FORCE

FORCE – A force is that physical cause which changes (or tends to change) either the size or shape or the state of rest or motion of the body.

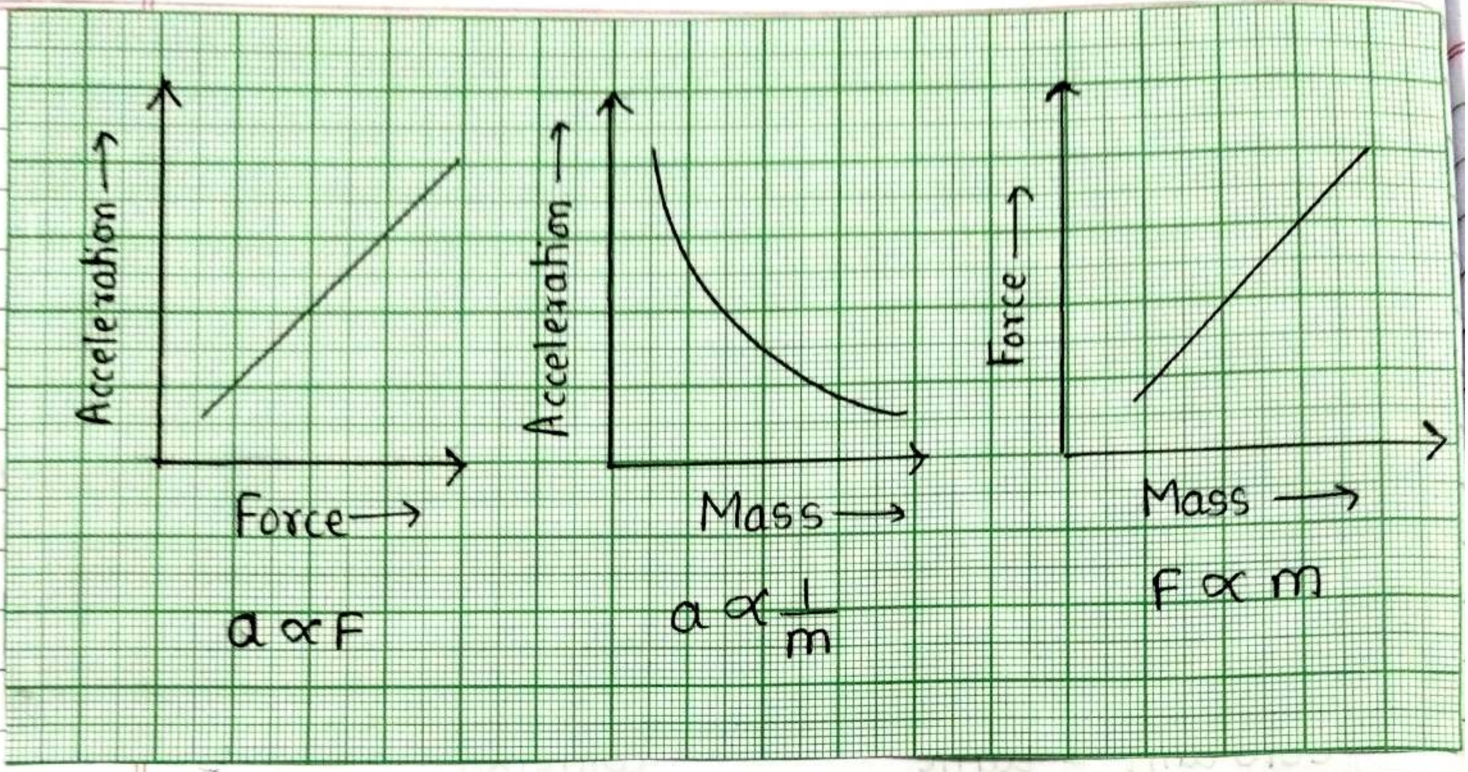
S.I. unit = Newton (N)
CGS unit = dyne
$1\ N = 10^5$ dyne

KINDS OF FORCE

CONTACT FORCE	NON CONTACT FORCE
– Frictional	– Gravitational
– Normal reaction	– Electrostatic
– Tension	– Magnetic
– Spring force	
– Force due to collision	

