## MADE EASY

## MECHANICAL ENGINEERING

### Engineering Mechanics

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- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

# Engg. Mechanics

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

- Statics (Rest)
  - Equilibrium
  - Plane Trusses (Imp)
  - Principle of virtual work
  - (C) centroid & centre of gravity (G)
- 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

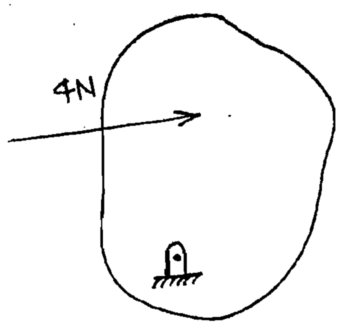
• **Actual Force :→**

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**

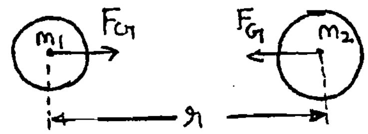
1. Gravity (W)

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

3. Tension (T)

4. Spring Force ($F_s$)

- **Gravity** →



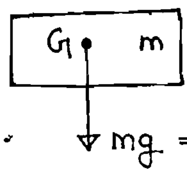

$$F_G = \frac{G m_1 m_2}{r^2}$$ ★

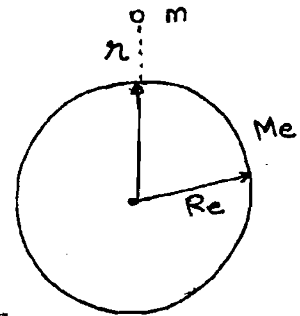
$G = 6.67 \times 10^{-11}$

$$g = \frac{G M_e}{R_e^2}$$ ★

$M_e$ = Mass of Earth
$R_e$ = Radius of Earth

★ $W = mg$ (Pulling)



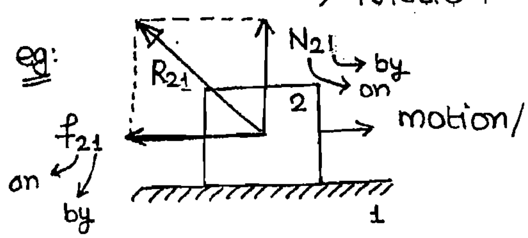

$$F_G = \frac{G M_e m}{R_e^2}$$

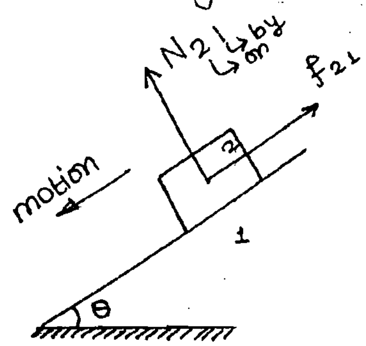
$F_G = mg$

$(R_e + r \simeq R_e)$

- **Contact Force** →
  - → Normal Reaction (Pushing)
  - → Friction

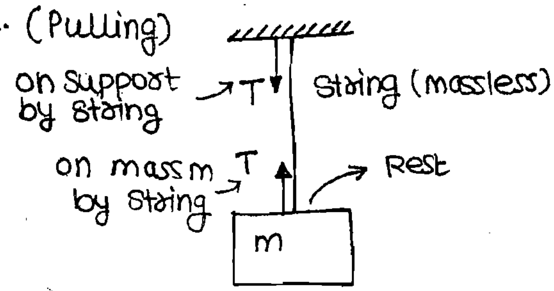
eg:



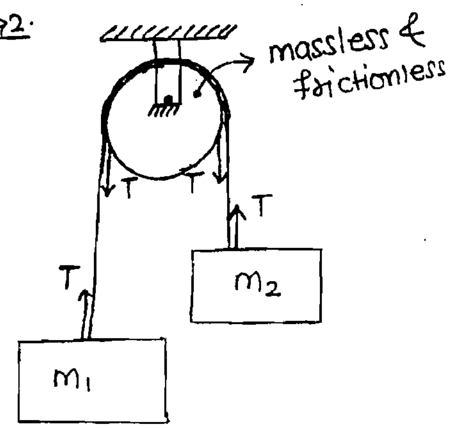




- **Tension** →

Ex→1. (Pulling)




Ex→2.




- **Spring Force** ($F_s$) ⇒
(Can be Pulling or Pushing)

$F_s = K(\Delta x)$
- $K$ → Spring constant
- $\Delta x$ → elongation or compression from Natural Length

## • Newton's First Law (NFL):→

**For a Particle**

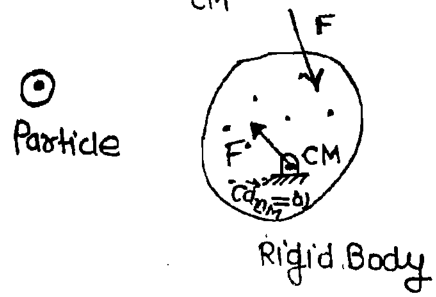
if $\Sigma \vec{F} = 0$ then $\vec{a} = 0$ → at the same Instant

