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Engineering Mechanics
By-Ravendar SIR

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

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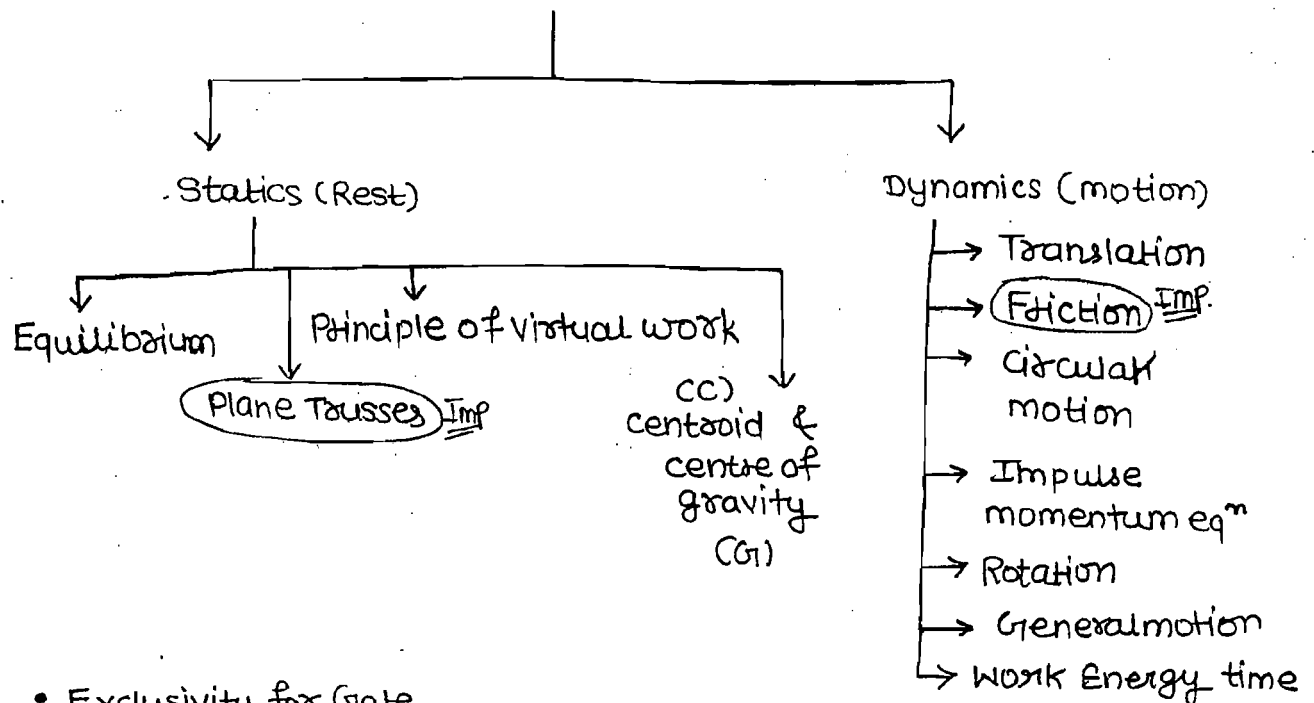
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Engg. Mechanics

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



- Exclusivity for Gate
- friction & its application
 - Rolling friction
 - wedge
 - Screw Jack
 - Application in vehicles
 - Belt friction
- * Lange's Equation

• Actual Force : \rightarrow

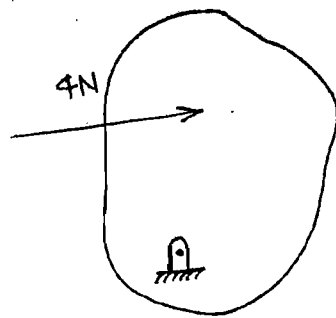
If a force has been Acted on the body then it must have been applied by some other Body

• Pseudo force : \rightarrow

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

To define a force \rightarrow

- \rightarrow Magnitude (Intensity)
- \rightarrow direction (orientation)
- \rightarrow Point of application



• Types of forces

1. Gravity (W)

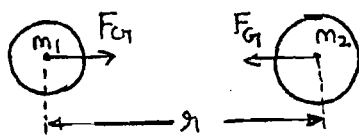
2. Contact force (R) \rightarrow

- \rightarrow Normal Reaction (N)
- \rightarrow friction (f)

