# Physics Notes

BY

Er. Lalit Sharma
B.Tech (Electrical)
Ex. Lecturer Govt. Engg. College Bathinda
Physics Faculty Ranker's Point, Bathinda

Arun Garg
M.Sc. Physics
Gold Medalist
Physics Faculty Ranker's Point, Bathinda

Class:10+1
Unit: III
Topic: Laws of Motion

*SYLLABUS*: UNIT-III-*A,B*

Force and inertia, Newton's first law of motion; Momentum, Newton's second law of motion, Impulse; Newton's third law of motion; Law of conservation of linear momentum and its application;

Equilibrium of concurrent forces; Static and Kinetic friction, laws of friction, rolling friction, lubrication; Example of variable-mass situation.

Dynamics of uniform circular motion, Centripetal force, examples of circular motion (vehicle on level circular road, vehicle on banked road); Inertial and non-inertial frames (elementary idea).

**Q1.a) What is force? Units? Dimensions?**
**b) Discuss different outcomes of force?**
**c) "Contact" and "Non-Contact" type of force?**

Ans.a) **<u>Force</u>**:- A push or pull

- Produces or tries to produce a motion in object at rest.
- Stops or tries to stop a moving body
- Changes or tries to change direction of a body

<u>Units</u>:- newton, N
<u>Dimensions</u>:- $[F] = [M^1 L^1 T^{-2}]$

b) **<u>Different outcomes of force</u>**:-

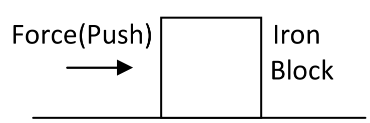
(i) When we push a ball lying on the ground, it starts rolling. The force exerted has thus produced motion in the ball. However, when we push a heavy stone, it does not move. The effort made in this case has only **tried** to produce motion.

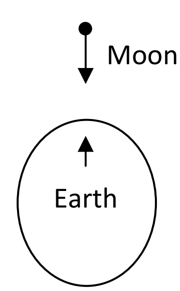
(ii) A ball falling downwards can be easily caught by our hands. The motion of the ball has thus been destroyed however, a big piece of rock rolling down a hill cannot be stopped even when we try our best to stop it.

(iii) When a piece of stone tied to one end of a string is whirled in a circle, a constant force has to be exerted by the hand along the string. Force is used in changing the direction of motion of the body from straight line path to circular path.

c) **<u>Contact and Non–Contact Forces</u>**:-

<u>Contact Forces</u>
Force is acting only when we touch the block.



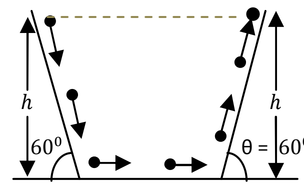

<u>Non – Contact Force</u>
Earth attracts moon from distance without any contact between the two. It is action from distance

**Q2.a) What is Inertia?**
**c) Galileo's Experiments on Inertia Concept?**

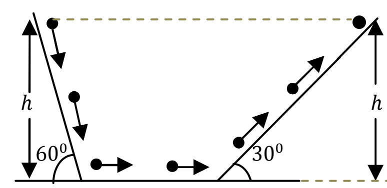
Ans.a)Inertia:-

Inertia is property of object by virtue of which they cannot change by themselves their state of rest or of uniform motion along a straight line.

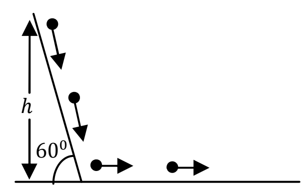
bi) When the slopes of the two planes are same, the distance covered in rolling down one inclined is same as the distance covered in climbing up other incline.




ii) When the slope of second smooth inclined plane is decreased, and experiment is repeated still it reaches the same height. As in doing so, it travels a larger distance.




iii) When the slope of second smooth inclined plane is made zero the ball travels an infinite distance. In this case, the ball will never stop.



