MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

ENGINEERING MECHANICS

By- Ravinder Sir

Engg. Mechanics

"Study of motion of rigid bodies under the action of external forces."

- Statics (Rest)
  - Equilibrium
  - Plane Trusses (Imp)
  - Principle of virtual work
  - CC) centroid & centre of gravity (CG)
- Dynamics (motion)
  - → Translation
  - → Friction (Imp.)
  - → Circular motion
  - → Impulse momentum eq^n
  - → Rotation
  - → General motion
  - → Work Energy time

- **Exclusivity for Gate**

- friction & its application
- → Rolling friction
- → wedge
- → Screw Jack
- → Application in vehicles
- → Belt friction
- ✳ Lagrange's Equation

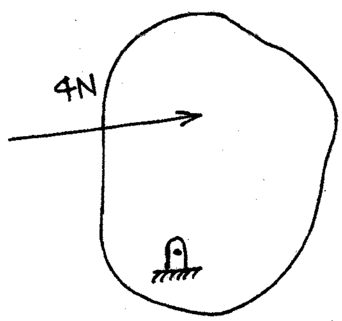
• **Actual Force :→**

If a force has been Acted on the body then it must have been applied by some other Body

• **Pseudo Force :→**

If a force is acted upon a body but has Not been applied by any other body.

To define a force →
- Magnitude (Intensity)
- direction (orientation)
- Point of application



• **Types of Forces**

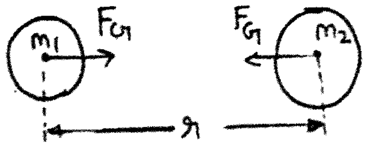
1. Gravity (W)

2. Contact force (R) →
   - Normal Reaction (N)
   - friction (f)

3. Tension (T)

4. Spring force (F_s)

• Gravity →



$$\boxed{F_G = \frac{G m_1 m_2}{r^2}}\ \star$$

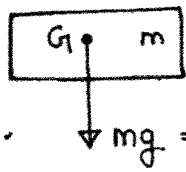
$G = 6.67 \times 10^{-11}$

$$\boxed{g = \frac{G M_e}{R_e^2}}\ \star$$

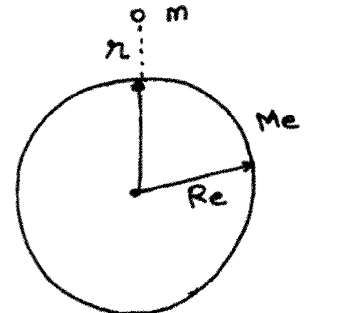
M_e = Mass of Earth

R_e = Radius of Earth

$\star$ $\boxed{W = mg \text{ (Pulling)}}$



mg ⇒ on mass m by Earth

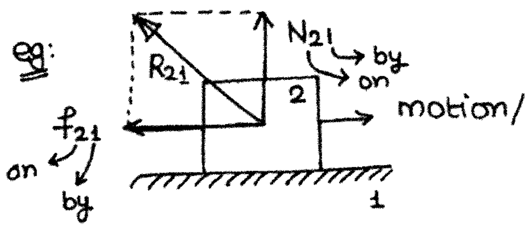


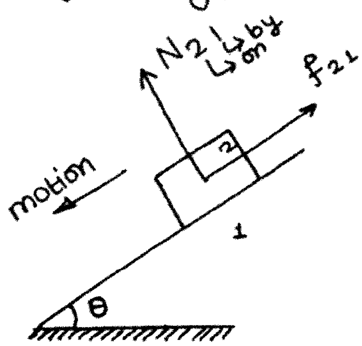
$F_G = \frac{G M_e m}{R_e^2}$

$\boxed{F_G = mg}$ $(R_e + r \simeq R_e)$

• contact Force →
- → Normal Reaction (Pushing)
- → Friction

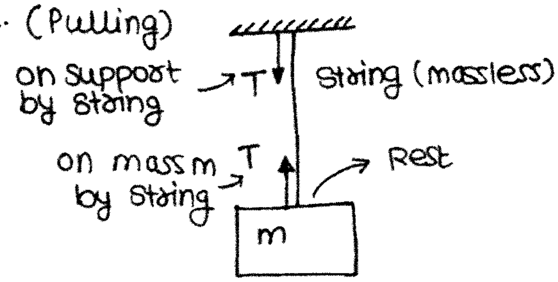
eg:



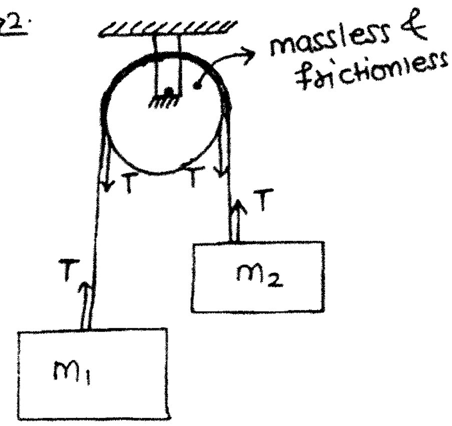


• Tension →

ex→1. (Pulling)



ex→2.



