FORCE (LAWS OF MOTION)

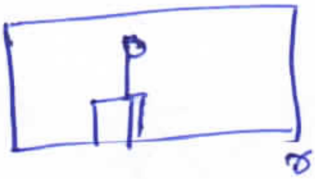
INERTIA — Inherent property of an object which opposes the change in its state.
(Inertia in a linear motion is measured as its mass)

rest → motion	motion → rest	Change in direction
Inertia of Rest	Inertia of motion	Inertia of direction
Force is required to change the state	Force is required to change the state.	Force is required to change its direction.

1ST LAW OF MOTION (LAW OF INERTIA)

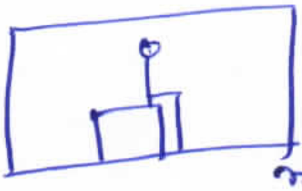
A body at rest will continue in rest and a body in motion will keep moving in same direction unless an external force is applied on it.

Force is a phenomenon which changes state of motion.



BUS STARTS TO MOVE, YOU LEAN BACK (INERTIA OF REST)

rest. → move.



BUS BREAKS, YOU LEAN FORWARD (INERTIA OF MOTION)

motion → rest.

MOMENTUM is a characteristic of a body in motion; which tries to remain constant on its own.

$$\vec{p} = m\vec{v}$$

2nd law of MOTION (Magnitude of Force)

Rate of change of Momentum is directly proportional to the external force applied.

$$\vec{F} = k\frac{d\vec{p}}{dt}$$

$\hookrightarrow k = 1.$

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}$$

When mass is treated constant

$$\frac{dm}{dt} = 0$$

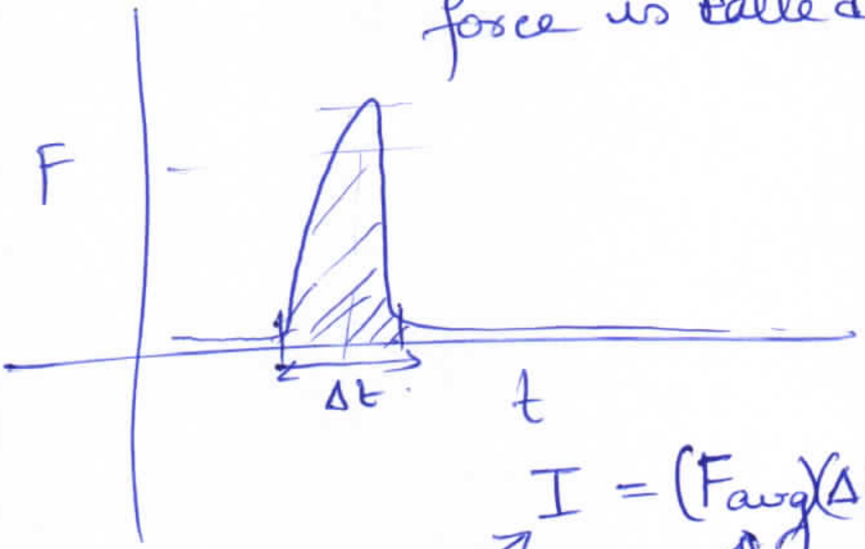
$$\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a}$$

$$\vec{F} = m\vec{a}$$

Unit of $\vec{F}$ is $1\,kg\,ms^{-2} = 1\,N$

Newton (N) is the derived SI unit of force

IMPULSE : When a very large force is acting for a very short interval of time it creates an impulse and this force is called the Impulsive force.



$$I = \int_0^{\Delta t} F\,dt$$

$$I = (F_{avg})(\Delta t)$$

Impulse

Impulsive force

short interval of time

$$I = \frac{\Delta \vec{p}}{\cancel{\Delta t}} \times \cancel{\Delta t} = \text{change in momentum}$$

$$= m\vec{v_2} - m\vec{v_1} \qquad (kg\,ms^{-1})$$

$$I = F_{avg}(\Delta t)$$

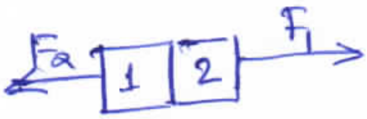
$$F_{avg} = \frac{I}{\Delta t}$$

if $\Delta t \uparrow$ $F_{avg} \downarrow$

Impulsive force.

3rd law of Motion.

To every action there is an equal and opposite reaction.

