1823

Octr 10th brt home from Town 1 bbl flour 3/-
150 lb brn sugar
35 lb soap do
1/2 Gal. rum
100 lb bacon 11.53
[illegible] upon the inn[illegible]

1824

Dec 1st Mr [illegible] got by [illegible] within the last 5 weeks by his account 2303 [illegible] for a pair shoes for his daughter $1 [illegible] some little things. I settled with [illegible] 56 cents for him [illegible]

7-6 / 4-4	31-5-4		28-4-8
7-6 / 4-4	14-2-4 / 2 / 28-4-8		28-4-8
16-3 / 7-4	13-2-2 / 2 / 26-4-4		26-4-4
17-6 / 5-2	10-[illegible]-5		10-[illegible]-5
17-6 / 9-0	twice 18-4-3 / 2 / 36-8-6		36-8-6
9-6 / 5-2	twice 4-1 / 2 / 10-8-2		10-8-2
17-6 / 15-4	29-7-4		29-7-4
17-6 / 7-4	twice 14-2-4 / 28-4-8		28-4-8
15-4 / 7-4	twice 12-4-9 / 24-8-18		24-8-10
11-8 / 13-8	17-4-6		17-4-6
[illegible]	twice 12-2-10 / 2 / 24-5-8		24-5-8
13-6 / 9-6	twice 14-2-3 / 2 / 28-4-6		28-4-6
24- / 11-9	31-3		31-3
9-1 / 6-6	twice 8-5-120 / 17-1-4		17-1-4
			346-8-3
29-7 / 35-7	117-7-120		117-7-11
14=4 / 7=3	6 times 11-9-11 144		69-2-11

balance without [illegible] any allowance for [illegible] shoes [illegible] afterwards $2.00 then [illegible] 25 [illegible] 1 [illegible] meal [illegible] 11 [illegible] 23rd 30 Mr [illegible] counted 500 [illegible] before [illegible] Xmas 700 more [illegible] to 29th Jany 1825 [illegible] bacon - whole [illegible] to 15 Feb 4175 = $11.[illegible] say 4000 = $10 ——

[illegible] 8.65 1/2

15 Feb 1825

balance in his [illegible] $1.34 1/2 [illegible] him [illegible] 18 lb bacon [illegible] March 1st 1825

[illegible] $2 Mr [illegible] to this time since last settlement 2000

Robert D. Murchie

William & Mary

Virginia

1809

Book containing notes on natural philosophy taken from the lectures of James Madison by Robert D. Murchie, student at William and Mary College, 1809. [3], 202, [20] pages. 13 x 8 1/4 inches. Presented by F. B. Dunford of Richmond, Virginia. December 1922.

Note: The book contains also notes on elocution and the following notations, apparently made by Robert D. Murchie, though the hand is not the same:
- A list of members of the Manchester troop of cavalry, 1821.
- A letter from Robert D. Murchie to Mr. Thomas P. Coke in Philadelphia, asking for a position for his nephew, James A. Clarke. 10 Dec 1822.
- Memoranda, 1820-1824, some of these being in the form of a diary.

A Compendium of Lectures

as delivered by

James Madison

President

of

William & Mary

Index.

Natural Philosophy

Lecture 1st introductory

What is meant by the word phenomenon?

It signifies an appearance, or in a more enlarged acceptation, whatever is perceived by our senses. Thus the fall of a stone, evaporation of water, a flash of lightning &c. are all phenomena.

On what do all phenomena depend?

On properties peculiar to different bodies. For instance, it is the property of a stone to fall towards the earth, of water to be evaporable &c.

What is the design of natural philosophy?

To become acquainted with the properties of natural bodies, investigate their causes, and thence to infer useful deductions. Thus the properties of the air we breathe; the action and power of our limbs; the light, the sound, and other perceptions of our senses; the actions of engines; the vicissitudes of the seasons, the movements of the celestial bodies, &c. do all fall under the consideration of the philosopher.

Are the axioms of philosophy as evident as those of geometry?

No; they only assert things which have been constantly shewn and confirmed by experience, & are not contradicted either by reason or experiment, but they are not absolutely certain.

Illustrate the third axiom.

Some persons may perhaps be inclined to doubt the propriety of this axiom, seeing that a great many things appear to be utterly destroyed by the action of fire; also that water may be caused to disappear by means of evaporation, &c. But it must be observed that in those cases the substances are not annihilated; but are only dispersed, or removed from one place to another, or they are divided into particles so minute as to elude our senses. For instance if a piece of

wood

wood be placed on the fire, it will in a short time be reduced to a heap of ashes, which does not exceed the one hundredth part of the weight & bulk of the original piece of wood; although in this case, an apparent annihilation takes place, yet the wood is only separated into its component parts — The fluid part becomes steam, the light coaly part either adheres to the chimney or is dispersed through the air, and in fine, if after the combustion all these parts were collected (which can in a great measure be done) the result of all their weights taken together would equal the weight of the original body.

Why have the rules of philosophizing been formed?

To prevent errors as much as possible, and to facilitate the progress of the student in acquiring true and useful knowledge.

What degree of evidence should be annexed to natural philosophy?

Physical matters are not capable of such absolute certainty as the branches of mathematics. We can only say in natural philosophy, that because some particular effects have been constantly produced under certain circumstances; therefore that they will continue to be produced as long as the same circumstances exist; and likewise that they do, most probably, depend upon those circumstances.

What is time?

It is incapable of proper definition. All that can be said in regard to it is, that it is divided into absolute and relative. Absolute time flows equably but does not refer to the motion of bodies. Relative time is that portion of absolute time during which a certain movement is performed and when they are equably and steadily performed we assume some of those movements as the measures of time. For instance, the apparent movement of the sun round the earth we call a day; the 24th part of that day, an hour

What are the laws of nature?

They are those immutable laws by which every phenomenon in nature is regulated, and which preserve uniformity and order throughout the stupendous system of materialism.

What is the method which the rules of philosophizing point out for our enquiries into the laws of nature?

Instead of forming vain hypotheses, the philosopher should first collect a history of facts, observe the laws by which, under the same circumstances, they are always governed, and thence deduce the causes of those effects.

What are the inducements to study natural philosophy?

They are very great and very numerous, & drawn principally from five sources. 1st Its extensive utility. 2nd The gratification which the mind feels in pursuit of it. 3d The novelty and grandeur of the subject. 4th It is the best field for exercising the human intellects. 5th It is the source of the sublimest conceptions of the author of the universe. First from its extensive utility. The science of mechanics alone, by the invention of machinery which abridge human labour, has rendered infinite service to society. By this science mankind have been able to erect superb edifices, and when assisted by the discoveries of philosophy in the science of magnetism, to build vessels, and endow them as it were, with a soul, which should direct their course over boundless tracts of water, in order to convey to one nation the necessaries and luxuries of others the most remote, and in order to keep up that mutual communication between the different quarters of the globe, so essential to human knowledge as well as happiness. Secondly the human mind is so constituted as to receive pleasure from a variety of objects and sources, but as these are principally to be found in the works of nature, a mind employed in the study of philosophy, whose object is nature, must necessarily receive great additional inducements from this source to study this science, especially as, thirdly, something new or grand is constantly presenting itself in the course of this study. Fourthly, here the mind of man finds ample room to exert and display its faculties, in a field to which imagination itself can set no bounds. After contemplating all inferior things, and observing the wonderful adaption of means to ends, the mind, disdaining to be confined to this terestial scene, springs aloft into the etherial regions of unbounded space, and while it contemplates the infinite wisdom and power to form so many suns and systems of worlds, and to adjust their bulks, orbits, and periods with such exactness, is led to form the sublimest conceptions of the author of the universe. The mind becomes expanded and enlarged in viewing the astonishing wisdom and ingenuity displayed in the mechanism of such immense systems of being in the contemplation of which it is itself overwhelmed and swallowed up.

What the general view of the progress of this science together with the causes which so long retarded that progress?

Man being surrounded by a variety of objects and inhabiting a world whose innumerable new appearances were constantly presenting themselves to his view, the natural curiosity of his mind must from the earliest ages have drawn his attention to them and led him to enquire into their causes; but having nothing to direct him in his researches, and being unacquainted with the wisdom and ingenuity displayed in the works of nature, he wandered about in the mazes of uncertainty & had recourse at last to his own imagination to invent a system by which he might account for the appearances which presented themselves. But this could be nothing more than a system of conjecture without proof to support it, and could challenge the belief of none but the author, whose reason was lost in the warmth of his imagination, because no improvement being hitherto made in the method of recording events, no history of phenomena had been yet collected, & there could be no foundation upon which to erect a superstructure. To undermine its shallow foundation would therefore be no difficult task & would be immediately attempted by those who envious of his fame wished to raise their own on its ruins. But the foundation of this second being not more solid than the former, would in its turn be unable to withstand the test of examination. Thus was one hypothesis raised on the ruins of another which in its turn gave way to a succeeding one, for many thousand years without arriving any nearer the truth. A lucky concurrence of fortunate events contributed however gradually to elevate man from this degraded state, and to open to his view those secret principles which had been long concealed in the womb of nature. The principal of these events were 1st the invention or improvement of the mariner's compass in the year 1302 by means of which commerce has been extended over the globe and knowledge disseminated through every class of men. One discovery gradually brought to light another. The extension of navigation consequent on the discovery of the compass enabled every individual to avail himself in some measure of the discoveries and improvements made in every other country even the most distant. About the year 1430 the art of printing was invented. The union of these two very important inventions began to form all the nations of the earth into one formidable republic of science. From this time an amelioration of the condition of the human species began to take place and the human mind was roused from that state of lethargy in which it had remained for many ages. Philosophers began to arise who turned their attention to the works of nature that noblest field of improvement to man, which had been totally neglected during the long reigns of ignorance and superstition. About the year 1610 Gallileo a Citizen of Florence introduced the telescope into use which had been just invented in Holland, by means of which he discovered the satellites of Saturn. But Sir Francis Bacon was the first who pointed out the proper method to be pursued in philosophical researches, in a collegiate exercise at the age of 16. This method was afterwards pursued by Mr. Boyle who made many important experiments and discoveries. But it was Sir Isaac Newton who first discovered the general law of nature namely, gravity, which operates throughout the universe, keeps the planets in their orbits, and preserves the whole fabric of nature from confusion and disorder. He laid the foundation of the present system of philosophy which has finally overthrown the chimerical hypotheses which so long retarded the progress of the true philosophy. The bare mention of the names of those illustrious heroes of science who have since turned their attention to the cultivation of philosophy, would be too tedious a task to attempt.

