№ 3.

Heads of a course of
Lectures on
Natural Philosophy

Mechanics

Center of Gravity.

— The center of gravity of a body is that point round which all the parts of the body are in equilibrio — This definition applies also to the C. of G. of a system of bodies — Consequently when the C. of G. is supported the body is at rest —

— A line passing thro' the C. of G. and perp.r to the horizon is the line of direction —

— A body will stand or fall according as the line falls within or without the base —

— Since the case or difficulty of overturning some bodies on one end — round bodies —

— When a body moves by Gravity the C. of G must always descend — Appearances to the contrary — Cylinder on the inclined plane — Double cone — Tumblers —

— A system is sometimes ~~of places~~ supported when the center of gravity appears not supported — — But with weight on the projecting end —

— Standing, sitting — walking — rising — running

— To find the center of Gravity — Geometrically — ~~Mathematically~~ — By Experiments

— Suspend any body any two points & plumb &c

— Centre of G. in a Globe — Cylinder — Cones and every other regular Body, is the same with the centre of Magnitude — or of the Body —

— Centre of Gravity of a Triangle is a line drawn from any angle bisecting the opposite side, at $\frac{2}{3}$ distance from the vertex —

— C. G of a Cone or Pyramid is $\frac{3}{4}$ from the Vertex &c —

Bodies Sliding — rolling down inclined Plane

— The centre of G. of two bodies is in a line joining their centres of Gravity — its distance inversely proportional to the quantity of matter —

— If a body projected in the air has a rotatory motion that motion is performed on an axis passing thro' the centre of gravity —

— The motion of a body or System of bodies is the same with that of the C. of G. —

— The mutual actions of two bodies on each other makes no change of the centre of Gravity — Moon and earth no change on the annual orb—

— If a plane passes thro' the centre of Gravity of any number of bodies and each body be multiplied by its distance from that plane the sum of the products on both sides are equal — as Emmon — Archmi —

— A body will remain at rest only when
the center of Gravity is supported and in
the line of bearing passes under to the
horizon this the center of motion —
under the Arch — with great difficulty above
Attention to the center of Gravity of great im-
portance in the construction of Machines
in Architecture, civil, military and Naval
Shall work. — Observation also of the centre
of motion necessary —

— Mechanical Powers —

— Compound Engines consists of two or more simple Elementary Mechanisms — Chemical analysis —

— Lever — wheel and axle — Inclined Plane wedge and Screw —

1 — Lever — F. between W. and P —
2 — Hand — W — F — P —
3 — Hand — P — F — W —

In all the three kinds there will be an Equilibrium between the Powers and W when they are reciprocally as their distances from the fulcrum —

— Demonstrations —

— Illustration by numerical Examples —

— 1 Kind or bended Lever — various forms — In every kind of Lever the fundamental Distance from the fulcrum to the line of direction of the Power and Weight must be taken as the true acting distance.

Let P = Power W = weight
a = Distance of P from the fulcrum
b = Distance of W from the fulcrum —
Then —

Problems Solution

1st Given P. a. b } $\frac{P \times a}{b} = W$
req'd W

2. Given P. W, a } $\frac{P.a}{W} = b$
req'd b

3. Given W. a, b } $\frac{W \times b}{a} = P$
req'd P

4. Given P. W. b } $\frac{W \times b}{P} = a$
req'd a

— The above suppose the lever to be an inflexible line without weights — In levers of the 1st and second kind, the weight of the lever is generally usefull in practical application of this instrument

— Instruments referred to the lever — This power must have been known in the earliest and most uncultivated state of mankind — Neptunes Trident — Greek name for lever and Trident the same = mochlos — Aristotles treatise on Mechanics —

+ When different weights are hung on the arms of a lever at different distances from the fulcrum — there will be an equilibrium when the sum of the products arising

from the multiplication of each weight into its distance from the fulcrum on one side, is equal to the product obtained in the same manner on the other — This calculation applies to Equilibrium in all sorts of machines —

— Aristotle's treatise on Mechanics the first, he makes the proportion of the power to the weight to be reciprocally as their distances — Archimedes's demonstration — Huygens — Newton's — McLaurin — Hamiltons —