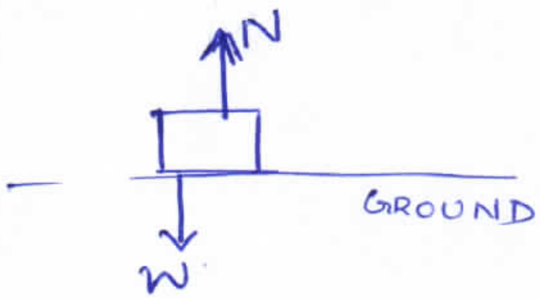


$$|\vec{F_1}| = |\vec{F_2}|$$

$$\vec{F_1} = -\vec{F_2}$$

ACTION REACTION PAIR

$$\vec{F_1} + \vec{F_2} = 0$$



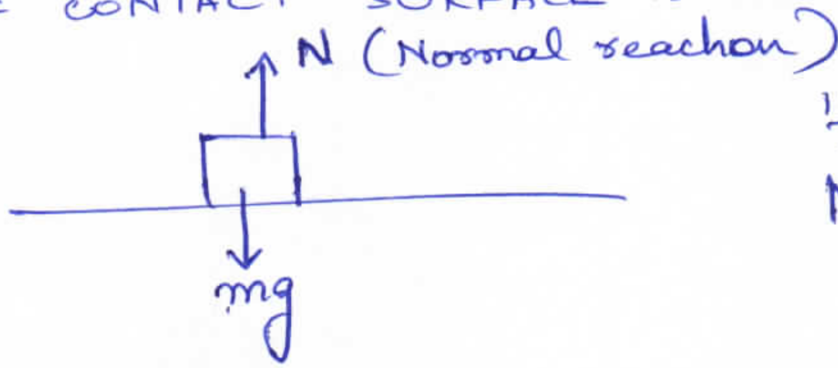
$$N = W$$

TYPES OF FORCES

1) FIELD FORCES – (Contact between the bodies is not required)

2) CONTACT FORCES – Two bodies in contact exert equal & opposite force on each other.

IF CONTACT SURFACE IS SMOOTH.

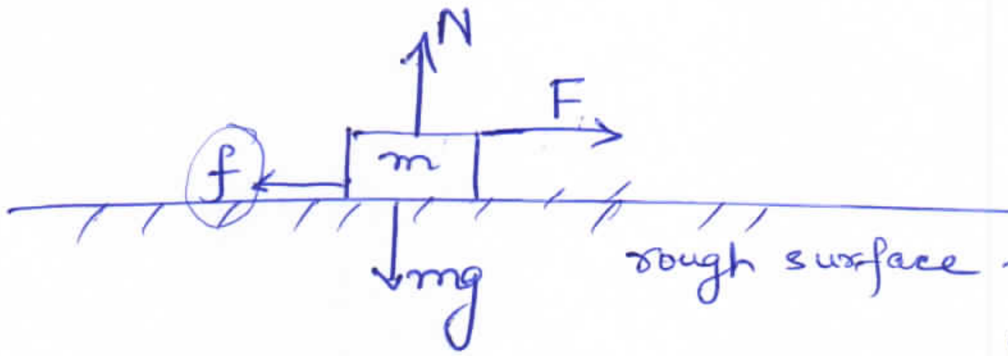


If body is at rest.

$$N - mg = 0$$

$$N = mg$$

IF CONTACT SURFACE IS NOT SMOOTH.



coefficiant of friction

$f_{max} = \mu N$ ← normal reaction

$f_{max} = \mu mg$

F

$\mu = 0.5$

$m = 1\,kg$

$g = 10$

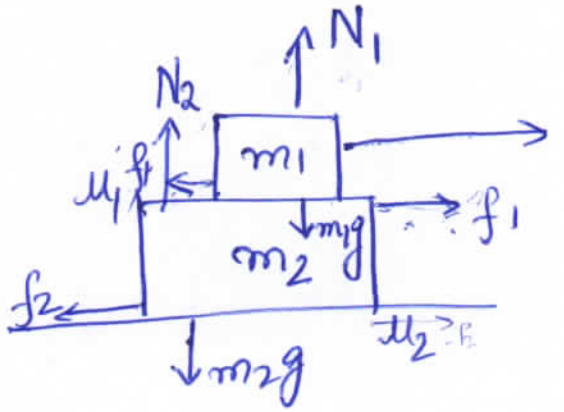
$f_{max} = 5N$

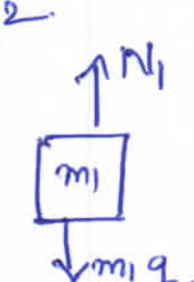
F	f
1N	1N
3N	3N
5N	5N
6N	5N

$$F - f = m\vec{a}$$

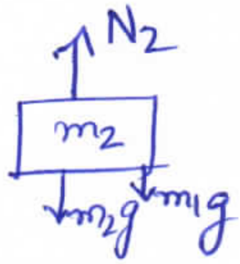
$$6 - 1 = 1\,\vec{a}$$

$$\vec{a} = 1\,m/s^2$$





$N_1 = m_1 g$



$\Rightarrow N_2 - m_2g - m_1g = 0$

$N_2 = m_1g + m_2g$.

EQUILIBRIUM

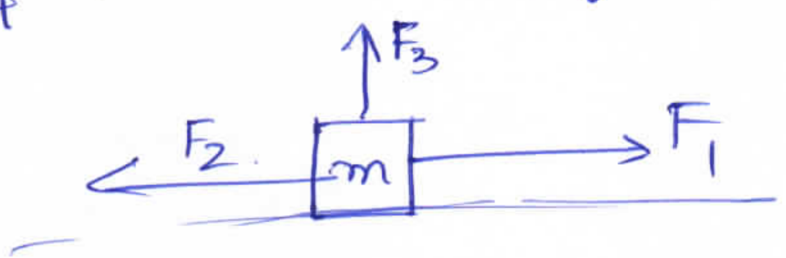
If the Net force acting on the body produces no linear motion or turning motion then the body is said to be in equilibrium.