What are the qualities necessary for a student who would profit by this course?

He should endeavour to divest himself as much as possible of every kind of prejudice. He should take nothing for granted that is not satisfactorily

proved, but
of whatever
strictest ...
Unremitted
always ne...
progress i...

proved, but enter with spirit in the consideration of whatever is offered, and examine it with the strictest attention, and utmost impartiality. Unremitted attendance & diligent application are always necessary for those who wish to make any progress in science.

Lecture 2nd of matter or bodies in general

What is understood by matter?

Matter is that which has length breadth & thickness and resists the touch. —

What are the inherent properties of matter? the definitions and explanations of each?

The inherent properties of matter are Extension, Solidity or Impenetrability, Mobility, Divisibility, Attraction, Figurability & Porosity. **Extension** is that property of a body by which it occupies some part of universal space. — That all bodies possess this property is evident, it being impossible to conceive a body which has not length breadth and thickness in extension. **Solidity** called also **Impenetrability** is the power which every body has of excluding all others from the space which itself occupies. That every body is possessed of this property is also selfevident, for otherwise two bodies might exist in the same place which is absurd. Hence it follows that the softest bodies are equally solid with the hardest. **Inactivity, Vis Inertia** or **Passiveness** of matter is the tendency which it has to continue in its present state, either of rest or motion until some external force acts upon it. This tendency is always proportionable to the quantity of matter. Therefore if one body contains twice as much matter as another it will require twice as much force to put it in motion; for that a body, as a stone for instance, is unable to move itself is evident to all. And that a body moving with double the velocity of another will require double the force to stop it, if their quantities of matter be equal is also equally true. And a body once put in motion would continue moving forward unless resisted by some impeding power. —
Mobility is that essential property whereby a body is capable of being moved from one part of absolute space to another. That this property exists follows from matter's being finite; and to suppose it —

infinite is absurd, because it consists of parts. **Divisibility** is the property by which all matter may be divided into parts. It evidently exists, because the particles of bodies are all distinct and no two can exist in the same place. **Attraction** is the property by which one body tends to, or endeavours to approach another. **Figurability** is the property by which matter is capable of an infinite variety of shapes. It arises from this, that matter is not infinite and must therefore be circumscribed by limits which constitute the figure. **Porosity** consists in the interstice between the particles of matter, which are found in all bodies.

What are the experiments to prove the solidity of bodies apparently the least solid?

Take a glass tube open at one end only, immerse the open end into water & you will find that the included air will not suffer the water to rise in the tube which it would do were the other end of the tube open. Therefore air is solid according to the definition of solidity.

Is matter infinitely divisible?

That matter is infinitely divisible may be demonstrated mathematically; but when we come to apply this principle to actual experiment, we shall find that the powers of man have not arrived at that degree of perfection to be capable of carrying on the division to such an extent.

Is the mathematical demonstration applicable to the material world?

Is it not on account of the imperfection of the powers of man, which prevents him carrying on the division to such an extent.

General properties of matter are the following; Extension, Solidity, Inactivity (or vis inertia) Divisibility, and Mobility; to which have been added, Configurability, Porosity, Rarefactibility, Condensibility, Compressibility, and Elasticity. Rarefactibility is that property of bodies by which they become inflated or expanded by heat. **Condensibility** is the reverse of rarefactibility, being that property which bodies have to become warped or contracted by cold. Compressibility is the property whereby bodies are capable of being brought into a smaller compass. Elasticity is that tendency which all bodies have whenever compressed or extended to reassume their former state. To prove the solidity of water or air (which of all bodies appears the least solid) fill a bladder with air or water, and the sides cannot be brought into contact. Some have denied that matter is infinitely divisible, but let them consider, that if the smallest particle of matter be placed on a smooth surface, some part of it will be farther from the surface than another. But that matter, if not infinitely divisible, is at least, indeterminately so, may be proved by mathematical demonstration.

With respect to divisibility, there are two remarkable instances which deserve to be mentioned. A single grain of gold may be beat out into a leaf containing 50 square inches which may be divided into 500,000 parts visible to the naked eye. These again, by a Telescope magnifying only ten times, may be divided so as to make the 50 millionth part visible. But nature goes still further than art; for we are told by Dr. N. Leuwenhoek that there are more animals in the milt of a single Cod fish, than there are inhabitants on the earth; and comparing these with grains of common sand, by means of a microscope, it appeared that a single grain was larger than 4 millions of them. The porosity of bodies is made evident by the following experiment. Exhaust the air from a receiver which has a piece of wood on top; on this pour Mercury and it will pass thro' the pores of the wood. To this is also owing the easy transmission of light thro' glass. It was believed by Des Cartes, and his followers that a vacuum could not exist in nature. But the Platonic argument completely refutes their belief; for of all the infinite variety of forms which matter can assume, Plato proved that there were only five which could be so placed as to leave no Interstices or vacuities between them: hence the assertors of a plenum were obliged to prove, that though matter is liable to numberless different forms, yet all its particles must have some one of the five following, Tetrahedron, Hexahedron, Octohedron, Dodecahedron, and Icosahedron, which are called the Platonic bodies; for, if the particles assumed any other form whatever; it is very evident that they admit vacuities in the composition of any body. Since the invention of the air pump, the error of Des Cartes has been plainly shewn; for a guinea and a feather will fall to the bottom of an exhausted receiver in the same time. The Cartesians contended that there was a certain subtle fluid, which would penetrate the hardest bodies, by which all space was filled up. The ancients supposed Fire, Earth, Air and Water to be the elements or primary principles of all bodies. It is true they are found in all bodies whatever: yet the Chemists of modern days have discovered that they are not in a simple state. Water has been decomposed, and found to consist of two different kinds of Gas. It is concluded by the moderns, that to discover the elements of bodies, is beyond the capacity of man, and they have with more reason classed them under different heads, according to their most distinguishing and striking properties, as Watery, Earthy, Inflamable, Saline, & Metalic. Attraction and Repulsion are among the general properties of bodies, being that tendency which they have to approach, or the power to recede from each other: yet in using these terms, they are not to be considered as the physical cause, but only as the effect of some unknown cause. There are several different kinds of attraction, as that of Cohesion, of Gravitation, of Magnetism, of Electricity, and Elective force attraction. The first is that which takes place between the minute particles of bodies. Attraction of gravitation is that power by which distant bodies tend towards each other. That of Magnetism, is the peculiar attraction which the loadstone has for iron and all ferruginous substances.

Attraction of Electricity, is that which several bodies, as Amber, Wax, Glass &c. exhibit when heated by rubbing. Elective attraction is when a menstruum dissolves some bodies in preference to others. There are three laws belonging to attraction of cohesion. 1st. It takes place only at a small distance, and between the smallest particles of bodies. 2nd. It is in proportion to the quantity of surface. 3rd. It is mutual and common between all bodies. The simplest instance of water, or two globules of mercury. It is by this attraction that several phenomena are accounted for, as the ascent of sap in trees, the rise of nutritive juice, or the moisture of the earth, in plants, & the stems of flowers, the rise of water in capillary tubes* above the external surface, the water being attracted by the annule of the tube. Upon this principle depends the rationale of cements & solderings &c. for the surfaces being brought into contact, the attraction of cohesion immediately takes place. By this attraction we account for hardness, softness, fluidity, fermentation &c. When the particles are flat the body is hard, when they touch in fewer points & are more round, they are soft, when sperical or nearly so, they form a fluid. Fermentation too, is produced by this attraction, as it consists in an internal agitation arising from the mutual action & attraction of the particles. As to Elasticity, the real cause is not yet known. In all cases the attraction of cohesion is destroyed by separating the parts a very small distance.

* The height of water rising in capillary tubes will be inversely as their diameters.

Lecture 3rd

Chemical Affinity.

On the general laws which tend to bring the particles of bodies together, and to maintain them in a state of combination.