• Spring Force (F_S) ⇒

(Can be Pulling or Pushing)

$F_S = K(\Delta x)$

- K → Spring constant
- Δx → elongation or Compression from Natural Length

- **Newton's First Law (NFL):** →

For a Particle

if $\sum \vec{F} = 0$ then $\vec{a} = 0$ (at the same Instant)

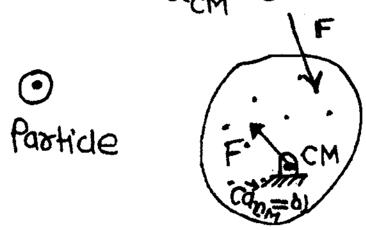
$\vec{a} = 0$

- Rest
- Uniform Linear Velocity

For a Rigid body

If $\sum \vec{F}_{ext} = 0$

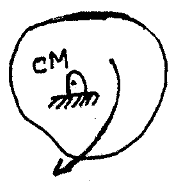
then $\vec{a}_{CM} = 0$



Rigid Body

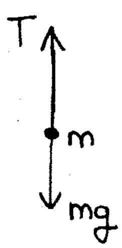
$\vec{a}_{CM} = 0$

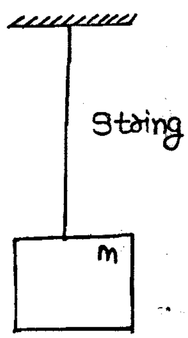
- Rest
- $\vec{V}_{cm} = \text{Const.}$
- A Body is rotating about it's CM.



$\vec{a}_{CM} = 0$

Eg:-1





(m) → Rest ⇒ $\vec{a}_{CM} = 0$

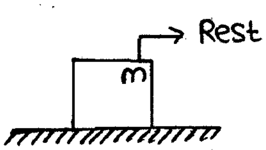
$\sum \vec{F}_{ext} = 0$

↳ Newton's 1st Law

$T - mg = 0$ [Newton's First Law]

$\boxed{T = mg}$ [NFL]

Eg: 2

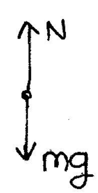


(m) → Rest

$\vec{a}_{CM} = 0$

$\sum \vec{F}_{ext} = 0$

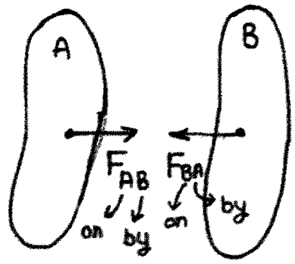
↳ (NFL)

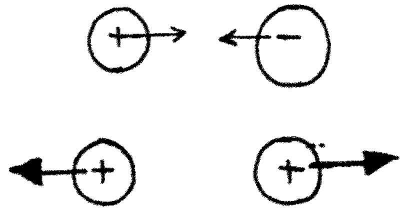


$N - mg = 0$

$\boxed{N = mg}$ [NFL]

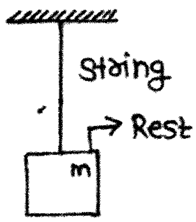
• Newton's Third Law (NTL) →

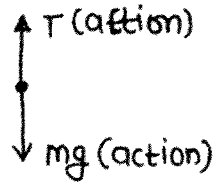




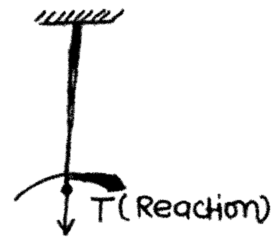
$$\vec{F}_{AB} = -\vec{F}_{BA}$$

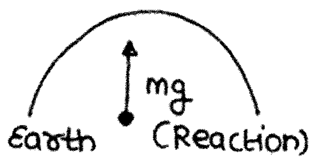
Ex : 1



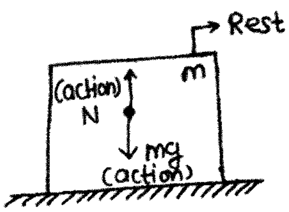


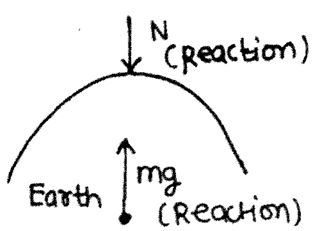
$$g = \frac{GM_e}{R_e^2}$$





Ex : 2





"If a Body A exerts Force on Body B, then certainly Body B will exert Force on Body A, they will equal in magnitude and opposite in direction, Colinear in action and Same in Nature."