for translational equilibrium –

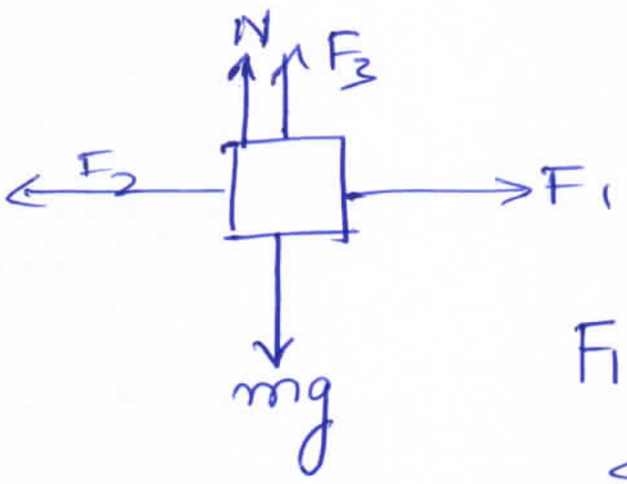
$$\sum_i \vec{F} = 0$$

$$\Downarrow$$

$$\sum_i \vec{F_x} = 0 \qquad \sum_i \vec{F_y} = 0 \qquad \sum_i \vec{F_z} = 0$$



body is in equilibrium.



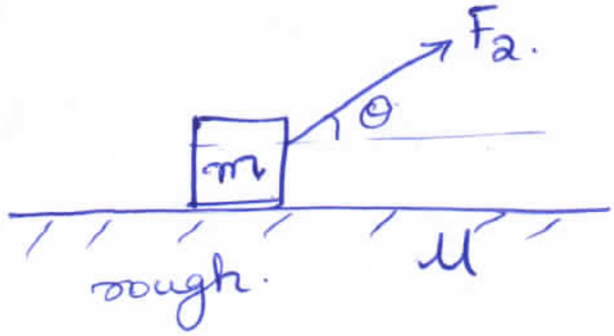
$$\sum_i F_x = 0$$

$$F_1 - F_2 = 0$$

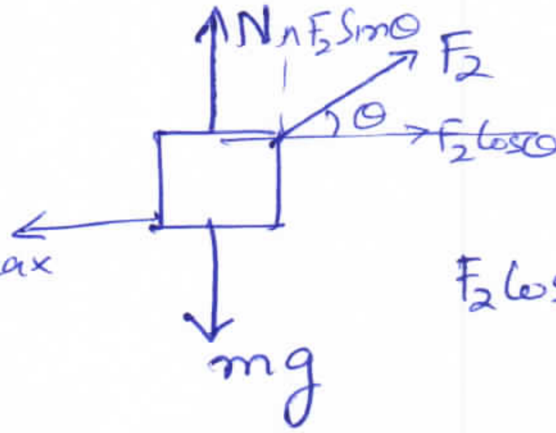
$$\sum_i F_z = 0$$

$$N + F_3 - mg = 0$$

find ~~[illegible]~~ N ?



body is moving with constant velocity.



$f_{max} = \mu N$

$N + F_2 \sin\theta - mg = 0$

$N = mg - F_2 \sin\theta$

$F_2 \cos\theta = \mu N$

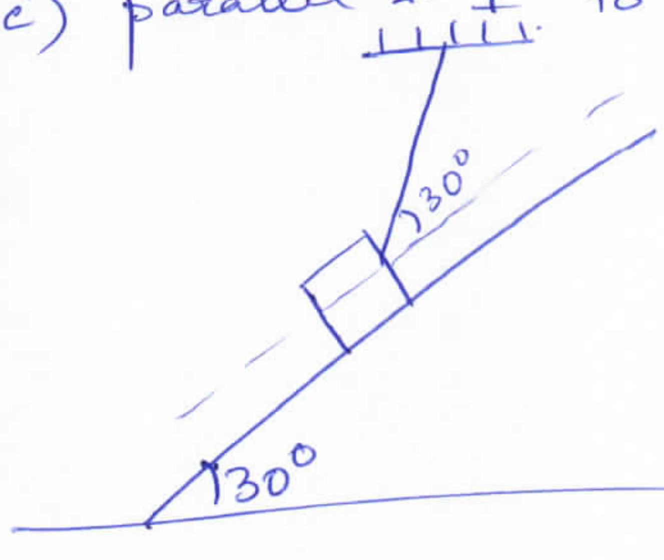
$N = \dfrac{F_2 \cos\theta}{\mu}$

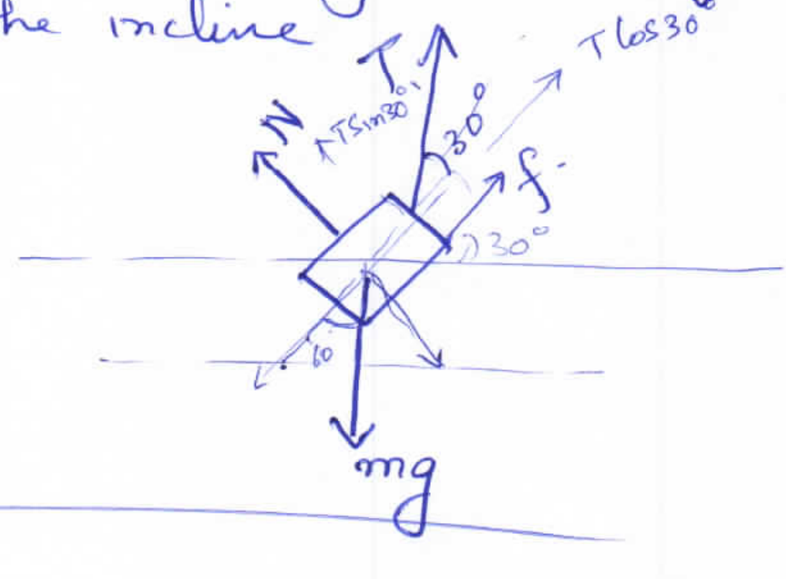
Q2 If a body is supported on a rough inclined plane at 30° with horizontal by a string attached to the body and held at an angle 30° to the plane

