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The Heads of Lectures, on Natural Philosophy

delivered in the University of the Wm & Mary

by the Right Revd James Madison

The Parts. — Parts

Lecture 1st Introduction

It is the object of natural Philosophy to investigate and explain those causes which give rise to the various phenomena every where observable in the material world, and to trace thro' the intricate chain of causes and effects, those immutable laws, which govern the universe, which give harmony to the different operations of nature, and which preserve uniformity and order throughout the stupendous system of materialism. These are denominated the laws of Nature. To direct our researches into them, certain rules of Philosophising have been laid down, the excellence of which has been confirmed by experience, by the successful practice of the immortal Newton, and other Philosophers, whose labors have adorned the latter ages of the world, with the brightest radiance of truth & science. Of these rules of philosophising, Dr Madison has delivered the four following. First, More causes of natural things are not

to be admitted, than are both true & sufficient to produce the effects. Secondly, For similar effects, similar causes are to be assigned. Thirdly. Those properties which are found in all bodies upon which experiments can be made, are to be considered as qualities of all bodies whatsoever. Fourthly. Propositions, collected from phenomena, are to be considered as true, or nearly so, till other phenomena occur to confirm or to confute them. Hence we may clearly perceive, that a young natural Philosopher ought to begin by observing the most familiar and common phenomena, finding out the laws by which they are regulated & thence proceeding to others more complicated, and that instead of forming Hypotheses, and vague conjectures, he should collect a history of facts, and observe the laws which, under certain circumstances always take place. * It was by raising Systems upon uncertain Hypotheses, which were always liable to be superse[illegible] by the greater ingenuity and more plau[illegible] Conjecture of a succeeding Philosoph[illegible] they

* See number of conjectures enumerated in Anacharsis travels thro' Greece Vol 2 Ch. 30 and 31

The science of Physics was so much re-
tarded in the earlier ages of Mankind.
And it may not be uninteresting to us,
who behold it in its advanced stage, to
trace the history of its infancy, and
Growth. The following account is taken from
Guthrie's Geography.

"Mankind must have made a very con-
"siderable progress in observing the Motions
"of the heavenly bodies, before they could so
"far disengage themselves from the pre-
"judices of Sense and popular Opinion,
"as to believe that the earth, upon which
"we live, was not fixed and immoveable.
"We find accordingly, that Thales the
"Milesian who, about 580 years before Christ,
"first taught astronomy in Europe, had
"gone so far in this Subject as to calculate
"Eclipses, or interpositions of the Moon be-
"tween the earth and sun, or of the earth
"between the Sun and Moon. Pythagoras
"a great Philosopher, flourished about
"50 years after Thales, and was no doubt
"equally acquainted with the Motion

"of the heavenly bodies. This led Pythagoras to
"conceive an idea, which there is no reason to
"believe had ever been thought of before, namely
"that the Earth itself was at motion, and the
"the sun was at rest. He found that it was
"impossible in any other way to give a
"consistent account of the heavenly Motions.
"The System, however was extremely opposite
"to all the prejudices of sense and opinion,
"that it never made great progress, nor
"was ever widely diffused in the ancient world.
"The Philosophers of antiquity, despairing of
"being able to overcome ignorance by reason
"set themselves to work to adapt the one to the
"other, and to form a reconciliation between
"them. This was the case with Ptolemy, an
"Egyptian Philosopher, who flourished 138
"A.C. He supposed, with the vulgar who
"measure every thing by themselves, that the
"Earth was fixed immoveably in the center
"of the universe and that the seven planets
"considering the Moon as one of the primaries
"was placed near to it; above them, was the

"firmament of fixed stars; then the chris-
"talline orbs; then the primum mobile;
"and, last of all, the Celum empyreum,
"or heaven of heavens. All these vast orbs
"he supposed to move round the Earth once
"in 24 hours, and besides that, in certain
"stated and periodical times. To account
"for these motions, he was obliged to conceive
"a number of circles called excentrics and
"Epicycles, crossing and interfering with
"one another. The system was universally
"maintained by the Peripatetic Philoso-
"phers, who were the most considerable sect
"in Europe from the time of Ptolemy, to
"the arrival of learning in 16th Century. —
"At length Copernicus, a native of Poland,
"a bold and original genius adopted the
"Pythagorean or true system of the universe;
"and published it to the world in the year
"1530. This doctrine had been so long in
"obscurity that the restorer of it, was con-
"sidered as the inventor; and the system

"obtained the name of the Copernican philoso-
"phy, though only revived by that great Man.
"Europe, however, was still immersed in ig-
"norance; and the general ideas of the world
"could not keep pace with those of a refined
"Philosophy. This occasions Copernicus to
"have few abettors, but many opponents.
"Tycho Brahe, in particular a noble Dane
"sensible of the defects of the ptolemaic system
"but unwilling to acknowledge the motion of
"the Earth, endeavoured about 1586, to establish
"a new system of his own, which was still more
"perplexed and embarrassed than that of
"Ptolemy. It allows a monthly motion to
"the Moon round the Earth, as the Centre
"of its Orbit; and it makes the Sun to
"be the Centre of the Orbits of Mercury,
"Venus, Mars, Jupiter and Saturn.
"The Sun however with all the Planets
"is supposed to be wheeled round the Earth
"in a year. Venus once in 24 Hours. —

"This System notwithstanding its absurdity
"met with its advocates. Longomontanus
"and others, so far refined upon it, as to
"admit the diurnal motion of the earth
"tho' they insisted that it had no annual
"motion.— About this time after a
"darkness of a great many ages, the
"first dawn of learning and taste began
"to appear in Europe. Learned Men in
"different Countries began to Cultivate
"astronomy. Galileo, a Florentine,
"about the year 1610, introduced the
"Use of Telescopes, which discovered New
"Arguments in Support of the Motion of
"the Earth, and confirmed the old
"ones. Bigotry and Superstition,
"took the alarm; and the fury of the
"Clergy, had almost checked the flou-
"rishing bud: Galileo was obliged to

"renounce the Copernican System as a damnable
"heresy. The happy reformation in religion,
"however, placed one half of Europe beyond
"the reach of the papal Thunder. It taught
"mankind, that the Scriptures were not
"given for explaining systems of N. Philoso-
"phy, but for a much nobler purpose, to
"make us just, virtuous and humane; that
"instead of opposing the word of God, which
"in speaking of Natural things suits itself
"to the prejudices of weak mortals, we em-
"ployed our faculties in a manner highly
"agreeable to God himself, in tracing the
"Nature of his works, which, the more
"they are considered, afford us the greater
"reason to admire his glorious attributes of
"power, wisdom and goodness.— From
"this time, therefore, noble discoveries
"were made in all the branches of
"Natural Philosophy." A long list of

able Philosophers is presented us in the modern history of that inestimable Science. But the fame of their genius and the Lustre of their works, render an enumeration of them unnecessary.
I have called Nat. Philosophy, an "inestimable Science". The known advantages, which have resulted from it, demonstrate the justness of the epithet. By its assistance, the Ocean has become a medium of Commerce amongst the Sons of Men, and most distant quarters of the Globe, communicate with each other, exchange their superfluous Commodities, obtain the mutual benefit of Civilization: and the race of Man resembles more and more, every day, the great ideal family of the Universe. In vain the Thunder rumbles in the Skies; in vain the lightning darts its rapid fury at the

humble habitation of Man: N. Philosophy fair daughter of heaven, parent of the Arts Source of the conveniences and Elegancies of life, has taught him to avoid the threat end ruin. But the study of this Science unites amusement with utility. It opens to our view scenes and beauties never contemplated before, feeds the restless Curiosity of the human mind, and exalts it, above its former level, to the Sublimest conceptions of Nature & Nature's God. — But the truth of these observations will be more conspicuous, as we advance farther. Diligence, a mind divested of prejudice, & persevering investigation, are the principal qualifications requisite in a Student of this Science.

Lecture 2^d^. of the properties of Matter.

We are to begin, with explaining the properties of Matter, because as it will be remembered, the object of Natural Philosophy, is to investigate the causes of the Phænomina of the material World. Matter is defined to be every thing, which has length, breadth, thickness, and which resists the touch. Dr. M. enumerates six inherent properties of Matter; 1. Solidity; 2. Inactivity; or Vis Inertiæ. 3. mobility, or a Capacity of being moved; 4. Divisibility; 5. Configubility; and 6. Porosity. In the Course commencing October 1800 he adds Rarefactibility, Condensibility Compressibility & elasticity.

1. The Solidity of Matter arises from its having Length, breadth & thickness. This property may be incontrovertibly proved by experiments upon bodies apparently the least solid. Immerge a tube, hermetically sealed at one end into water; the water will rise

but very little way in the tube: the air is in some degree compressed, but it cannot be excluded. Again, fill a bladder with air, and the sides of it cannot be brought in contact. Both these experiments prove the solidity of Air, and show at the same time the justness of the definition of Solidity, namely, that it is a property by which one body excludes every other from the place which it occupies. 2. Inactivity, or Vis inertiæ is that property of Matter by which it endeavours to remain in the state it is in, whether of rest or motion. That matter cannot put itself into motion requires no proof. But its propensity to remain in a State of Motion is not so self evident. A little observation, however, confirms the truth of the position. It is in virtue of this principle that a Boat continues to move, notwithstanding, the resistance it meets with in the water, after the impelling force has ceased. Thence also, the sudden stoppage of a Carriage by a jolt, causes the persons in it to be thrown forwards. There are many other instances equally ample, and equally satisfactory, which would be endless to Collect.— *

3. Mobility or the capacity of Matter to be moved, requires no proof, since every body knows that any bulk of Matter may be moved if sufficient force be applied to overcome its resistance. Nor is it necessary that this property be defined, for a sufficient explanation of it is contained in its name, which is also the case in another name of a Property of Matter, Viz.