— Balance —

Is a lever with equal arms — no mechanical advantage — to Athea — Instrument placed in the heav— — Balance with unequal arms. Statera Romana — Italy — Aristotle — Phalanx — False balance — unequal arms nearly equal — will determine accurately the true weight of a body — True wt. is a Geometrical mean between the false weights — If the difference between the arms be small the arithmetical mean may be taken instead of the G.l — If the arms be 9 and 10, and the true weight 10 Oz the two false will be 9 — 11 1/9 for 9 : 10 : 11 1/9

— A man standing in one scale of a balance and pressing against any part of the beam except against his own point of suspension, will make himself heavier — The longer the arms the better — little friction — adjusting screw — care about the points of suspense — ~~they~~ Zugostatai overseers of the weights and measures — Great care of the Jews with respect to weights and measures — Standards preserved with religious ceremony in the sanctuary by the Priests and Levites

— Wheel and Axle —

— The defect of the lever is raising weights but to a small distance — this remedied by the axis in Peritrochio or wheel and axle — By this Instrument a weight may be raised to any given height less than that of the wheel[1]. There will be an Equilibrium when the power is to the Wt. as the radius of the axle is to the radius of the wheel —

— When the thickness of the rope is considerable it should be taken to account, adding half the thickness of each rope to the radius of both wheel and axle —

— Instruments referable to the axis in peritrochio

— Capstan — remarks — Bucket cylinder for a well

— Clock wheels — remarks — Diameters as the No. of teeth

— Wheel and axle called by Aristotle onos

Pulley

On every fixed pulley there will be an Equilibrium when the power is equal to the weight. A fixt pulley therefore wh̄ether above or below, serves only to alter the direction, and render the application of the power more convenient — Exemplified —

— On a single moveable pulley — Elq^m. is the P. : W : 1 : 2

— There will be Eq^m. in any system of pullies where the same string goes over all the pullies contained in two blocks when the P. : W :: 1 : No. strings at the lower block —

— When every moveable pulley has a separate string, Eq^m. P. : W : 2^{no pullies}

— In a System where the string that goes round each pulley has one end fixed to the weight — Eq^m. P. : W :: as that power of 2 − 1 of which the index is the No. of moveable pullies —

Examples 3 moveable pullies give a purchase = 15. 4 = 31. 5 = 63. 6 = 127.

— In all the other systems the weight of the moveable pullies acts against the

proves; but in the last mentioned system
it is in favour of it —
— Other combinations —
— Advantage of the Pulley — easily moved
each in every direction
— Should call a movable block
with two pulleys Differentes with three
pulleys — with many Polyspastos —

— Inclined Plane —

If the direction of the power be parallel to the plane. — Eg^ms P. : W : : H. : L. —

If the direction be parallel to the line Eg^ms P. : W. : : B. H. —

If the direction is any how inclined Eg^ms P. : W. : : sine of the plane elevation is to the Co. sine of the angle formed by the direction of the power and the plane

Equilibrium on two inclined planes

Wedge

- If the resistance acts perpendicularly on the sides of the wedge and the power perpendicularly on the back, then the will be an equilibrium when D. B :: Length of the back : to the sum of the sides or as the sine of the semi-angle at the Vertex is to the Radius

- Resistance oblique — Cases failed ——

X Various determinations respecting the power of the wedge ——

Screw —

— Formed by wrapping a right angled triangle round a Cylinder —

— Eqn when the P: W:: Distance between two contiguous threads is to the Circumference described by the Power —

— N.B. The distance between the threads must be taken in a line parallel to the axis is ——

— Hunters Screw — principle Salu-

Miscellaneous Observations on the Mechanic Powers

— The preceding calculations suppose the Levers an inflexible straight Line without weight, that ropes are perfectly flexible that there is neither friction nor inertia in the matter of the machine — But notwithstanding these the conclusions drawn from theory will not correspond with Experiment unless an allowance is made which must be determined by Experiment —

— In the Lever there is little friction and the weight of the matter of Lever is the most common application of it adds to the friction —

— In the wheel and Axle the friction on the Gudgeons or pivots is considerable and encreases with the diameter of the pivots — The rapidity of the axle also encreases the power of the Instrument — To ascertain the Loss of power by friction &c — Produce an Eq.n as formerly directed, then add to the power as much weight as will just put the machine in motion, this will measure the resistance. —