NEWTONS LAWS OF MOTION –

FIRST LAW	SECOND LAW	THIRD LAW
A body continues to be in its state of rest or of uniform motion in a straight line unless an external force is applied on it. This law is also called "LAW OF INERTIA"	The rate of change of momentum of a body is directly proportional to the force applied on it and this change in momentum takes place in the direction of applied force. $F \propto \frac{\Delta p}{\Delta t} = \frac{m \Delta v}{\Delta t}$ $F = ma$	To every action there is alway an equal and opposite reaction. $\vec{F_{12}} = -\vec{F_{21}}$



MOMENTUM –

The momentum of a body in linear motion is the product of the mass of the body and its velocity.

$$p = mv$$

It is vector quantity.

S.I unit = $kg\,m\,s^{-1}$

C.G.S. unit = $g\,cm\,s^{-1}$

EQUATIONS OF MOTION –

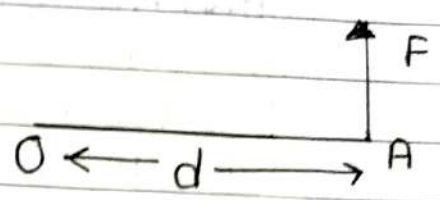
i) $v = u + at$

ii) $s = ut + \frac{1}{2}at^2$

iii) $v^2 = u^2 + 2as$

MOMENT OF FORCE -

The turning effect produced by a force on a rigid body about a point, pivot or fulcrum is called moment of force.



$\tau = d \times F$

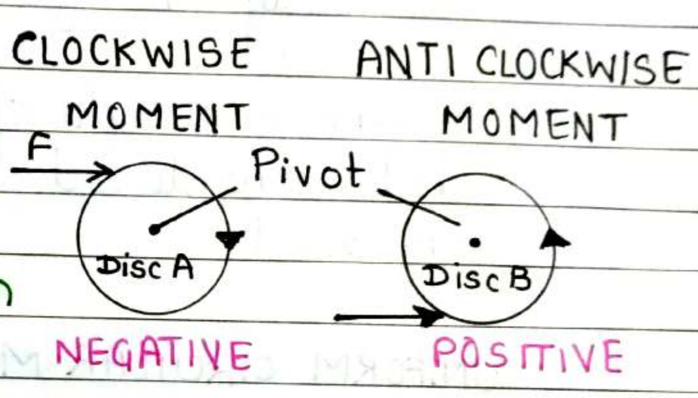
S.I. unit ⇒ Nm

C.G.S. unit ⇒ dyne cm

$1\,Nm = 10^7$ dyne cm

1 kgf m = 9.8 N m

1 gf cm = 980 dyne cm



EQUILIBRIUM OF BODIES

When a number of forces acting on a body produce no change in its state of rest or of motion the body is said to be in equilibrium.

KINDS OF EQUILIBRIUM

- STATIC EQUILIBRIUM
- DYNAMIC EQUILIBRIUM

CONDITIONS FOR EQUILIBRIUM -

1) The resultant of all the forces acting on a body should be 0.
2) Algebraic sum of moments acting on a body should be 0.