4 Divisibility, of which there can be no end. A single grain of Gold

* Adams denies this for: Inertia of Matter to continue in a State of Motion

may be divided, after being beat out into a leaf, into 500,000 parts, each part being Visible to the bare eye: one of these parts viewed thro' a microscopes which magnifies the diameter of an object 10 times, will be magnified in the area 100 times; and then the 100th part of a grain of gold (that is, the 50 millionth part) will be visible. But nature goes still farther than art. Mr. Lewenhock tells us that there are more Animals in the Milt of a Codfish, than there are men upon the whole earth: and that by comparing these animals in a Microscope with a common grain of Sand it appeared that one single grain is larger than 4 Millions of them. If these bodies are to the particles of their blood in the same proportion as another animals, conceptions cannot picture their Minuteness. It has been calculated that One of these particles must be contained as often in a globe, the 10th of an inch in diameter, as such a globe would be contained in the whole earth. Yet these Particles, must be to the particles of light (if light be a body) as mountains are to grains of sand. "For the force of any "body striking against an obstacle, is "directly in proportion to its quantity, "multiplied into its Velocity: and since "the Velocity of the particles of light is "demonstrated to be at least a Million "of times, greater than the Velocity of "a Cannon ball, it is plain, that if "a million of these particles were as big "as a single grain of sand, we durst "no more open our eyes to the light than "we durst expose them to sand, shot "point blank from a Cannon". —

Some authors, I am told, doubt, and deny, the infinite divisibility of

A Globe of Gold (I need not add that more may be contained under the same surface in a Globular than in any other Shape) was filled with water, and pressed by a very powerful screw. The water being incompressible, or at least compressible in a very small degree*, was forced thro' the pores of the Gold & appeared in drops on the outside like dew. The ready transmission of light thro' diamonds, glass and other hard substances, proves them also to be porous.

Des Cartes and his followers (& that celebrated genius has been followed by a very large train of Philosophers) have advocated a notion, that nature abhors a vacuum. They contend that there is a certain materia subtilis which pervades the

* Water was formerly thought incompressible but Dr M. in his last lectures remarked that it was acknowledged to be compressible, tho' in a very small deg[ree]

hardest bodies and fills up all Space. The Newtonians controvert this Opinion. But the arguments of Plato long ago demonstrated its fallacy. He made 5 Bodies,* generally called after their inventor, the platonic bodies, and maintained that in order that the Particles of bodies should come into close contact, they must all be of one or other of these Shapes, which he supposed improbable, & even absurd. Hence he inferred that bodies could not be so perfectly compact as not to contain innumerable vacuums. But since the invention of the air pump, the possibility of making a vacuum has been experimentally proved. The air may be so exhausted out of a receiver

* Viz 1 A Tetrahedron a figure of 4 equal triangular sides: 2 a Cube of 6 equal squares. 3 an Octahedron of 8 equal pentagonal sides: 4 a Duodecahedron of 12 equal triangular sides 5 Icosahedron of 20 equal triangular Sides

that a guinea & a feather will fall to the bottom in the same time.

Having frequently spoken of the particles of matter we are naturally led to enquire whether the elements, or primary particles of matter are or can be ascertained? The ancients were of opinion that Earth, Air fire and water were the elementary principles of all bodies. It is true that they are found in all bodies: But the skilful Chemists of the modern age, have proved that they are not themselves simple substances. Water has been actually decomposed into two different airs. A late opinion added salt to the 4 elements of the ancients. The truth is, that to determine the elementary principles of bodies, is a task too great for the limitted Capacity of man. It requires a nicety of discernment, which the eye, nor the mind of man can never hope to attain

Philosophers, therefore, instead of seeking into the elements of bodies, have much more conformably to reason, classed bodies under different heads, agreeable to their predominant properties; as inflammable, metallic, saline, watery and earthy. We come now to speak of attraction and repulsion. And first what is understood by these terms? — They may be defined, to be that tendency which bodies have to accede to, or to recede from, each other. But there is still a caution necessary as to the use of these terms. Sir Isaac Newton used them, not to express the unknown cause of this tendency in bodies, but to express the tendency itself, the effect. In this sense they should allways be used. — There are many different species of attraction, Viz, 1 The attraction of Cohesion, defended to be that principle whereby, the

Particles of bodies adhere to each other. 2 Attraction of gravitation, or that power by which distant bodies tend to each other. 3. The attraction of magnetism, is that peculiar attraction, which the loadstone has for Iron, and all ferruginous bodies. 4 The attraction of electricity, is that exhibited by some bodies when rubbed, as Glass amber wax. 5. Chemical or electric attraction, is that exhibited by a menstruum in dissolving some bodies in preference to others. This Lecture will be concluded with some observations respecting the attraction of Cohesion. The simplest experiments to prove its existence, are the running together of 2 drops of Water, the rising of Water in a Spunge &c &c. Hence from the attraction of Cohesion arises the difficulty of separating the particles of bodies. The laws of this attraction are three

1. It is in proportion to the surfaces of the contracting particles, and not the quantity of matter. 2. It extends only to a small distance, and 3. It is mutual between all bodies, or rather between the attracting ~~particles~~ Surfaces. Upon this attraction depends the rationale of Cements and Soldering, for by their means the surfaces of bodies are brought into so close contact that the attraction of Cohesion takes place. It is owing to this attraction that water will ascend in a Capillary tube, higher than the exterior Surface, the water being attracted by the annuli of the Tube: and in a similar manner, we may imagine the sap ascends thro' the pores of trees. From hence, also it is easy to account*

* The reason why their distances from each other renders them fluids, is, that Caloric insinuates itself between them: as we shall see hereafter —

for hardness, softness, fluidity. When the surfaces of the particles are flat & come into contact, the body is hard: those Particles which are more round & touch in fewer points, are soft: particles, spherical or nearly of that figure will form a fluid." As to elasticity we are ignorant as yet of the cause. In all cases, however, this attraction is destroyed by separating the Contingent cohering Particles. —

Lect: 3d Of Chemical Affinity

On the general laws which tend to bring bodies together, and to maintain them in a state of mixture and Combination, — This attraction, which the Chemists call Chemical affinity is absolutely necessary to maintain bodies in a solid state. That subtle principle called Caloric has allways a tendency to insinuate itself into all bodies, and thereby to reduce them into a state of Gas. Were this principle to operate uncontrouled, the whole mass of matter would soon be reduced to the gaseous state. To balance its power the affinity has been established by the wise author of nature. The various solid substances in nature, are the simplest instances of its existance. It has been called affinity, to distinguish it from Cohesion; first, because it was supposed to depend upon a certain analogy between particles of bodies; 2^d to distinguish it from the planetary attraction discovered by Newton, of which it appears to be a modification. It takes place either between similar or dissimilar bodies. Hence it is considered in a twofold view, 1. The affinity of aggregation, or that which takes place between bodies of a similar nature; 2. The affinity of

Composition, or that which takes place between bodies of a dissimilar nature;

First of the affinity of aggregation, or of the affinity which takes place between homogeneous bodies.– Two drops of mercury running together form an aggregate. Hence it may be clearly perceived that it does not change the nature of two bodies: the union of mercury with mercury can only produce mercury. An aggregate differs from a heap, in as much as the particles composing the heap have no coherence; thus the grains on a heap of barley, or wheat, have no adherence among each other. An aggregate and a heap differ from a mixture inasmuch as a mixture is a confusion of different bodies: take two masses of the same composition as for instance two grains of gunpowder by pressure they may become an aggregate. We may illustrate what we call a mixture thus: two different powders jumbled together do not form a consistence in that state of separation they form a mixture. The force of affinity, in different aggregates, is directly as the effort necessary to separate them. There are four kinds of aggregates, comprehending all the bodies in nature. Viz. the hard, the soft, the liquid, the aeriform. Water presents us with a complete illustration of them all. When in a state of ice it is hard, when in a mushy state, intermediate between ice & fluidity, it is then soft; when in a fluid state, it is the liquid; and when its particles are disunited by a very large degree of Caloric & assume the appearance of Vapor, or gas, it is then the aeriform aggregate.

2^d. Of the affinity between heterogenous bodies, or the affinity of Composition. Upon this principle the whole Science

of Chemistry depends; without it, the Chemists would never be able to decompose any substance whatever; and without the power of decomposing, he would be unable to continue his researches into the constituent principles of bodies. It is necessary then, that we should accurately & fully understand this principle. The general phenomena of its operation are reducible to 7 Laws, which we shall enumerate and illustrate. 1^st. The affinity of composition takes place only between heterogenous bodies. This law is inseparable from the idea of this affinity. So true it is, indeed, that it is observable, that the affinity is strongest, where, the substances are most dissimilar in their natures. To illustrate this, we must explain the ~~term~~ meaning of the Terms Acid and Alkali. An Alkali is any vegetable salt, any substance which when mixed with an Acid

26 30. produces fermentation; An acid is a mixture of vital air or oxygenous gas, with an elementary substance. These are the most dissimilar bodies in nature; yet none so readily combine with each other. 2d Law The affinity of Composition exists only between small bodies, or the smallest particles; hence the necessity of trituration, pulverizing &c before it acts. The affinity of composition is the inverse of aggregation; the force of composition is ~~the~~ inversely as that of aggregation. Thus in no substance whatever is the force of aggregation so weak as in Gases. & none have so strong a tendency to combine. 3d Law. The affinity of composition may take place between many bodies. But of this Law, it must be observed

31. That our knowledge is very limited. We are well acquainted with the combination of 2 bodies, much less however of 3, and not at all of 4.
4th Law. That the affinity of composition may take place between two bodies, one at least must be in a fluid State. "Corpora non agunt nisi sint Fluida" There are indeed, instances of bodies finely pulverized, combining together and producing a third substance of quite a different nature. But this is a general law, liable to but very little exception. Under this head we may explain the phænomina of Solution When the particles of a solid body are so suspended in a fluid as entirely to disappear, the phænomena is termed solution. It is caused by the superiority of the affinity of

Composition to that of aggregation.
Viz. it takes place when the particles of the solid, have a greater affinity to those of the fluid, than it has to its' own. (It was supposed formerly & is so supposed, now by some, that heat caused a fusion & separation in bodies, by the repulsive principle which it communicates to their particles; but it has been discovered that heat produ:ces this effect, only by its tendency to unite with the particles of bodies, which have a greater affinity for it, than they have for themselves). To return. The Test of Solution is transparency. The action of a Solid & fluid body is per:fectly reciprocal. The parts of a Solid are equally diffused thro' the solvent fluid. You may put so much of a Solid into a liquid, that it will

dissolve no more. The fluid is then said to be saturated. But tho' so much of one solid can be put in, that it can no longer be dissolved yet the same fluid will dissolve another solid. The solvent fluid is sometimes called a men:struum.