Were it not for this force which Chemists call affinity, there would be no such thing as solidity. It is the agent employed by nature to maintain its equilibrium by forming a balance to the power of repulsion, or that extremely subtile fluid called calore, which is ever tending to disunite the particles of bodies. Water affords the simplest instance of existence. Place two drops near each other, & they will mutually approach & form one globule. Two polished surfaces when brought into contact afford another instance. They will cohere so very strongly, as to require considerable force or weight to separate them. This affinity is exerted between particles of the same nature, & also between those of a different nature. That species of attraction which exists between the minute particles of bodies, has been called affinity, 1st. Because Chemists supposed it depended on a certain analogy, or conformity in the principles of those bodies between which it existed, & 2ndly, to distinguish it from the planetary attraction discovered by Newton, of which it appears to be a modification. Hence it is considered in a twofold view. First, that which exists between bodies of a similar nature, or affinity of aggregation. By this attraction the real properties of bodies cannot be changed, for if water be united with water, the union must still remain water.— But it must be distinguished from both a mixture & a heap; for, tho' an heap consists of similar parts, these parts are disposed loosely & without adhesion. A mixture is composed of particles of a different nature, united incoherently. An heap may become an aggregate by fusion & cooling, thus; melt the flowers of sulphur, and while they are in a state of liquifaction; this attraction will act, and render them when cool a complete aggregate. The affinity of aggregation exists in different degrees, & is measured by the force requisite to separate the integrant parts of the aggregate body. Aggregates are distinguished into four kinds, 1st the hard or solid aggregate, whose parts are so forcibly united that a considerable effort is necessary to separate them. 2nd The soft aggregate whose constituent parts may be made to change their relative situations without separation. 3rd the aeriform aggregate, whose parts are so small & subtile as to escape the eye. The atmosphere affords an example of it. 4th The fluid aggregate, whose integrant parts are separated by the slightest efforts. Water presents us with an instance of each of the four kinds. When frozen, it forms the hard, or solid aggregate, when mushy, or in a state between the solid & fluid, it forms the soft. In the common state, it is the fluid, and when its parts are disengaged by a large quantity of caloric, it exhibits an example of the aeriform aggregate. Thus we see that the four kinds of aggregates are in reality but different degrees of the same force. Secondly, the attraction which takes place between particles of a dissimilar nature, or the affinity of composition — It is this dissimilarity of particles which constitutes its basis, and without which it could not exist. This affinity is highly important, as without it, no composition or decomposition could have a being bodies would continue unchanged, and all the researches of Chemists would terminate precisely as they began. All its phenomena are comprised in seven laws. 1st It acts only between bodies of a different nature, and is strongest when the bodies are most dissimilar. An Alkali combines more forcibly with an Acid than any other substance, tho' these are the most opposite in their natures. An Alkali is any vegetable substance which effervesces when mixed with an acid. It is known by the following properties. It has an acid urinous taste, turns syrup of violets green, it forms glass when used with quartzous substances, and also, it renders water miscible with oil. An acid is a combination of Oxygen gas with any elementary substance. It possesses sourness in the highest degree, turns blue vegetables into red, and forms a rapid combination with an alkali.—

2nd Law. It acts only between the smallest particles of bodies. Here we may observe a striking difference between the two affinities, for whenever the force of one is weakest, that of the other is always strongest. The force of aggregation exists less in gasses than any other body, and these by the affinity of composition combine with other bodies with the greatest facility imaginable. Hence it is infered as an axiom, that the affinity of aggregation is inversely as that of composition, and vice versa.—

3rd Law. It unites more than two bodies. This law is indeed very confined. We are acquainted with many combinations of two bodies, a few of three, but scarcely any of four. Metals alone exhibit an instance of the last.—

4th Law. In order that it may take place between two bodies, one at least must be in a fluid state. Corpora non agunt nisi sint fluida. There are some bodies, which, when reduced to a very fine powder, will form a compound. In instances of this kind, during their state × of pulverization the atmosphere is attracted by the particles whose moisture in some measure combines them and renders them still subject to the last law; and indeed this law acts with very little exception. When a solid is so suspended in a fluid as to disappear it is called* solution. This phenomenon is easily accounted for by the superiority of the affinity of composition over that of aggregation. Transparency is the test of solution. The action of a solid and fluid in solution is perfectly reciprocal, tho' that perhaps of the solid body is the greater, for its tendency to combine with the fluid is so great, as to prevail over it, and destroy its aggregation entirely— When so much of a solid is suspended in a fluid that it will dissolve no more, it is then said to be saturated, and this quantity is usually one fourth. By taking equal quantities of the combination, and finding that they are equally impregnated with the solid, we conclude that the solid is

* Solution is the attenuation, the division, and entire disappearance of a solid body, when immersed in a fluid.—

equally diffused throughout the whole fluid.

5th Law. When two or more bodies are combined by this affinity, their temperature changes at the instant of their union. This phenomenon is explained by considering heat as a distinct body having a considerable part to act in all chemical operations, and from the absorption, or disengagement of this body arises a temperature. Pour water into a glass tube, & observe the height to which it rises; put salt in water, and it will rise the marked height, then gradually sink below it, and at last will rise to the original height, and be of the same temperature with the circumambient atmosphere. As water can only be dilated by heat or compressed by cold, this rising plainly indicates a change of temperature. —

6th Law. Two or more bodies united by the affinity of composition form a substance whose properties are different from those which either of the others possessed before their union. It was the opinion of   and his followers, that compounds always partake of the properties of their constituent parts. But there are many phenomena that incontestibly establish this law. Bodies that have no taste in their simple state acquire a strong one when combined. Others by combination lose their former taste. Some that are odoriferous when seperate, become inoderous when united with other bodies & the contrary. A few grains of mercury, or oxygenated muriatic acid taken in a little water can be no way hurtful, but combine them so as to form the oxygenated mercurial muriatic (or corrosive sublimate) and they make an infallible poison. If we attend to the phenomena exhibited by bodies in combination, we shall readily perceive that their taste, their form, and their consistence are changed by composition, and we cannot establish any rule to indicate, a priori, all the changes which may arise, and the nature and properties of the body which may be formed. —

7th Law. Every individual substance has its peculiar affinity with various substances presented to it. If all bodies had the same degree of affinity with each other, no change could take place amongst them: we could not be able to displace any principle by applying one body to another. Nature has therefore wisely varied the affinities, and appointed to each body its relative with all those that can be presented to it. It is in consequence of this difference in the affinities, that all decompositions are made in chemical operations. — The affinity of composition has received different names according to its effects. It is divided into Simple Affinity, Double Affinity, the Affinity of an Intermedium, and Reciprocal Affinity. Two principles united together, and separated by means of a third, afford an example of simple affinity: thus an acid has to a metal an affinity equal to 4, an alkali equal to 6 to an acid; the alkali will separate the acid from the metal with a force equal to 2. Bergman has given the name of Elective Attraction to this force; a name well adapted to it, as it appears to have a choice in uniting with one substance rather than another. The body which is disengaged or displaced, is known by the name of the Precipitate; that which causes it to fall, is called the Precipitant; and the action itself called Precipitation. Dissolve Silver in nitric acid, and add copper; the silver will be precipitated; add iron, and the copper in turn will fall to the bottom. When the combination of two principles cannot be destroyed by means of a third or fourth body separately applied, but by taking them both united to separate the compound, or precipitate one of the bodies, it is called double affinity. Thus the sulphate of pot ash, or vitriolated tartar, is not completely decomposed by the nitric acid, or by lime, when either of them is separately applied; but if the nitric acid be combined with lime, this nitrate of lime will decompose the sulphate of pot ash. In this last case, the affinity of the sulphuric acid with the alkali, is weakened by its affinity to the lime. There are cases in which two bodies having no perceptible affinity to each other, obtain a disposition to unite by the intervention of a third: thus water is rendered miscible with oil, by uniting it with an alkali. This is called the affinity of an intermedium. Reciprocal affinity is, when a compound of two bodies being separated by a third, is again destroyed by the separated body, so that there seems to exist a reciprocity in its effects: thus the vitriolic acid has a stronger affinity than the nitrous acid for fixed alkali, and it will separate this alkali when combined with the last acid. But the nitrous acid can in its turn separate the vitriolic acid, if the nitrous acid be heated — Some Chemists have supposed this force, and the Newtonian attraction, on account of their analogy to be the same, and that the greater the gravity of any body, the greater also was its affinity. The cause of this latter is altogether unknown; however there is a remarkable difference observable in its laws and those of attraction. The latter acts between the largest masses, affinity takes place only between the smallest particles. Attraction operates at the greatest distance, affinity only in contact. Hence we see that if affinity be not entirely distinct from attraction, it can only be a modification of it.

Alkalies are fixed or volatile: the former are not volatilized even in the focus of a burning mirror, and emit no characteristic smell. The latter are reduced into vapours, and emit a very penetrating odour. There are only two kinds of fixed alkali, vegetable and pot ash, and mineral, as soda, volatile (and sal ammoniac —

Lecture 4th

Gravitation

Attraction of Gravitation is that force by which distant bodies tend towards one another. But do bodies really attract each other, or are they urged by an exterior force? Of this we are completely ignorant. This impulsion has only been supposed, but never proved. Newton himself has never given attraction as the physical cause of the gravity of bodies, he only uses that word to express the fact, and not to assign a reason for it. Thus, he says in his principles of philosophy. &c I use in the same sense, attraction, and accelerating, or moving, impulsion; and I use indifferently the words, impulse, attraction and propensity to a centre — for I consider these forces mathematically and not physically. The reader then should guard himself against believing that I have desired to express the cause, or assign the physical reason for this kind of action; and when I say centres attract, or when I speak of their force, he must not think that I have intended to attribute any force to those centres, which I consider only as mathematical points. It follows therefore, that we do not know what is the physical cause of gravity, tho' many systems have been invented to assign a reason for it. But if any one wishes to see those hypotheses, he may consult Des Cartes, and also see what Newton has said in his mathematical principles of Natural Philosophy.

Let us then, consider gravitation agreeably to the Newtonian system, as a universal property of matter; so that by this property, not only one body tends towards another, but the parts of the same body all tend to each other.

We see that all bodies fall to the earth, when their support is removed; that thrown upwards, they invariably return. We also see, that all motion is performed in straight lines, unless there be some cause which turns the moving body from that line. Hence bodies which in their motions describe curved lines, must be forced into that direction by some adequate power which acts constantly upon them — But the planets make their revolutions in curvilinear orbits, or nearly in circles. There is therefore some power, whose continual action prevents them from flying out of their orbits or the circles in which they move, and from moving on forever in straight lines. It is that power, whatever may be the cause of it, that we call gravity. In reality, the planets could not continue one moment in their orbits, if there were not some force which retained them, or which urged them towards the centre of their revolution. This force then, of gravity, is universally acting, not only upon our earth, but throughout all the planetary system; and tho' we are ignorant of the cause, still we must admit its agency. We shall see according to what laws this agency is exerted.