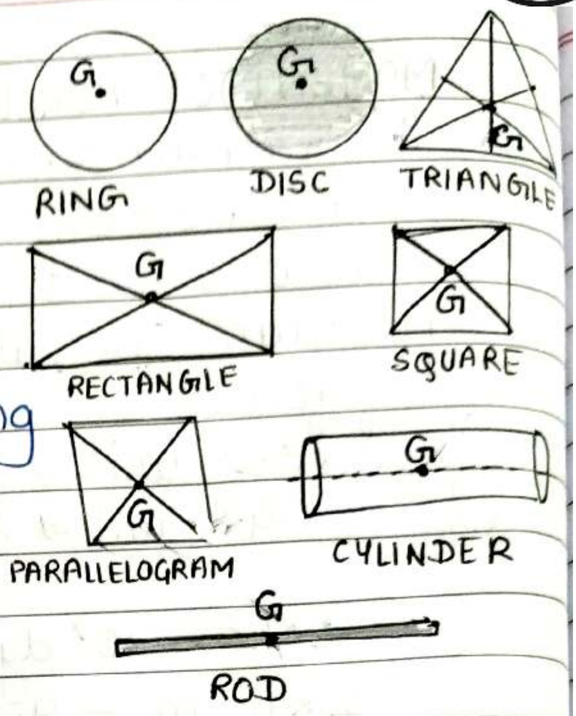
PRINCIPLE OF MOMENTS -

According to principle of moments in equilibrium

Sum of anticlockwise moment = Sum of clockwise moment

CENTRE OF GRAVITY –

The centre of gravity (C.G.) of a body is the point about which the algebraic sum of moments of weights of all the particles constituting the body is zero.

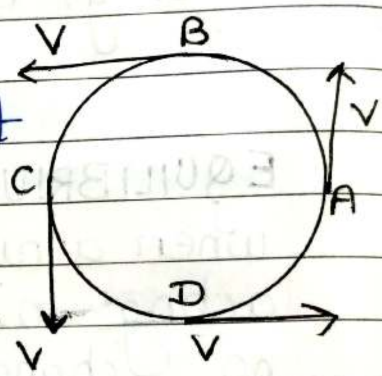


The entire weight of the body can be considered to act at this point.

UNIFORM CIRCULAR MOTION –

When a particle moves with constant speed in a circular path, its motion is said to be the uniform circular motion.

It is accelerated motion



CENTRIPETAL FORCE	CENTRIFUGAL FORCE
A force that acts towards the center of circle, keeping object moving in circular path.	A force that acts away from center of a circle.
It is a real force.	It doesn't really exists

FORMULA SHEET

1) Momentum (p)

$$p = mv$$

p - momentum, m - mass, v - velocity

2) Force (F)

$$F = ma$$

F → Force, m - mass, a - acceleration

3) Equations of motion

$$v = u + at$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

u - initial velocity
v - final velocity
t - time
a - acceleration
s - distance travelled

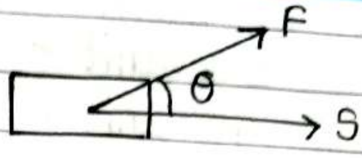
4) Moment of force (τ)

$$\tau = d \times F$$

d - perpendicular distance from pivot, F → Force

WORK, ENERGY AND POWER

WORK - Work is said to be done only when the force applied on a body makes the body move.
It is scalar quantity.



$W = FS\cos\theta$

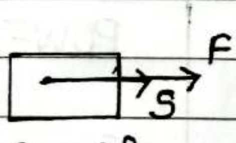
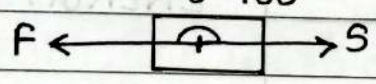
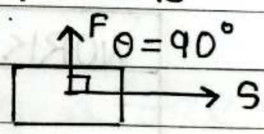
F - applied force
S - displacement
θ - ∠ b/w force and displacement

S.I. unit = joule (J)
C.G.S. unit = erg

$1\,J = 10^7\,erg$

$1\,kJ = 10^3\,J$, $1\,MJ = 10^6\,J$, $1\,GJ = 10^9\,J$

DIFFERENT CASES OF WORK DONE -

W → POSITIVE	W → NEGATIVE	W → ZERO
 θ = 0°	θ = 180° 	θ = 90° 

POWER - The rate of doing work is called power.
It is a scalar quantity

$$\text{Power } P = \frac{\text{Work done } W}{\text{Time taken } t} \qquad P = \frac{W}{t}$$

$$P = \frac{F \times S}{t} = F \times V$$

F → force V → Avg. speed

S.I. unit = watt (W)
C.G.S. unit ⇒ erg s^{-1}

$1\,W = 10^7\,erg\,s^{-1}$
$1\,H.P. = 746\,W = 0.746\,kW$

ENERGY - The energy of a body is its capacity to do work.