5th Law. When two or more bodies unite, by the affinity of composition, their tempe:rature changes at the instant of their Union. (Pour water into a glass tube, to a certain height; mark the height; pour Salt into the water; the water will at first rise above the mark; then gradu:ally sink below it, which proves that the Combination changes the tempe:rature of the combining substances; and at length they will become again of the same temperature of the surround:ing atmosphere & rise to the original

mark.). To account for this phæno=
=mena it has been supposed that
Caloric is itself a fluid, & that in every
combination, it is disengaged or absor=
=bed. 6th Law. Two or more bodies
united by the affinity of composition
form a third, whose properties are to=
=tally distinct from those which ei=
=ther of the two bodies had before their
Union. Sthal, and his followers
supposed, that the compound par=
=ticipating of the properties of the Com=
=ponent bodies, form a mean between
them. But we have many phæno=
=mina which establish the erroneous=
=ness of Sthal's idea, & the truth of
this 6th Law. Two bodies which, se=
=perate, have no taste, acquire a very
strong one by combination. Mercury
and muriatic acid, taken separately

cannot hurt the animal system; in com=
=bination, they are a most violent poison, &
corrosive in their taste: Substances, which
separate have taste, loose it when com=
=bined, Nor can we reason at all, a pri=
=ori, what will be the properties of the
third body. — 7th Law. Every particular
Substance has its peculiar affinity, with
the various substances presented to it.
Hence the changes which take place
in bodies. Thus, for instance, an acid
has to a metal, an affinity = 4, an
alkaline has to the acid an affinity =
6. The alkali then will seperate the acid
from the metal, with a force = 2. To prove,
that bodies have greater affinities to
some than to others, we shall explain
the meaning of the terms of precipitant,
p—tate, & p—tation; which is necessary
to understand the experiment. When
a body in solution, or another solid
being thrown into the solvent fluid,
falls to the bottom this is called

Precipitation; the solid which being put in produces the effect is the p—tant. & the solid precipitated is the p— tate. Dissolve silver in Nitric acid (commonly called aqua fortis) put copper into the same acid. the silver will be precipi=tated & the copper dissolved. put iron in; the copper will be precipitated and the iron dissolved. This was called by Bergman, elective attraction from the kind of choice which one of the constituents of the composition has to the matter added. When the composition of 2 bodies cannot be des=troyed by a 3d. or a 4th., sometimes a composition of these last, will decompose the first. while at the same time the last will be decomposed by the first: and this is called double affinity. When two bodies will not unite,

sometimes the introduction of a third will produce an union: thus oil & water will not unite, introduce an alkali, & their union is effected. This is called the affinity of an intermedium. There is also reciprocal affinity, which may be thus illustrated. The Vitriolic acid has a stronger affinity, than the nitrous acid, for fixed alkali, and will decom=pose the union of that alkali with the last acid: however the nitrous acid can, in its ~~time~~ turn, separate the vitriolic acid; if the nitrous acid be heated. — Some Chemists have thought they discovered great resemblance be=tween this affinity & the Newtonian at=traction. Nature is simple & uniform in her operations. They believe, therefore the property of reciprocal union depends on that attraction, which exists between all bodies. They have composed several Chemical bodies, between which affinity takes place, tho' they be in large Masses. Conformably to this opinion, they believe, that affinity is the cause of weight and the heavier bodies are, the greater the affinity. This Hypothesis holds good, especially of metallic substances. From what has been said, it appears that the cause of Chemical affinity is unknown. If it be the same as the Newtonian attraction, at least the difference observable between its laws & those of attraction serve to shew, that it is only a particular modification of it. This will appear more clearly by comparing our knowledge of them. The first takes place only between small bodies, & is absolutely nugatory, between bodies whose volume is considerable. The 2d. takes place only between large bodies & is in direct proportion to the mass or quantity of matter. Attraction operates at great distances: affinity never takes

place but in bodies which are in contact. Hence it appears that affinity, if not entirely different from, is at least barely a modification of the attraction of Gravitation -

Lect: 4th Of Gravitation

I define attraction of gravitation to be that force by which distant bodies tend towards each other. It is by this force that men are enabled to inhabit the Earth. It is by this force, that the edifice reared, by the art of the architect are maintained firm upon their bases. It is by this force, that the seas are confined to their Beds. It is by this force, in fine, that the whole planetary System is preserved. Were it ceases to exist, a stone thrown into the Air, will never return, the Creatures which cover the face of the Earth, & the unattached, still remain upon it, will be thrown off into the boundless regions of space: and the Planets, no longer confined to their orbits, will cease to perform their periodical revolutions round the sun. — The laws of attraction are the 4 following to wit. 1st It is common to all bodies, & mutual between them: Thus when a stone falls to the Earth tho' we say that the stone gravitates towards the Earth, yet we would not be understood, as tho the earth did not also gravitate towards the stone; but then the space thro' which the earth gravitates will be so much less than that thro' which the stone gravitates, as the earth is bigger than the stone: now no body falling falling to the Earth, bears so large a proportion to the earth, as to render the earths gravitation towards it perceptible. 2d Gravitation is in direct proportion to the quantity of matter in bodies. Two Pendulums of equal

length, one containing 10 & the other 1 pound will vibrate in equal times; which proves that ten times as much gravitation is exerted upon the first as on the last. 3d It is exerted every way from the center of the attracting body in right lined directions.

4th It decreases as the squares of the distances increase. This law cannot be collected from the falling of bodies to the earth, because they cannot be carried so high as to produce any perceptible alteration. It was discovered by observation upon the heavenly bodies, as the moon &c &c

A body would entirely lose its weight, were it placed in the center of the earth, for then it would be equally attracted every way. But in any other position, there is no such thing as absolute levity in nature; smoke is among the lightest bodies, with which we are acquainted; place a candle in a

There is no difference in the terms Gravity and Gravitation; the former is regarded as the effect of the latter; & by the difference in this effect we determine the relative force of gravitation upon different bodies. The physical cause of gravitation is unknown. See page 62.

receiver of an air pump: exhaust the receiver the smoke of the candle will fall to the bottom; which demonstrates that smoke has gravity. Some Philosophers however contend for the principle of absolute levity & ground their arguments upon the following experi=ment. (Place a bar of iron in an exhausted receiver; find the centre the Centre of the bar; at equal distances above & below the centre place a thermometer, throw the focus of a burning glass upon the Centre & it will be found that the upper Thermometer stands the highest; heat therefore has an ascensive principle, even in a place where the atmosphere can have no effect to buoy it upas it were) And indeed this experiment has a great deal of weight in their favour. —

The gravity of Bodies is not the same in all parts of the Earth. This phaeno=mi non proceeds from 2 Causes. 1 since the centrifugal force (which term will

hereafter be explained) is greater towards the Equator, than towards the poles, it is plain that the tendency of Bodies to fly off the Earth, diminishes their gravity, more in the former, than in the latter case; which is one reason why bodies weigh more or less as they approach towards the Equator, or the Poles. 2dly The Earth has been found by actual mea=surement not to be a perfect sphere, but an oblate Spheroid; hence bodies towards the poles are nearer the center of the earth, than when they are situated towards the equator & this also produces a difference. Sir Isaac Newton calculates this difference to be a 230th part of the weight of a body. Bodies of the same bulk have different weights according to their densities. — To measure the intrinsic gra=vity of bodies, they should be weighed in Vacuo. — were a body to pass thro' the Earth towards its Centre the attraction of the Earth & around it, would destroy that gravity which otherwise it would acquire in its approach towards the Centre Whoever has any idea of the motion of the heavenly Bodies, will readily perceive the universality of this law of gravitation; & yet we fear the Cause must remain forever unknown to us.

Lect. 5th Of Magnetism Part 1st

The name "magnet" is supposed to be taken from a Shepherds name, by whom it is supposed to have been discovered on Mount Idan. Some suppose it to have been found near Heraclea, a city of magnesia; Whence it has been called "lapis Heracleus". It has been called also "Sideritis" from a greek word signifying iron. Whatever the magnet be called, it is that substance, which attracts iron & ferruginous bodies, & those only, if we except a Substance called nickel, which it has been found to attract. The Magnet is unknown to us where its having the properties which will be presently enumerated. Magnetism is the unknown cause of these Properties. Here they follow.

1. The magnet attraction of a Substance

called Nickel only: and the attraction is mutual & equal between the Substance & the magnet. (Experiments to prove this mutual attraction) 1. Ballance a Bar of iron in a scale; apply a magnet to the bar & it will be drawn down with its scale, by the magnetic attraction. See then how much weight, placed in the opposite scale will overcome the force of the Magnet, & restore the equilibrium: afterwards ballance the magnet in the scale; apply the iron, & the magnet, with its scale will ~~restore the equilibrium~~ be drawn down; & the same weight, placed in the opposite scale will restore the equilibrium as before. 2d. Take two sewing needles, stick them thro' 2 thin bits of cork, touch one of them, with the magnet, put both in water: bring them within the Sphere of each others attraction; & then they will be seen mutually to approach each other. 2. If a magnet be suffered to traverse freely it will arrange itself so that one end will constantly point North & the other South.

46 This is called "magnetic polarity". The end which points N is called ye N pole; that which points S the S pole; the middle is called the equator. (Experiment to prove the polarity of the magnet.) Take a sewing needle, which has not been touched with the magnet; stick it thro a thin bit of Cork; put it into the Water; and it will lie indifferently in every position: But touch ye needle with the magnet, & immediately, one end will point North & the other South. — It is to be observed also, that the poles are endued with the strongest attraction (Experiments to prove this fact.) — A key may be suspended at the poles of a magnet: move this key nearer the equator: and it will drop from the magnet. The natural magnet is the loadstone dug out of ye Earth, the artificial is a ferruginous bar, to which magnetism has been communicated.

