A COMPENDIOUS SYSTEM OF ASTRONOMY.

LECTURE I.

GENERAL INTRODUCTORY REFLECTIONS ON VARIOUS SUBJECTS. ON OPTICS.—THE EYE.—LIGHT.—REFRACTION.—REFLECTION.—GRAVITATION.—PENDULUMS, &c.

NATURAL objects, when properly contemplated, continually admonish us in the important science of Divine Wisdom, leading us to consider our situation in this sublunary state, our connections and dependencies;—from which we learn the duties required of us, and the exertions we are capable of making.

From the consideration of our mental faculties, we infer the exalted idea of a future state of existence, so naturally rising in the intelligent mind; which reflects on the never-ceasing energy of the mental power, and its independency of all mortal circumstances.

Thus perceiving what is the purer essence of our nature, and what the grosser, we are conscious that our present existence was not the primary or principal intention of our Creator: yet, as it is allotted us preparatory to that for which we were created, it claims our particular attention; becoming either advantageous to us or otherwise, accordingly as we deal with the objects which surround us.

Our superiority in the scale of beings, gives us the power of applying to our own use, the gifts of Providence by which we are surrounded, with the greatest advantage, not only so as to supply the necessities of our mortal nature, but also to derive considerable mental gratification from them.

Shall we then neglect rightly to use the gift of reason, and thereby become unworthy of such a boon, as well as lose all the benefits to be derived from it? Certainly not. Let us rather, on the contrary, so exercise and improve our understanding, as to form a right judgment of the value of things, by which alone we can be enabled to conduct ourselves according to the proper circumstances of the state in which we are placed: a business which requires more caution in the investigation than young minds are apt to imagine;—implying a thorough knowledge of the human mind, which can be obtained only by a careful examination of its capacities and infirmities.

Before entering upon this important investigation, my duty prompts me to offer some reflections on that Hand which formed us,—that Divine Mind which directs all our involuntary operations,—and that Benevolence which renders these operations instrumental to the comfort and happiness of all its creatures.

Yet, how can I presume to recount the works of the Almighty, or shew the wisdom of his counsels! Far above the narrow scale of human enquiry, far out of the reach of the feeble efforts of human comprehension, are such investigations: yet are his attributes discoverable in his wise administration, made evident to us through the medium of our senses.—Let us then receive these emanations of the Divine Mind shed down upon us, with as much joy and thankfulness as we do the rays of the sun when falling upon our crops of corn, making them yield forth their abundance.

This world is by no means barren of comforts to those who cultivate a relish for the delights it offers, avoiding satiety; for by a

proper application of the objects of sense, we shall learn how to render the things of this life not only serviceable but delightful to us.

If we attentively regard the wonders of creation, we shall discover gradations; some rising superior to others in that excellence, of some kind or other, which is peculiar to each particular species. In vegetable and mere animal nature, this is unavoidable; but in the higher class of animated nature, in man, much depends on his own exertions, as is evident from the instances of the learned men of all ages and all climates; some of whom, though born under all the disadvantages of superstition and barbarism, yet by a right application of their understanding, they have signalized themselves in the delightful fields of science and virtue, not excelled even by those who have lived and studied in the most civilized nations with all the advantage of instruction and method to regulate their researches:—and this excellence the former have attained to by a due cultivation of their minds, by which they have increased in knowledge, by regular gradations, till they have arrived at the highest pitch of mental improvement.

The operations of the mind distinguished by logicians, are four.

The first is perception, from which result our ideas.

The second, judgment; which is the assembling ideas together, and comparing them.

The third is reasoning, which is the exercising our minds in producing proofs to apply to the discovery of facts.

The fourth, which is the last operation of the mind, is called method;—as we must perceive, judge, and reason, before we can methodize. The mind must be stored with the knowledge resulting from the foregoing operations, before it can be capable of disposing its intellectual acquirements into classes, or of uniting them according to their proper connections and dependencies.

How delightful is the task of enquiry! how important the advantages resulting from investigation! Amply is the searcher into nature rewarded, by the extention of ideas and the strength of judgment acquired; by which the human understanding is enabled to soar above vulgar prejudices, and to view the works of God with satisfaction,—deriving consolation from every object in nature.

Suppose we employ the operations of the mind at present on an object which aptly offers itself; being so connected with the subjects of these Lectures, that, without it, we could never have contemplated the wonders of those regions they treat of—namely, the organ of sight. Do we not perceive its fitness to the office assigned it? and do we not from thence infer, the power and wisdom of that Being who constructed it? "He that made the eye, doth not he see?" Thus proceeding, according to the natural operations of the mind, we discover not only its use, but the necessity of such an organ to rational beings, as well as to almost all animated nature, capable of self-action; as, without it, how could existence have been continued? how could the latter have sought their food, or the former have prepared it? From this evidence of God's preventing goodness we naturally infer, that every part of his creation is replete with the like instances of benevolence in their several dispensations.

