Being & finite things {illeg} be instead of their sensible pictures formed by motion in our Brain; those laws may be of Universal extent.

I have hitherto been arguing from the effects to their causes & carried the argument up to certain forces by which little bodies act on one another at small distances. These forces may be reckoned among the laws of motion, but whether they depend on Bodies alone considered only a long broad & thick bodies alone may be a question For are passive. By their *vis inertiae* they continue in their state of moving or resting & receive motion proportional to the force impressing it & resist as much as they are resisted, but they cannot move themselves; & without some other principle then the *vis inertiae* there could be no motion in the world. And if there be another Principle of motion there must be other laws of motion depending on that Principle. And the first thing to be done in Philosophy is to find out all the general laws of motion on which the frame of nature depends. We find in our selves a power of moving our bodies by our thoughts] & see the same power in other living creatures but how this is done & by what laws we do not know. We cannot say that all Nature is not alive. not know her laws or powers any further then we gather them from *Phænomena*.

If the body is compact & bends or yealds inward to pressure without any sliding of its parts, it is hard & elastic returning to its figure with a force arising from the mutual attraction of its parts. If the parts slide upon one another the body is malleable and soft. If they slip easily & are of a size most apt to be agitated by heat & the heat is big enough to keep its parts in agitation the body is fluid, & if it be apt to stick to things it is humid; & the drops of every fluid affect a round figure by the mutual attraction of its parts as the globe of the earth & sea affects a round figure by the mutual attraction of its parts by gravity.

<621r>

But how two *Æthers* can be diffused through all space one of which acts upon the other & by consequence is reacted upon, without retarding slackening shattering & confounding one anothers motions, is inconceivable. And against filling the heavens with fluid Medium unless they be exceeding rare a great objection arises from the regular & very lasting motions of the Planets & Comets through the heavens in all — — —

By a vacuum I do not mean a space void of all substances. Glass cannot attract light without a Medium. I mean only such a Vacuum as may be made by drawing Air out of a vessel of glass.

What I mean in this Question by a Vacuum, & the attractions of the rays of light towards the glass or crystall, may be understood by what was said in the 18th Question.

Now in bodies — — — — — forces more easily. And for the like reason Gravity in the surfaces of small globes is greater in proportion to the globes then in the surfaces of great globes of equal density. And therefore since the rays of light are the smallest bodies yet known to us (For I do not here consider the

particles of æther) we may expect to find their attractions very strong. And how strong they are may be gathered by this Rule — — — — —; — to be above an hundred million of millions of millions of times greater in proportion to the matter in them then the gravity of the Earth towards the Sun in proportion to the matter in it.

As attraction is stronger in small magnets then in great ones in proportion to their bulk, & gravity is greater in the surfaces of small Planets then in those of great ones in proportion to their bulk so the smallness of the rays of light may very much contribute to the force by which they are refracted. And so if any one should suppose that Ether (like our aer) may {containe} particles which endeavour to recede from one another (for I do not know what the Ether is) & that its particles are exceedingly smaller then those of aer, or even the{ir} those of light, the the exceeding smalness of its particles may contribute to the greatness of the force by which those particles recede from one another & thereby make that medium exceedingly more rare & elastick then Aer.

And that the gravity of the Planets towards the Sun may not be thought too great to be produced by the cause of gravity here suggested: upon a fair computation it will found that the gravity of our earth towards the Sun in proportion to the quantity of its matter is above ten hundred millions of millions of millions of millions of times less then the force by which a ray of light in entring into glass or crystall is drawn or f{orced} impelled towards the refracting body. And therefore the gravity of the earth towards the Sun requires a variation of the density of the Ether at the Orb of the Earth an hundred millions of millions of millions of millions of times slower then the variation of the density of the Ether at the surface of glass or crystal requisite to refract light. For the velocity of light is to the velocity of the Earth in the Orbis magnus as 58 days the time in the Earth describes the ; that is an earth equal to the radius of its orb to about 7 minutes, the time in which light comes fro ☉ to {as} as about 12000 to 1. And the the curvity of a ray of light during it refraction at the surface of glass on which it falls very obliquely, is to the curvity of the earths Orb, as the radius of that Orb to the radius of the curvity of the ray or as above 1000000000000000000 to 1. And the force which bends the ray is to the force which keeps the earth or any Projectile in its orb or line of Projection in a ratio compounded of the duplicate ratio of the velocities & this ratio of the curvities of the lines of projection.