Pulley was called by the Latin writers Cochlea
Friction in the best common blocks used
in the Navy = $\frac{1}{4}$ so that two under pulleys
in one moveable block produces instead of 4
an effective purchase only of 3 —
Friction rollers — patent blocks —
Smeatons combinations — prevents cording
which position greatly increases friction
Seamen ~~seldom~~ over rate ~~the~~ purchase by
blocks — reason — mode of applying the
power —
The Inclined plane is not mentioned
by ~~the~~ ancient writers as a mechanical
power —
Wedge is described by Aristotle num-
Screw not mentioned by Aristotle, but
afterwards it is described by Pappus — and
Persian screw — It is highly probable that
Archimedes used the Screw — Helix
The Great friction of the screw of sever
in practice, it detains the purchase —
The action of a fly on a compound
machine — has not been sufficiently consi-
dered — Two sorts of flies — resistance of
the air — Its own weight —

+ General property of all Machines whether simple or compound is that, —
There is an Eqm. on every Machine when P. : W : as the space through which the W. moves is to the space through which the P. moves, in the same time and consequently the product of the P. into its velocity is equal to the product of the W. into its velocity — Hence
— What is gained in power is lost in the time of working any machine —
— Strictly speaking there is no gain of force by any Mechanical Engine — only convenience in the application — If a man raises five weights one after another, he will take the same time to raise them by a tackle producing a purchase of five
— Should it be reqd. to raise one weight equal to the five, here it must be done either by five men or one man in five times the space of time — Hence a perpetual motion seems impossible. — Other reasons.
— In a populous country powerful Engines are of less use — Answer of the Emperor to a proposal of the Jesuits to erect corn Mills Should I starve 5 Millions of my Subjects? —

were the particles of matter in contact and the fibres straight, the resistance in the first instance would be unsurmountable. This very great. In the 2 it is less and in the least of all —

From a medium of a number of Exp it is appears that the strength

of Oak is as —	12
— Yew —	11
— Ash —	10
— Elm —	9
— Walnutt —	8
— Fir, Alder, plane —	7
Beech, Hazzle, Birch, Willow	6

— Remarks — The results of Experiments made on the absolute strength of timber are various differing considerably among themselves —

— Strongest oak to the best fir appeared by one set to be as 3 to 2 —

—Beams ~~are~~ of different dimensions are as their sections multiplied into ~~hain~~ ~~the~~ dist: of the Centr. G^{2} from the base, and divided by the length—

—Beams of the same length are as their sections multiplied into ~~the~~ distance of their Center of G^{r} from the base—

—Common joists as the square of the depth × base—

—Hence the advantage of placing joists on their least side for a base—

—A beam will ~~twice the~~ support wt. spread equally over it, that it will support when hung to ~~the~~ center—

—A beam fixed down at ~~the~~ extremities continued beyond the props will bear ~~twice~~ the weight as when lying loose on its support.

Triangular

—Beam placed with angle downwards will bear but half the weight it will when the angle is placed upwards, the beam is supp~~orted~~ supported on both ends—

a
Short of Stone 3 ...

— Method of trussing beams

— wedge driven in from above will raise the beam

— Pieces nailed to the beam obliquely

— Best position of a mortise is in the middle of the beam —

— Beams of equal strength

— Couples and rafters will bear a wt. which is proportional to what they would bear in a horizontal position as the Radius is to ~~to the~~ Co-sine of the angle of elevation —

— Of Roofs — Bridge Centers &c —

If a beam is supported at both ends a mortis ~~taken~~ out above is stronger than when ~~taken~~ out below provided the tenon be driven in hard — fixed

— If a piece is to be spliced on a beam to strengthen it, it will have the best effect when put on the upper side, if the beam be supported at both ends; but if only at one end it should be applied below —

— A Slender rod is most firmly supported by two Supports $\frac{3}{5}$ Distant from each other and equidistant from the two extremities —

— The Natural Strength of a hollow Cylinder is to that of a Solid Cylinder of the Section of the former including the Bore is to the Cubes of the Second and the Diameter of the first to the Diameter of the second nearly — Hence the use of Gudgeons in Fowls —