47 To find the poles of either, let them be placed upon a Plane: sprinkle steel filings over them and these filings will so arrange themselves as to discover the poles. 3. Similar Poles repel & dissimilar poles attract. (Experiment to prove this law) place a magnetic needle, so as to traverse freely; it will quickly point North & South; To its north end, bring the north end of another magnet, & the needle, which traverses freely, will be repelled; But put the magnet N end near the S end of the needle, & it will be attracted; & vice versa. But if the N or S end of the one be brought very near the N or S end of the other, the similar poles will attract. This is an apparent exception to the general law it is however only apparent. For in truth, the larger magnet when in contact with the smaller communicates to the end which it touches, a contrary Polarity. 4. The interposition of other bodies do not interrupt the magnetic

attraction. (Experiment in proof.) —
Put a needle in a Plate; it will be very strongly affected by a magnet applied under the plate; put the plate upon a table: & the needle, therein, will be as strongly affected by a magnet under the table. 5. Each pole attracts or repels, at equal distances, in all directions.
6. The attractive force decreases as the square of the distances increase, and vice versâ, according to some Philosophers.+
Dr M. says that different magnets have different attractive forces; that the attractive force of the same magnets is different at different times (The experiment to prove this Law is, this, viz) Ballance a bar of iron in a pr of Scales; place a magnet at the distance of one inch from the Bar, and as much weight in the opposite scale, as will in spite of the magnetic force preserve ye equilibrium; then according to

+ Muschenbroek &c.

this Law, a 4th of that weight ought to preserve the equilibrium, if the magnet be removed to the distance of 2 inches. The experiment according to Dr M. sometimes may & sometimes may not answer.
7. The magnet will communicate its properties without any diminution of its own: & upon this property depends our power of making artificial magnets. 8. Iron acquires & loses magnetism sooner than steel; soft iron, sooner than hard. To use a phraze of my own, its tendency to lose, is directly as its faculty to acquire, magnetism.
It is remarkable also that small magnets have greater proportional strength than large ones. There was one in Mr Boyle's ring which would support 250 times its own weight; it weighed 3 gr. & could raise 746 grs. 9. It attracts iron in a duplicate ratio of its power of communicating.
10. A magnet will communicate its properties to iron without touching it. (experiment in proof)
In communicating magnetism to iron, the touching end of the magnet communicates to the touched end of the iron a contrary polarity, that is a north end will communicate a S. polarity & vice versa.

Let there be a magnet placed upon a table so as to traverse freely; place y^e 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 y^e iron bar next the communicating magnet, will acquire a south polarity, & the other end a north: now the last end was opposed to N. end of the traversing magnet, which will be repelled; and thus repulsion could not take place if the iron bar, were not rendered magnetic.

The earliest knowledge which men had of the use of the magnet, or of its directive property, (for its attractive power was known to Homer & others of the ancients) cannot be traced farther back, than the 13^th Century. It was not till after y^t time that it was employed in commerce, to the improvement of which it has greatly contributed. In Corinth it used to be said, that he who doubled Cape Malea (a Cape of Peloponnesus) should forget all he held dearest in the world. See

Anacharsis's travels Vol. 2. 6. 37. But in later times by the aid of the compass, Columbus has discovered what is emphatically called the New world. It is not now, as formerly, the stars but it is the magnet which guides the voyager. The magnet is the medium, thro' which distant countries exchange their commodities. The mariners compass is an artificial steel magnet so placed in a box as to remain horizontal, [in] any position of the ship. We cannot describe it now at large in this place. The best shape of the needle is that it should terminate in a point. The best support of a needle is a steel point in an agate cap. &c. Some attribute y^e invention of the compass to John de Gioja, who in Cavallo's opinion, has the best title to it. D^r Gilbert says that Paul Venetus brought it from China, into Italy in y^e year 1260. Ludi Vertomannus affirms that in the east Indies, Anno. 1500. he saw a magnet, contrived as those now used, employed by a Pilot. M^r Barlow

52 relates, that, anno 1597 he himself saw 2 East Indians who mentioned to him a contrivance, for using the magnet in navigation different from the compass. These observations are of a date posterior to the use of the magnet in Europe & therefore conclude nothing as to the original invention. P. Duhalde in his history of China confirms the supposition, that the compass is a Chinese invention, in two passages; the latter of which induces us to believe that Tcheou Hong was the inventor of Tchi Nan (the Chinese name for the sea compass). If this be true, it was invented in the 22 Cycle, above 1040 years A.C. Renaudo adduces reasons to ~~believe~~ shew that the Chinese were not the inventors of the Compass. Sir G. Wheeler says, that he has authority to believe, that the needle was used for astronomy before the year 1320, but not for navigation. An old French poet Guyot de Provins, obliquely hints at the use of it for navigation, he wrote, about

53 anno 1180. The Spanish Jesuit Pineda and Kircher affirm that Solomon knew the use of the compass, & that his subjects actually used it in navigation. After all Dr. H. attributes the original invention to the Chinese as the most probable. The needle does not allways point N & S, but sometimes declines to ye E or W. This is called the variation or declination of the needle; or in other words the variation of the needle is the difference between ye magnetic & the true meridian; the angle made by ye magnetic & the true meridian. We always reckon ye variation at the N point. The variation is different at different times & places. This is called the annual variation of the variation. In 1694 in Lonesburg when the College lands were surveyed, the variation of the needle was 5° W: at present (1799) the variation is between 2° & 3° E,* the needle therefore in about 100 years has travelled 7°. (I am inclined to believe that it might have travelled more: how do we know that it went no more than 5° degrees west after ye observation in 1694?) In London

* Variation Nov.r 29th Wynsberg 1° 30' E

Anno 1596. the declination was 11°15′ E: in 1622, 6.° 0′ E; in 1657. 0.° 0′; in 1672. 2.° 30′ W. in 1730. 13.° 0′; 1760 19.° 12′; 1775, 21.° 3′; in 1799, 23.° 0′ W. In Europe, then the variation is to the west: in America to the E. In crossing the atlantic the seamen will observe this remarkable fact: the variation of the needle will be continually decreasing till they arrive in a part of the ocean, where there is no variation. For this & other singular Phenomina the diligence of Philosophy has not yet been able to account. The Cause is veiled, & I fear ever will be veiled. Columbus first discovered this variation in 1492. Sebastian Cabot made more particular observations on it in 1500. Dr Halley for the Convenience of Seamen drew a Chart of the needles variation; but as these variations are themselves varying, the Chart should be renewed about once in 8 or 10 years to be useful; in which case it would be a great

Convenience for navigators. To find the variation of the needle, many methods have been mentioned. I select one of the most simple. On the 20th of March & 21st Sept the sun rises precisely in the East; place the E & W. points of y^e compass, directly in a line with the rising sun; the N & S points will then be in the true meridian; and the variation of the needle will then be seen on 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 west; from 3 to 8 O'Clock, the needle travels east. This diurnal variation it is remarkable, is extremely affected by an Aurora Borealis. It is observed to be the greatest in the months of June & July and least in the months of January & February. A needle if suffered to play freely every way will dip. 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; on the S side, the S. end dips. At the equator the needle is horizontal. At Wmsbg it dips 67°; at London, 72°. At the Poles the needle would stand perpendicular. (Illustration) Suspend 3 Sewing needles, two over the two poles of a Magnet, & one over its equator: those over the poles will be perpendicular, & that over the equator horizontal. The dipping needle is proposed to be used for the determination of the latitude, of places; but what will not fail to obstruct their use, is that the dip is not uniform in receding or approaching the equator of ye earth, nor even in the same place at different times, thus in London about ye year 1576 the north end of the dipping needle stood 71°. 50' below the horizon, & in the year 1775, 72°. 3.

Part 2d. - Of Communicated Magnetism. -

Of the Theories of Magnetism. —

It is observed, that artificial magnets are stronger & better than natural ones. Hence it is necessary that we should become acquainted with the method of making them. This may be done without or with the aid of a natural magnet. 1 with the N. magnet prepare a piece of steel: find the poles of the nat: magnet as above directed. rub on one end of the steele the pole contrary to that you wish to give to the rubed end. & vice versa. - Without the aid of Natl. Magnets: - 1st by placing a bar of iron in a perpendicular situation. 2d by striking the end of a bar of iron with a hammer. 3d by making it red hot & cooling it gradually. 4. by hammering. - The method of preserving Magnets. - The magnet will continue to weaken & at length will lose its properties alltogether if suffered to remain when it may rust &c. This diminution may be prevented by arming the magnet. The magnet will lose its properties by not being used for a length of time; by heat; by concussion; by cold &c. These therefore should be avoided. The theories of magnetism are so long, so many so tedious & so absurd that they neither can, nor deserve to be inserted in this place. See Martin & Cavallo.

Lect. 6th Part 1st 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 motions of bodies are considered & compared with each other, then are they relative or apparent only: they are relative, as they are compared with each other: & they are apparent only, inasmuch as not their true

 or absolute motion, but the sum or difference of the motion only is perceivable by us." (Martin). — "Again: Motion is considered as equable, accelerated, or retarded. Equable motion is that by which a body passes over equal spaces in equal times. Accelerated Motion is that which is continually augmented & increased; & retarded motion is that which continually decreases: And if the increase or decrease of motion be equal in equal times, the motion is then said to be equally accelerated or retarded. We discover the true motion of bodies only when we are ourselves at rest. There are 3 laws of motion. 1. All bodies continue in a state of rest, or uniform motion in a right line till they are made to change that state by some external force impressed upon them. This law is only a consequence of the vis inertia of matter; thus a top ceases to turn round only on account of the resistance of the air, & the friction

it meets with on the Plane whereon it moves.
2.^d The change of motion in any body is allways proportional to the force whereby it is effected and in the same direction wherein that force acts. This is an immediate consequence of this axiom. The effect is allways proportional to its cause. For instance if a certain force produce a certain motion a double force will produce a double the motion, a triple force triple the motion &c.
3. Reaction is allways contrary & equal to action. This law may so easily be understood that it needs no illustration.