$\vec{a} = 0$
- ↓ Rest
- ↓ Uniform Linear Velocity

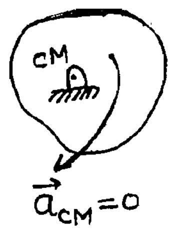
**For a Rigid body**

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

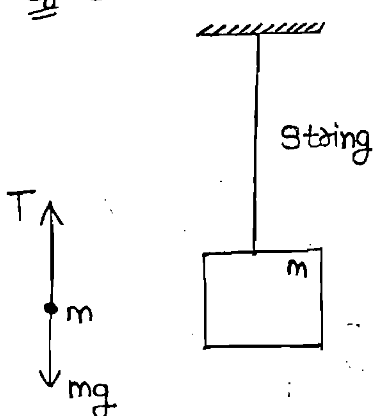
then.. $\vec{a}_{CM} = 0$




$\vec{a}_{CM} = 0$
- ↓ Rest
- ↓ $\vec{V}_{cm}$ = Const.
- ↓ A Body is rotating about it's CM.




Eg:-1




(m) → Rest ⇒ $\vec{a}_{CM} = 0$

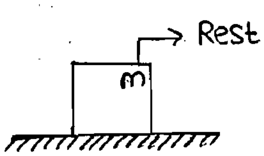
$\Sigma \vec{F}_{ext} = 0$

↳ Newton's 1st Law

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

$T = mg$ [NFL]

Eg:2

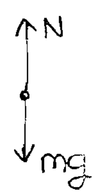



(m) → Rest

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

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

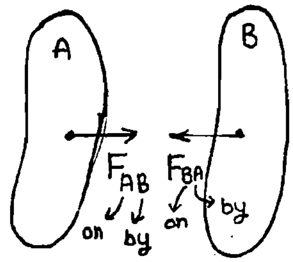
↳ (NFL)

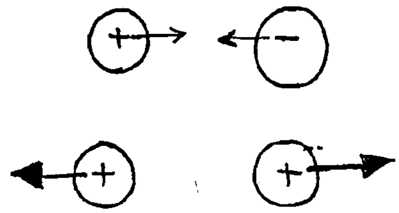



$N - mg = 0$

$N = mg$ [NFL]

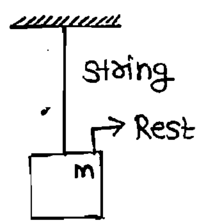
- Newton's Third Law (NTL) →

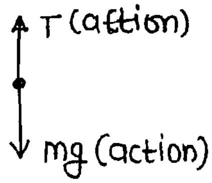


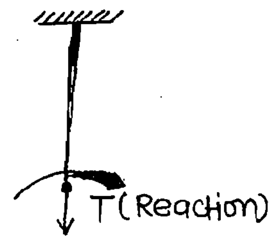
$$\vec{F}_{AB} = -\vec{F}_{BA}$$

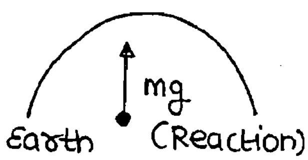
Ex : 1



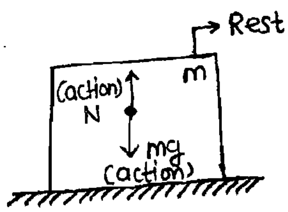



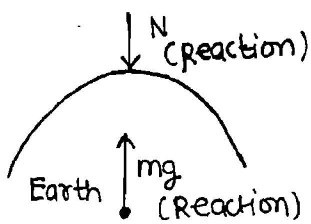

$$g = \frac{GM_e}{R_e^2}$$




Ex : 2




Reading of weighting

"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

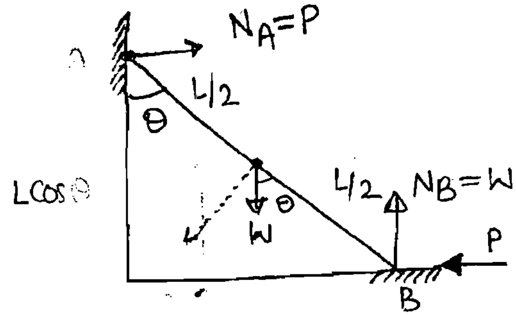
NOTE: → In FBD Surrounding should not be shown.