It happens frequently, that gravitation acts alone upon bodies, and that they fall according to the laws which we shall mention. At other times, gravitation acts upon bodies conjointly with some other power, which produces a compound motion. We must speak of those two cases respectively. Let us begin with the first, (i.e.) let us examine the phenomena which take place, when gravitation acts alone upon bodies. 1st. We must not confound gravitation & weight — they express two different things. The gravitation of a body, is the force which solicits it to descend, and its weight is the sum of the gravitating particles contained in its mass. Gravity belongs equally to all the particles of the same body. This force neither diminishes, nor augments by their union, or their separation; but the weight of a body changes with the quantity of matter which composes it — We may then say, that altho' a small body has less weight than a large one, yet it has as much gravity, for they will both fall to the earth, from an elevated place, with the same velocity.

2nd. It is necessary to consider in gravity, what we consider in all other powers — viz. 1st.. Its direction 2nd. Its intensity, i.e. the measure or quantity of attraction upon bodies.

1st. Its direction is always perpendicular to the horizon — We express this direction still further, by a tendency to the centre of the earth, which would be precisely the same as this, if the earth were spherical; for then every line perpendicular to its surface would only be an extension, or prolongation of a radius. But the earth being a spheroid, flatted at the poles, lines perpendicular to the surface do not all meet at the centre, but at different points, which form a space or circle at the centre. But as this space is very small, we may without any sensible error, regard the centre of the earth as that to which heavy bodies tend.

With respect to the intensity of this power, or the measure of its action upon bodies, there are many questions which it is necessary to examine, and to resolve — 1st. It is necessary to know, whether the action is the same in all bodies, or whether it tends to make all bodies descend with equal velocity. 2nd. Whether the measure of this action is the same at all times. 3rd. Whether it is the same in all places. 4th. Whether it varies in the same body. 5th. In the case where it varies, whether it augments or diminishes — and 6th. In either case what is its progress.

Experiment only teaches very nearly, what space a body will fall through in a given time in consequence of its gravity; because it has always to overcome obstacles inseparable from its natural state, as, for instance, all bodies which obey any other power — Such as the resistance of a medium thro' which the body moves; which resistance varies. 1st. with the density. 2nd. the figure of the falling body. 3rd. the proportion of its mass, or quantity of matter, to its volume or bulk. 4th. the proportion of its weight, which it loses in air. All these circumstances prevent us from knowing precisely the primitive measure of the action of gravity upon bodies. We know only, that in the latitude of Paris, a body which has but little bulk, and much mass, (as a ball of lead) will fall through the air, at the rate of 15 Paris feet in the first second of its fall. The Paris foot is to the English, or our foot, as 233 to 278, which makes 15 Paris feet equal to 16 English.

The measure of the action of gravity.

Is it the same in all bodies? It was for a long time supposed, that gravity and weight were synonomous, and that a body had a tendency to fall so much the greater, as it has more mass or weight. This was probable. In effect it was seen (as we still see) in air, that a body less dense, as a feather, will fall with less velocity than one more dense, as a stone, or a piece of metal. Gallileo finding that the difference of their velocity was not in proportion to their masses, first imagined that the difference of their fall arose from the resistance of the air, which acted more powerfully upon bodies which had least mass, in proportion to their surface. The experiment made upon a guinea and a feather conforms the justness of this reasoning. In vacuo all bodies fall with equal velocity. The measure of the action of gravity is then the same in all bodies, and it is only the resistance of the air, which is the cause of the difference of their fall in plans, or through the atmosphere.

The measure of the action of gravity is the same at all times. There appears no variation in this respect.

Is the measure of the action of gravity the same in all places? Regarding the centre of the earth as the point to which heavy bodies tend, it was suspected that at different distances from this centre, the intensity of gravity would not be the same. But that it would act with less force, as bodies were farther removed from it. Accordingly experiments were made at the greatest heights, and greatest depths which could be found, but no sensible difference could be noticed. It was then thought that gravity was uniform at all distances. But such an error could not escape the penetrating eye of Newton. He has on the contrary shewn, that gravity acts so much the less upon bodies as they are more remote from the centre of the earth, and has proved according to what law that diminution is regulated viz. that gravity decreases as the squares of the distances increase. As gravity exerts a power equal in all directions it must necessarily decrease according to that ratio.—

Sir Isaac Newton shews, that if the moon were abandoned to the force of gravity alone, it would fall to the earth, and pass over 16 feet and one inch in the first minute of its fall. But this is the space, which a body near the surface of the earth runs over in consequence of gravity, in the first second of its fall; and if it fell freely during one minute, it would run over (in consequence of the manner in which its fall would be accelerated, as will be hereafter shewn) 3600 times that space. A body which should fall from the moon towards the earth, would, therefore, fall 3600 more slowly than one near the earth. But the distance is nearly 60 times as far from the centre of the earth, as that of bodies upon its surface. And 3600 is the square of 60— of course, gravity decreases as the squares of the distances increase. But how is this law collected? 1st. from geometrical reasoning upon straight lined emanations of any force, and 2nd. from observations upon the revolution of the moon.

We have not elevation sufficiently high to establish by experiment this theory of the direct fall of bodies; but Mess. Bouguer and Condamine have supplied the want, by the following ingenious experiment. They caused a pendulum to vibrate during the revolution of a fixed star (we may here observe that every vibration is the effect of gravity) first at the foot of one of the Cordilleries, then at the top, and measured the difference of the perpendicular altitude of these two stations. The number of vibrations was less during the same time, at the top, than at the base, of the mountain, and the difference accorded with the theory of Newton. A body which weighs 11 lbs. carried to the top of a mountain three miles high, would weigh 10 lbs 15 oz only. The intensity of gravity ought also to be different, in different climates of the earth. 1st. On account of the greater velocity of bodies near the equator which communicates a centrifugal force directly opposite to gravity under the equator, and obliquely to it every where else, and so much the more obliquely as we approach the poles. This may be illustrated by a common globe— Bodies then, fall more slowly near the Equator, than towards the poles, and this, in effect has been proved by experiments made in Cayenne in 1672 by Richer. He observed that a pendulum which vibrated at Paris, measured a longer time, or vibrated more slowly at Cayenne: a proof that the gravity was less. This experiment has been repeated by many good observers, but particularly by the academicians who went to Paris, and those who went to a very high north latitude, to ascertain the figure of the earth. And it has always been proved that bodies fall more slowly near the equator than near the poles, and that this retardation diminishes as the latitude augments. It is, indeed, this experiment which has proved demonstratively the revolution of the earth upon its axis, and that it is not truly spherical.

Does the measure of the action of gravity vary in the same body? To this we may answer, that it will vary as the body is hot or cold, as the proportion of its mass to its volume varies, and also as its figure varies. But these are only accidental variations, which would have no effect in an unresisting medium. There is, however, a variation which depends solely upon gravity; for a body in falling will have its velocity continually increased. Every one knows, that the higher the place from which a body falls, the greater is its shock. And the intensity of this shock, or blow, can result only from an increase of velocity.

The intensity of gravity is then always increasing in the same body while it falls. But according to what law does its velocity increase? Experiment shews that the increase of velocity is proportioned to the altitude of the fall, and not to its duration. If we let fall different bodies of the same figure from altitudes which are in the inversed ratio of their masses, they will all produce the same effect. Then, they have also an equal quantity of motion, which would not be the case, if the velocities acquired at the end of each fall, were not in proportion to the altitude of those falls. A large mass, therefore, coming from a less height, will produce the same effect as a small mass coming from a greater height. We may, of course, choose between these two means, either to augment the mass, or to augment the velocity. But it is often advantageous to substitute weight for elevation as in Forges or driving of Piles. The attraction of gravitation differs from that of cohesion or chemical attraction in this, that the latter may be destroyed, whereas the former is indestructible. It is a law of this attraction, that it is mutual between bodies. Hence the earth must move towards every body which falls to it, however small that body may be: yet the earth will move over a space towards the body, so much the smaller as it has more matter than it; so that the proximity of bodies to the earth and the great disproportion which their masses bear to that of the earth, render the motion of the latter totally imperceptible.

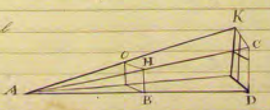
Doctor Maskelyne from an observation on a fixed star, found that a pendulum deviated from the perpendicular, when held near a mountain in Scotland, being drawn from the true line in which it would otherwise have rested, by the power of attraction.

Another law of this attraction is, that it is always in proportion to the quantity of matter. The experiment to prove this law was, to shew that a guinea and a feather placed at the top of a receiver, upon exhausting it of air, would fall with equal velocities. This experiment is conclusive; for say the guinea has 1000 times as much matter as the feather then it has 1000 times as much inertia to retain it where it is, &c consequently 1000 times as much force must urge it to descend or it would not fall in the same time as the feather.

Owing to the form of the earth, gravitation is different in different latitudes. A body loses a 230th part of its weight, when carried from the poles to the equator.

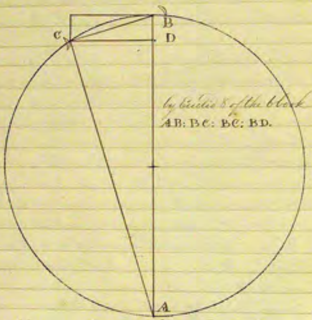
A third law of this attraction is, that its power decreases as the squares of the distances from the centre of attraction increase.

Let AD be equal to twice AB. The area KD is four times greater than



BC or those areas are as the squares of the distances from A. This is easily shewn thus; AHB, ACD being equiangular triangles (Eucl. P.29 B.1) we have (Eucl. P.4 B.6) AB: AC :: BH: DC. But BH, DC, are the homologous sides of the similar plane figures BC and KD; and (Eucl. P.20 B.6) those figures are as the squares, or in the duplicate ratio of those sides — This diminution of intensibility, in proportion of the squares of the distances from the centre of emaneation, seems to take place not only with the force of gravity, but also with all sorts of emanations from a centre, such as light, sound &c.