The velocity of bodies is the space passed over in given times, or rather is measured by such space. The motion or momentum of bodies is the impetus compounded of the bodies quantity of matter & the velocity. Thus a body weighing 2 lb moving with a velocity = 3. will have a momentum = 6. Thus by increasing its velocity, a small body may be made to possess the same momentum as a larger one. A cannon ball

moving at the rate of 1142 feet in a second of time, & weighing only 36 lb. will have a momentum equal to that of a battering ram weighing 41112 lb. and moving at the rate of 1 foot p^r second which requires 1000 Men to manage it. — We come now to consider the effect of forces impressed in oblique directions. The moving body will take a new direction more or less different from the former according to the number & direction of the impressed forces. If the proportions or direction of two forces, acting upon a body at the same time, be represented by the sides of a parrallelogram, the diagonal will shew the proportion & direction of their united forces. By the assistance of a Parrallelogram we may understand the doctrine of the Composition & resolution of forces. If the sides of a Parrallelogram represent the forces, they are comprehended by describing the diagonal: If the diagonal represents a force, it is resolved by describing the sides. — The Velocity along the diagonal is to the velocity along either of the sides, as the Radius to the sine; See Martin. ~~~~~~~

Part 2d. of the Centre of Gravity. —

The centre of gravity is that point in a body, in which the whole force of its gravity or weight is united. — An imaginary line drawn from this point to the centre of the Earth is the line of direction. We shall enumerate the chief Properties of each. Those of the centre of gravity are, 1. If a body be suspended freely by the Centre of Gravity, it will remain at rest at any position indifferently. 2. The centre of gravity of any body being supported, the body is also. 3. A body will apparently ascend, if placed in such a situation as that the centre of gravity should descend: which happens to a double Cone, when placed upon two inclined rods. — The chief properties of the line of direction are, 1. If it falls within ye base, the body is supported. 2. Therefore the nearer it is to the middle of the

base, the more firmly the body stands. The reason of this is obvious. For so long as the line of direction is within the base, the centre of gravity is supported supported, since that line is conceived to pass directly from ye Centre of gravity to the centre of ye earth; & so long as the centre of gravity is supported, so long, is the body also supported. When any body slides down an inclined plane, the Centre of gravity is within the base, but the inclination of ye plane being sufficient to overcome the friction of the body upon it, ye weight of the body carries it down. Should the line of direction happen to fall without the base, the body tumbles. Round bodies rest upon a very small point, the line of direction upon the smallest alteration of the situation of the body, falls without the base, & then the body rolls. From these observations, it is easy to perceive why it is so difficult to make a pointed body stand upon the point. Hence we learn the principle upon which rope-dancers, balance masters &c. perform their feats. The centre of motion is the point around

These observations on bodies Elastic & Non elastic are extracted entirely from Bonnycastle Phy.

which a body moves. The centre of manginatude is the point from which all the parts of a body are of equal bulk. The centre of gravity & the centre of motion differ when the body revolves round an axis which does not pass thro' the centre of gravity. A body will remain at rest in a perpendicular situation, when suspended by a point directly above or directly below the centre of gravity. For the method of finding the centre of gravity of any body - See Adams.

Part 3.^d of the communication of motion 1.^st in bodies non Elastic. -

"Those bodies are said to be non Elastic w.^h when impinging on another body do not rebound, but retain the impression made upon them. - When one body impinges on another at rest, or moving with less velocity the same way, the momentum of both together remains y.^e same after impact as before: For the reaction of one being = to y.^e action of the other, what one gains the other must lose." Thus suppose 2 = bodies, one impinging with 12.^o of Velocity upon the

other at rest: the quantities of matter in both being = their moments & velocities the same the sum in both 12, equally divided between them: they have therefore six a piece that is y.^e impinging body communicates half its velocity & keeps half. - When 2 bodies impinge on each other, by moving contrary ways, the quantity of motion they retain after, is equal to the difference of y.^e motion they had before impact. - For instance, let there be two bodies = meeting each other, the one with 3.^o of velocity, the other with 5.^o The difference their moments or velocities will be two. this remains the same after impact & is equally divided between them, they have therefore one a piece. The body which has 5.^o of velocity, loses 3.^o (as much as the other had) communicates half and retains half.

2.^d In bodies Elastic. - Bodies perfectly elastic, are such as perfectly rebound with a force = to that of impact. - Since the action of elastic bodies on each other (that of the Spring being = to that of the stroke) is twice as much as in bodies void of elasticity. Therefore when Elastic bodies impinge on each other, the one loses & the other gains twice as much motion as if they had not been elastic. We may ascertain thus the change of motion in elastic bodies, by knowing first what it would have been in the same circumstances, had the bodies been void of elasticity. — Thus if there be 2 elastic bodies, the one in motion with 12° of velocity, impinging on the other at rest, the impinging body will communicate twice as much velocity as if it had not been elastic. i.e. 12° or all it had; consequently will itself be at rest. Bodies non-elastic sometimes lose more than ½ their velocity, in which case were they elastic, they would lose more than all. This surplus is to be reckoned the contrary way, Thus suppose the circumstances of impact such, that the impinging body with 12° of Velocity loses 16°; the body impinged on will receive the velocity of 12° & the body impinging will rebound with that of 4°. — It is

sufficient that one of the bodies be elastic if the other be infinitely hard. — These laws are founded on the supposition of perfect elasticity, & infinite hardness: but we know of no bodies which have these properties to such a degree of perfection. Therefore the different accuracy with which, different bodies observe these laws, may be regarded as the measure of their Elasticity or hardness. — Sir I. Newton found that the elastic power exerted itself in a constant proportion to the compressing Force.

Sect 7th Of Central Forces

In the lecture we should begin by recollecting the laws of motion (See Sect. 6.) We are next to define certain terms which will be used in the course thereof. That tendency which a body has to fly from the centre of the orbit in which it moves is called the centrifugal force. That, which it has to approach the centre is called the centripetal force. Both together take the name of central forces. That

Force with which a body is thrown in an up-right, oblique or horizontal direction, is called the projectile force. It is from the joint action of the centrifugal and centripetal forces that bodies are made to move in curve lines. We have already seen, that if two contrary forces act upon the same body uniformly, that body will therefore describe the diagonal of a Parallel-ogram, the two sides whereof represent ye forces. But were one of these forces so ordered, as to accelerate the velocity of the body it wd describe a diagonal which wd be curvilinear. Hence we may perceive the cause of curvilinear motion of the Planets. Gravity draws them from ye straight line in which they were originally projected, accelerates the velocity & thus causes them to move in curves. It is therefore by the due adjustment of ye centrifugal and centripetal forces, that harmony is preserved in our planetary System. In order that a Planet may move in a circle, its projectile force should be equal to the velocity wh the body wd acquire in falling the ½ the

Semidiameter of its orbit.

The following propositions are demonstrated by experiments upon the whirling table, for a description of which, see Ferguson, Lect 2d. But let us first give the definition of our terms. 1 Periodical time, is that in which a body makes one revolution. 2. Direct proportion is when more requires more & less requires less. 3 Inverse proportion is when more requires less, & less requires more. I have now to explain the following characters; = equal: σ, centrifugal force: ⊙, centripetal: ⊙, periodic times: — x, multiplied.

Propositions

1 Matter has a propensity to keep in its present State, whether of motion or rest

2 Bodies revolving in circles, have a propensity to fly out of their orbits.

3 When bodies of equal quantities of matter revolve in = circles, in = ⊙ times, their σ are equal.

4. The centrifugal forces of revolving bodies are in direct proportion to their quantities of

Matter × into the velocity. 5. A double
Velocity in the same circle is a balance to
quadruple the power of gravity. Keplers
Law. If bodies of = weights revolve in un=
circles in such a manner that y^e squares
of their ⊙ times, are as the cubes of their dis-
tances from the centre of the circles they des-
cribe; their centrifugal forces are inversely
as y^e squares of the distances from their Centers.
7. Bodies move faster in smaller orbits than in large
ones. 8. When two or more bodies are joined
together, or connected by any force, if one re-
volves round the other, they will both revolve
round their common centre of gravity, as
their centres of motion. 9. When any num-
ber of bodies are carried in a vortex; if y^e
Vortex be denser than the body, it will fly
off & leave the body behind, which will
then fall to y^e center; if the vortex be
lighter, the body will fly off; if both be of
equal density, all bodies at whatever dis-
tances will perform their revolutions in

the same times ⊙. Hence the absurdity of the
Cartesian vortex. 10. The ⊙ force will cause
the waters to rise on the side of the earth op-
posite the moon in the same manner as the
attractive force doth on the side next the Moon.
11. The laws of central forces afford a proof
that the earth revolves around the sun & not
the sun around the Earth.
12. The Earth is an oblate spheroid; Cause
of its having this figure is, that the Centri-
fugal force is greater at the Equator, than at
the Poles, & the Earth composed of a yielding
substance. - I must refer to Ferguson for
the experiments upon which these laws are founded.

Sect. 8. Of Bodies falling perpendicularly, or
of the nature of that motion, which bodies acquire
in falling freely from a State of rest. Part 1^st.

