LAWS OF Motion

FORCE → It is a cause which brings about change in the state of a body.

- ➡ Its SI unit is Newton[N] and CGS unit is dyne

$$1\,dyne = 10^{-5} N$$

- ➡ Force is a vector quantity.

Types Of Force

Non Contact force (Field Force)

These are the forces in which contact b/w two object is not necessary

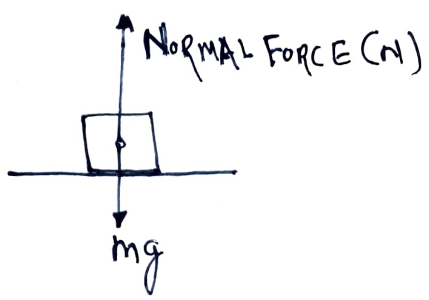
example → Magnetic force, gravitational force, Electric force.

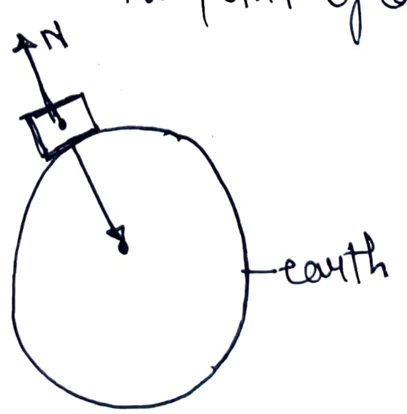
CONTACT Force

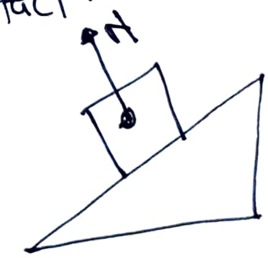
Two bodies in contact exert equal and opposite on each other.

Example ⇒ Frictional force.
Push on an object.
Normal Reaction force. Tension

NORMAL Reaction force → It is the force that acts perpendicular to the surface at the point of contact.



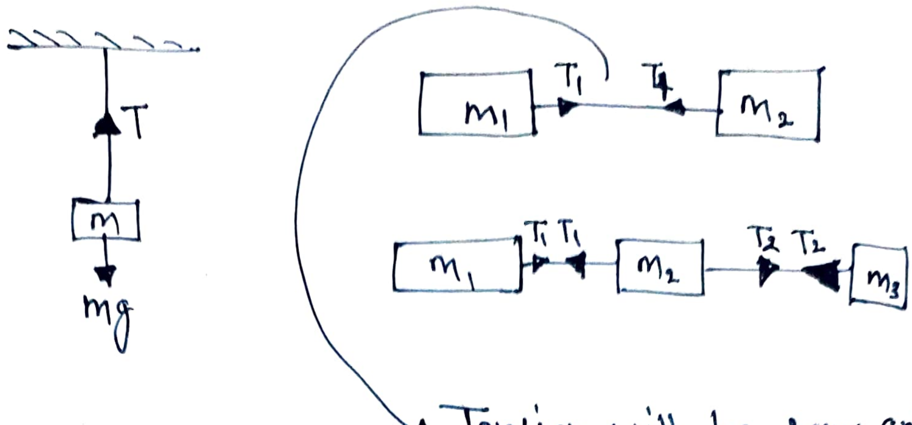




When the object is placed on a sphere then then Normal Reaction force will always pass through centre of sphere

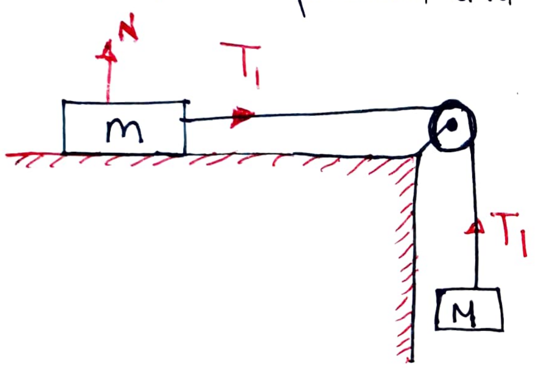
TENSION FORCE ⇒ It is a type of contact force which acts on a string.

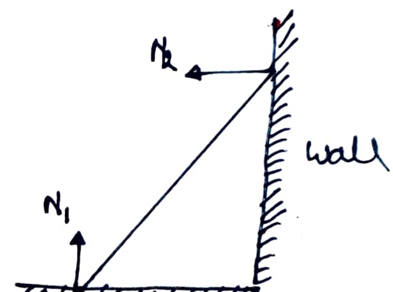
Example →



→ Tension will be same only when the string or rope is mass less.

Q → Draw Normal Reaction and Tension Force.





Normal force will be always there wherever there is two surfaces are in contact.

FREE Body DIAGRAM

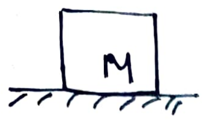
RULE → (i) Any Body which may have any shape size will be assumed as point size body.

(ii) Show all the forces acting on it.

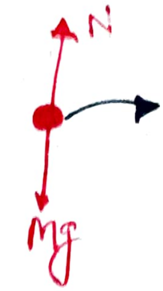
(iii) No. of forces acting on a body depends upon frame of reference. [Types of Reference → Inertial, Non inertial]

DRAW F.B.D FOR The following Case →

(I)

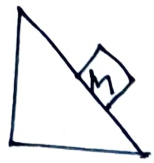


⇒

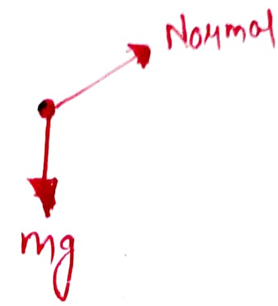


Mass is replaced by point.