Calculation for determining the distance that the moon would fall towards the earth in one minute of time, if acted upon by gravity alone.



AB is 480000 miles equal the diamr. of the moon's orbit with respect to the Earth and supposing her periodical time 27 days 7 hours. Required her motion in one minute of time in her orbit, and the versed sine of that arch. Viz the space she would fall thro' by the force of Gravity alone!

2 × 240000 × 3 1/7 = 1511429 the orbit in miles. Then 1511429 divided by the minutes in 27d. 7h. viz by 39300 gives 38. 46 miles —

then 38.46 miles squared gives 1479.1716 and this multipl.
by 5280 feet in a mile gives 7810026.048 feet which divided
480000 mile gives 16 feet & 4/15.
NB The result is too great by reason of the ratio 1 : 3 1/7 having
been used instead of 1 : 3.1416.
The moon's period from change to change is $29^{ds} : 12^{hs}$ suppose
the sun's app.t motion one degree per day
then as $360° + 29½° : 29^{ds} : 12^{hs} :: 29½°$ to 53 hours $= 2^{ds} : 5^{hs}$
then from 29^{ds} 12 hours sub $2^{ds} 5^{hs}$ there remains 27^{ds} 7 hours for
the moon's periodical time.

Lecture V.

Magnetism.

The name magnet is said to have been taken from the name of a shepherd by whom it is supposed to have been discovered on mount Ida. Some suppose it to have been first found near Heraclea a city of Magnesia, and hence it has been called lapis Heraclius. Whatever the magnet be called, it is found to be a mineral substance (so hard as almost to resist the file) of a dark grey, and sometimes nearly black, colour. It is an iron ore which attracts iron and ferruginous bodies, and them only, if we except two substances (viz Nickel and Platina) which it has been found to attract in a small degree.

It is very probable that this substance received the name of magnet, on account of its peculiar and astonishing properties. So that we should search no higher for its etymology, than the latin word magnus, great.

There are two kinds of magnets, natural and artificial. The natural magnet is the load stone dug out of the earth. The artificial one, is an iron bar, to which magnetism has been communicated. And here it may be observed that the artificial is by far more powerful than the natural magnet.

The common properties of a magnet are six in number, viz. Attraction and Repulsion, Direction, Inclination, Declination, and Communication. And there is no instance of a magnet possessing one without all these properties. There are many laws by which the magnetic properties are governed.

1st. The tenoncy of the magnet to such bodies as it is said to attract, is mutual and equal between it and those substances. This may be seen by a variety of experiments: thus, two sewing needles (one of which shall be touched with a magnet) stuck through small pieces of cork, and put near each other in water, will be observed mutually to approach until they come in contact &c.

2nd. If a magnet be suffered to traverse freely, it will arrange itself so that one will constantly point North, and the other South. This is called magnetic polarity. The end that points north, is called the north pole, and the other one that points south, the south pole, and the middle is called the equator. This is the most distinguished and the most useful property of the magnet. By the aid of the mariner's compass (which is an artificial steel magnet so placed in a box, as to remain horizontal in any position of the ship) America has been discovered, and is enabled to exchange commodities with the most distant nations.

It is to be observed that the poles of the magnet are endued with the strongest attraction; for a key, or any bit of iron suspended at one of the poles will drop when moved towards the equator. To find the poles of a natural or artificial magnet, let it be placed upon a plane and sprinkled with steel filings. These filings will so arrange themselves as to discover the poles. Still we may not know the North from the South pole. This may be found by placing the magnet on a thin board floating on water. It frequently happens that the same magnet has several poles, which principally arises from its irregular shape. The phenomenon of the magnetic polarity is accounted for from the hypotheses that the earth itself is an immense magnet, with a south polarity at its north pole, and a north polarity at its south pole.

3rd. Similar poles repel, and dissimilar attract. To the north end of a magnet which traverses freely, bring the north end of another magnet, and the former will be repel'd; but if the north end be applied to the south end the latter will be attracted. If the north or south end of a magnet be brought very near the similar end of a needle it will be attracted; which is an apparent exception to the general law. It is however only apparent; for in truth when the larger magnet is in contact with, or very near, the smaller, it communicates to it a contrary polarity. This is evident by experiment.

4th. The interposition of other bodies does not interrupt the magnetic attraction. A needle in a plate will be effected by applying the magnet under it; and even if the plate should rest on a table, the needle therein will be strongly attracted by a magnet under the table.

5th. Each pole attracts and repels at equal distances in all directions.

6th. Attraction of magnetism decreases as the squares of the distances increase, and vice versa, according to some philosophers. Dr. M. says that different magnets have different attractive forces; and that the attractive force of the same magnet is different at different times. Balance a bar of iron in a pair of scales, place a magnet at the distance of one inch from the bar, and as much weight in the opposite scale as will balance the magnetic force: then, according to the law, if the magnet be removed to the distance of two inches, a fourth part of that weight ought to preserve the equilibrium. The experiment, according to Dr. M. sometimes will, and sometimes will not answer. The conclusion that this law is true, has been deduced from observing the number of vibrations that were made in the same time by a needle placed at distances which were as 1 & 2.

7th. The magnet will communicate its properties to iron without any diminution of its own. Upon this property depends our power of making artificial magnets.

8th. Iron acquires and loses magnetism sooner than steel, soft iron sooner than hard, and their tendency to lose is directly as their faculty to acquire. It is remarkable also, that small magnets have greater strength in proportion to their size than large ones. A magnet in Mr. Boyle's ring could support 256 times its own weight. It weighs 3 grs. and could raise 74.

9th. It attracts iron in a duplicate ratio of its communicative power.

10th. A magnet will communicate its properties to iron without touching it. In communicating magnetism to iron, the N. end of the magnet will give a S. polarity, and vice versa. Let a magnet be placed upon a table so as to traverse freely. Place the end of a bar of iron near either end say N. Bring near the opposite end of the iron bar, another magnet's N. end, in which case the end of the iron bar next to the communicating magnet, will acquire a south polarity, and the other end of course, a north. Now the last end was opposed to the N. end of the traversing magnet, which will be repelled, and the repulsion could not take place, if the iron bar were not rendered magnetic. Here is another and a more satisfactory experiment which proves this law. Place a magnet at a small distance from a bar of soft iron (suspended for conveniency) and it will communicate attraction sufficient to support a small needle or bit of wire, at the end of the bar.

Some authors suppose that there is a current of magnetic fluid circulating constantly from one pole to the other. By the following experiment, however, this supposition is manifestly proved to be incorrect. If a magnet be put into water, so as barely to be covered, and steel filings dropt on the surface, these filings will be seen to separate at the equator, and approach each pole, where every particle becomes a distinct magnet, and presents a contrary pole to that by which it is attracted, to the magnet under water. The strength of magnetic attraction being accumulated at the poles or ends, those particles can never circulate around the large magnet, but will ever remain fixed to it at those poles on account of the superior attraction.

The earliest knowledge which man had of the use of the magnet (or of its directive property for its attractive power was known to Homer, and others of the ancients) cannot be traced further back than the 13th century. It was not till after this time that it was employed in commerce, to the advancement of which it has greatly contributed.

Some attribute the invention of the compass to John de Gioja who in Cavallo's opinion has the best title to it. Dr. Gilbert says that Paul Venetus brought it from China into Italy in the year 1260. Ludi Vertomanus affirms that in the east indies about the year 1500, he saw a magnet contrived like those now used, employed by a pilot. Mr. Barlow relates that in the year 1597 he saw two east indians who mentioned to him a contrivance, different from the compass for using the magnet in navigation. These observations are in date posterior to the use of the magnet in Europe, and, therefore, conclude nothing as to the invention. The Spanish Jesuit Peneda, and Kircher affirm that Solomon knew the use of the compass, and that his subjects actually used it in navigation. However, the original invention is attributed, with most probability, to the Chinese. The needle does not always point directly N. and S. but sometimes declines to the E. or W. This is called the variation or declination of the needle — It is the angle made by the magnetic and the true meridian. We always reckon the variation at the N. point. The variation is different at different times and places, so that there is a variation of the variation. In 1694 in Williamsburg when the college lands were surveyed the variation of the needle was 5° west. At present (1807) it is

The needle therefore in about 112 years has travelled nearly

In Europe the variation is to the west, in America to the E. the variation at London and Paris is different. There are four places where the needle is stationary, & its variation entirely ceases. 1st At a particular point in the atlantic ocean. 2nd Along the American coast. 3rd In the Indian ocean, near the Philippine isles, and 4th In the   sea. For this phenomenon the diligence of philosophy has never been able to account. Columbus first discovered the variation in 1492. and Sebastian Cabot made some particular observations on it in the year 1566.

To find the variation of the needle many methods are mentioned. I will select one of the most simple. On the 20th of March and 21st of Sept, the sun rises precisely in the east. Place the E. and W. points of a compass directly in a line with the rising sun; the N. and S. points will then be in the same meridian; and the variation of the needle will then be seen in the graduated circle in which it plays. But the needle has also a diurnal variation. From 8 till 3 o'clock the needle travels a little way W. and from 3 till 8 o'clock it travels E. It is remarkable that the diurnal variation is extremely effected by the Aurora Borealis. It is observed to be the greatest in the months of june and july, and least in the months of January and February. In the former month, it is about 15°, in the latter 6° or 7°.