In order to your understanding the wonderful contrivance manifested in this little organ, to fit it for the rays of light, it will be necessary to contemplate the nature and properties of that subtile fluid.

The particles of light are inconceivably small, and their velocity exceeds human conception. The laws by which they are governed, and by which other bodies act upon them, by reflections and refractions, without altering their original properties, and the facility with which they insinuate themselves into substances of the compactest texture,—are circumstances which excite astonishment in the most cultivated minds.

The Sun is the fountain of heat and light, which are kindred properties, only differently modified; sometimes they act unitedly, and sometimes independantly of each other.

This fluid is universally diffused, and perpetually flowing from its source, the sun. Mixing with our atmosphere, it supports animal and vegetable existence, adorns all nature, and is the first natural principle of motion and vitality.

That light is a material substance, has been proved by its being subject to those laws which characterize materiality; such as decomposition, force, and being prevented from pursuing its strait course by the interposition of an opake body. Its natural motion, like that of all bodies, is uniformly progressive, as has been proved by many experiments; also that its velocity is the same, whether original, as from the sun, or reflected, as by the planets.

From observations of the eclipses of the satellites of Jupiter, it has been discovered, that light is propagated from the Sun to our Earth in 8 minutes 12 seconds. These eclipses, when they happen at the time the Earth is interposed between the Sun and Jupiter, are observed about 8 minutes 12 seconds sooner than they should do by the tables; and when the Sun is between the Earth and Jupiter, they happen 8 minutes 12 seconds later than they are calculated for. These circumstances are owing to the light of the satellites having further to come in one case, than in the other, by the whole diameter of the Earth's orbit.

These observations clearly prove the progressive motion of light, and ascertain its velocity, as these inequalities are certainly occasioned by the time which the light takes in traversing that quantity of space, which is equal to the diameter of the Earth's orbit, and not to any inequality in the motions of the satellites in their orbits; for the same happens in all parts of their revolutions.

Although it is impossible to convey an adequate idea of the amazing velocity of light, yet, that we may form some conception

of it, I shall just observe, that it moves at the rate of twelve millions of miles in a minute; as is known, by comparing the Earth's mean distance from the Sun with the foregoing phœnomenon.

The unlearned in the sciences are astonished at the minute calculations made by mathematicians, of the distances, sizes, &c. of the heavenly bodies, and of our Earth; because, they are not acquainted with the principles of this science. I hope in its proper place to convince my pupils, that such calculations may be accurately made by those versed in the mathematical sciences.

I shall not enlarge on the subject of optics, or the nature and properties of light, in these lectures, more than will be necessary to your conceiving the nature and extent of celestial observations, after having recalled the attention of my dear pupils to a retrospect of those clear evidences they have perceived of this admirable subject, in my lectures on optics—The wonderful organization of the eye! the uses of its different parts, and the delight it affords.

The rapture with which we have contemplated the separated rays of light,—in all their distinct and glowing colours,—when charmed with the variegated hues, we have almost forgotten what they were to authenticate,—till anxious for conviction we have returned to the theory,—when, on comparing the admirable experiments of Sir Isaac Newton, with his inferences, we have been doubly gratified by truths so clearly elucidated.

Then, on comparing the properties of light with the mechanism of the eye, we have perceived that the eye was formed for the rays of light—that it had the power, in a great degree, of adjusting itself to their strongest and weakest impressions—that its humors were adapted by their powers of uniting, refracting, and reuniting, to answer, in the most perfect manner, the purposes of vision.

Then considering the powers employed externally to aid this delicate machinery, such as the muscles, by which all its motions are regulated, and that each of these has its particular office as-

signed it;—one raising and supporting the eye, another lowering it;—one drawing it towards the nose, another towards the temple, another making it roll about with ease, and the last moderating the movements of all the rest, so that they should not exceed certain limits—how has the prescient and preventing providence of God, thus manifested to us, filled our hearts with love and admiration! —how sensibly have we felt this conviction of an all-wise, all-seeing, and all-bountiful Creator!

In proceeding with the subject which occasioned this digression, I shall endeavour to be as concise and intelligible as possible, avoiding all superfluous illustration and abstruse terms of science.

By a ray of light, is meant the least particle of light that can be separately impelled.

By a pencil of rays, a parcel of rays issuing from a point, or proceeding towards one.

When an object is illuminated by the sun, or a candle, every physical point on the surface of that object which is turned towards the light, sends forth rays in all directions, by which power it is, that it becomes visible to us.

That side of the object which is turned from the light, may also be seen, but it appears dimmer, that part not receiving the direct influence of the light, but receiving it by reflection only from surrounding objects. All objects would be invisible on the side turned from the radiant point, if it were not for that property of light which causeth it to be reflected.