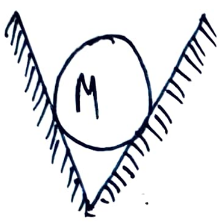
(II)



→

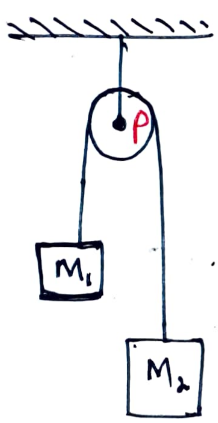


III

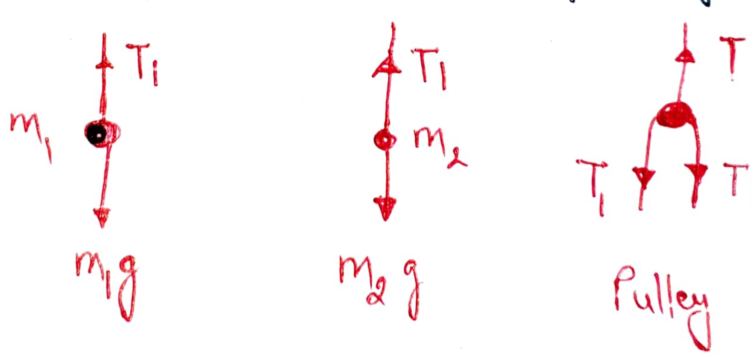


→

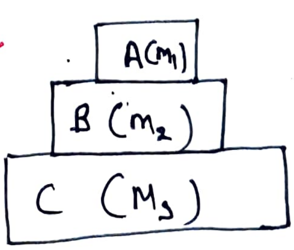
(IV)



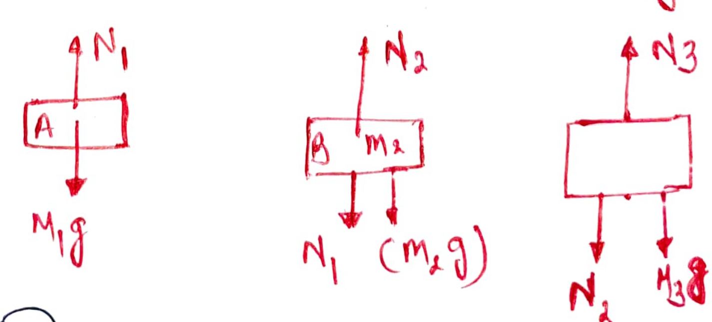
In this there are three body i.e pulley, m_1 and m_2 so we will draw F.B.D for all the three body separately.



(V)



→



$N_1 = M_1 g$

$N_2 = N_1 + m_2 g$

$N_3 = N_2 + M_3 g$

→ These Relation will be possible only when blocks are at rest.

Newton's First Law Of Motion

According to Newton's First law of Motion an object will remain in a state of rest or uniform motion untill and unless some unbalanced external force is applied on the body.

If $F_{NET} = 0$ then $a_{net} = 0$ ⇒ That mean state of the object will not change.

This means body will be in equilibrium.

* If body is at rest it will remain in rest
* If body is in motion it will continue to move with velocity.
* ☆☆ **No** force is required to move a body with constant velocity.

Numerical Based On NFLM

NEWTON'S FIRST LAW OF MOTION

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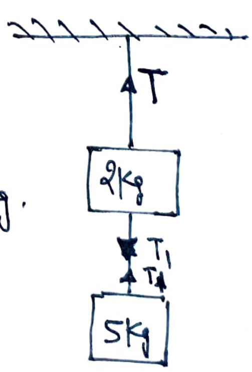
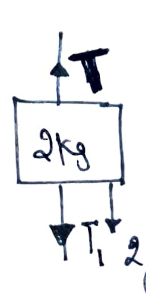
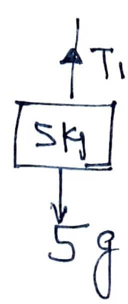
NUMERICAL BASED ON NFLM

Q→1 If the system is in Equilibrium then find the value of tension the spring.



Sol → Draw F.B.D for the mass 2 kg and 5kg.