S.I. unit = joule (J)

C.G.S. unit = erg

Bigger unit of energy kilowatt hour (kWh)

$$1\,kWh = 3.6 \times 10^6\,J = 3.6\,MJ$$

Heat energy is usually measured in calorie.

$$1\,J = 0.24 \text{ calories}, \quad 1 \text{ calorie} = 4.18\,J$$

The energy of atomic particles is measured in electron volt (eV).

$$1\,eV = 1.6 \times 10^{-19}\,J$$

WORK	ENERGY	POWER
It is equal to product of force & displacement in direction of force	Capacity to do work.	The rate of doing work.
Does not depend on time.	Does not depend on time.	Depends on time
S.I. unit → joule	S.I. unit → joule	S.I. unit → watt

DIFFERENT FORMS OF ENERGY -

1) MECHANICAL ENERGY - The energy possessed by a body due to its state of rest or of motion is called mechanical energy. It is in two forms:
(i) Kinetic energy (ii) Potential energy

↦ Kinetic energy - Energy possessed by a body by virtue of its state of motion.

$$K = \frac{1}{2}mv^2$$

K → kinetic energy
m → mass
v → velocity

There are 3 forms of K.E. -
① Translational K.E.
② Rotational K.E.
③ Vibrational K.E.

Relation b/w K.E. & momentum

$$p = \sqrt{2mK} \text{ or } K = \frac{p^2}{2m}$$

Work energy theorem - The work done by a force on moving body is equal to the increase in its kinetic energy.

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

↦ Potential energy - Energy possessed by a body by virtue of its specific position (or changed configuration) is called potential energy.
It is usually denoted by symbol U.
It is mainly of two types -
① Gravitational P.E.
② Elastic P.E.

Gravitational P.E. is the amount of work done in raising a body from ground to a point at height h, against gravity.

$$U = mgh$$

m- mass of object, g → acceleration due to gravity
h → height through which object is raised

2) Solar energy - energy radiated by sun.

3) Heat energy - Energy released on burning coal, oil, wood, gas.

4) Light energy - Energy in presence of which other objects are seen.

5) Chemical energy - Energy possessed by fossil fuels.

6) Hydro energy - Energy of fast moving water.

7) Electrical energy - Energy possessed by charged body due to movement of free electrons.

8) Nuclear energy - Energy released due to process of nuclear fission or fusion.

ENERGY CONVERSION -

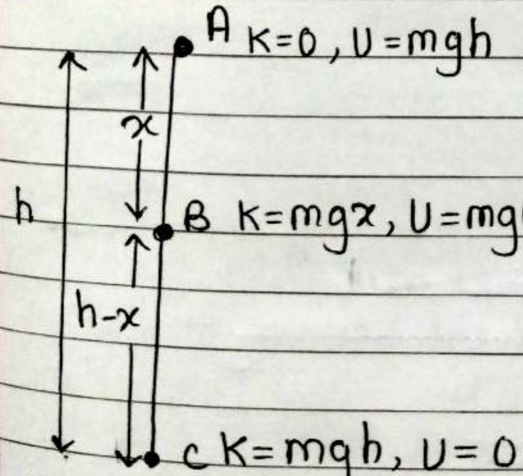
i) mechanical → electrical = Electric generator (dynamo)
ii) electrical → mechanical = fan, washing machine, mixer
iii) electrical → heat = heater, oven, geyser, toaster
iv) heat → electrical = thermocouple
v) electrical → sound = loudspeaker
vi) sound → electrical = microphone
vii) light → chemical = photosynthesis
viii) light → electrical = photoelectric cell

ENERGY SOURCES -

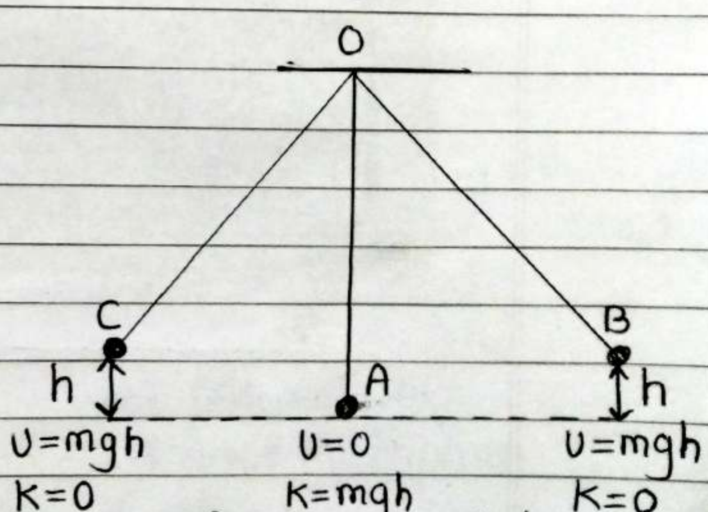
Renewable or non conventional source	Non-Renewable or conventional source
A natural source providing us energy continuously is called renewable source of energy.	These are the sources from which energy cannot be continuously obtained over a long period of time.
These sources can be regenerated.	These sources cannot be regenerated.
Eg- sun, wind, flowing water, tides, oceans, geothermal spots, nuclear fuel	Eg- coal, petroleum, natural gas