The Atmosphere by its weight presses the Quicksilver into the glass to the height of 29 or 30 inches. And some other Agent raises it higher, not by pressing it into the glass but by making its parts stick to the glass & to one another. For upon any discontinuation of parts made either by bubbles or by shaking the glass, the whole liquor falls down.

<621v>

And if it were not for these Principles the Bodies of the Earth Planets Comets Sun & all things in them would grow cold, & freeze & become inactive masses, & putrefaction generation vegetation & life would cease, & the Planets & Comets would not remain in their Orbs.

— causes be not yet explained. For these are manifest qualities & their causes only are occult. [Occult qualities are not manifest qualities but are specific qualities which do not yet appear but are only supposed to be in the species for producing manifest effects whose causes are unko] To tell — — extent & leave their causes to be enquired into.

of any third thing. The Organs of sense are not for enabling the soul to perceive the species of things in its Sensorium, but only for conveying them thither & God has no need of such Organs, . he being every where present to the things themselves.

& in arguing from them by Induction & admitting of no objections but from Experiments this sort of argument is not demonstrative but yet it is the best which the nature of things admits off, & may be looked upon as so much the stronger by how much the induction is more general. And if no exception occur from Phenomena, the Conclusion may be pronounced generally. But if at any time afterwards any exception occur from Experiments, it may then begin to be pronounced with such exceptions as occur.

— & admitting of no objections against the conclusions but such as are taken from Experiments. For Hypotheses are not to be regarded in Experimental Philosophy. Nor are we here to regard Metaphysical Principles unless so far as they are founded upon experience. For all Metaphysicks not founded upon

experience is Hypothetical: And so far as Metaphysical Propositions are founded upon experience they are a part of experimental Philosophy. Even that celebrated Proposition Ego cogito ergo sum is known to us by experience. We know that we think by an inward sensation of our thoughts. And therefore from that Proposition we cannot conclude that any thing more is true then what we deduce from experience † < insertion from lower down f 622r > †

† And even in proving a Deity all arguments not taken from Phænomena are little better then dreams. Now {altho} the arguing from experiments & observations by Induction be no demonstration of general Propositions, yet it is the best way of

Even in Metaphy < text from f 621v resumes > . Now altho the arguing from experiments & observations by Induction is not fully demonstrative yet it is the best way of arguing which the nature of things admits of, & may be looked — — — as ocean. By this way of arguing we may proceed from compositions to ingredients & from motions to the forces producing them & in general from effects — — — the most general. This is the Analysis & the Synthesis consists in assuming

<622r>

If two plane polished plates of glass three or four inches broad & about twenty long be laid one of them parallel to the horizon the other upon the first so as to touch it & make an angle with it. of about 10 or 15 minutes at one of their ends & the same be first moistened on their inward sides with a cleane cloth dipt into oyle of Oranges, & rubbed upon it & a drop or two of the oyle be let fall upon he lower glass at the other end: so soon as the upper glass is laid down upon the lower so as to touch it at one end & to touch the drop at the other end making with the lower glass an angle of about 10 or 15 as above; the drop will begin to move towards the concourse of the glasses & will continue to move with an accelerated motion till it arrives at that concourse of the glasses. [And if you then open the glasses where they met & touched & make them meet & touch at their other end in the same acute angle as before; the drop will run back to that end of the glasses where they now touch, & where it was at first.] For the two glasses attract the drop, & by the attraction make it run that way towards which the attractions incline. And if when the drop is in motion you lift up that end of the glasses where they meet & towards which the drop moves: the drop will ascend between the glasses, & therefore is attracted. And as you lift up the glasses, more & more the drop will ascend slower & slower & at length rest. And when you see it rest you may reckon that it then carried downward by its weight as much as upwards by the attraction. And thereby you may know the force by which the drop is attracted at all distances from the contact of the glasses. And by some experiments, the attraction is almost reciprocally as in a duplicate proportion of the distance of the {middle} of the drop from the concours of the glasses. viz reciprocally in a simple proportion by reason of the spreading of the drop & its touching the glasses in alarger surface; & again reciprocally in a simple proportion by reason of the attractions growing stronger within the same quantity of attracting surface. The attraction therefore within the same quantity of surface is reciprocally as the distance between the glasses. And therefore where the distance is very small, suppose the ten-thousand-thousandth part of an inch, the attraction must be exceeding great; so great perhaps as within in a circle of an inch in diameter to suffice to hold up a weight equal to a cylinder of water of an inch in diameter, & above a mile in length. There are therefore Agents in Nature able to to make the particles of bodies attract one another very strongly & to stick together strongly those by attractions. One of those Agents may be the Æther above mentioned whereby light is refracted. Another may be the Agent or Spirit which causes electrical attraction. For tho this Agent acts not at great distances except when it is excited by the friction of electrick bodies: yet it may act perpetually at very small distances without friction, & that not only in bodies accounted electric, but also in some others. And there are still other mediums which may cause attractions, (such as are the Magnetick effluvia; it is the business of experimental Philosophy to find out all these Mediums with their properties.