It has been before laid down as a law that gra-
vity decreases as the squares of the distances increase.
But the distances from the earth, at which we
can let bodies fall, are so comparatively small
that the motion of falling bodies may be con-
sidered as uniformly accelerated. Hence

they acquire, at every instant an equal ad-
ditional degree of velocity, proportion to the
time taken up in falling. The accelerated
force of gravity is measured by the spaces
passed through, which are in a ratio com-
pounded of the times and velocities. Thus ye
Space may be expressed by a right-angled
Triangle. For let the Perpendicular
AB represent ye time taken up in falling: and the

base BC, the Velo-
city with which it falls: then the
Area ABC will express the spaces passed
through. From a knowledge of this figure
the following corollaries will be abundantly
evident. 1. That the Space passed over
in any time, reckoning from the beginning
of the fall, is = to half what it would des-
cribe in the same time moving with the
last acquired velocity. For AB × AC
= the whole square ABC; which is twice
the Triangle ABC. Now AB represents ye
time of falling, BC the last acquired

Velocity. & the Triangle ABC the space passed
over in the first portion of time. – 2. That the
Spaces passed through, are as the squares of
the times or velocities. For we see that the Spa-
ces or different ~~triang~~les contained in the
large Triangle ABC are 16 in number,
which is the square of the times, Val or of the
Velocities. – 3. That a Body moves three times
as far in the second period of time as in the
first, five times as far in the third, seven
times as far in the fourth, &c in a series of odd
numbers; for else, it could not fall 4 spaces
in 2 minutes, & 9 in 3 as the figure represents.
4. That the accelerative motion of a body falling
approaches nearer & nearer to an uniform mo-
tion. The Spaces described in each portion of
time are as the odd numbers 1. 3. 5. 7. 9. 11. 13.
15. Now 11 has to 13 a less proportion than 1 to 3.
But when we come to a million & one, & a million
& three, the proportion is scarcely conceivable.
In like manner, when bodies are thrown up
perpendicularly, their velocities decrease as the

times, they ascend in increase; then gravity destroying an equal portion of the velocity every instant of their ascent. The heights bodies rise to, when thrown perpendicularly upwards are as the square of the times spent from their first setting out to the moment they cease to rise. That is if a body is thrown with such a de=gree of velocity as to continue rising twice as long as another, it shall ascend four times as high; if thrice, 9 times as high &c.

From the doctrine of falling bodies, we have an easy method of determining heights and depths. We know that bodies fall thro' 16 feet in a second of time. To measure then the height of a tower let fall a stone from the top: count the seconds taken up by the body in falling, from the beginning of its fall, till you hear it strike y^e^ ground allow for the 1^st^ second, 16 feet, for the 2^d^ 48.* &c. But some little allowance must be made for the time, which the sound takes up in passing from y^e^ place (where

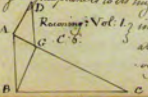
* In making this allowance you have only to multiply 16 by a series of odd numbers, 3. 5. 7. 9. 11. 13. 15. 17 &c.

the body strikes y^e^ ground) to the measurer.

We shall add only two other observations; 1^st^ that the density y^e^ medium, the more the mo=tion of the body falling approaches to an uni=form motion. 2. If a body be thrown per=pendicularly upwards, so that it fall down precisely on the place from which it began to ascend, the body describes a parabola, ∩; owing to the motion of the Earth.

Part 2^d^. Of bodies descending on inclined Planes

Gravity has the same power of accelerating the motion of bodies descending on an inclined plane as it has of accelerating that of those which descend freely & perpendicularly: tho' it can exert this pow=er only in a reduced degree. In general we may observe. That the effect which gravity has on bodies, descending on inclined Planes is to that w^h^ it has on bodies falling perpendicularly, as the length of the plane is to its height. — Let AC be the inclined Plane, the body at A, & the action of gra=vity, whereby it is drawn



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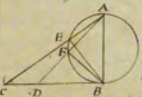
(turn over)

to fall perpendicularly represented by the line AB: let AD be perpendicular to AC, AD will, then represent the direction by which the Plane acts upon the body (for all bodies act in lines perpendicular to their surfaces) let then these two forces be resolved into one, in the direction AC, by compleating the parrallelogram BD, whose diagonal will be AG. In order to this, BG must be let fall perpendicularly, upon AC (that it may be parrallel to the opposite side of 4.[e] Parrallelogram AD) consequently (8. Elem.[ts] Euc.[d] 6) AG is to AB as AB to AC, i.e, the tendency of the body down the plane is to its perpendicular tendency as AB to AC. Q.E.D.— 2. as the Perpendicular height : the length of an inclined plane :: the Space thro which a body falls down the oblique side of a Plane : that thro' w.[ch] it would fall perpendicularly in the same time. Thus a body would fall from A to G, in the same time that

it would fall from A to B: because AB is to AC so is AG to AB.— 3 The Velocity which a body acquires by falling perpendicularly is to that which it acquires by falling obliquely in the same time, as the Space of its perpendicular descent is to that of its oblique one.— 4. as the length of the inclined Plane : its height :: the time in which a body descends along the one : that in w.[h] it falls thro' the other.— 5. If a body descends along an inclined Plane & another falls thro its perpendicular height; they will both have acquired the same Velocity.— 6. A body takes up the same time in falling thro the Chord of a circle, whether it be long or short, as it does in falling perpendicularly thro' the diameter of the same circle.

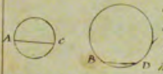


The angles AEB & AFB are right angles (by the 31.[st] 3[d] El.[t] Euclid) being angles in a Semicircle. By y.[e] demonstration of the 1st Proposition, it is clear that a body will fall from A to E or A to F in the same time that it would fall thro' the diameter AB. Now AE & AF are Chords of the circle AFB; therefore a body will fall thro' any chord of a circle in the same time that it would fall thro' the diameter of that Circle —

Lect: 9th Of Pendulums

A Pendulum is any body suspended about a point, so as to play freely about it, as about a Center. The time of the oscillation or vibration of a Pendulum is the time which it takes in passing from the highest part of the arch wherein it moves to the on one side, to the highest point on the other. The whole Theory of Pendulums depends upon the Proposition established in the former Lecture, viz. that a body will fall thro' any chord of a circle in the same time that it falls thro' the Diameter thereof.

From hence it follows, that if a Pendulum be made to vibrate in the Chord of a Circle instead of the arch, all its vibrations would be isochronous, i.e. they would be performed in the same time. But this is impossible, for the length of a Pendulum being its radius, it must of consequence, swing in an arch or not at all. Hence the smaller the arch, & the larger the circle of which it is the arch, the nearer will the vibrations of the Pendulum approach to Isochronism, because in that case the arch will be more nearly coincident with the chord of the Circle.



Thus it is plain, that the arch AC of the smaller circle is not so nearly coincident with the Chord AC, as the arch BD of the larger circle is with chord BD of the same circle. Since bodies cannot be made to vibrate in a Chord of a Circle, Hence we cannot hope for perfect isochronism unless this could be done, Mathematicians to remedy this evil, direct that the Pendulum be made to vibrate in a Cycloid.

"The nature of this curve is such, that the
"tendency of a Pendulum to the lowest point
"of it, is allways in proportion to its distance
"from thence; & consequently let that distance
"be what it will, it will be allways run over
"by the Pendulum in the same time." For a
more particular description of the Cycloid, see
Rowning, Vol: 1. C: 6. S: 9. But there are great
inconveniences attending this remedy: insomuch,
that it is worse than the evil: & it is now
generally thought best that a Pendulum should
vibrate in very small arches of large circles.
The time of the vibration of a Pendulum is
equal to the time, in which a body falling
freely in an unresisting medium would fall
thro 8 times the length of the Pendulum:
supposing that Pendulum to vibrate in the
Chord of a circle. For a body in descending
acquires a velocity sufficient to carry it as
high as the point from whence it fell.
But the time of the descent only of the
Pendulum is equal to that in which a

body would fall thro the diameter of ye circle.
In twice that time therefore that is in the time
of descent & ascent or of one whole vibration, the
body will fall four times as far, that is four
times the diameter of the circle of which the Pen=
dulum is the radius, or half diameter. Therefore
the body will thro 8 ye radius, or the length of ye
Pendulum. Rowning says "that the squares of
the times, in which the Pendulums acted up-
on by different degrees of gravity, perform
their vibrations, are to each other, inversely as
the gravities. The Principle is false. I'll
suspended a cork & an ounce of metal by two
strings of the same length: their vibrations were
performed in the same time. The weight therefore
does not affect the vibrations of the Pendulum.
They are affected by the length only.
The times in which Pendulums of unequal
lengths perform their vibrations are as the square
roots of their lengths.
+ The length of the second Pendulum is 39 in

+ Mr. T. suggested an observation on this head.
[illegible]

Inches; of the half second Pendulum is $9\frac{8}{10}$

The centre of oscillation in any Pendulum is that Point, which if impeded, the vibration will cease without any jarring ye Pendulum. If then the Point of oscillation in an uniform rod be as far distant from the Point of Suspension, as it is in a second Pendulum, they will Perform their vibrations in the same time.

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that deserves mention. "We know that a body "will fall thro' sixteen feet in one second of "time. But in the same time a Pendulum "39 2/10 inches, will perform a vibration. During "the time taken up in performing this vibration "a body will fall thro 8 times the length of the "Pendulum; that is, in one second of time "a body will fall thro' 8 times 39 Inches. "Without calculating fractions, $39 \times 8 = 312$ "Inches $\div 12 = 26$ feet. Therefore the body will "fall thro 26 feet in one second: but it is known "that it will fall thro' only 16 feet. This contradiction "between 2 Principles, both so well established to all "appearance, is strange, & remains yet to be reconciled.

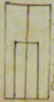
in Pag 99 Dr Marrions answer

When the uniform rod is longer than the second Pendulum by one third, the point of oscillation will be thus situated, & the rod will vibrate in the same time with the Pendulum. — The number of vibrations in a given time, by different Pendulums is proportional to their lengths. We may delineate these times, by extracting the square roots of the lengths. Pendulums are usually suspended on metallic rods. These are expanded & contracted by heat & Cold. Hence Pendulums do not vibrate in the same time in all seasons & Climates. They become longer & longer & vibrate proportionably slower & slower. To remedy this irregularity many methods have been adopted: But of these hereafter.

The great use of Pendulums is the accurate method of measuring time they afford. Time is not an object of our perception. We are not capable of judging of it so nicely, as accurately to compare one Portion of it with another. A Succession of pleasurable ideas, or a painful suspense may make the same portion of

Time appears to us longer or shorter than it really is. Hence it is requisite that we should resort to some method which shall render ye passing of time visible to our senses. Motion is most applicable to this purpose; since it has a very evident analogy to the diurnal succession of time. There is a very copious account of the ancient & modern divisions of time in Rownings second Volume C. 17th. – The ancients had many methods of measuring time. The Jews reckoned 12 hours between the rising and setting of the sun; & 12 between the setting & rising. Hence their diurnal hours were sometimes longer than their nocturnal: & the nocturnal sometimes longer than the diurnal: For the length of days & nights is not equal except at ye equinoxes. Hence therefore the measure of time, derived from the suns apparent motion is evidently inaccurate. Time was formerly measured by the running of sand or water thro' glasses which held a certain quantity.