LAW OF CONSERVATION OF ENERGY -

Energy can neither be created nor can it be destroyed. It only changes from one form to another.



Free fall of body



motion of simple pendulum

FORMULA SHEET

① Work (W)

$$W = FS\cos\theta$$

W - work, F → Force, S → Displacement, θ → ∠ b/w F & S

② Power (P)

$$P = \frac{W}{t}$$

P → power, W → work
t → time

$$P = F \times V$$

F → force
V → avg. speed

③ Kinetic energy (K)

$$K = \frac{1}{2}mv^2$$

$$K = \frac{p^2}{2m}$$

K - K.E., m → mass, v → velocity, p → momentum

④ Gravitation P.E. (U)

$$U = mgh$$

m → mass, g → acceleration due to gravity, h → height

⑤ Work energy theorem -

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

MACHINES

MACHINE - It is a device by which we can either overcome a large resistive force (or load) at some point by applying a small force (or effort) at a convenient point and in a desired direction or by which we can obtain a gain in speed.

Uses of machine-
- Multiply force
- To change direction of the force
- To increase or decrease speed

Terms related to machine-

1) LOAD - The resistive or opposing force to be overcome by machine.

2) EFFORT - The force applied on machine to overcome load.

3) MECHANICAL ADVANTAGE (M.A.)
Ratio of the load (L) to the effort (E)

$$M.A. = \frac{Load (L)}{Effort (E)}$$

It has no unit.

M.A. > 1 ⇒ force multiplier
M.A. < 1 ⇒ gains speed
M.A. = 1 ⇒ change in direction of effort.

4) VELOCITY RATIO (V.R.)
Ratio of distance moved by effort (d_E) to the distance moved by load (d_L).

$$V.R. = \frac{\text{Velocity of effort } (v_E)}{\text{Velocity of load } (v_L)}$$

$$V.R. = \frac{V_E}{V_L} = \frac{d_E}{d_L}$$

It has no unit.

V.R. < 1 ⇒ gains speed | V.R. > 1 ⇒ force multiplier
V.R. = 1 ⇒ changes direction of effort

5) WORK INPUT - (W_{input}) - The work done on the machine by the effort.

6) WORK OUTPUT (W_{output}) - The work done by machine on the load.

7) EFFICIENCY (η) - It is the ratio of work done on load by machine to the work done on machine by effort.

$$\text{Efficiency}(\eta) = \frac{\text{Work output}}{\text{Work input}}$$

It can be expressed in percentage, It has no unit.

$$\eta = \frac{W_{output}}{W_{input}} \times 100$$

IDEAL MACHINE - An ideal machine is that in which there is no loss of energy in any manner. The efficiency of ideal machine is 100%.

Relation between η, M.A. and V.R. -

$$\eta = \frac{M.A.}{V.R.}$$

MACHINE

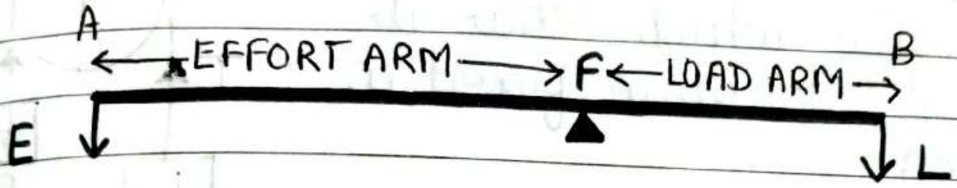
- LEVER
- PULLEY

LEVERS – A lever is a rigid straight (or bent) bar which is capable of turning about a fixed axis.