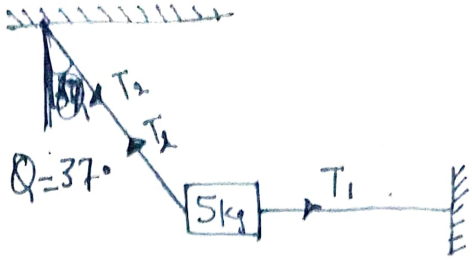


$T = T_1 + 2g$ $\qquad$ $T_1 = 5g$ $\qquad$ $T_1 = 5 \times 10 = 50N$

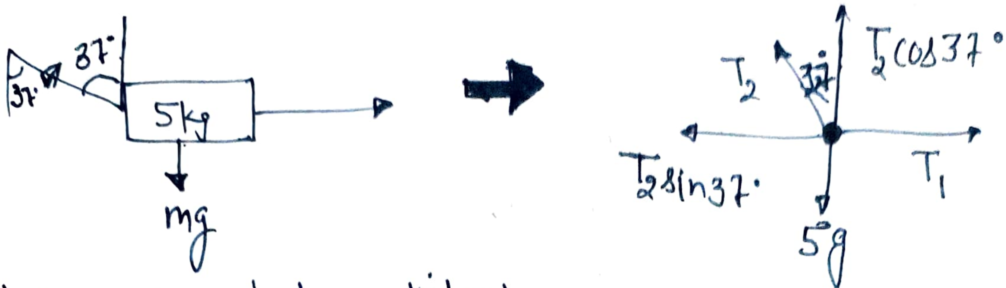
$T = 50 + 2 \times 10$

$T = 70 N$

Q→2 If the system is in equilibrium then Find T_1 and T_2



Sol Draw F.B.D



Since system is in equilibrium

$\Sigma F_x = 0$

$T_2 \cos 37° = 5g$

$T_2 \times \frac{4}{5} = 5 \times 10$

$T_2 = \frac{5 \times 10 \times 5}{4}$

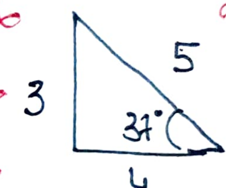
$T_2 = 62.5N$

$\Sigma F_y = 0$

$T_1 = T_2 \sin 37°$

$T_1 = 62.5 \times \frac{3}{5}$

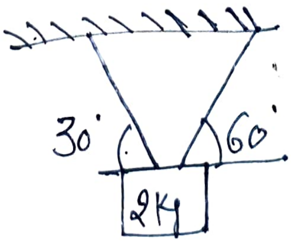
$T_1 = 37.5N$



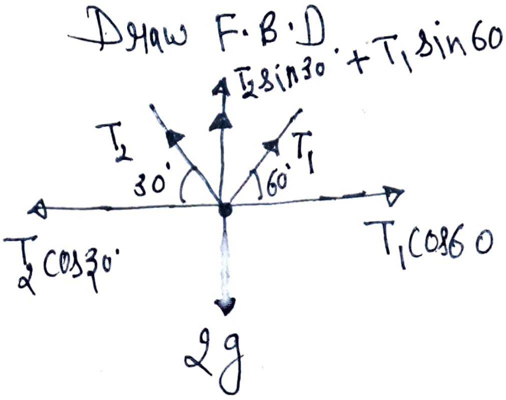
$\cos 37° = \frac{4}{5}$

$\sin 37° = \frac{3}{5}$

Q→3 Find tension in both string.



Sol Draw F.B.D



$F_x = 0$

$T_1 \cos 60° = T_2 \cos 30$

$\frac{T_1}{2} = T_2 \times \frac{\sqrt{3}}{2}$

$T_1 = \sqrt{3} T_2$

$F_y = 0$

$T_2 \sin 30° + T_1 \sin 60 = 2g$

$T_2 \times \frac{1}{2} + T_1 \frac{\sqrt{3}}{2} = 20$

$T_2 + \sqrt{3} T_1 = 40$

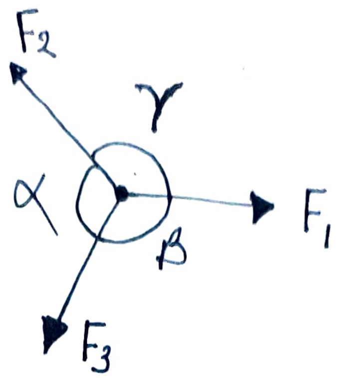
$T_2 + 3T_2 = 40$

$\Rightarrow T_2 = 10N$

$T_1 = 10\sqrt{3}N$

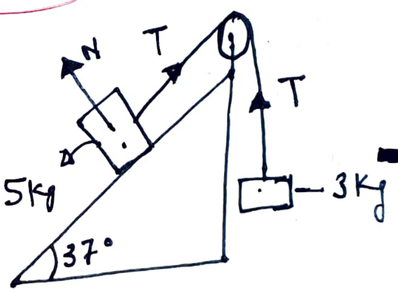
LAMI'S THEOREM

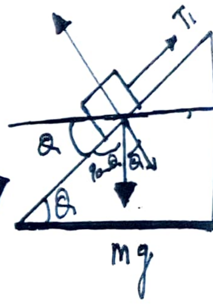
If an object is in equilibrium under three forces which are concurrent i.e F_1, F_2 and F_3 then



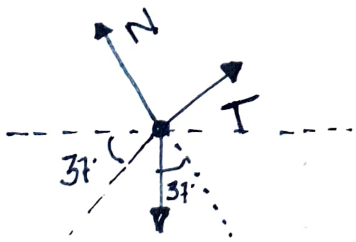
$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

Q→1 Find the value N And T if the system in under Equilibrium.



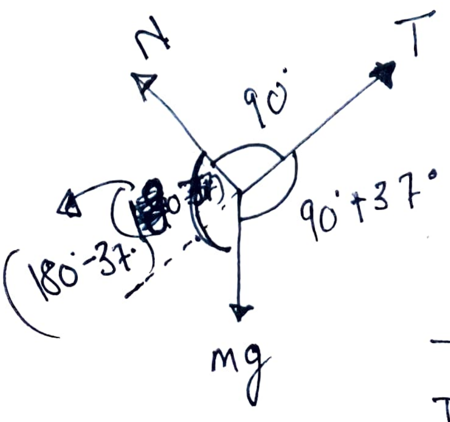


Sol Draw F.B.D



T = 30 N

N = 40 N



$$\frac{T}{\sin(180-37^\circ)} = \frac{N}{\sin(90+37^\circ)} = \frac{mg}{\sin 90^\circ}$$

$$\frac{T}{\sin(180-37^\circ)} = mg$$

$T = 50 \sin 37^\circ$

$T = 50 \times \frac{3}{5} = 30 N$

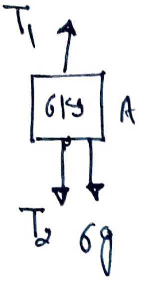
$$\frac{N}{\cos 37^\circ} = mg = 50$$

$N = 50 \cos 37^\circ$

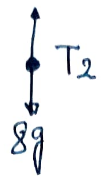
$N = 50 \times \frac{4}{5} = 40 N$

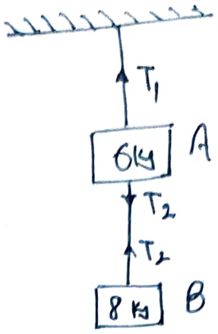
Q→ Find T_1 and T_2 if the system is in equilibrium

Sol F.B.D of A



F.B.D of B





$T_2 = 80\,N$

$T_1 = T_2 + 60$

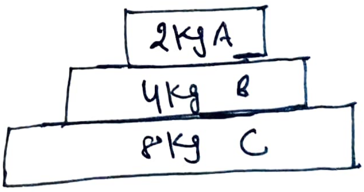
$T_1 = 80 + 60 = 140\,N$

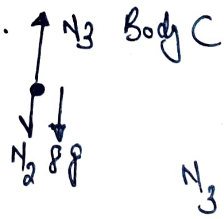
$T_1 = 140\,N$ $T_2 = 80\,N$

Q→ If the system is in equilibrium Find all the Value of Normal reaction

Sol Body A

Body B





$N_1 = 2g$

$N_1 = 2 \times 10$

$N_1 = 20\,N$

$N_2 = N_1 + 4g$

$N_2 = 20 + 4 \times 10$

$N_2 = 60\,N$

$N_3 = N_2 + 8g$

$N_3 = 60 + 80$

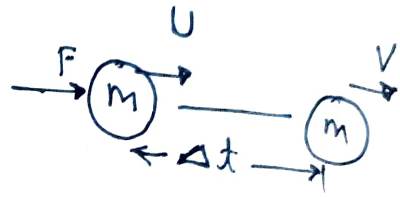
$N_3 = 140\,N$

Newton's Second Law Of Motion

According to Newton's Second law of Motion the rate of change of Linear momentum is directly proportional to force applied on the body in the direction of motion.