Before the admirable Newton, by his judicious and well conducted experiments, discovered that the particles of light were turned back, before they touched the reflecting surface, it was generally supposed that the rays of light were reflected by striking against the impervious parts of solids, as other bodies are; but that great and penetrating genius discovered the error of this supposition, and has taught us, that the matter of light coming in contact with

some unknown subtile medium, which is equally diffused over the whole surfaces of those substances, and striking it with a determined force, is thrown back by the re-action of this fluid medium; which fluid he conceives to be subtler than air, or light, and an intermediate agent.

"If light, says this great man, were reflected by striking on the solid parts of bodies, their reflections would not be so regular as they are found to be: as, however polished the smoothest surface may appear to our sight, or feel to our touch, yet is it an assemblage of inequalities; for in polishing glass with sand, it is not otherwise polished than by bringing its surface to a very fine grain, and from such a surface, the small particles of light would be as much scattered as from the roughest."

This conclusion is so convincing, that although we cannot discover the invisible agent which causes reflection, yet we must admit the probability of its existence.

That there is such an active medium, whose agency cannot be perceived but by its effects, we are certain, as, without allowing that there is, how can we account for all the effects we call gravity? of which I shall say more hereafter.

That the rays of the sun, or a candle, proceed in strait lines, whilst moving in the same medium, is evident by the shadows cast by opake bodies; but that in falling obliquely from one medium on to another, of a different density, they are refracted, is proved by experiments.

By a medium, is meant any transparent body which suffers light to pass through it, as air, glass, water, &c. These mediums differ in density, therefore the light, in passing from one to the other, is refracted; and the deviation is in some proportion to the difference of density of the two mediums.

The rays of the sun, in passing out of the ethereal region into our gross atmosphere, are refracted, so that we see that luminary

before it has risen above our horizon, of a morning, and after it has sunk below it, of an evening; so that by this refractive power of our atmosphere, we enjoy the light of the sun a considerable time longer than we otherwise should do, and escape the disagreeableness of a sudden transition from one extreme to another.

The rays of light which fall perpendicularly on a different medium are not refracted, as when they fall obliquely; and when the sun is in the zenith of any place, that spot to which it is vertical, receives its direct influence, and suffers the extremest heat, receiving a greater quantity of the sun's rays, in proportion to the space.

The refraction which light is subject to, is easily seen in a familiar instance, by placing any object at the bottom of a bason, and withdrawing yourself from it, till it is lost to your view, when, if another person pours water into the bason, it will become visible to you, even in the very situation which before rendered it invisible. This is the consequence of the rays of light being refracted, which causes the image of the object to appear higher in the bason.

I think it proper to acquaint you with the nature and limitations of the laws of refraction and reflection, although it is not necessary to these Lectures to go into a close investigation of those laws.

Sir Isaac Newton's Theory, as I comprehend it, supposes all bodies to be filled with a subtile fluid, and that its action extends all over, and to some distance from their surfaces; and that it is the action of this fluid which causeth refraction, and the re-action of it, when it receives a given impulse, that causeth reflection. Thus the same fluid, by its different mode of action, is supposed to transmit and reflect light, and the latter, apparently from the substances themselves.

This subtile fluid, that great man conceives also to be the cause of gravity or attraction, and that it exists in all space; that this medium is condensed in our atmosphere, and still more so in the

substances on our earth; and that its density is in proportion to the number of particles in the substances it penetrates. That if we admit such a fluid to be diffused through imaginary space, it must be in its natural state more rare than we can conceive, otherwise it would resist the motions of the planets very considerably; whereas the contrary being the case, as is evident by the regularity of their motions, we may be certain that this fluid must be very rare, so rare indeed, that it freely penetrates the pores of glass and the densest bodies.

Refraction and reflection are distinct properties, yet are they analogous, as being the operations of the same agent, this subtile medium.

The general laws of refraction are, that a ray of light, in passing out of a rarer into a denser medium, is refracted towards the perpendicular, that is, towards the axis of refraction, and hence the angle of refraction is less than the angle of incidence; whereas those two angles would have been equal, had the ray not been refracted. The physical cause of this may be, that the attraction of the denser medium, acting perpendicularly to the oblique direction of the incident ray, diverts the ray out of its course, in proportion to the superior force it exerts. But when a perpendicular ray falls upon a denser medium, in that case it suffers no refraction, because (we may still suppose) the attracting power, acting in the same direction with the ray, cannot cause it to deviate from its strait course.

On the other hand, when a ray of light passes obliquely from a denser to a rarer medium, it is refracted from the perpendicular; so that the angle of incidence is less than the angle of refraction.

I shall endeavour to explain the laws of refraction upon Sir Isaac Newton's principles of attraction, referring to *Dia. fig.* 1. *plate* 1. Suppose the line HI to be the boundary of two mediums, air and water, N and O; the upper one N the rarer, as the air; the lower one O the denser, as water; which latter is included between the