**Q3.a) Define Linear Momentum? Units? Dimensions?**

**b) Plot**

**i) Plot þ-$v$ graph (m-constant)**

**ii) Plot þ-m graph ($v$- constant)**

**iii) Plot $v$-m graph (P-constant)**

Ans.a) **<u>Linear Momentum</u>**:- It is defined as product of mass of a body and velocity

$\vec{p}$ = m. $\vec{v}$ is vector

<u>Units:</u>- kg - $\frac{m}{sec}$

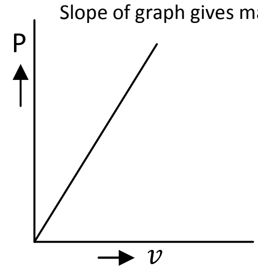
<u>Dimensions</u>:- $M^1L^1T^{-1}$

b)i) þ = m. $v$
↓
Constant

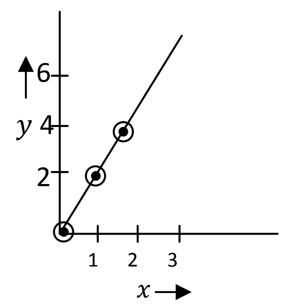
Y = 2(x)

| x | Y |
|---|---|
| 0 | 0 |
| 1 | 2 |
| 2 | 4 |

m → constatnt
Slope of graph gives mass *m*




$m = constant$

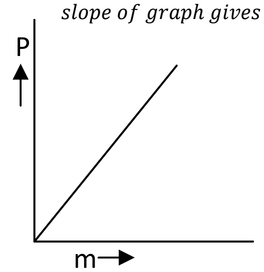



ii) þ = m. $v$
↓
Constant

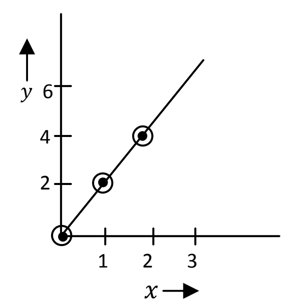
Y = x(2)

| x | Y |
|---|---|
| 0 | 0 |
| 1 | 2 |
| 2 | 4 |

$v$ → constatnt
*slope of graph gives velocity*




$v = constant$



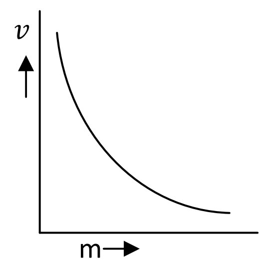

iii) þ = m. $v$
↓
Constant

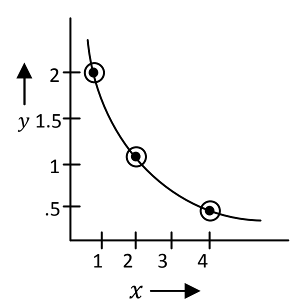
2 = x.y

$\frac{2}{x}$ = y

| x | Y |
|---|---|
| 1 | 2 |
| 2 | 1 |
| 4 | .5 |

þ → constatnt



**Q4. State Newton's Laws of Motion?**

Ans. **First Law**:-

According to this law a body continues to be state of rest or of uniform motion along a straight line unless it is acted upon by some external force to change the state

**Second Law**:-

Force ∝ the rate of change of momentum

$$F \propto \frac{dp}{dt}$$

According to this law, the rate of change of linear momentum of a body is directly proportional to external force applied on the body and this change takes place in the direction of force applied.

**Third Law**:-

"Action and Reaction" are always equal and opposite.

**Q5. State and Explain Newton's First Law?**

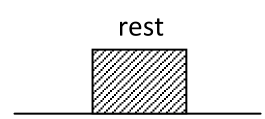
Ans. **Statement**:-

If the net external force on the body is zero, its accelerations is zero. Acceleration can be zero if there is no net external force on the body.

**Explanation**:-

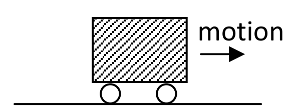
Rest , Motion and Direction

(i) Rest :- A body at rest will continues to be at rest.



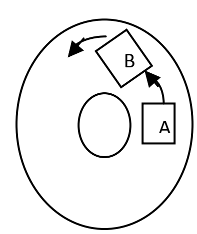

For ex:- A chair at rest will continues to be at rest.

(ii) Motion:- A body in motion will continues to be in motion.




For ex:- When the engine of the car is switched off it stops after some time because there is a some external force applied.