— To cut out of a round tree the Strongest Possible Beam possible Divide the Diameter of the circle into three equal Parts, from the two Points of Division Draw lines perpendicular on opposite sides of the Diameter to the circumference. Join the two Points where the lines meet the circumference and the ends of the Diameter of the circle. The Rectangular Beam set on its edge is the strongest possible —

— To determine the best angle of a Flood-gate

— The tendency of every Beam to break by its own weight increases in a higher proportion than the Strength with given Dimensions —

Consequences

— Hence a Beam may be increased, and proportionally in its Dimensions, so as to fall to pieces by its own

— Now also there is but one beam that will just
support—
Engines may be constructed so large as not only
to fail of the effect expected, but to fail to move, by their
own weight.—
— Small Engines stronger than large ones in proportion
— The same observations especially to animals
× If a beam supported at one end just breaks by its
own weight = Two Double the length, and supported
at both ends with just breaks —
— A rope of good hemp an inch in circumference will
bear 100 lb, and ropes generally as the square
of the diameter —
— Comparison between Models and
Engines at Large — Models shew the
manner but not the proportionable
quantity of work done by a large Engine
— This the cause of failure frequently in
constructing large Engines
— Experiments to determine the proportion
of an Engine, should be made on the
machine at Large, not on the model
— Examplified on Shot carriages —
+ An engine may be in perfect proportion
in a good model and yet not be able to bear its
own weight —

Friction —

Increases with weight and velocity in the direct ratio of the former, but not of the latter. If the pressure and velocity remain the same, the surface makes little change in the friction —

Wood on the ground has less friction in wet weather ~~than~~ then in dry — slides ~~more easily than iron in dry~~, but iron more easily in wet wr. — Soft wood on hard has a friction equal to $\frac{1}{6}$ part of its weight — Hard wood on hard about $\frac{1}{8}$ of its weight — Oil or grease makes the frictn of wood on wood $\frac{2}{3}$ less — Wheel axles have 2 times less friction ~~than~~ when greased ~~than~~ when wet

— Polished steel on steel or pewter properly oiled ~~the~~ friction is about $\frac{1}{4}$ of the weight — on copper or lead $\frac{1}{5}$ — on brass $\frac{1}{6}$, and like produce more friction than unlike metals

— Black lead stirred into oil or melted tallow diminish the friction much on Mill cogs —

— Of Friction wheels — their principle of action —

— Applied to waggons — Carriages — Blocks &c —

+ To ascertain the friction of a Wheel carriag. Incline the plane till it begin to roll. The friction then is ~~as the~~ to the wr ~~length~~ height of the plane to the ~~perpendicular~~ ~~height~~ Length —

Compound Engines

Powers calculated —

Compound Lever — Jacks — Pile Engine

Clocks and watches — Wheel Carriages

Ploughs — Engines for raising water

— Steam Engines — Machines used in

Manufactures — Silk mills, Cotton Mills

— Spinning frames — Boring Engines

— Engines of War Ancient and Mo-

— dern — Engines belonging to Naval

Architecture — See Tactics —

— Engines for inland Navigation —

— Flood gates — Locks — Piers — Jetties

— and Embankments &c

Perpetual Motion

– Various Schemes

1 By Magnetism

2 By Syrups – Archimedes's Screw –

3. By a wheel with ~~spiral~~ hollow spokes containing mercury – a lead ball

4. By a wheel whose spokes are jointed so as hang on one side and project out on the opposite

---

5. By the pressure of the Atmosphere on the Mercury i.e. Barometer so constructed as to wind up a clock – Cox's Museum

Friction — additional resistance which increases with the velocity to a certain degree, after which it is diminished — Every moment has not time to fall into very cavity immediately before it —

— Friction be minified in many cases it is useful in some — Viz. Compasses — Screws &c. —

— The friction in the best common clocks in the Royal Dockyards Portsmouth is reckoned about ¼ of the Purchase

— Ropes —

— Commonly too much Cordage
fibres are weakened by being twisted
to oblique. —

— Hemp — Flax — Coir — Grass &c
Yarn —

— Experiment — All the Strands of
a rope will when untwisted bear
a greater weight than the rope when
made —