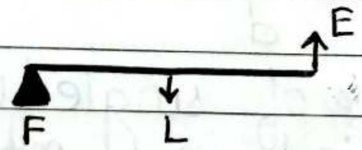
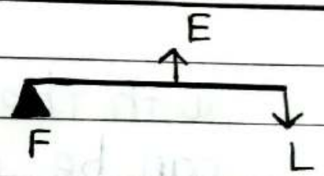
According to principle of lever,

Movement of load about fulcrum = Movement of effort about fulcrum

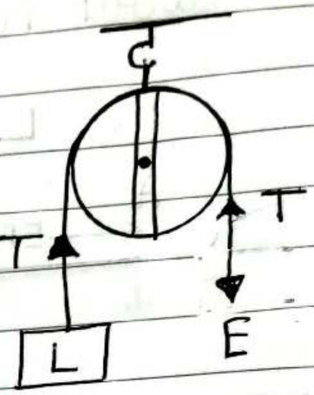
$$L \times d_L = E \times d_E$$



KINDS OF LEVERS –

CLASS I	CLASS II	CLASS III
		
M.A. =1, M.A. <1, M.A. >1	M.A. >1	M.A. <1
V.R. =1, V.R. <1, V.R. >1	V.R. >1	V.R. <1
Eg- A pair of scissors, handle of water pump, a catapult, noding of human head.	Eg- Bottle opener, wheel barrow, paper cutter, raising weight of human body on toes.	Eg- Sugar tongs, foot treadle, spade lifting load, forearm used for lifting a load

PULLEY - It is a wheel on an axle that is designed to support movement and change the direction of a cable or belt along its circumference. A set of pulleys assembled so that they rotate independently on the same axle to form a block is called pulley system.



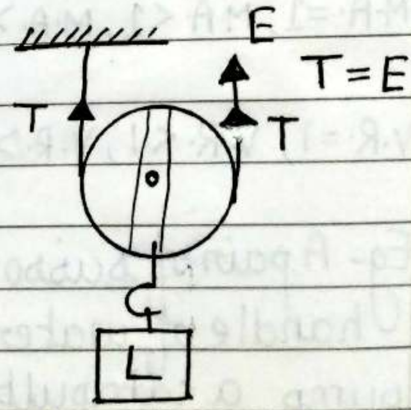
Single Fixed Pulley -
A pulley which has its axis of rotation fixed in position.

$$M.A. = \frac{Load}{Effort} = \frac{T}{T} = 1$$

$$\eta = \frac{MA}{VR} = 1 \text{ or } 100\%$$

$$V.R. = \frac{d_E}{d_L} = \frac{d}{d} = 1$$

With the use of single fixed pulley effort can be applied in more convenient direction.



Single Movable Pulley -
A pulley whose axis of rotation is not fixed.

$$M.A. = \frac{Load}{Effort} = \frac{2T}{T} = 2$$

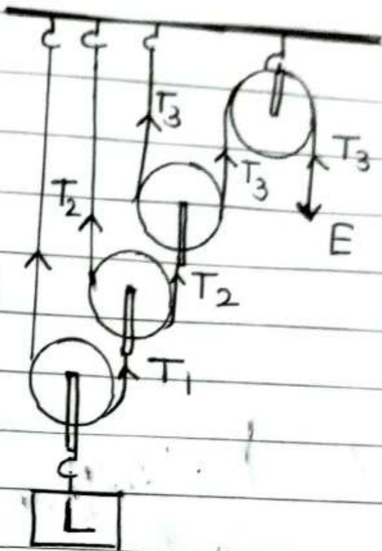
$$V.R. = \frac{d_E}{d_L} = \frac{2d}{d} = 2$$

$$\eta = \frac{MA}{VR} = \frac{2}{2} = 1 \text{ or } 100\%$$

It is used as force multiplier.