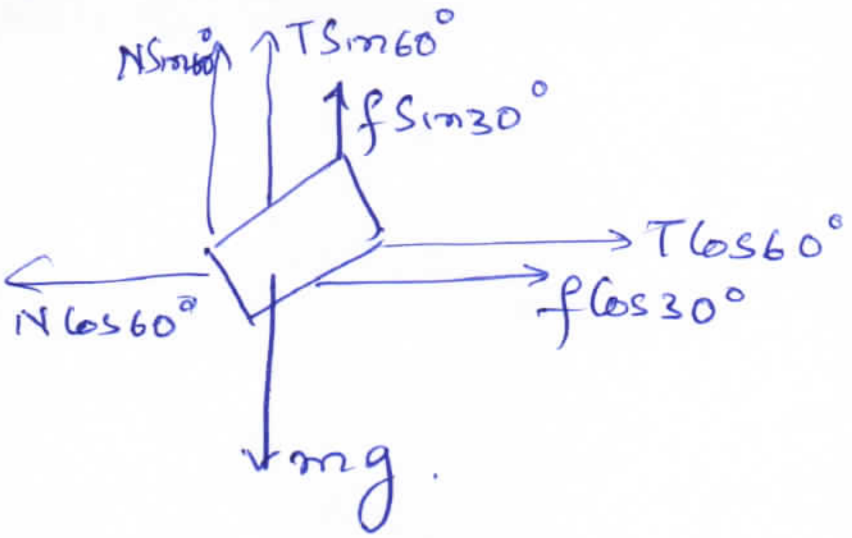
a) Draw FBD

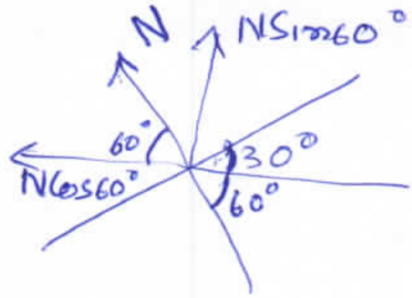
b) ~~Relo.~~ Resolve forces horizontally & Vertically.

c) parallel & ⊥ to the incline

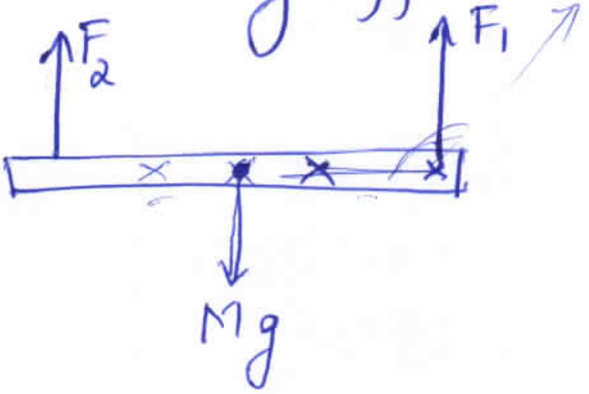


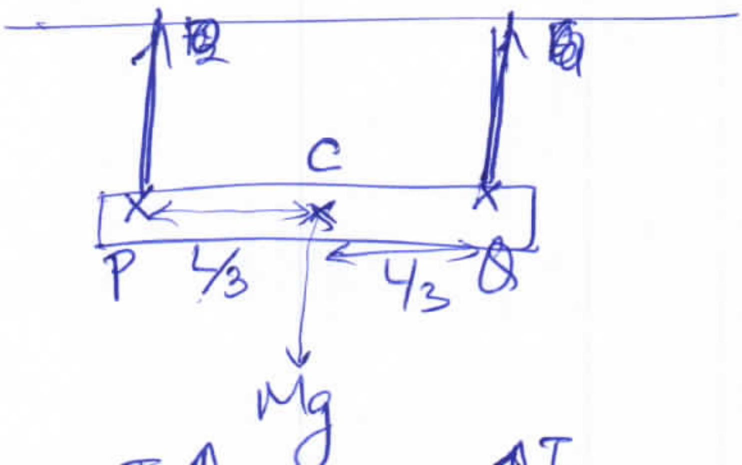


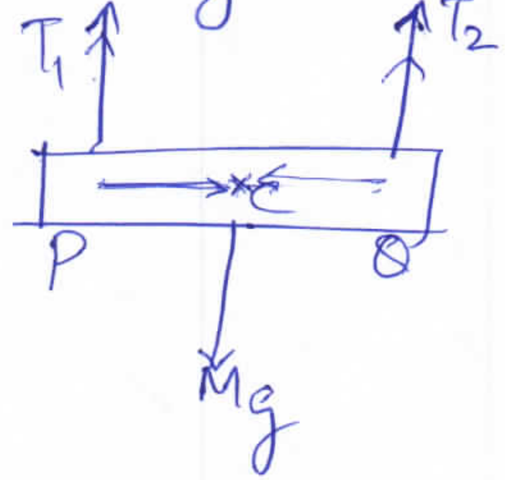




Zero turning Effect.







$$\tau_F = \vec{F}(r_\perp)$$
$$= \vec{r} \times \vec{F}$$

$\vec{r}$ = line joining point of contact of Force to the point about which torque is being calculate.