$$F \propto \frac{\Delta P}{\Delta T} \Rightarrow F = K\frac{\Delta P}{\Delta t}$$

Formula Of Force when mass is Constant



$$F = K\frac{m\Delta V}{\Delta T}$$

$$F = Km\frac{[V-U]}{\Delta t} \quad \{\Delta V = V-u\}$$

$$F = Kma$$

$$K=1 \qquad F = ma$$

Now if Mass and velocity is also variable then

$$F \propto \frac{\Delta P}{\Delta t}$$

$$F = K\frac{\Delta p}{\Delta t}$$

if time time interval is very small then

$$F = K\frac{dp}{dt}$$

$$K=1 \qquad p = mV$$

$$F = K\frac{d(mV)}{dt}$$

$$F = K\, m\frac{dv}{dt} + V\frac{dm}{dt}$$

$$F = m\frac{dV}{dt} + V\frac{dm}{dt}$$

→ Differential form of Newton's Second law of motion.

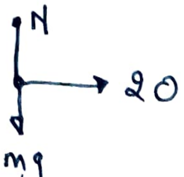
NUMERICAL ON SECOND LAW OF MOTION

Q→1 Find Acceleration In Following Case.

$F_1 > F_2$

(i)

Sol F.B.D



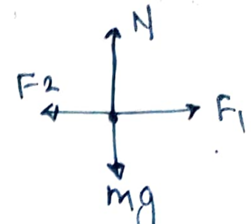
$N = mg$

Since body is having Net force on y axis is Zero so it will move along x axis

$ma = 20 \Rightarrow a = \frac{m}{20}$

(ii)

Sol



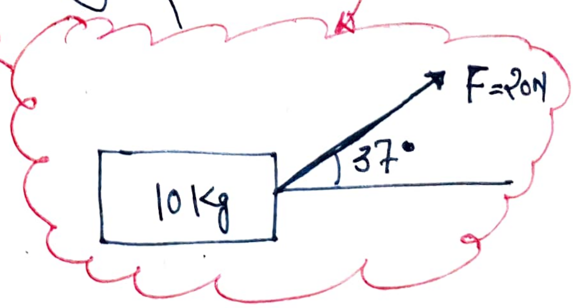
$N = mg$ along y axis — Body is in equilibrium

But along x axis body is going to Accelerate

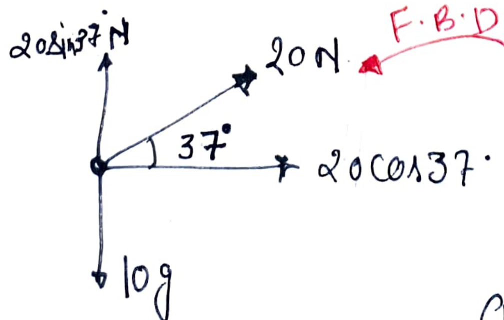
$a = \frac{F_{net}}{m} = \frac{F_1 - F_2}{m}$

$a = \frac{F_1 - F_2}{m}$ → Direction of Acceleration will in the direction where body will move.

Q→2 Find Normal Reaction In the following Case also acceleration



Sol F.B.D



$20\sin37° + N = mg$

$N = mg - 20\sin37°$

$N = 10 \times 10 - 20 \times \frac{3}{5}$

$N = 100 - 12$

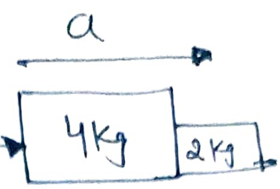
$N = 88N$

$a = \frac{F_{net}}{m} = \frac{20\cos37°}{10}$

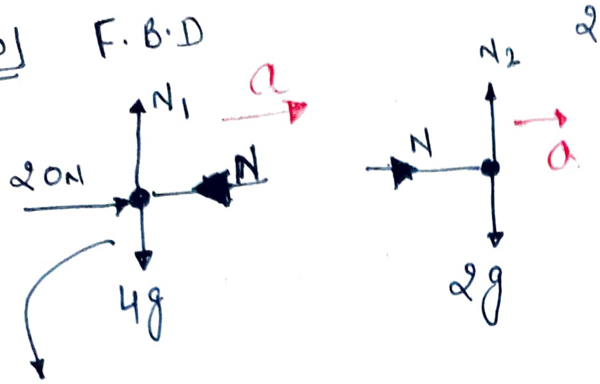
$a = \frac{20 \times \frac{4}{5}}{10} = 1.6\ ms^{-2}$

$a = 1.6\ ms^{-2}$

Q→ Find the Normal Reaction Between the block and acceleration.



Sol F.B.D



$F_{Net} = ma$

$20 - N = ma$

$20 - ma = N \Rightarrow N = 20 - 4 \times \frac{10}{3}$

$N = \frac{20}{3}$ Newton

Acceleration = $\frac{F_{net}}{\text{Mass of system}}$

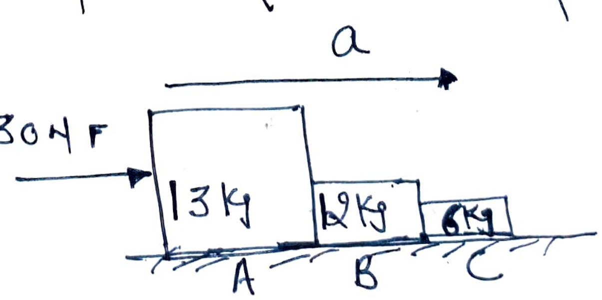
$a = \frac{20}{4+2} = \frac{20}{6} = \frac{10}{3}$

$a = \frac{10}{3} m/s^2$

IMPORTAN POINT

* Net force in Y direction is zero because the body is only accelerating in x axis only.