3. Tension (T)

4. Spring force (F_s)

• Gravity →

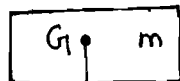


$$F_G = \frac{G m_1 m_2}{r^2} \quad \star$$

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

$$g = \frac{G M_E}{R_E^2} \quad \star$$

M_E = Mass of Earth
 R_E = Radius of Earth



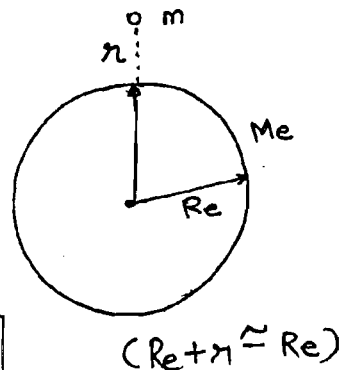
$\downarrow mg \Rightarrow$ on mass m by Earth

$$W = mg \quad \star$$

(Pulling)

$$F_G = \frac{G M_E m}{R_E^2}$$

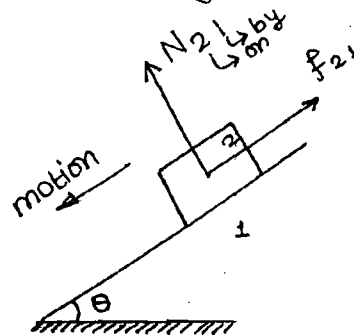
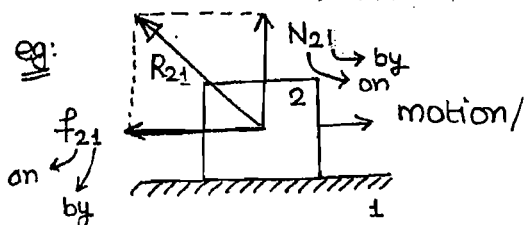
$$F_G = mg$$



• contact force →

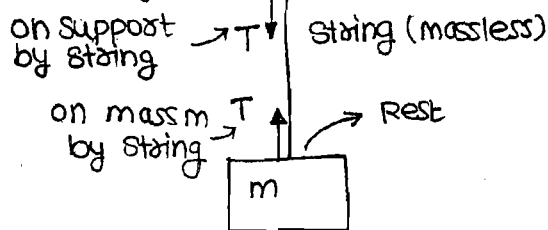
Normal Reaction (Pushing)

Friction

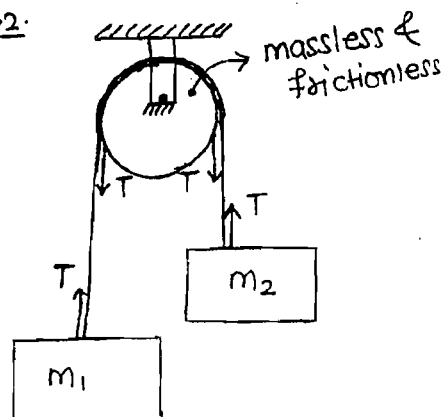


• Tension →

ex 1. (Pulling)



ex 2.



• Spring Force (F_s) →
 (Can be Pulling or Pushing)

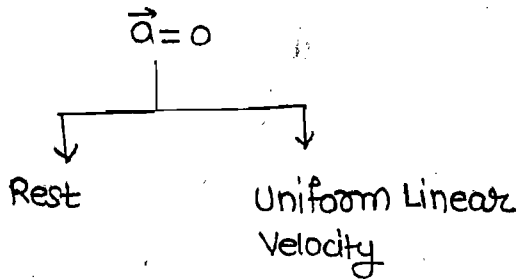
$$F_s = K(\Delta x)$$

Spring Constant

elongation or compression from Natural Length

• Newton's First Law (NFL): →

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



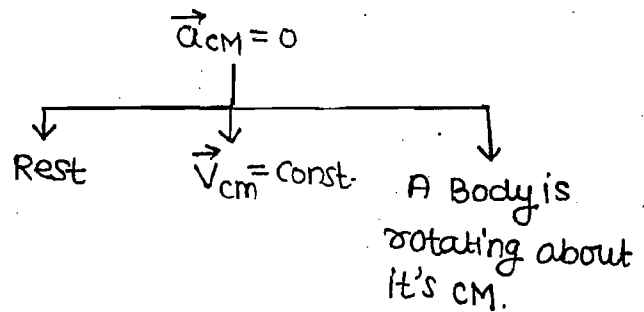
For a Rigid body

If $\sum \vec{F}_{\text{ext}} = 0$
then $\vec{a}_{\text{cm}} = 0$

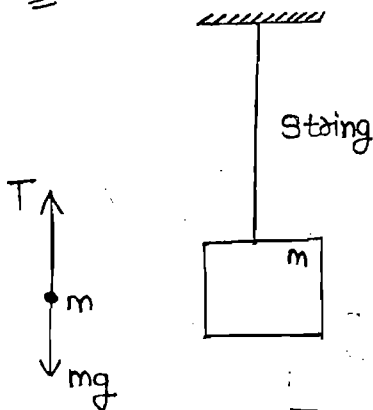
Particle



Rigid Body



Ex: -1



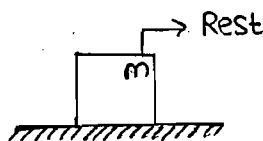
(m) → Rest $\Rightarrow \vec{a}_{\text{cm}} = 0$