Torque about C

$$\tau_{T_1} = +\frac{L}{3}(T_1)\sin 90^\circ = \frac{LT_1}{3}\hat{j}$$

$$\tau_{Mg} = 0 \times Mg = 0$$

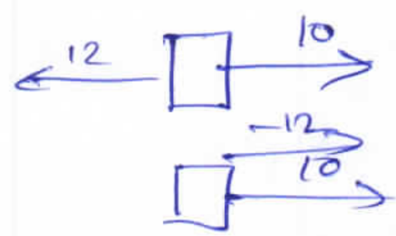
$$\tau_{T_2} = -\frac{L}{3}(T_2)\sin 90^\circ = -\frac{LT_2}{3}\hat{j}$$

$$\text{Net } \tau = \left(\frac{LT_1}{3} - \frac{LT_2}{3}\right)\hat{j}$$

$$= \frac{L}{3}(T_1 - T_2)$$

$$\text{if Eq} = \tau = 0 \Rightarrow T_1 = T_2$$

About point Q



$$\tau_{T_2} = 0$$

$$\tau_{T_1} = -\frac{2L}{3} \times T_1 \sin 90^\circ$$

$$\tau_{Mg} \pm \frac{L}{3} \times Mg \sin 90^\circ$$

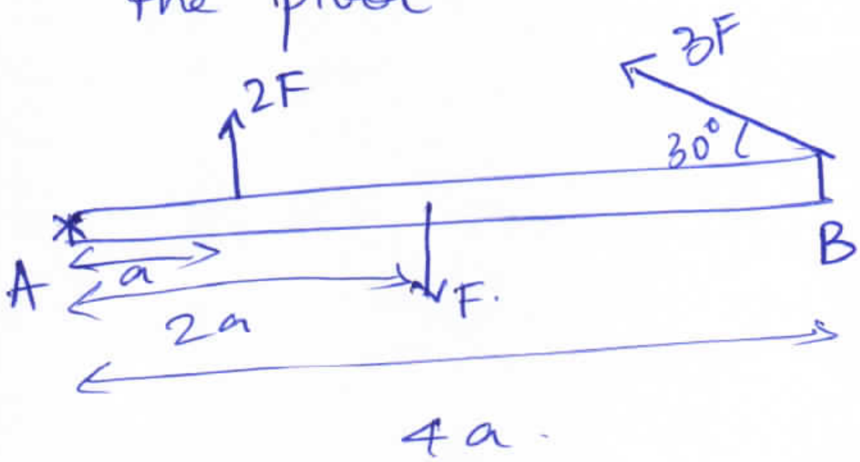
$$\text{Net } \tau = \frac{L}{3}\left(Mg - 2T_1\right)$$

If string is same tension in string is same (for massless string)

×

Q. Forces act as indicated on a massless rod AB which is pivoted at A.

Find net anticlockwise Torque about the pivot.