Imp

• F.B.D. ⇒ It is Representation of all the forces acting on the system by the surrounding

Reading of weighting

NOTE: → In FBD Surrounding should not be shown.

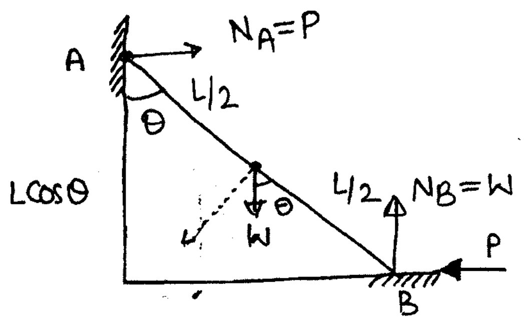
• **Equilibrium** → Rest / → uniform Linear Velocity

(I) $\Sigma \vec{F} = 0$ $[\Sigma F_x = \Sigma F_y = \Sigma F_z = 0]$

(II) $\Sigma \vec{T} = 0$

(about any Point 'or' Line)

Que →



A uniform Ladder AB of Length L and weight W is held in equilibrium by Horizontal force P at B as shown in figure: Assume all the surfaces to be smooth

find P

~~W × L = P tan~~

$$\Sigma M_B = 0$$

$$W \sin\theta \times \frac{L}{2} = P L \cos\theta$$

$$\boxed{P = \frac{W}{2} \tan\theta}$$

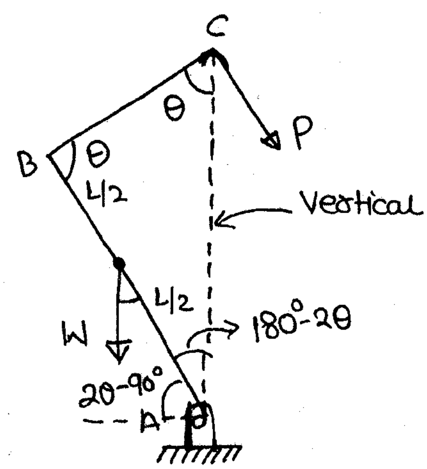
Que A uniform Rod of weight W and Length L is movable in vertical Plane about hinge at A but it is held in equilibrium by a ~~string be~~ force P which is attached to a string BC Passing over a Smooth Peg C. If AB = AC then the force P is

(a) $W \cos\theta$

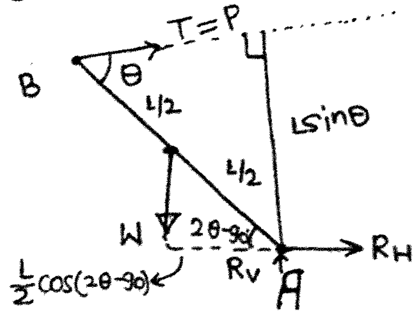
(b) $\frac{W}{\cos\theta}$

(c) $W \tan\theta$

(d) $W \sin\theta$



Considering equilibrium of Rod 'AB'



$\Sigma \vec{T}_A = 0$

$$W \times \frac{L}{2}\cos(2\theta-90) = PL\sin\theta$$

$$2\times\frac{W}{2}\sin\theta\cos\theta = P\sin\theta$$

$$\boxed{P = W\cos\theta}$$

- **Moment of a force 'or' Torque :→**

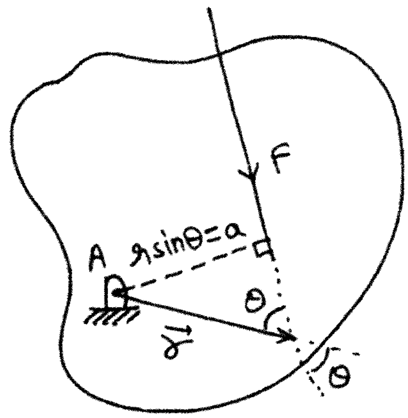
($\vec{M}$ 'or' $\vec{T}$)