But this method is subject to many inaccuracies or inconveniences owing to friction: to external circumstances, operating to make the sand or water run faster than usual; & when water is used, to the different degrees of evaporation according to the difference of the weather; lastly to the inconvenience of constantly replenishing the vessel made use of. Now the motion of the Pendulum is so regular as to obviate all these inconveniences. The idea of a Pendulum was first suggested to Galileo by the swingings of a lamp in his room. It was first applied to clocks by Huygens. The motion of the Pendulum is not entirely regular, owing to the Power of heat & cold to expand and contract the Pendulum, & thereby render its vibrations longer or shorter. Hence the invention of different kinds of Pendulums. The Pendulum used by Mr. Rittenhouse was a glass rod. Glass is most affected by heat and cold; but is most regular in its affection. By applying a Thermometer to it, he knew the degree of expansion or contraction, so that by making a proper allowance for the error, he arrived at the greatest certainty — some Particular kinds of wood such as deal wood, sapadillo &c are very little affected by heat & cold, & therefore make very good Pendulum rods. — A glass tube filled with mercury has also been used and is by some thought best: because while the glass lengthens by heat, the Mercury rises in the tube, so as to preserve the Centre of oscillation in the same point; and when the cold shortens the tube, the mercury condensed falls & thus produces a similar effect. The Grid-iron Pendulum is prefered by some. It is constructed upon this Principle: Brass is more liable to expansion than iron or steel; insomuch that by the same degree of heat it is expanded more than steel in a ratio of 5 to 3.



See Adams
Vol. III.
Gridiron
Pendulum

Let then there be five alternate rods of brass & steel, united at the bottom Now when the

steel expands downwards at the rate of 3, the brass will expand upwards at the rate of 5; and by that means the centre of oscillation will be preserved in its original point & at the same distance from the centre of suspension. The cross pieces which unite the bars can make no difference either one way or the other because they expand laterally. There is another kind of Pendulum which is represented by the figure below

Angular Pendulum

At every one of these corners there is a joint. When the iron expands they counteract the expansion by drawing up and forming a more acute angle; so that what it gains by expansion it losses by contraction.

The Pendulum is of still further use. By its assistance we may very conveniently and accurately measure distances. Suppose we wish to measure the distance of one house to another. Let a gun be fired at one of them. Let a person standing at the other count the number of Vibrations of a second Pendulum from the time he

see the flash to the time he hears ye report.
Sound passes over 1142 feet in a second.
Multiply the number of the seconds by 1142.
& you have the distance between the houses
in feet. — The Pendulum affords an
universal standard of measure. Thus.
Let the second Pendulum be divided
into an hundred parts, and at every
nation take so many thereof for its foot
& they have thus an universal measure of
distance. Let these feet be divided into
inches, and let a Piece of lead of as ma-
ny square inches for instance 3, be a
pound all the world over, & thus you
have a standard of Weights. Let a
bushel be so many of these feet deep; so many
in circumference &c. & then you have a stand-
ard measure of quantity. End of ye 1st Part

Part 2d. Of Mechanicks

Lect. 16th. Of the mechanical Powers

The science of Mechanics contemplates" the
"nature, kinds, and various affections of mo-
"tion, and moving bodies; and the structure
"and mechanism of all kinds of machines,
"commonly called the mechanical powers,
"whether simple or compound." No branch
of Philosophy has been of more real and
general utility to man than this. The ad-
vantages which are to be derived from it
constitute the external marks which dis-
tinguish civilized societies from savage bands.
"Those fair buildings whose magnificence &
grandeur awaken in the mind of the beholder
sensations of admiration & sublimity; those proud
cities, which cover the extended plain where
busy men resort, where commerce flourishes
where the arts have established the place
of their abode; those tall ships which defy
the wintry Tempests, while the winds sweep
with unbroken force the surface of the Ocean
plough up the billows, and howling over the
deep threaten dangers and horrors & death,
yet threaten in vain: all these are

offspring of that science; whose principles it is the object of this part of ye course to develope and explain. –

"Of the nature, kinds, and various affections of Motion and moving bodies" we have already spoken. This part has for its subject particularly mechanical Powers & mechanical machines.

Mechanics is divided into two parts, Rational and practical. The first of these comprehends the whole Theory of mechanics. The second will shew you how you may employ a given force to produce any proposed effect, by means of any machine or engine.

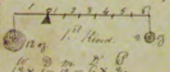
The mechanical Powers are, the Lever, the wheel & axle, the Pulley, the inclined Plane, the wedge, and the screw. Authors make different enumerations of them. Some make seven by taking in the balance. others make only five by rejecting the Screw. However these differences are not worth attending. In all mechanical machines the first thing that merits our attention is the Proportion, which the weight of

the body to be raised bears to that of the Power; for by making the velocity of the power as much greater than that of ye weight as the weight is heavier than the Power their momenta will be equal: whence they will exactly ballance each other. In all mechanical operations the two following Problems must be resolved, viz. 1. The proportion which the velocity of the power sh.d bear to that of the weight, in order to produce an equilibrium: & 2.dly The proportion in which a given force may produce the greatest possible effect. – (N B the weight is the resistance to overcome; the power is the force applied; the fulcrum is the point on wh. the machine is supported.) –

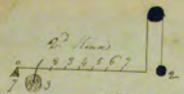
"There is one general rule of determining when the Power & weight will be in equilibrium. – When the intensity of the weight is to that of the Power as the velocity of the power is to that of ye weight, or in other words, when the power multiplied into its distance from the fulcrum, is equal to the weight multiplied into its distance (for their velocities increase according to their

respective distances; then will a balance take place between them. The advantage gained by any machine is as the excess of the momentum of the Power over ye momentum of ye weight. Four things then are principally to be considered, 1. the Power, 2d the weight, 3 the Prop. 4th the respective velocities of the Power and the weight.
Having premised thus much, we come to consider the mechanical powers, separately.

1st Of the Lever. A Lever is a right line (or bar whose weight in theory is not considered) moveable on a centre, which is called its fulcrum or fixed Point. There are four kinds of them. 1. where the weight is at one end, the Power at the other, & the prop between. 2. Where the prop is at one end, the power at the other, and the weight between, 3. Where the power is between the prop & weight wh. are at one end each. 4. the bended lever

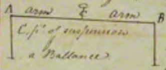


W D m D' P
12 × 1 = 12 = 6 × 2.

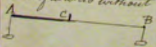


Which differs from the first kind only in shape, but not in its nature. Universally they will be in equilibrio when ye Power × into its distance from the Prop = weight × into its distance from prop.
To the first kind of lever may be referred the Steelyard. several sorts of Instruments, scissors, pincers, snuffers. To the 2d kind are referred, oars, rudders of ships, doors turning upon hinges, cutting knives &c. To the 3d kind are referred the bones in a mans arm, some of the muscles in the human body. the wheels in a clock &c. To the 4th kind we may refer the case of drawing a nail with a hammer & such like operations. The advantage gained by each

of these machines is as the excess of the Velocity of the Power over that of ye weight. The ballance tho' not a mechanical power deserves to be considered in this place. The Principal things requisite in its construction are 1st that the arms be in equilibrio; 2d that they be exactly of equal lengths; & 3d that the point of suspension be in the

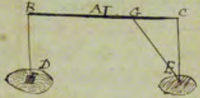


a Point directly below the Centre of gravity of the Beam; for the Beam must have an horizontal Position & if the point of suspension be the centre of gravity, it will rest indifferently in any Position. It is requisite that the arms be of the same length. They may be in equilibrio without this. Thus the



shorter arm AC may balance the longer CB: but what the first loses

in length, it makes up in thickness. This is what is called the deceitful balance. The seller may put his weight in the scale A, & the commodity in the scale B. From the difference in length of lever, it results that a weight of commodity less than the wt. in A will produce the equilibrium. The fraud may be detected by changing ye wghts.



There is a very curious property of the balance: let GE represent a man standing in the scale E pushing against the beam at G. Now altho he was at first completely balanced by the weight in D before he pushes the beam up; yet as soon as he does push it up, the scale E will descend. The reason is that the force, which he exerts against the Beam reacts in the scale E; so that he adds to his former intensity which was before the addition equal to the intensity of the wt D: therefore he descends.

2° of the Wheel & axle. This machine is a wheel, that turns round together with its axle: the Power here is applied to the circumference of the wheel & the weight is drawn up by means of a rope wound round the axis. And thus, there will be an equilibrium, when the wght is to the power, as the Diameter of the wheel is to that of the axle. The advantage of this machine is its capacity of raising weights higher than the lever can do, because it can turn round, & thereby renew, & continue the motion of the weight.

3° of The Pulley. This machine is composed of one or more wheels moveable in their axis. A simple pulley of its

 axis be fixed has no other effect than to alter the direction of the Power; for the Power & the weight will move with equal velocities; & therefore no advantage will be gained on either side. But in a moveable Pulley, or in a combination of pulleys, the equilibrium will be, when the power is to ye weight as 1. to the number of ropes, that pass between the upper & lower pulleys; or as twice the number of Pulleys. The advantage of this machine is, that it occupies a small space & is therefore portable & convenient. The disadvantage attending it, is the great degree of Friction, resulting from the small proportion, which the circumference of the Pulley bears to its axis. The rubbing of the pulleys against each other. The stiffness of the ropes.

4 Of the inclined Plane. We have given an Idea of an inclined Plane in a Preceeding Lecture. To produce an Equilibrium

the Power must be to the weight, as the height of the Plane to the length thereof; and the advantage gained by it is as great as the length exceeds the perpendicular height. If weight be fixed & a duly proportioned power be applied to the inclined Plane so as to produce an equilibrium; then if a little additional weight be added to ye power it will descend & draw the inclined Plane under the weight.