$$\tau_A = +2F \times a + 3F \times 4a \sin 30^\circ - F \times 2a$$

$$= 2Fa + 6Fa - 2Fa$$

$$= 6Fa$$

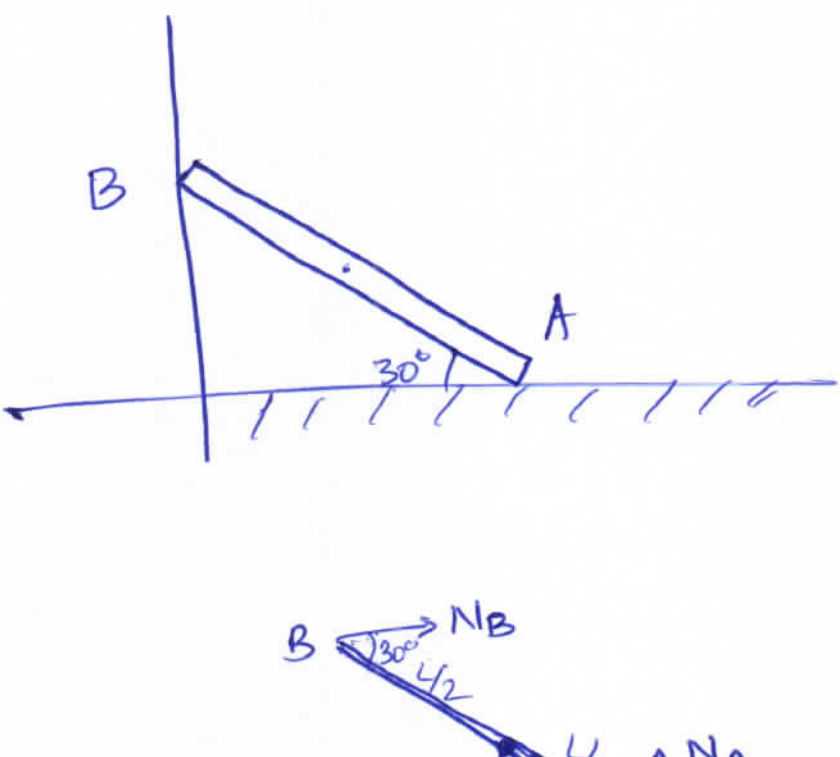
Q

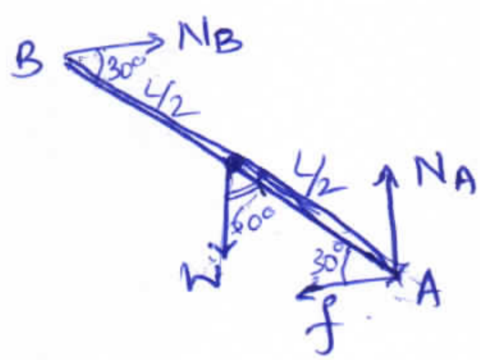
A rod AB rests with the end A on a rough horizontal ground and the end B against a smooth vertical wall. The rod is uniform and has a weight W. If rod is in equilibrium position as shown

Find a) frictional force at A

b) Normal reaction at A

c) normal reaction at B





linear eq :

$f = N_B$

& $N_A = W$

$$\tau_A = +W\frac{L}{2}\sin 60^\circ - N_B \times L\sin 30^\circ$$

rotational Eq

$$\tau_A = 0 \Rightarrow \frac{W\cancel{L}}{2}\sin 60^\circ = N_B\cancel{L}\sin 30^\circ$$

$$\Rightarrow N_B = W\frac{\sqrt{3}}{2} = f$$

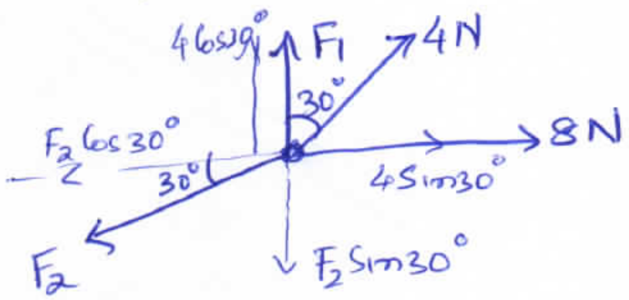
If body is in equilibrium.

$\sum_{i} F_x = 0 \qquad \sum_{i} F_y = 0 \qquad \sum_{i} F_z = 0$

~~$\sum F = ma$~~

$\sum_{i} \tau_{\text{any point}} = 0$

Q) If body (massless) is in equilibrium under four concurrent forces as shown find $\vec{F_1}$ & $\vec{F_2}$

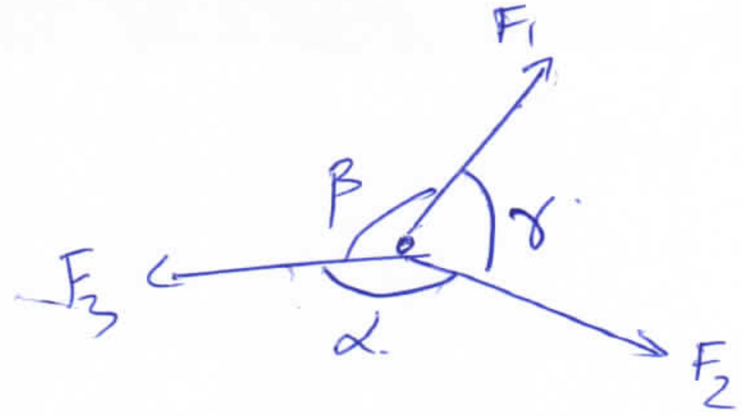


$$F_1 + 4\cos 30 = F_2 \sin 30°$$

$$8 + 4\sin 30° = F_2 \cos 30°$$

$$F_1 = \frac{4}{\sqrt{3}} \text{ N}$$

$$F_2 = \frac{20}{\sqrt{3}} \text{ N}$$

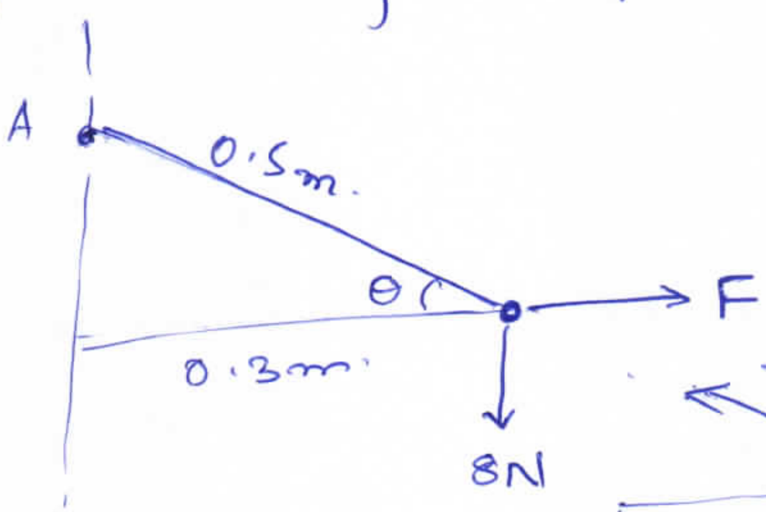


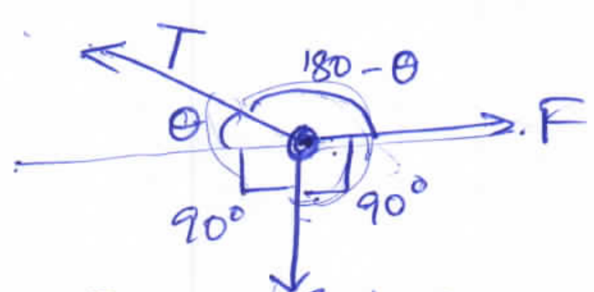
Lami's Thm.