$\sum \vec{F}_{\text{ext}} = 0$
↳ Newton's 1st Law

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

$T = mg$ [NFL]

Ex: 2



(m) → Rest

$\vec{a}_{\text{cm}} = 0$

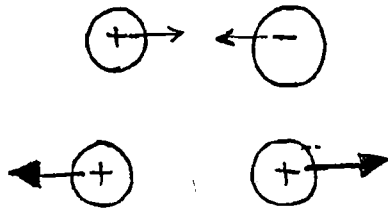
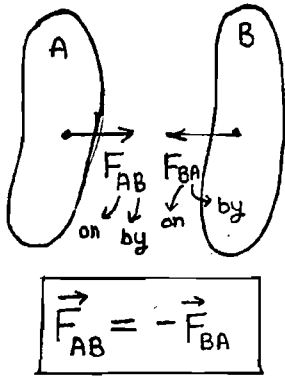
$\sum \vec{F}_{\text{ext}} = 0$
↳ (NFL)



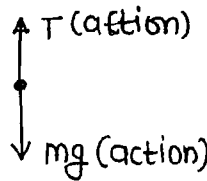
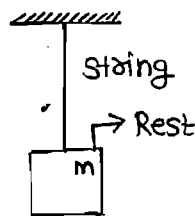
$N - mg = 0$

$N = mg$ [NFL]

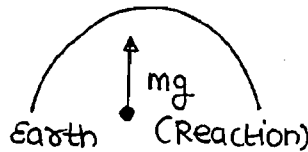
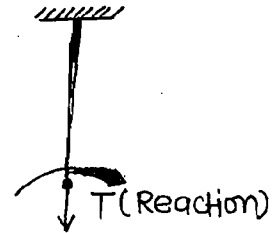
• Newton's Third Law (NTL) →



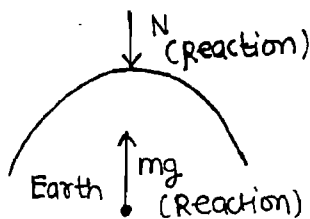
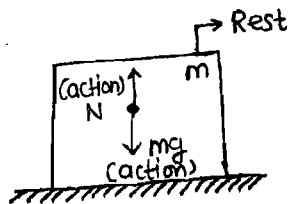
Ex: 1



$$g = \frac{G M_E}{R_E^2}$$



Ex: 2



"If a Body A exerts ~~the~~ Force on Body B. then ~~a~~ 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."

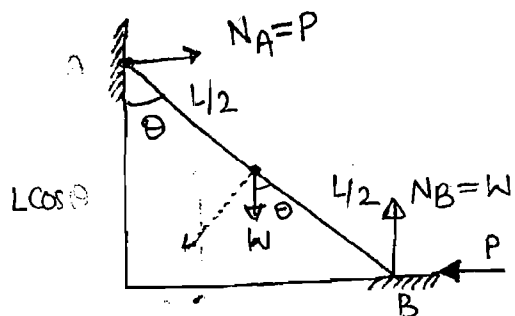
Imp
• F.B.D. ⇒ It is Representation of all the forces acting on the system by the surrounding

Reading of weighing

NOTE → In F.B.D surrounding should not be shown.

- Equilibrium — $\begin{cases} \text{Rest} \\ \text{uniform Linear Velocity} \end{cases}$
- (i) $\sum \vec{F} = 0$ [$\sum F_x = \sum F_y = \sum F_z = 0$]
- (ii) $\sum \vec{\tau} = 0$
(about any Point
'or' Line)

Que



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

$$\cancel{W \times L} = P \tan \theta$$

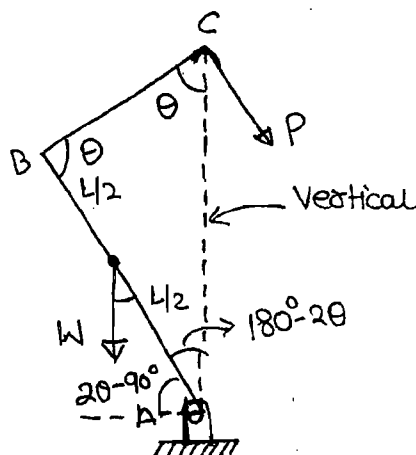
$$\sum M_B = 0$$

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

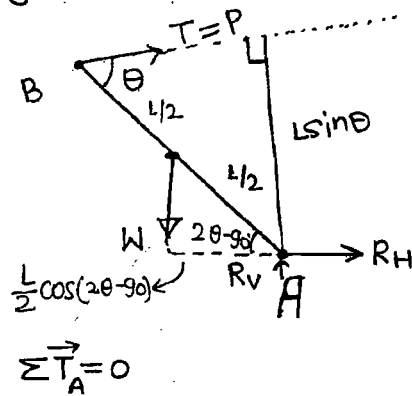
$$P = \frac{W}{2} \tan \theta$$

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~~ 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'