$$\vec{T}_A = \vec{r} \times \vec{F}$$

$$|\vec{T}_A| = rF\sin\theta$$

$$\boxed{|\vec{T}_A| = Fa}$$

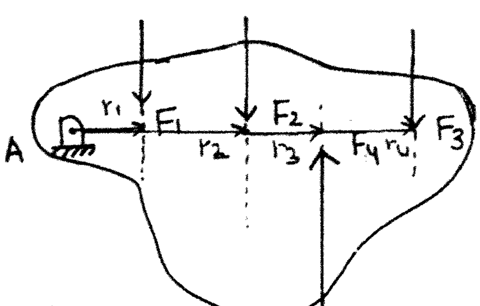
direction → ⊥r inward through A

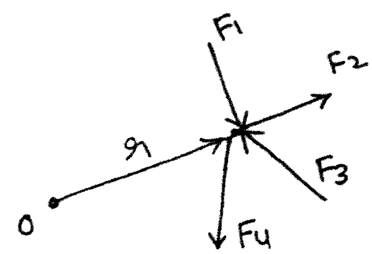


*** Imp: Property of Numericals (Vector algebra)

- **Varignon's Theorem**

For a concurrent force system Net Torque about a point will be Torque of resultant force about that Point





$$\Sigma \vec{T}_O = \vec{r}_1 \times \vec{F}_1 + \vec{r}_2 \times \vec{F}_2 + \vec{r}_3 \times \vec{F}_3 + \cdots$$

$$= \vec{r} \times \vec{F}_1 + \vec{r} \times \vec{F}_2 + \vec{r} \times \vec{F}_3 + \cdots$$

$$= \vec{r} \times (\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots)$$

$$\boxed{\Sigma \vec{T}_O = \vec{r} \times \vec{F}_R}$$

Application →

For a concurrent force system

if $\Sigma \vec{F} = 0$

$\Sigma \vec{T} = 0$

↳ at any Point

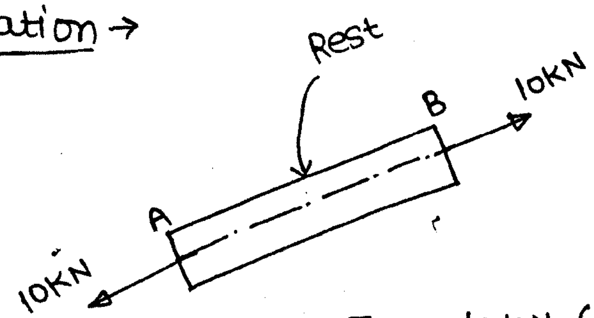
Ex. Joints in Truss

- Systems of Equilibrium :→

1. Two Force System →

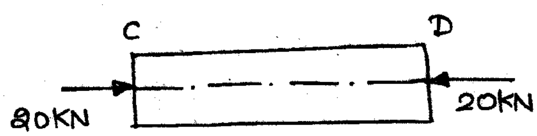
   To keep a body in equilibrium under the action of two-force, they must be equal in magnitute and opposite in direction and colinear in action.

Application →



$F_{AB} = 10 \text{KN}$ (Tensile)

(F_{AB}: Intensity of Internal resisting force)



$F_{CD} = 20 \text{KN}$ (Compressive)

(F_{CD}: Intensity of internal resisting force in member CD)

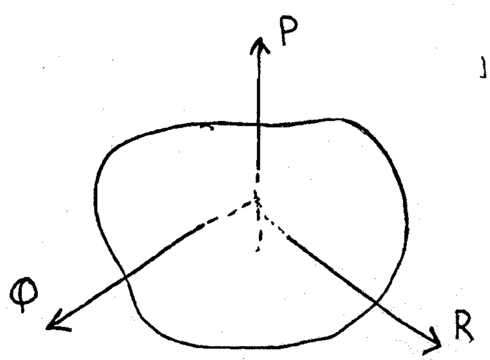
2. Three Force system →

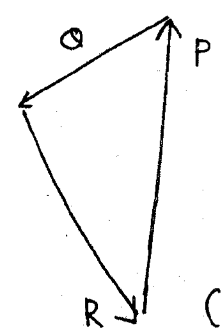
   To keep a body in equilibrium under the action of 3 forces they must be coplaner and concurrent.

$\vec{P}, \vec{Q}$ & $\vec{R}$

(a) $\vec{P} + \vec{Q} + \vec{R} = 0 \Rightarrow$ Coplaner

(b) $\Sigma \vec{T} = 0$





(Force Triangle)