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

Q) One end of a string 0.5m long is fixed to a point A and the other end is fastened to small object of weight 8N The object is pulled aside by a horizontal force F until it is 0.3m from the vertical through A.

Find magnitudes of tension T in the string & the force F.





$$\cos\theta = \frac{0.3}{0.5}$$

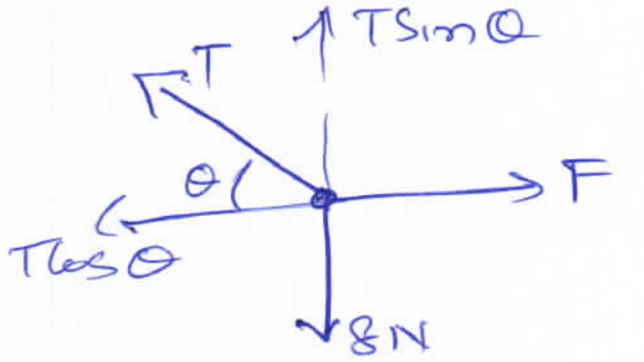
$$\sin\theta = \frac{4}{5}$$

$$\frac{T}{\sin 90^\circ} = \frac{8}{\sin(180-\theta)} = \frac{F}{\sin(90+\theta)}$$

$$\frac{T}{1} = \frac{8}{\sin\theta} = \frac{F}{\cos\theta}$$

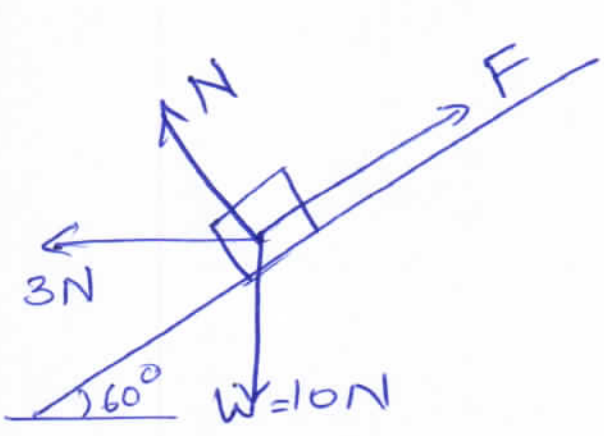
$$F = T\cos\theta = 10 \times \frac{3}{5} = 6N$$

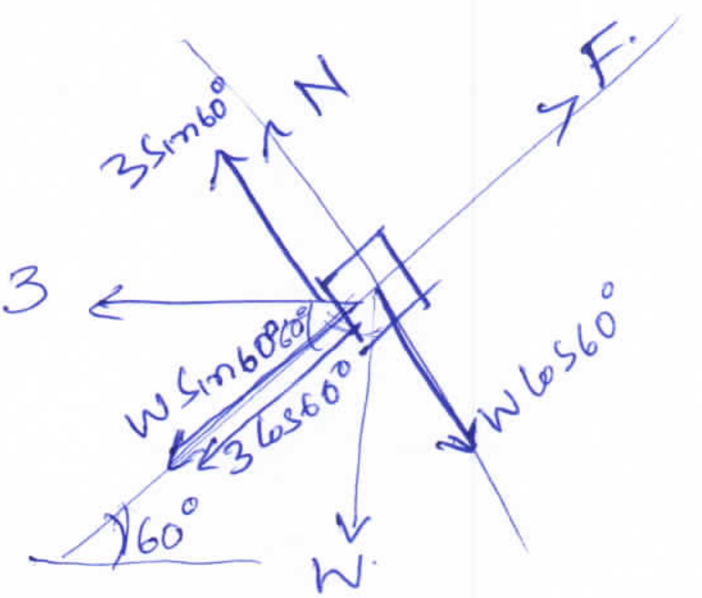
$$T = \frac{8^2}{4/5} = 10N$$



$$\Rightarrow \quad T\sin\theta = 8$$
$$T\cos\theta = F$$

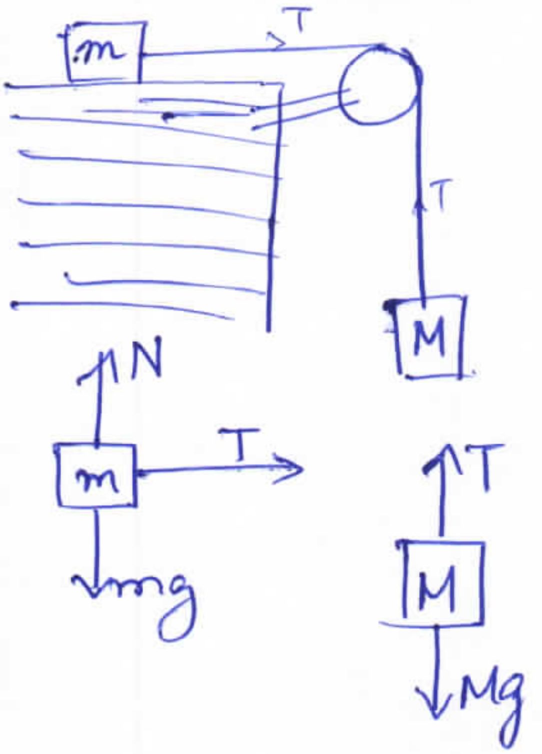
Q Find the value of unknown forces.