A needle if suffered to play freely will dip. This is called the inclination of the needle. The dip is greater or less as it approaches the poles or the equator. On the N. side of the equator the N. end dips, and on the S. side the S. At the equator the needle is horizontal. At Williamsburg it dips 67° and at London 72°. At the poles, the needle would stand perpendicular. Three sewing needles rendered magnetic, and suspended by threads, one over each pole, and one over the equator of a large magnet, will exhibit a clear proof of this phenomenon. Those over the poles will be perpendicular, while that over the equator will remain perfectly horizontal. The dipping needle is proposed to be used for determining the latitude of places. But what will not fail to obstruct this use, is, that it is not uniform in receding from, or approaching towards, the equator of the earth, nor even in the same place at different times. In London about the year 1576 the N. end of the dipping needle stood 11° 56' below the horizon and in the year 1775. 72. 3 m

It has been observed that the artificial magnets are stronger & more useful than the natural ones. Hence it is necessary that we should be acquainted with the methods of making them, which are several. 1st With the aid of the natural magnet. It appears that the best manner of making artificial magnets, consists in applying one or more powerful magnets to pieces of the hardest steel, because those pieces will thereby acquire a considerable magnetic power, and retain it for a very long time. In this operation care must be taken to apply the N. pole of the magnet to the extremity of the steel which is required to be made a S. pole, and to apply the S. pole of the magnet to the opposite extremity of the piece of steel. 2nd Without the aid of a natural magnet, or the method of magnetizing steel without any magnet. Strictly speaking, this method does not exist; for there is no magnetism communicated, but by the action of a magnet, and in the above mentioned method the magnetic power is originally communicated by the earth, which is a real magnet, of which (as has been already said) a S magnetism is attributed to its N. pole, and vice versa. By this it is meant, that the earth has a magnetic polarity, and that its poles are directly contrary to those of the needle; and as we call one end of the needle a north magnetic pole, we must of necessity attribute a contrary polarity, viz. a S magnetic polarity to the astronomical pole, or northern parts of the earth. It follows that the astronomical S pole, or southern part of the earth, must be possessed of a N magnetic polarity. That the earth is really a vast magnet, is evidently and easily shewn by the following experiment. A straight bar of soft iron being kept in a vertical position, viz. with one end towards the ground and the other upwards, you will find, that the bar in that situation is magnetic, the lower extremity (in the northern part of the world) being a N pole capable of attracting the S pole of a magnetic needle, and of repelling its N. pole, and the upper extremity becoming a S. pole. If you invert the bar, its polarity will be instantly reversed. The explanation of this curious phenomenon is easily deduced from the preceding laws; for since the northern parts of the earth are possessed of a S polarity, the lowest part of the iron bar, by being nearest it, must acquire the contrary, viz. a N polarity, the other extremity of the bar being of course a S pole. It follows likewise (and is confirmed by actual experiment) 1st That in the southern parts of the earth the lowest part of the iron bar acquires a S polarity. 2nd That on the equator the iron bar must be kept horizontal, to acquire magnetism from the earth; and 3rd That the most advantageous situation is not the perpendicular, but a little inclined to the horizon. In short, in every part of the world, the bar must be placed in the magnetical line, to wit, in the direction of the dipping needle. Thus bars of iron which have stood long in a favorable position, viz. either N.° or S. or perpendicular, acquire a permanent magnetism. If an oblong piece of pretty hard iron be made red hot, and then be left to cool in the magnetical line, it will thereby acquire a degree of permanent magnetism. If an iron bar, while standing in the magnetical line, be struck forcibly & repeatedly with an hammer on one of its ends, it frequently acquires permanent magnetism from it. In short, whatever seems to render the iron or steel more susceptible of magnetism, be it heat, or vibration, or friction, if administered while the iron or steel is in the proper direction, is likely to fix the magnetism in it. Hence an electric shock, or a stroke of lightning, or drilling, or hammering, frequently magnetizes the tools, or other pieces of iron concerned. A magnet will continue to weaken, and at last will lose its properties altogether if suffered to remain in an improper position where it may rust &c. It loses them also, by not being used for a length of time, by heat, concussion, cold &c. These ought therefore to be avoided. The first may be remedied by keeping the magnet with its N.° pole towards the N.° and by keeping two small pieces of iron appended to it. If there be many magnets, their properties are preserved in any situation, by putting their contrary ends together, in which case they are said to be neutralized; for they have not in that position sufficient strength to raise a small key or bit of iron.

It is to be observed, that neither the magnetic equator, nor the magnetic poles of the earth, coincide with its real equator, and astronomical poles; for if they did, or even if the magnetic poles stood constantly at a fixed distance from them, the inclination of the needle, as well as its declination, would remain unalterable: hence from observing the direction of the magnetic needle in any place, the latitude, and longitude of that place might be ascertained. But the case is far different; for the magnetic poles of the earth do not coincide with its real poles, neither are they equidistant from them — they are, in fact, continually shifting their places. Hence the magnetic needle changes continually, and irregularly, not only its horizontal direction, but likewise its inclination, accordingly as it is removed from one place to another, as also, while it remains in the very same place.

The vast masses of iron found in different states in the bowels of the earth, and which are frequently magnetic, prove beyond a doubt, that the earth is a real, but irregular magnet, and that its magnetism arises from the magnetism of all the ferruginous bodies that are contained in it; so that the magnetic poles of the earth must be considered as the centres or collected powers of all those magnetic ferruginous substances. It follows likewise, that according as these masses of iron are affected by heat or cold, by decomposition, by mixture with other substances, by volcanoes, by earth quakes, or mechanical derangements &c. so the magnetic poles of the earth must change their situation: and this is the cause of the variation of the magnetic needle. The properties of a magnet are not affected either by the presence or the absence of air. — The magnet is found in great quantities, in the counties of Albemarle, Amherst, and Orange, in the state of Virginia.

The great desideratum in magnetics is, to know the cause of the magnetic attraction, repulsion &c. Human ingenuity has contrived abundance of hypotheses in explanation of these phenomena. Halley supposed, that there was a large magnet inclosed in the earth, which not being fixed to its external surface, was moveable within it, and produced all the magnetic phenomena. Some philosophers (among whom was Rittenhouse) imagined that the pores of all ferruginous bodies were full of valves which permitted the fluid to pass through them one way, but by closing immediately, prevented it from returning. Descartes supposed from the experiment of placing a magnet on a sheet of paper, and sprinkling iron filings over it, which would arrange themselves almost circularly round it, that there was a current of magnetic fluid issuing from one pole and entering the other. But if this were the case, the iron filings would be all driven upon one of the poles. The theory of Æpinus is founded upon the strong analogy between magnetism and electricity. He was led to imagine that there existed a fluid productive of all the magnetic phenomena. That like the electric fluid, it is so subtile as to penetrate the pores of all bodies, is elastic, and highly repulsive of itself. He also supposes that there is a mutual attraction between this fluid and iron, or ferruginous substances, but that no other bodies have an action upon it. Thus when a ferruginous body is not magnetic, this fluid is equally diffused throughout its parts, in which state they shew no attraction or repulsion: but when this fluid is driven to one end, the body becomes magnetic, one extremity being overcharged, and the other undercharged.

There is no attraction between the overcharged extremities of two magnetic bodies, on account of the attraction between the fluid and the matter of the body. But the same difficulty occurs as in electricity to account for the repulsion between the undercharged extremities. A piece of iron is rendered magnetic by the action of a magnet, because when the overcharged pole is presented to it, the overplus of magnetic fluid in that pole repels the fluid from the nearest extremity of the iron, which therefore becomes undercharged, to a more remote part of the iron. If the under-charged pole of the magnet be applied, then its matter attracts the magnetic fluid of the iron to that extremity of the iron which lies nearest to itself.

Lecture VI.

Of Motion.

Motion is considered as absolute, relative, or apparent. All motion is in itself absolute, or the change of absolute space. But when the motion of bodies is compared with that of each other, then it is relative, or apparent only. It is relative as it is compared with another, and apparent only in as much as not its true or absolute, but the sum or difference of the motion is perceivable by us.

Almost all the phenomena of nature are owing to motion. the appearance and disappearance of the heavenly bodies, the increase of animals and vegetables, the composition of complex substances, all arise from motion, the laws of which may therefore be looked upon as the foundation of natural philosophy.

Motion is either simple or compound. It is simple, when there is one uniform impulse, and compound when several powers act together in many different directions. In treating of motion we are to consider seven things. 1st The power, or force that causes a body to move. 2nd The mass or quantity of matter. 3rd Its direction. 4th The space it moves over. 5th the time it takes to move. 6th Its velocity, and 7th Its momentum. the moving force or power which causes motion does not communicate any thing to the body (unless giving it motion can be said to be a communication) It only moves it through a certain space in a certain time, after which, a body being left to itself will continue to move at the same rate in an unresisting medium; that is, it will continue to run over like spaces in like portions of time, and that merely in consequence of its vis inertiae, of which vis inertiae we do not pretend to know any thing more, than that it is a general property of matter.

The quantity of matter in bodies is estimated by their weight, and is often termed the mass. Bodies resist equally whether at rest or in motion, and the force of resistance is always in proportion to the quantity of matter; the greater the mass, the less motion they receive from force. the velocity is always inversely as the quantity of matter; for if two bodies one of which weighs 8lbs and the other 4lbs be moved with a force equal to 2, the latter will pass over double the space of the former in the same time.

The direction of motion is the position of the line along which it is performed— When the motion is curvilineal, the direction at any instant of time is the position of a tangent to that point of the curve where the moving point is situated.

The space thro' which a body moves is the line it runs over— The time a body employs in moving over space, is greater or less in proportion to the length of the space, and the velocity with which it moves—

The velocity of bodies, is their power of passing over space in a given time; so that it always has relation to space and time— If two bodies run over equal spaces in equal times, their velocities are equal. If over unequal spaces in equal times, or equal spaces in unequal times, then their velocities are unequal. When the velocity of a body is continually increasing, it is said to be accelerated, and the farther it moves, the greater is its velocity.