Q→ FIND ACCELERATION B/W BLOCK and Normal Reaction b/w block

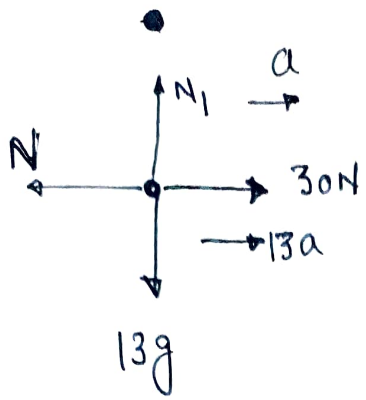


Sol Since all the blocks are moving together so they will move with constant acceleration.

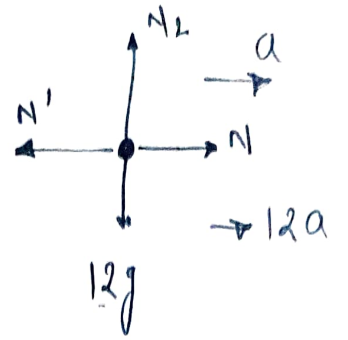
$$a = \frac{F_{net}}{\text{Mass of the system}} = \frac{30}{13+12+6} = \frac{30}{31} m/s^2$$

$a = \frac{30}{31} m/s^2$

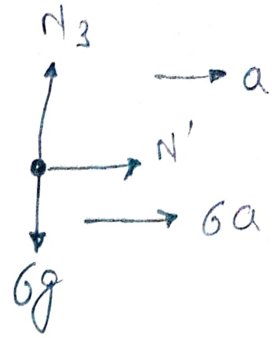
F.B.D of A



F.B.D of B



F.B.D of C



$N_1 = 13g \quad \Sigma F_y = 0$

$30 - N = 13a$

$N = 30 - 13a$

$N = 30 - 13 \times \frac{30}{31}$

$N = 30\left[\frac{31-13}{31}\right]$

$N = \frac{18 \times 30}{31} N$

$N = \frac{540}{31} N$

$N - N' = 12a$

$N = 12a + N'$

$N = 12 \times \frac{30}{31} + \frac{180}{31}$

$N = \frac{180}{31}\left[2+1\right]$

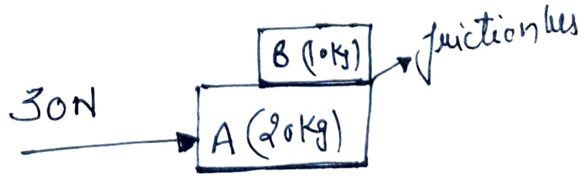
$N = \frac{540}{31} N$

$N' = 6a$

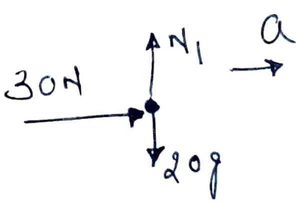
$N' = 6 \times \frac{30}{31}$

$N' = \frac{180}{31} N$

Q→ FIND Acceleration of Block A and Block B if the the surface are smooth when a force F is applied on the Lower block



Sol F.B.D of A



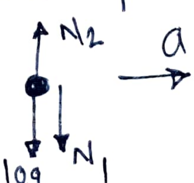
$N_1 = 20g$

$F_{net} = ma$

$30 = ma \Rightarrow a = \frac{30}{20} = \frac{3}{2}$

$a = \frac{3}{2} m/s^2$

F.B.D of B

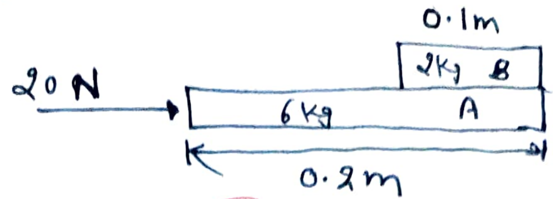


Since No external force is acting on the block in x direction of a

$a = 0$

Q→ Find the time taken by the block (B) to slip down if the surface in contact are frictionless.

Sol



Net acceleration of A

$= \frac{20}{6} = 3.3\ m/s^2$

$a_{net} = \frac{20}{6+2}$ we will not take this because surface are frictionless ~~not contact~~ with

Acceleration will be zero with respect to some observer on the ground.

But if calculate the acceleration of block b with respect to Block A then B will have an acceleration

$a = -3.3\ m/s^2$

Now time taken to fall of block B

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

$-(0.2+0.1) = 0t + \frac{1}{2}(-3.3)t^2$

$\cancel{-}0.3 = \cancel{-}\frac{1}{2}3.3t^2$

$\frac{3\times2}{33} = t^2$

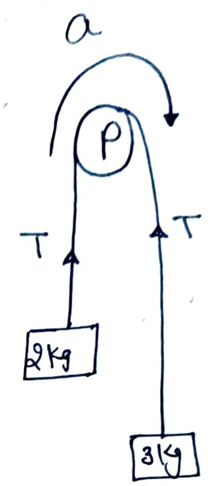
$t = \sqrt{\frac{6}{33}}$

$s = -(0.2+0.1)$

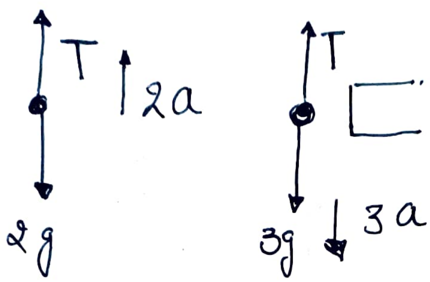
$s = -0.3$

The displacement is negative because the block B is moving in backward direction with respect to A

Q→ Find Acceleration and Tension in the string. If string and pulley are Massless



Q→ Sol F.B.D



$T - 2g = 2a$ $\qquad$ $T = 3g + 3a$

$T = 2g + 2a$

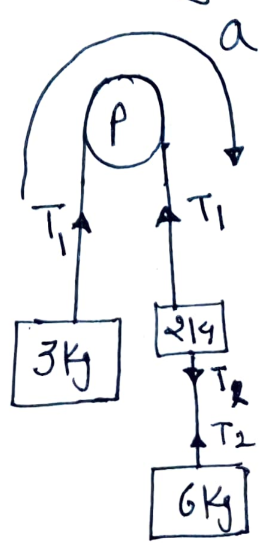
$T = 2\left(10 + \frac{1}{5}\right) \Rightarrow T = \frac{102}{5}\,N$

$a = \frac{\text{Net Pulling force}}{\text{Total Mass of system}}$

$a = \frac{3g - 2g}{2 + 3} = \frac{1}{5}$

$a = \frac{1}{5}\ m/s^2$

Q→ Find Net Acceleration Tension in the string is string and pully are massless.