• Equilibrium → Rest / uniform Linear Velocity

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

(II) $\Sigma \vec{M} = 0$
(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~~

$\Sigma M_B = 0$

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

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

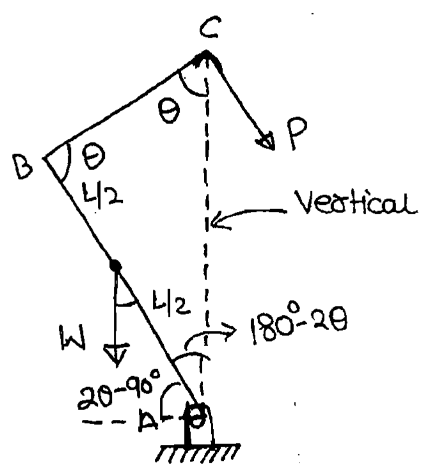
Que A uniform Rod of weight W and Length L is movable in vertical Plane about hinge at A but it is held in equilibrium by a ~~String Be~~ force P which is attached to a string BC Passing over a Smooth Peg C. If AB = AC then the force P is

(a) $W\cos\theta$

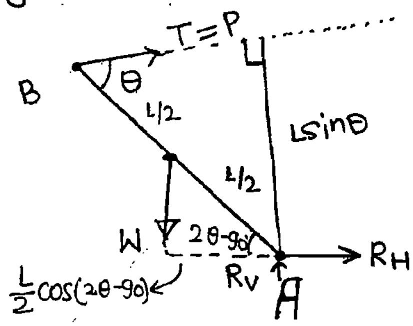
(b) $\frac{W}{\cos\theta}$

(c) $W\tan\theta$

(d) $W\sin\theta$



Considering equilibrium of Rod 'AB'




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

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

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

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

- Moment of a force 'or' Torque :→

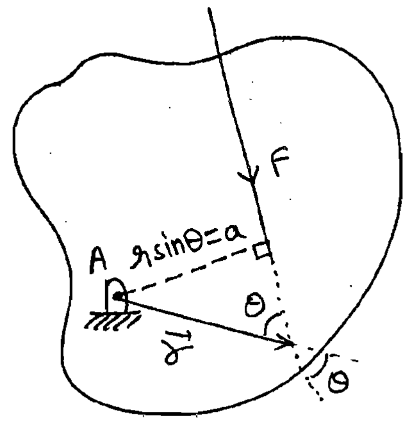
($\vec{M}$ 'or' $\vec{T}$)

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

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

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

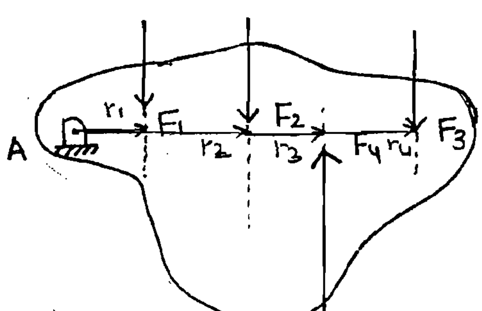
direction → ⊥r inward through A

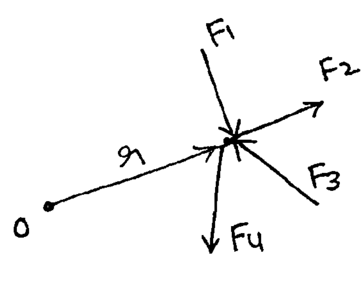



*** Imp: Property of Numericals (Vector algebra)

- 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

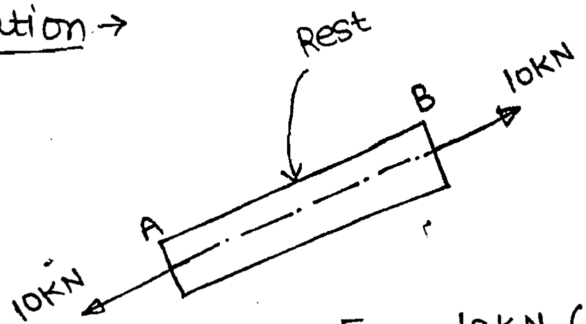
Ex. Joints in Truss

• Systems of Equilibrium :→

1. Two Force System →

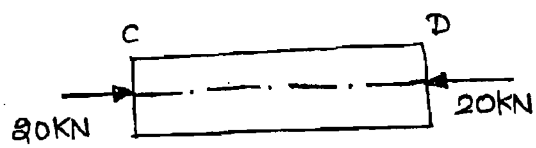
To keep a body in equilibrium under the action of two-force, they must be equal in magnitude and opposite in direction and colinear in action.

Application →




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

Intensity of Internal resisting force




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

Intensity of internal resisting force in member CD

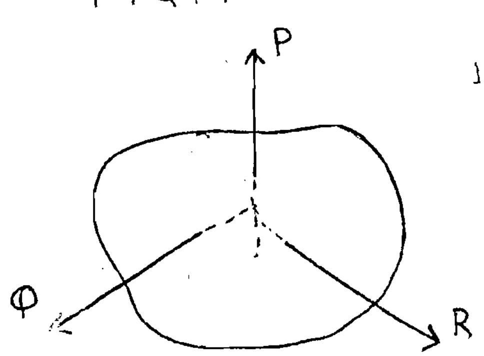
2. Three force system →

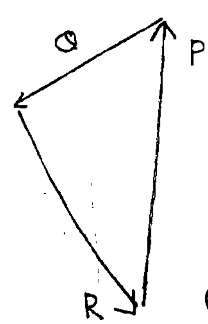
To keep a body in equilibrium under the action of 3 forces they must be coplaner and concurrent.

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

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

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




(Force Triangle)