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

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

$$P = W \cos \theta$$

• Moment of a force 'or' Torque \rightarrow

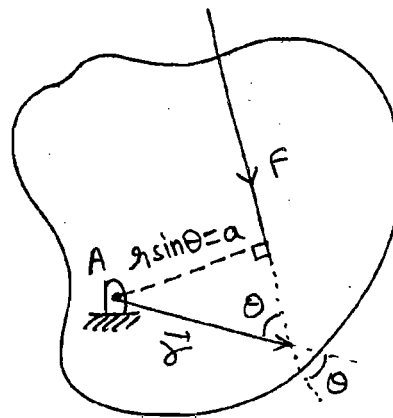
$$(\vec{M} \text{ 'or' } \vec{T})$$

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

$$|\vec{T}_A| = r F \sin \theta$$

$$|\vec{T}_A| = F a$$

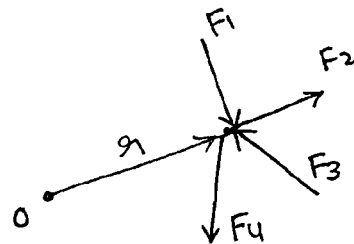
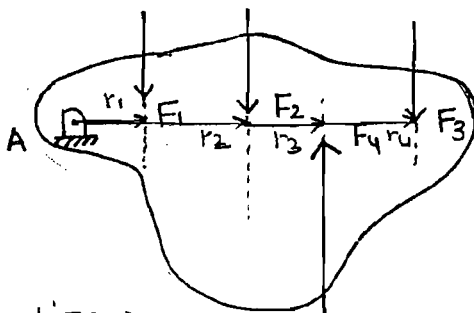
direction $\rightarrow \perp$ inward through A



*** 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



Application \rightarrow

For a concurrent force system
if $\sum \vec{F} = 0$

$$\sum \vec{T} = 0$$

\hookrightarrow at any Point

Ex. Joints in Truss

$$\begin{aligned} \sum \vec{T}_O &= \vec{r}_1 \times \vec{F}_1 + \vec{r}_2 \times \vec{F}_2 + \vec{r}_3 \times \vec{F}_3 + \dots \\ &= \vec{r}_1 \times \vec{F}_1 + \vec{r}_1 \times \vec{F}_2 + \vec{r}_1 \times \vec{F}_3 + \dots \\ &= \vec{r}_1 \times (\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots) \end{aligned}$$

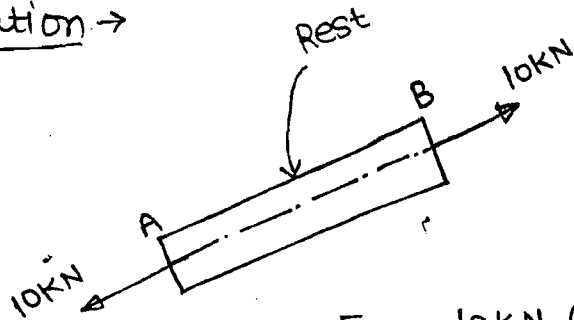
$$\sum \vec{T}_O = \vec{r}_1 \times \vec{F}_R$$

• Systems of Equilibrium: →

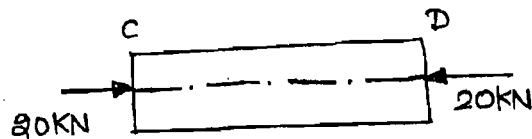
1. Two Force System →

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

Application →



$F_{AB} = 10 \text{ kN (Tensile)}$
 Intensity of
 Internal resisting force



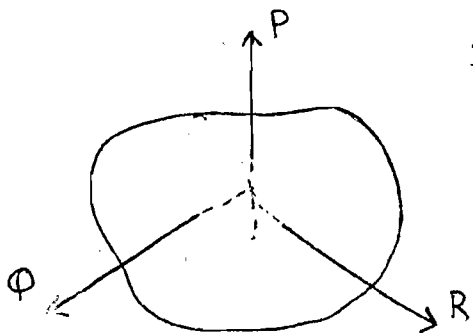
$F_{CD} = 20 \text{ kN (Compressive)}$
 Intensity of internal
 resisting force in member CD

2. Three force system →

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

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

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



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