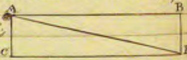
The momentum of bodies, is the force arising from the sum of their moving particles, and is found by multiplying the velocity into the quantity of matter— Thus a body weighing 3lbs, moving with a velocity equal to 6 degrees, will have a momentum equal to 18. By increasing the velocity of a small body, it may be made to possess as much momentum as a large one. A common ball moving 1142 in a second, and weighing 26lbs, will have a momentum equal to that of a battering ram weighing 41192lbs (and moving at the rate of 1 foot per second.

In computations relating to force, motions, times &c. the proportion of the quantities to each other is considered, and not the quantities themselves. In such computations, therefore, when any two quantities are compared together, we may substitute any other two quantities which have the same proportion to each other, as numbers, lines &c. It follows from what has been said on the quantity of motion, that if the velocity of a body increases, while its mass remains the same, its force will be augmented, as the velocity is increased. Or if several bodies of the same mass move with different degrees of velocity, their force will be as the velocities with which they move. If several bodies are possessed of the same velocity, their forces will be as their masses, i.e. they will have as much more force as they have more mass, being possessed of a greater number of parts animated with the same force. Simple motion (it has been said) is that which is produced by one force acting instantaneously on the body, and causing it to describe a right line with an uniform velocity, i.e. describing equal spaces in equal times. It will be shown, that there is no single motion, but what may be considered as resulting from various forces tending jointly to carry the moving body to the same point, and reciprocally, that there is no rectilineal uniform motion so compounded, but what it may be considered as produced by the simple action of one force.

Laws of Motion.

1st. Every body will continue in its present state, whether of rest or motion, unless it be compelled to change that by forces impressed. 2nd. Every motion, or change of motion in any body must be proportional to, and in the direction of, the force impressed. This is the immediate consequence of the axiom that, "the effect is always proportional to the cause." For instance, if a certain force produces a certain motion, a double force will produce double the motion, a tripple force tripple the motion &c. 3rd. law. Action and reaction are equal and contrary to each other. Action and reaction are correlatives. One cannot exist without the other. Resistance or reaction, is a necessary condition to action: action, indeed, becomes reaction by a mere change of circumstances. There are various phenomena which establish the universality of this law. When a cannon is discharged, the rarified powder acts equally on the ball and the breach of the gun. The reaction of water on the oar occasions a boat to advance & communicate to it as much motion as it received. The fish performs with its fins & tail, and aquatic birds with their feet, what the waterman effects with his oar, the mutual action and reaction impelling them along. Birds support themselves, and pass thro' long tracks of air, notwithstanding the weight of their bodies much exceeds that of an equal volume of the fluid in which they move. If their wings strike, and push the air towards the earth, its reaction supports their bodies, and causes them to ascend.

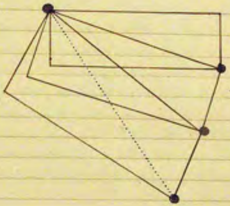
General law of compound motion. — Any body solicited to move by the simultaneous action of different forces acting in different directions, will take a mean direction between what each power tends to communicate to it, and will move with a velocity proportioned to the force acting efficaciously; for as the body cannot move in more directions than one at the same time, it must move in the direction resulting from the combination of the acting powers. Thus if two forces act at the same time on any body, and in the same direction, the body will move with a velocity equal to the sum of the velocity of the two forces acting upon it. If the forces are unequal, and acting in opposite directions, the body will move in a direction of the strongest, with a velocity equal to the difference of the velocity arising from the two given forces acting separately; so that the motion will take a new direction, more or less different from the former, according to the number and direction of the im=pressed forces. If the proportion or direction of two forces acting upon a body at the same time, be represented by the sides of a parallelogram, the diagonal will show the proportion and direction of their united forces. Let the body at A be impelled by a force acting upon it in the direction AC which would cause it to move from A to C in the same time that another force, which acts in the direction AB, would cause it to move from A to B. Complete the parallelogram, and draw the diagonal AD— this line will represent the direction



and distance the body will move in the same time, when acted upon by both conjointly.

The dotted diagonal AF represents the direction and proposition of a body impressed by three forces at the same time in the directions AB, AC, & AE.

In general, any body moving with a force represented by the diagonal of a parallelogram, may be considered as having its motion compounded of the forces represented by the sides; for the motion will be the same as if it had been impelled by two forces proportionable to those sides — And as upon the diagonal an infinite number of parallelograms may be constructed, any single force may be considered as compounded of more forces, and thus resolved into numberless pairs of forces, acting in the direction of the sides of those parallelograms, and proportional thereto. The velocity along the diagonal is to the velocity along either of the sides, as the radius to the sine. The practice of reducing compound forces to simple, and that of finding two or more forces equivalent to one, is called the composition or resolution of forces.



Motion is simple and compound, absolute and relative, rectilineal and curvilineal. All bodies have a tendency to move in straight lines. Thus a stone in a sling, flies off in a tangent to the circle in which it moved, and its stretching the string seems to be a proof that it has a tendency to move in a straight line: but here this endeavour is only in obedience to the impulse last communicated to it, all motion being naturally rectilineal where only one power acts. Reaction and action are equal and contrary. This law is founded on reason and experience. A bullet from a gun strikes a board with a force equal to 10. The bullet will still move, but only with half its former force, viz. 10 = V is as $\frac{S}{T}$; S is as V T; T is as $\frac{S}{V}$; M is as V Q; Q is as $\frac{M}{V}$ — The above is an expression of the manner in which the time, space, velocity, quantity of matter, and momentum are found.

Of the centre of gravity, and of percutient bodies.

The centre of magnitude of a body is that point, on each side of which are equal quantities of matter, and in bodies that are uniform and homogeneous, it is the same with the centre of motion; which is that part of any body, around which all the other parts move, but is itself at rest. And this again is the same in uniform bodies of the same matter throughout, as the centre of gravity; which is that point about which all the parts of a body do in any situation, exactly balance each other. An imaginary line drawn from this point to the centre of the earth, is called the line of direction. It is of great importance to understand well, the nature and properties of the centre of gravity, as it is the sole principle of all mechanical motions.

Its particular properties are as follows— 1st If a body be suspended by this point as the centre of motion, it will remain at rest in any position indifferently— 2nd If a body be suspended by any other point, it can rest only in two positions. viz. when the centre of gravity is directly above, or below, the point of suspension. 3rd When the centre of gravity is supported, the whole body is kept from falling. 4th When the centre of gravity is at liberty to descend, the whole body must also descend or fall, by tumbling, sliding, or rolling down. 5th The centre of gravity in regular, uniform, & homogeneal bodies, as squares, circles, spheres &c is the middle point in a line connecting any two opposite points or angles. 6th In a triangle it is the intersection of two lines, drawn from any two of its angles, and bisecting the opposite sides. The centre of gravity of a polygon is found by dividing it into triangles, of which the centres may be found as above.

If the line of direction fall within the base, the body is supported; therefore, the nearer it is to the middle of the base, the more firmly the body stands. The reason of this is obvious; for as long as the line of direction is within the base, the centre of gravity is supported, since that line is conceived to pass directly from the centre of gravity to the centre of the earth, and as long as the centre of gravity is supported, so long is the body kept from falling, as has been before said. When a body slides down an inclined plane, the centre of gravity is within the base, but the inclination of the plane being sufficient to overcome the friction of the body upon it, the weight of the body carries it down — Should the line of direction fall without the base, the body tumbles. Round bodies rest upon a very small point, and the line of direction is continually falling without the base at the slightest impulse — Hence all globular bodies are easily moved. —

The centre of gravity of two unequal bodies, is as much nearer to the larger, than to the smaller, as the quantity of matter of the former exceeds that of the latter — In order to find it we say, as the sum of the quantities of matter in each body, is to the quantity of matter in the smaller, so is the distance between them to a fourth proportional, which will be the distance of the centre of gravity from the larger body. The centre of gravity between three bodies is found by first getting the centre between two of them; then, — as the quantity of matter contained in the two first, is to the quantity contained in the last, so is the distance of the third from the centre of the two first, to a fourth proportional. The common centre of gravity of any number of bodies being supported, none of these bodies can fall, which is the reason of many very surprising phenomena in nature, as the common experiment of suspending a bucket of water at the end of a stick off the table without falling).

Communicated motion

1st. In bodies non elastic

Those bodies whose parts yield to the impression of another body, and when compelled to change their shape do not return to it, are called non elastic. When such bodies strike, they do not rebound, but accompany one another after impact as if they were joined. This proceeds from their retaining the impression made upon their surface, after the impressing force ceases to act. For all rebounding is occasioned by a certain spring in the surface of bodies, whereby those parts which receive the impression made by the stroke, immediately spring back & throw off the impinging body — Now this property being wanting in bodies void of elasticity, there follows no separation after impact.

When a non elastic body impinges on another which is at rest, or moving the same way with less velocity, the momentum of both bodies taken together, remains the same after impact as before; for by the third law of motion, the reaction of one being equal to the action of the other, what one gains the other must lose.

When two bodies impinge on each other by moving contrary ways the quantity of motion they retain after impact, is equal to the difference of the motion they had before; for by the third law of motion, that which has the least motion, will destroy an equal quantity in the other; after which they will move together with the remainder, that is, the difference.

2nd In elastic bodies

Bodies perfectly elastic, are such as rebound after impact with a force equal to that with which they impinge upon one another; those parts of their surfaces that receive the impression, immediately springing back, and throwing off the impinging body with a force equal to that of impact.