COMBINATION OF PULLEYS -

① Using one fixed pulley and other movable pulleys -

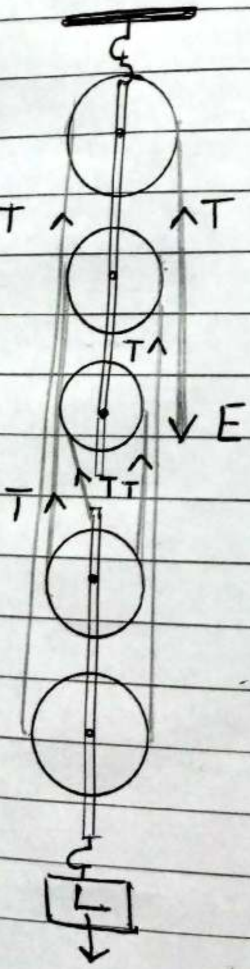


$$M.A. = 2^n$$

$$V.R. = 2^n$$

$n \Rightarrow$ number of movable pulleys

② Using several pulleys in two blocks (block and tackle system)



$$M.A. = \frac{Load}{Effort} = \frac{nT}{T} = n$$

$$V.R. = \frac{d_E}{d_L} = \frac{nd}{d} = n$$

$$\text{Efficiency } \eta = \frac{M.A.}{V.R.} = \frac{n}{n} = 1 \text{ or } 100\%$$

n = total number of pulleys

Effect of weight of pulleys on M.A., V.R. and η

$$M.A. = \frac{L}{E} = \frac{nE - W}{E} = n - \frac{W}{E}$$

$n \Rightarrow$ no. of pulleys, $w \Rightarrow$ weight of lower block (total)

FORMULA SHEET

① Mechanical Advantage $(M.A.) = \frac{\text{Load }(L)}{\text{Effort }(E)}$

② Velocity Ratio $(V.R.) = \frac{\text{Velocity of effort }(V_E)}{\text{Velocity of load }(V_L)} = \frac{d_E}{d_L}$

③ Efficiency $(\eta) = \frac{W_{output}}{W_{input}}$ | In % $\eta = \frac{W_{output}}{W_{input}} \times 100$

④ $\eta = \frac{MA}{VR}$

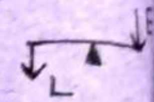
⑤ Principle of Lever ⇒ $L \times d_L = E \times d_E$

⑥ Kinds of Lever

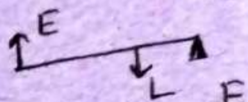
$M.A. = \frac{\text{Load Arm}}{\text{Effort Arm}}$

$V.R. = \frac{d_E}{d_L}$

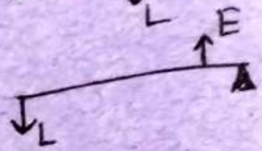
- Class I: MA = 1, MA > 1, MA < 1



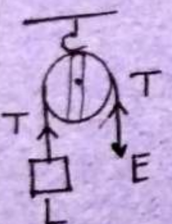
- Class II: MA > 1



- Class III: MA < 1



⑦ Single Fixed Pulley

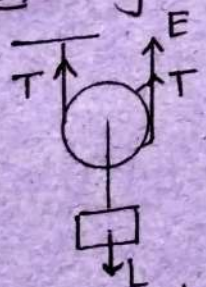


$M.A. = 1$

$V.R. = 1$

$\eta = 1$ or 100%

⑧ Single Movable pulley



$M.A. = 2$

$V.R. = 2$

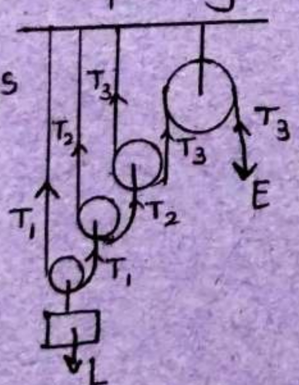
$\eta = 1$ or 100%

⑨ Combination of pulleys

1 fixed & n movable pulleys

$M.A. = 2^n$

$V.R. = 2^n$



⑩ Block and tackle system –

n number of pulleys

$M.A. = n$

$V.R. = n$

If total weight of pulleys in lower block is W

$M.A. = n - \frac{W}{E}$, $V.R. = n$

$\eta = 1 - \frac{W}{nE}$