Now the smallest particles of matter may cohere

By the Table in the second part of the second Book wherein the thicknesses of coloured plates of water between two glasses are set down, the thickness of the plate where it appears very black is three eighths of the thousand-thousandth part of an inch. And where the Oyle of Oranges between the glasses is of this thickness, the attraction seems to be so strong as within a circle of an inch in diameter to suffice to hold up a weight equal to that of a cylinder of water of an inch in diameter & two or three furlongs in length And

where it is of a less thickness the attraction may be proportionally greater. & increase untill the thickness be no bigger then that of a single particle of water.

<622v>

For the Velocitys of the pulses of Elastick mediums are a subduplicate ratio of the elasticities directly & densities inversely. For the squares of the velocities of the pulses of Elastick Mediums are as the elasticities & the rarities of the Mediums taken together

The parts — — — any sensible effect. All bodies — — — difficult to conceive The same thing — — — cohesion of its parts. It is not therefore by the pressure of the Æther upon the outside of the Marbles or Mercury (tho such a pressure may contribute to the effect) but by the action of either that or some other Medium or Mediums upon the inward parts of those bodies by which the contiguous parts of the Marbles & those of the glass & Mercury stick to one another. The like Experiment hath been tried with water — — — amongst themselves.

And of the same kind with these Experiments are those that follow. If two plane polished plates of glass (suppose two pieces of a broken looking-glass) be laid together so that their sides be parallel & at a very small distance from one another; & then their lower edges be dipped into water; the water will rise up between them. And the less the distance of the glasses is the greater will be the height to which the water will rise. If the distance be about the hundreth part of an inch, the water will rise to the light of about an inch & if the distance be greater or less in any proportion, the height will be reciprocally proportional to the distance very nearly. For the attractive force of the glasses is the same whether the distance between them be greater or less & the weight of the water drawn up is the same if the height of it be reciprocally proportional to the distance between the glasses. [And in like manner water ascends between two Marbles polished plane, when their polished sides are parallel, & at a very little distance from one another.] And if slender pipes of glass be dipt at one end into stagnating water the water will rise up within the pipe & the hight to which it rises will be reciprocally proportional to the diameter of the cavity of the pipe & will equall the height to which it rises between two planes of glass if the semidiameter of the cavity of the Pipe be equal to the distance between the planes, or thereabouts. And these experiments succeed after the same manner in vacuo as in the open air, & therefore are not influenced by the weight or pressure of the Atmosphere.

And if a wide pipe of glass be filled with sifted ashes well pressed together in the glass & one end of the pipe be dipped into stagnating water; the water will rise up slowly in the glass so as in the space of a week or fortnight to reach up to 30 or 40 inches above the surface of the stagnating water. And the water is raised to this height by the attraction of those particles of the ashes only which are upon the surface of the elevated water; the particles which are within the water, attracting it as much downwards as upwards. And therefore the attraction is very strong but it would be much stronger if the ashes upon the surface of the attracted water were one continued body, as the glass is which keeps quicksilver suspended to the hight of above 60 or 70 inches, & therefore attracts with a force which would keep water suspended to the height of above fifty feet. And the particles of glass, which lie closer to one another then they do or the quicksilver {mor} attracts one another with a force much stronger.

By the same principle a sponge sucks in water, & the glands in the bodies of animals according their several natures & dispositions suck in various juices from the blood