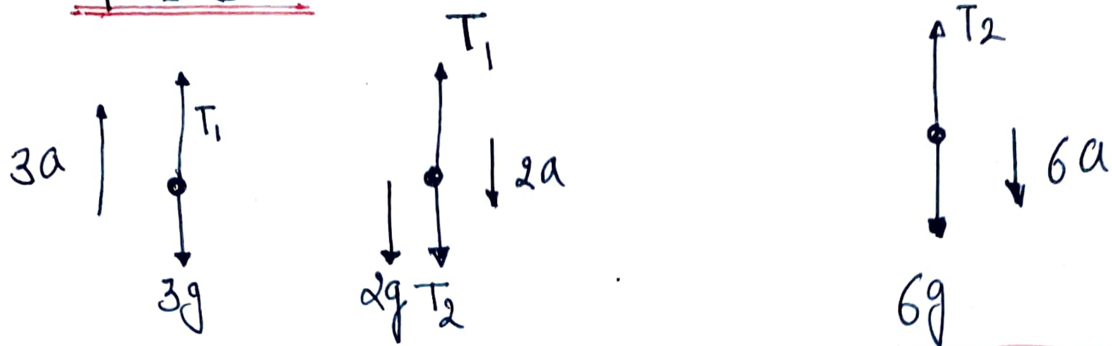
Sol Net acceleration

$a = \frac{\text{Net pulling force}}{\text{Total Mass}}$

$a = \frac{2\times10 + 6\times10 - 3\times10}{2+3+6} = \frac{50}{11}$

$a = \frac{50}{11}\ m/s^2$

F.B.D



$T_1 - 3g = 3a$ — (1)

$T_1 = 3g + 3a$

$T_1 = 3\left(10 + \frac{50}{11}\right)$

$T_1 = 16$

~~$T_1 = 2a + 2g + T_2$~~

$2g + T_2 - T_1 = 2a$ — (2)

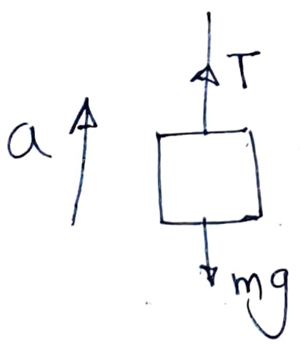
$6a = 6g - T_2$ — (3)

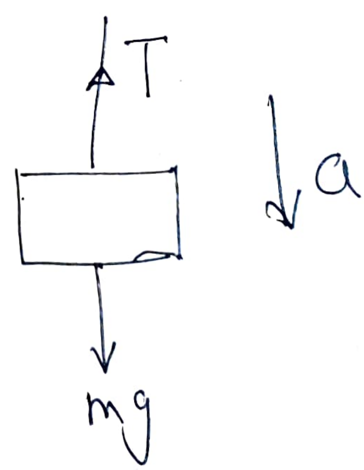
$T_2 = 6 \times 10 - 6 \times \frac{50}{11}$

$T_2 = 32.72$ N

You can also find out the value of a by solving equation (1), (2) and (3)

Import Point while writing equation





The force in the direction of net acceleration will be positive and against acceleration is negative.

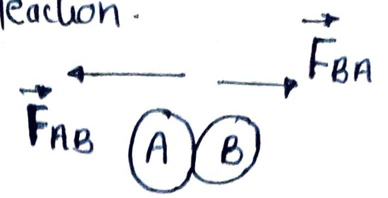
$T - mg = ma$

$mg - T = ma$

NEWTON'S THIRD LAW OF MOTION

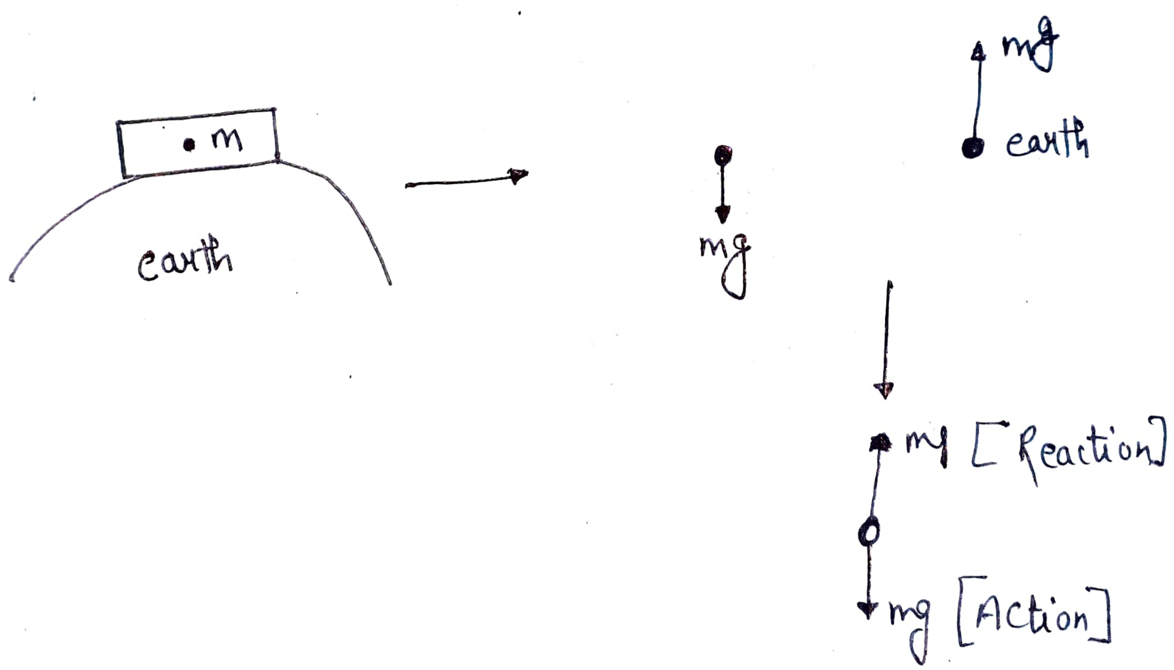
According to Newton's Third law of motion "For every action there is always an equal and opposite reaction.