If one elastic body impinge on another at rest, which is equally elastic, the first will communicate to the second all its motion — If two equally elastic bodies impinge on one another, they will (if moving with equal velocities) exchange their motion, and rebound to their former places. The action of elastic bodies on each other, is twice as great as if those bodies were void of elasticity. Thus, if two non elastic balls descending, the one through an arch of 30, the other of 15, impinge upon one another, the latter will destroy 15 of the motion of the former, and they will then move in the same direction with half the velocity that the former would move with, subtracting 15 from its motion, that is, they will move with a velocity of 7½ — Two elastic balls descending through similar arches with the above, would after impact move with a double velocity, or 15 in the same direction.

It has been seen that if one body fall on another of the same size, it will communicate to it all its motion, i.e. it will cause it to move through a space equal to that through which the striking body moved before impact. But it is also found by experiment that a small body falling on a large one, gives it more motion than it has itself. Thus one body impinging on another at rest of twice its quantity of matter, will cause it to move thro' more than half the space, that a body of equal quantity of matter with the one at rest would. The reason of this has not been given by philosophers. It is supposed to arise from a greater momentum of the small body in proportion to its size, its velocity being greater, as there is less surface to be resisted by the air through which it moves.

Lecture VII.

Central Forces.

Or the doctrine of circular motion.

All motion is naturally rectilineal; for a bullet projected from the hand or shot from a gun, would continue to move in the same direction it received at first, if no other power diverted its course. Therefore any body which moves in a curve of any kind, does so in consequence of two powers, one putting it in motion, and the other drawing it off from the rectilineal course it otherwise would have moved in. So that all bodies which move in curve lines, have a continual tendency to go in a rectilineal course, but being acted on by a second force which gives them another direction, they are perpetually forming a quantity of very obtuse angles, or rather, a regularly curved line.

If two forces act in different directions on a body in such a manner as to move it uniformly, the diagonal described will be a straight line; but if one of the forces act in such a manner as to make the body move faster and faster, then the line described will be a curve. The tendency which a body has to fly off the orbit in which it moves, is called the centrifugal force, that which it has to approach the centre, is called the centripetal, and both together have been called the central forces. From the uniform projectile motion of bodies in straight lines, and the universal power of gravity, or attraction, arises the curvilineal motion of all the heavenly bodies. If the central forces be in equilibrio, the body will always move in a circle. It is therefore by a due adjustment of the centripetal and centrifugal forces, that harmony is preserved in our planetary system. To make the projectile force a just balance to the gravitating power, so as to keep a planet moving in a circle, it must give such a velocity, as the planet would acquire by gravity, in falling thro' half the radius of that circle. To know the amount of a centrifugal force, three things are necessary. 1st. The mass of the moving body. 2nd. The distance at which it revolves. 3d. the velocity, and in calculating the last we must consider, 1st. The time, and 2nd. the greatness of the circle. The following propositions are demonstrated by experiments upon the whirling table, for a description of which see Ferguson. By periodical time is meant, the time in which bodies perform a particular revolution. Direct proportion is when more requires more and less requires less; as the first term is to the second, so is the third to the fourth: thus, 6 : 4 :: 3 : 2. Inverse proportion is when more requires less, and less more, thus. 4 : 6 :: 2 : 3.

1st Matter has a propensity to remain in its present state, — whether of motion or rest — Proved by a body placed on the whirling table board, which being turned, does not immediately communicate motion to the body; but after the body has acquired the motion, if the board be suddenly stopped by the hand, the body will still continue to move, until stopped by friction or the resistance of the air.

2nd Bodies moving in orbits have a tendency to fly out of those orbits — A body placed on the whirling table, and not confined, will fly off on turning the board. 3rd Bodies of equal quantities of matter, revolving in equal circles, with equal velocities, have their centrifugal forces equal. Thus two balls of equal weights, being placed at equal distances from their respective centres of motion, upon beams which have equal velocities, will raise equal weights in the towers at the same instant, upon turning the whirling board.

4th Bodies move faster in small orbits than in large ones — By shortening the cord with which a revolving body is confined to the middle of the whirling board, it will be found to move faster and faster as the radius diminishes. Those planets that are near the sun, move faster than those more remote, and not only go round sooner, because they describe smaller circles, but even move faster in every part of their respective circles.

5th The centrifugal forces of revolving bodies are in exact proportion to their quantities of matter multiplied into their distances from the centres of their respective circles. — Put a ball of 6 oz into one beam at 2 inches distance from the centre, and put a ball of 1 oz into the opposite beam, at 12 inches distance from the centre; then the ball which is six times as heavy as the other, being at the sixth part of the distance from its centre of motion, will revolve in a circle of only a sixth part of the circumference of the small one — Upon turning the machine, equal weights will be raised in the towers. Thus the ball of 6oz. being 2 inches from its centre of motion, when multiplied by its distance, gives a product of 12. And if the ball of 1oz. be multiplied into its distance, it will also give 12. And as they revolve in equal times, their velocities are as the distances from the centre, namely as 1 to 6.

6th A double projectile force balances a quadruple power of gravity. Place two equal weights, or balls, in the braces at equal distances from the centres, (so that the circles they describe will be the same) and cause one of the braces to move with a velocity double of the other: the weights in the towers being 4 to 1, will be raised at the same instant by turning the board.

7th If equal bodies revolve in equal circles, with unequal velocities, their centrifugal forces are as the squares of the velocities. The famous problem of Kepler, is confirmed by an experiment on the whirling table, to wit. If bodies of equal weights revolve in unequal circles, in such a manner that the squares of their periodical times, are as the cubes of their distances from the centres of the circles they describe, their centrifugal forces are inversely as the squares of the distances from their centres. Put two bodies of equal weights in the braces, one at the distance of 2 the other at 3¼, the one making two revolutions, while the other makes one, their periodical times will be as 1 and 2, the squares of which are 1 and 4: therefore the square of the period or revolution of one ball is contained 4 times in the square of the period of the other. But the distance of one is 2, the cube of which is 8, and the distance of the other 3¼, the cube of which is 32 nearly: and 32 contains 8 four times. Then the squares of the periods are to one another, as the cubes of the distances from the centres of the respective circles. If the weight in the one tower be 4oz. equal to the square of 2, the distance of one ball from the centre and the weight in the other tower be 10 oz. nearly equal to the square of 3¼, the distance of the other ball from its centre, it will be found, on turning the machine, that the balls will raise their respective weights at the same instant of time. Des Cartes entertained an idea that the heavenly bodies did not move in their orbits in consequence of the centrifugal and centripetal forces, but that the motion of the sun about its axis caused the planets to circulate in vortices which were promoted by this rotation. The absurdity of this doctrine is easily demonstrated; for if a planet be more dense or heavy than its bulk of the vortex, it will fly off therein farther and farther from the sun, if less dense, it will come down to the lowest part of the vortex at the sun, and, of course, could never move in a regular orbit. — Place in the braces of the whirling table, a tube about three parts full of water with a piece of cork floating on the top — Also another tube containing the same quantity of water, with some mercury at the bottom of it. On giving the machine a whirling motion, the centrifugal force, will cause, in the former tube, the heavier body, viz the water, to displace the cork, and occupy the upper part while the cork descends to the bottom. But in the other tube, the mercury being the heavier body, will displace the water and ascend to the top.

8th If one body move round another, both of them must move round their common centre of gravity. — If a body be placed on the whirling board, so that the centre of gravity of the body be directly over the centre of the board, and the board be put in ever so rapid a motion, the body will turn round with it, but will not move from its place; for as all the parts of the body are in equilibrium round its centre of gravity, and the centre of gravity is at rest in the centre of motion, the centrifugal force of all parts of the body will be equal at equal distances from its centre of motion, and therefore the body will remain in its place — But if the centre of gravity be placed ever so little out of the centre of motion, the body will fly off to that side on which the centre of gravity lies — If a small ball of one 20th part the weight of the body at the centre of the whirling board, be attached to it, by a wire, and the table put in motion, the large weight would be drawn from its place, and together with the small ball, would be thrown off the board. This shows that the sun and all the planets move round a common centre of gravity. —

The reason why the tides rise at the same absolute time on opposite sides of the earth, and consequently in opposite directions, is made plain by an experiment on the whirling table. As the moon goes round her orbit every month at the distance of 240,000 miles from the earth's centre, and of 234,000 miles from the centre of gravity of the earth and moon, so does the earth go round the same centre of gravity every month at the distance of 6000 from it i.e. from it to the centre of the earth. The earth is (in round numbers) 8000 miles in diameter its side next to the moon, is only 2000 miles from the common centre of gravity of the earth and moon, its centre 6000 miles distant therefrom, and its furthest side 10,000. The centrifugal forces of these parts are as 2000, 6000, & 10,000. That is, the centrifugal force of any side of the earth when turned from the moon, is five times as great as when turned towards the moon;

and as the moon's attraction at the earth's centre, keeps the earth from flying out of this monthly circle, it must be greater than the centrifugal force of the waters on the side next her, and consequently her greater degree of attraction on that side is sufficient to raise them; but as her attraction on the opposite side is less than the centrifugal force of the water, the excess of this force is just sufficient to raise the water as high on the opposite side. From the principles thus established, it is evident that the earth moves round the sun, and not the sun round the earth; for the centrifugal law will never allow a great body to move round a less in any orbit whatever and it is well known that the quantity of matter in the sun is 227,000 times as great as in the earth. All globular bodies whose parts can yield, and which do not turn on their axis, must be perfect spheres, because all parts of their surfaces are equally attracted towards their centres. But all such globes that do turn on their axis, will be oblate spheroids, i.e. their surfaces will be higher, or farther from the centre in the equatorial, than in the polar regions; for in the former, the centrifugal force is greatest. The equatorial diameter of the earth is 36 miles longer than its axis. The earth then being higher at the equator than at the poles, the sea would run towards the polar regions, and leave the equatorial parts dry, if the centrifugal force of the water which carried it to those parts, did not detain it, and prevent its returning again towards the poles of the earth.