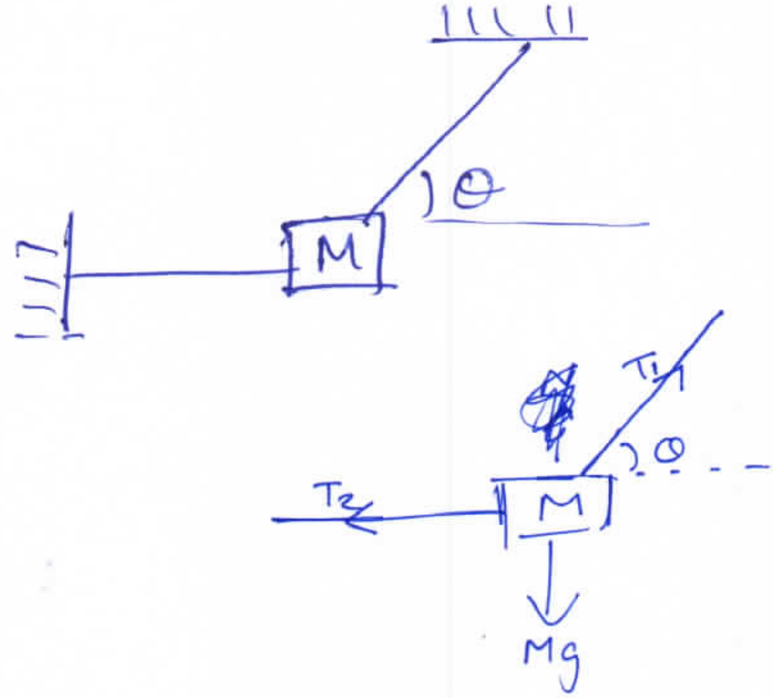


$$N + 3\sin 60^\circ - W\cos 60^\circ = 0$$

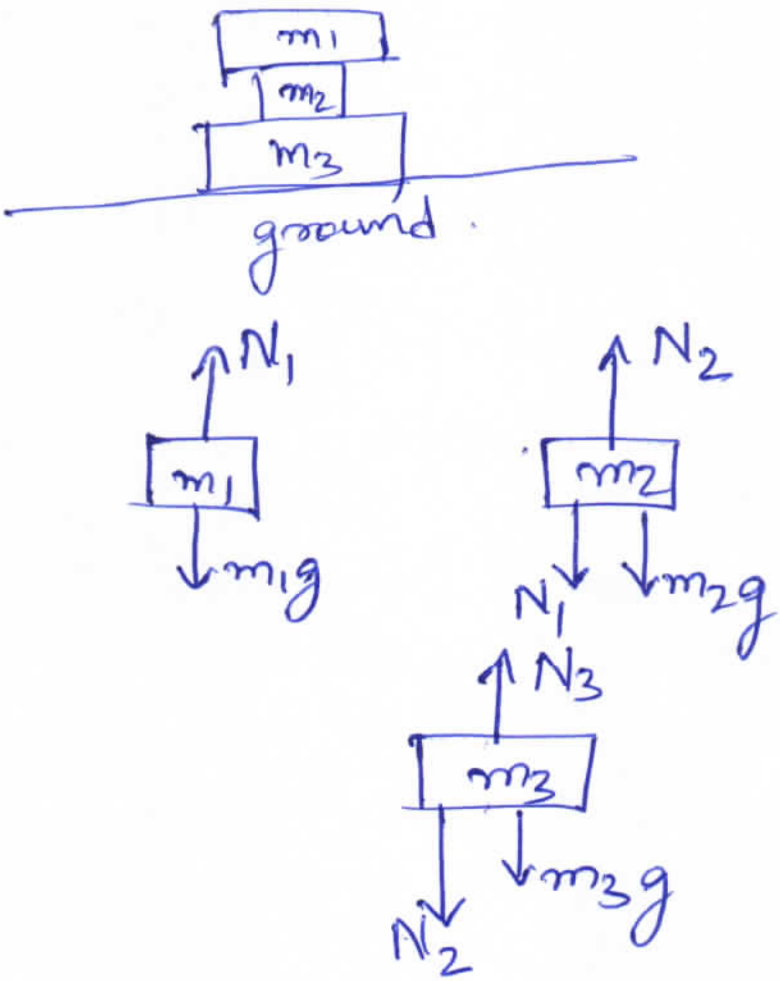
$$F = W\sin 60^\circ + 3\cos 60^\circ$$



m
T
T
M
N
m
T
mg
T
M
Mg



θ
M
T_1
θ
T_2
M
Mg



m_1
m_2
m_3
ground
N_1
m_1
m_1g
N_2
m_2
N_1
m_2g
N_3
m_3
N_2
m_3g