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



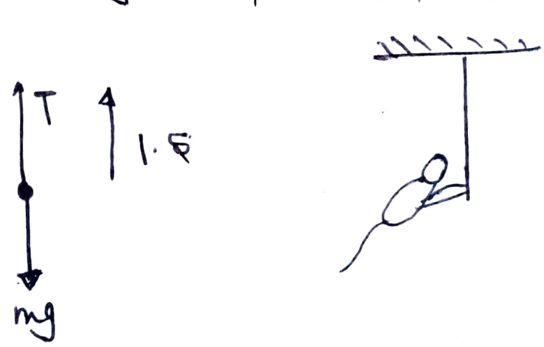
IMPORTANT POINTS RELATED TO NEWTON'S THIRD LAW OF MOTION

1. Action and Reaction acts on two different body.
2. Action and Reaction pair are of same Nature
3. Forces always exist in pair



Q→1 A monkey having mass of 30kg is climbing a rope with an acceleration of 1.5 m/s². Find the tension in the rope

Sol F.B.D



$$T - mg = ma$$

$$T = ma + mg$$

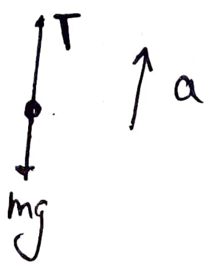
$$T = 30 \times 1.5 + 30 \times 10$$

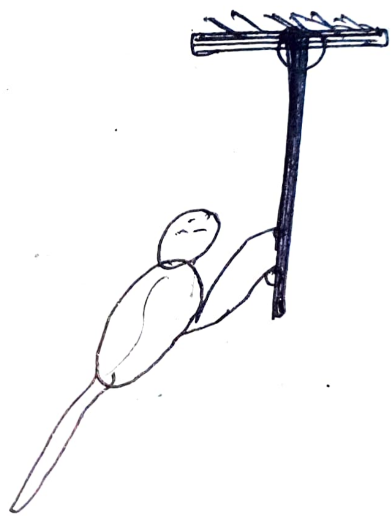
$$T = 345N$$

Q→ 2 Find the maximum acceleration with which a monkey can climb the rope when the breaking tension of the rope is 340 N and mass of the monkey is 20 kg.

Sol

$$T - mg = ma$$





$$a = \frac{T - mg}{m}$$

$$a = \frac{340 - 20 \times 10}{20}$$

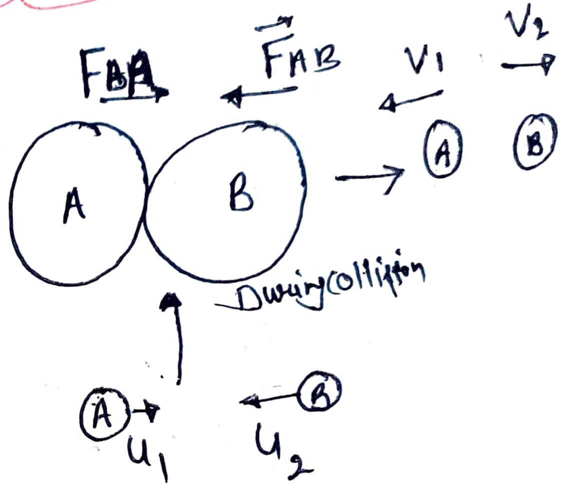
$$a = \frac{140}{20} \Rightarrow a = 7 \, m/s^2$$

LAW OF CONSERVATION OF MOMENTUM

When net external force acting on the system is zero then the momentum of the system is conserved.

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Sum of initial momentum = Sum of final momentum



Before collision

PROOF ⇒ Let us consider two objects A and B are colliding against each other when they they will exert force on each other and they will move with velocity V_1 and V_2.

so According to Newton's third law of motion

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

from Newton's second law of motion

$$\frac{dP_B}{dt} = -\frac{dP_A}{dt}$$

$$dP_B = -dP_A$$

$$m\,dV_B = -m\,dV_A$$

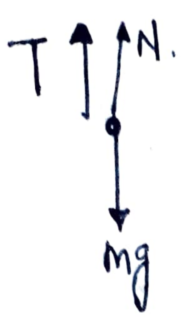
$$m(V_2 - U_2) = -m(V_1 - U_1)$$

$$m_2 V_2 + m_1 V_1 = m_1 U_1 + m_2 U_2$$

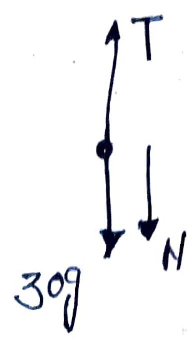
Law of conservation of momentum is result of first and second law's combination.

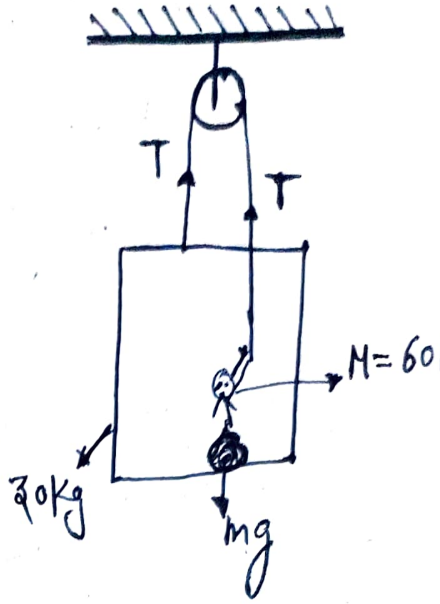
Q→ FIND THE FORCE exerted by man on the lift as shown by weighing scale when the whole system is in equilibrium.