5. Of the Wedge. The wedge is only a double inclined Plane. If the resistance to be overcome acts perpendicularly to the sides of the wedge, then ye balance is produced when the power is to the resistance to be overcome, as half the thickness of the wedge is to ye length thereof. But if the resistance to be overcome acts parallel to the back of the wedge, then there will be an Equi-

-librium, when the Power is to the resistance as half the back, is to the perpendicular height of the wedge. The advantage is as the length of one side of the wedge is to ½ the width of the back. This instrument is useful in cleaving wood, &c.

6. Of the Screw. The screw is a machine made for the Pressure or raising of weights. It is not properly a simple machine, because it is usually used with a winch or lever to turn it. Here the equilibrium will be, when the Power is to the weight as the distance between any two contiguous threads or spirals in the screw to the way described by the Power in one whole revolution. The advantage is proportionable to the length of the winch by which the screw is turned & the smallness of the distance between the Spirals. –

Dr. Macsons answer to Mr. Fashers observation. See page 81 and 82. (turn over) –

D[r] Sir. — The descent along the Chord of any circle is certainly performed in the same time, as the descent along the diameter of that circle. It follows then that the whole vibration, or the fall and rise of two Chords, taking up twice the same time must be performed in the same time, that a body would fall thro' four diameters; that is thro 8 times the length of the Pendulum. But a body will fall faster in an Arc than a Chord; & it has been demonstrated. That the time of the fall in an arc, is to that in its Chord nearly in the same proportion of 785 : 1000. — There is also a remarkable experiment of Desagaliers, mentioned by Adams — by which he found that a leaden ball fell thro' 272 feet in 4". 30‴ Whereas from the Theory, it ought to have descended thro 325.. 6/8 The difference arose from the resistance

of the air as Desagalier has shewn. We must apply these two principles, & observe y[e] result. First, 39. 2 × 8 = 313. 6 which ÷[d] by 12 = 26.13. This would be the space thro' which a body would fall according to the proposition, in one second of time. apply y[e] first correction. — 1000 : 785 :: 26.13 : 20.51 apply y[e] 2[d]. correction 325.6 : 272 :: 20.51 : 17.1

You see then by these two corrections, that the 26.13 feet are reduced to 17½ feet. But. By a writer of great eminence, it may be reduced still farther, viz M[r]. Clairaut; — for he observes that the time in a small arc is not the same with y[e] Chord, tho the equal = secant arc be equal to its chord. according to him the time is nearly as 4 : 3.

But as 4 : 3 :: 26.13 : 19.8. instead of 20.51

Then as 325.6 : 272 :: 19.8 : 16.5 feet. —

This last you observe, coincides very nearly w[th]. the actual Experiment.

Jan[y] 1[st]. 1800 Believe me to be

yours very sincerely

M[r] Henry S[t] G Tucker — J— M—

Lect 11th of Compound Machines & Mills

Part 1st of compound machines in General

Compound machines, are made up of two or more or all of the simple mechanical Powers. The principle upon which an Equilibrium is produced, in any machine how complicated soever, is the same as in the most simple power; i.e. when the power multiplied into its Velocity = the weight × into its Velocity. To estimate the advantage gained, in any compound machine, find the separate advantage of each of the simple powers which constitute ye compound: multiply them into each other their product is the advantage gained. For illustration: Suppose there be a machine compounded of the lever, ye wheel & axle, and the inclined Plane in which the Lever gives advantage of 4;

the wheel & axle that of 8, & the inclined Plane of 2: then $4 \times 8 \times 2 = 64$ = the whole advantage. — A Person at first view might be inclined to think that were the separate advantages added together, their sum would give the Compound advantage. But if 3 Levers be united, the former position may be established very satisfactorily; for their separate advantages × into each, will give the whole advantage: suppose, for instance each lever give an advantage of 4: (i.e. suppose in each 1 oz. placed on the long arm will balance 4 placed on the short one) then $4 \times 4 \times 4 = 64$; one in that case balancing 64 oz. — But there is in all compound machines (& the more in ye more complicated) a great loss of time: the power being obliged to have as much more velocity than the weight, as the latter is heavier in it; so that what is gained

in Power is lost in time. — In constructing a machine ⅓ more of the power, which produces the equilibrium, is required to be added. This much is absolutely requisite but to work the machine with the greatest possible effect ⅘ should be added. —
The use of a Fly is to regulate the Motion of the machine. In Clocks & Watches, the Power is the weight or spring. — The resistance to be overcome is the friction of the wheels & other Parts of the instrument. The fusee in a watch is that part around which the chain is wound up. It's shape should be necessarily be conical; the Spring is wound in the barrel; when it is entirely wound up its strength is greatest, & at the same time it has a shorter lever to turn y^e^ fusee, the chain then going round the smallest part thereof: as the spring expands it becomes weaker; but at the same time

the lever whereby it acts becomes longer, the chain being upon a larger part of the fusee. Thus, equable motion is preserved.

Part 2: of Mills. — We shall consider three kinds of common water mills; Viz. the overshot, the breast, and the undershot Mills and the principle upon which they are severally founded. The overshot mill depends upon the Velocity & Weight of the Water compounded. The breast mill depends upon the weight of the Water alone; & the undershot depends upon the Velocity. The overshot is preferable where there is a small body of water, & a large fall in the Stream; the breast mill, where there is a large body of water & a small fall; and the undershot where the fall is very small & the force very great. — To determine the force of the water issuing thro' the Penstock — find the height in feet of the water above the aperture — find also the area of y^e^ aperture

in feet – multiply them together, and
multiply this product by 62.5lb. – the
weight of a cubic foot of fresh Water; –
the product will give the force of the
Water expressed in lb. – To find the
Velocity which the water acquires by
falling thro' any given height – take the
square root of the height & multiply it
by 8. – To find the height – take the
Velocity divide by 8, & square the product.
To find the quantity discharged – find the
Velocity for one second & × it by 60 for a
minute, × it by the area and divide by
1282, the number of solid inches in a
gallon – your Product will be the
number of gallons discharged in a
minute. – The Proportion which the
Velocity of the wheel should bear to that
of the water, in a well constructed Mill
as commonly assigned, is $\frac{1}{3}$ but $\frac{1}{2}$ is better.

The Velocity of a turning stone is generally
fixed at one in a second; but it should turn
faster. In an overshot mill, the water should
strike the wheel in a Tangent. The Centri-
fugal force causes the meal continually to
recede from the centre of the stone till it
is thrown off. The stones should be far-
ther from each other in the middle than
at the Edges; – and they should be furrow-
ed so as to cut the corn;
Part 3d Barker's Mill. – Upon examining
the construction of the mill it will be found
the holes in the Tubes, thro' which the Water
falls, are on different sides thereof. The Wa-
ter naturally presses equally on all sides;
but having a vent on one side of the tube (the
hole) the pressure is diminished on that side
which difference puts the mill in motion
tis the principle upon which it depends.
By having the holes on different sides in yr
different tubes, the two pressures operate together.

The whole will be more easily understood by an inspection of the machine itself. The force of the mill will be greater accord-ing to the velocity of the water, the hight from which it falls, the quantity which runs thro the spout, & the distance of these holes from the centre. The proper dimensi-ons are, the arms 3 feet long, holes 4 Inches square, tube 6 or 8 feet long, & 8 Inches diameter. The inconvenience attending this contrivance, arises from the great degree of friction of the pivot upon which it turns.

Part 3. Lucas's Pendulum Mill. This is a contrivance to make a mill turn by a Pendulum. But owing to a great degree of friction the Pendulum will not keep in motion of itself. Some person there-fore must keep it in motion; hence the motion will not be equable, which is the Principal objection to it. It may be

clearly understood by seeing the figure.

Part 4th of Wind Mills. - The best shape of the sails is that of a birds wing. If they be set right with the wind, it cannot aff-ect them at all. If they be set right against it the mill will be blown down; or at least the sails can have no power to move. They should therefore be set obliquely; & that at an angle of 54°. 44'. for the great-est advantage.

Lect: 12th. Of Wheel Carriages

Wheel carriages were invented for the great-er facility of conveying goods by land, which will appear the more clearly when we consi-der their advantages over sledges. But before we do this, it may be necessary to explain the cause of the rotation of a wheel upon its axis. It is owing to friction. In a surface perfectly smooth there could be none at all. "But if we suppose a wheel drawn along a common road, then the parts will receive unequal obstructions, for it must

"with obstacles that retard it at bottom;
"therefore the upper part of the wheel which is
"not retarded, will move more swiftly than the
"lower part, which is; but this it cannot do un-
"less the wheel moves round. — And thus it
"is that the obstacles on a rough road cause
"the circulating motion in a wheel. The
"Utility of wheels arises from their turning
"on their axle, the resistance arising from
"friction is very much diminished, & the
"draught thereby rendered more easy. Accord-
"ing to Helsham, a carriage with 4 wheels
"will be drawn with 5 times as small an
"effort as one that slides on the same
"surface with a sledge." — The observations
upon this subject may be comprized under
the 4 following general propositions.

1. Large wheels are more advantageous
than small ones in all cases. Let there be
a Carriage drawn on 4 wheels; see what

Power will draw it; change the wheels into
a smaller set, which may be to the first
as 1 to 2: a smaller weight will be suffici-
ent to draw the carriage on the first than
in the latter case. Large wheels do not
sink into a hole so deep as small ones
they have the advantage of a longer lever
in overcoming the friction upon the axle
Their advantage, when moving on a Plane
is as the square roots of the radii of ye wheels.

2. A Carriage with 4 wheels of equal size
is drawn with less force, than when on
2 large & 2 small ones. An experiment
was made which demonstrated the fact
Small wheels are used for the greater fa-
cility of turning. Some have supposed that
the large wheels push on the small ones.
The idea, says Ferguson is too absurd
and unphilosophical to be refuted. In
going up hill, however, & then to there must
be some advantage in having the wheels