Sol F.B.D OF MAN



F.B.D OF Lift





$T + N = mg$

$T + N = 60g$ —(1)

$T = 30g + N$ —(2)

from (1) and (2) equation

$30g + N + N = 60g$

$2N = 30g$

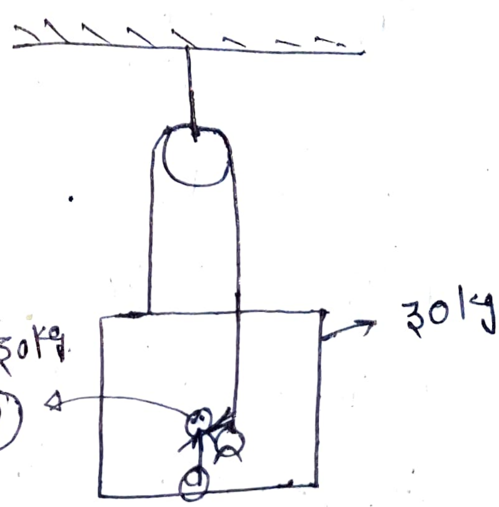
$N = 15g$

$N = 150N$ → This is the force exerted by man on lift.

Q Find the force that a man should apply to keep the system in equilibrium.

Sol F.B.D OF Man

F.B.D of Lift



$N + T = 50g$ —(1)

$30g + N = T$ —(2)

from (1) and (2)

$N + 30g + N = 50g$

$N = 10g$

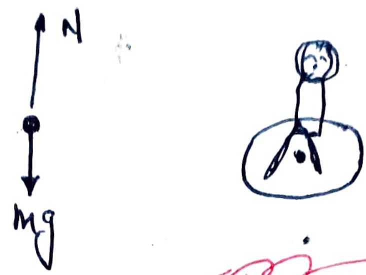
$T = 30g + 10g$

$T = 40g = 400N$

WEIGHING MACHINE

Weighing Machine always measure normal reaction exerted. by

Weight of the body = N



When the weighing Machine is at rest then $N = mg$ → This is known as actual weight.

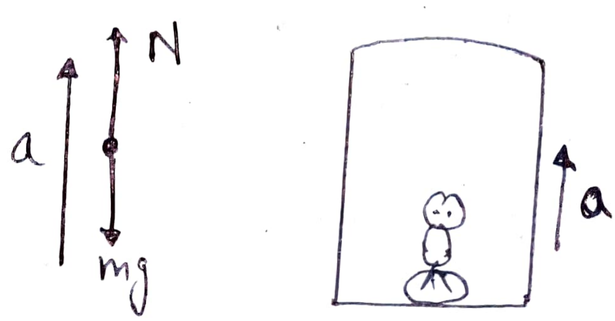
APPARENT WEIGHT ⇒ When the weighing machine is kept in a lift and the lift is accelerating upward or downward with some acceleration then weight of the person will increase or decrease. So this increased and decreased weight is known as apparent weight.

Case I When the lift is going upward with an acceleration a

$N - mg = ma$

$N = mg + ma$

$N = m(g + a)$



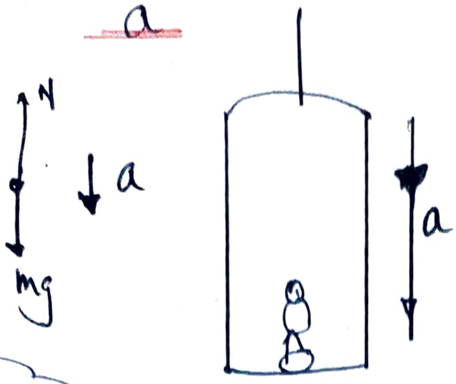
→ Apparent weight will be greater than actual weight

CASE-2 DOWNWARD With acceleration a

$Mg - N = Ma$

$N = Mg - Ma$

$N = M(g-a)$



In this condition actual weight will be greater than apparent weight

Case-3 Moving Downward with acceleration $a = g$

$Mg - N = Ma$

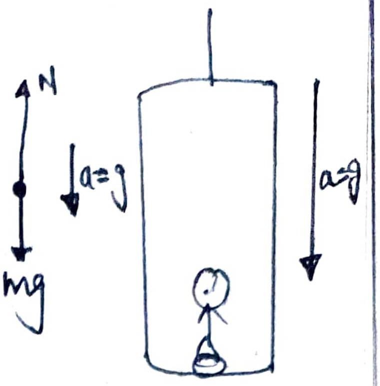
$a = g$

$Mg - N = Mg$

$N = Mg - Mg$

$N = 0$ → So in this condition apparent weight is zero

This is known as condition of weightlessness

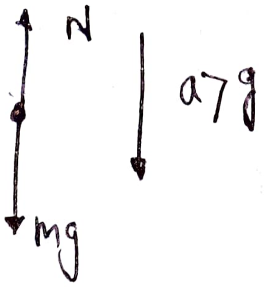


Case-4 When lift is going downward with $a > g$

$Mg - N = Ma$

$N = Mg - Ma$

$N = M(g-a)$



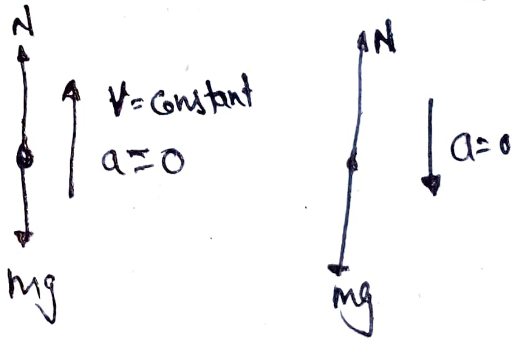
Since $a > g$

So $N = -ve$

But N can never be negative so $N = 0$

In this condition apparent weight is negative means the person will move away from the floor and his head will hit the roof

CASE 5 When the Lift is moving upward and downward with constant velocity



$N - Mg = 0$

$N = Mg$

$Mg - N = M \times 0$

$Mg = N$

In this apparent weight is equal to actual weight