(iii) Direction:- A body cannot changes its direction of motion i.e. It continues to move along a straight line.




For ex:- to turn a car along the straight road, we have to apply the force on the steering wheel of the car.

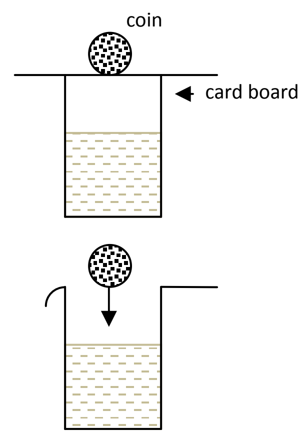
**Q6. Explain three types of inertia?**

Ans. **<u>Inertia of Rest</u>**:-

It is the inability of a body to change by itself its state of rest. This means a body at rest remains at rest and cannot start moving on its own.

Ex-1 Suppose we are standing in a stationary bus and the driver starts the bus suddenly. Then we get thrown backward with a jerk.

Ex-2 Place a coin on smooth cardboard piece. Strike the cardboard piece suddenly with a finger. The cardboard slips away and coin falls.




Ex-3 When we shake a branch of mango tree the mangoes falls down .This is because branch comes in motion and the mangoes tend to remain at rest.

**<u>Inertia of Motion</u>**:-

It is the inability of a body to change by itself its state of uniform motion. A body in uniform motion can neither accelerate nor retard on its own and come to rest.

Ex-1 Suppose we are standing in moving bus the driver stops the bus suddenly we get thrown forward with a jerk.

Ex-2 When a horse at full gallop stops suddenly, the rider falls forward on the account of inertia of motion.

Ex-3 A person jumping out of speeding train may fall forward. This is because his feet come to rest on touching the ground and the remaining body continues to move due to inertia of motion.

**<u>Inertia of direction</u>**:-

It is the inability of a body to change by itself its direction of motion i.e. a body continues to move along a straight line unless compelled by some external force to change it.

Ex-1 An umbrella protects us from rain. It is based on the property of inertia of direction. The rain falling vertical downwards cannot change their direction of motion and wet us with the umbrella on.

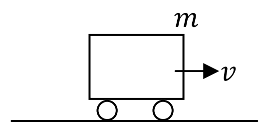
Ex-2 When a car rounds a curve suddenly, the person sitting inside is thrown outwards. This is because a person tries to maintain his direction of motion due to directional inertia while the car turns.

Ex-3 When a knife is sharpened by pressing it on grinding stone. The sparks fly off along the tangent to the grinding stone on a account of directional inertia.

**Q7. State and explain Newton's Second Law?**

Ans. **<u>Second law</u>**:-

Force ∝rate of change of linear momentum According to Newton second law of motion, Rate of change of linear momentum of a body is directly proportional to external force applied on the body and this change takes place always in the direction of force applied.




$$F \propto \frac{dp}{dt}$$

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

$$F = \frac{d}{dt}(m.\,v)$$

<u>Case I</u> m → Constant

$$F = \frac{d}{dt}(m.\,v) = m.\frac{dv}{dt}$$

F = m.a when m-constant

<u>Case II</u> $v$ -Constant

$$F = \frac{d}{dt}(m.\,v)$$

$$F = v.\frac{dm}{dt}$$ for constant speed

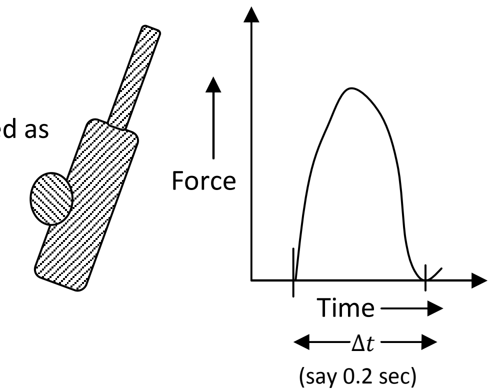
Example 1:-Numerical m → Constant

Example 2:-Numerical $v$ → Constant

**Q8.a) What are impulsive forces? What is impulse?**
**b) Application of Impulse?**

Ansa) **Impulsive Forces**:-

Forces which act for short interval of time are termed as impulsive forces.




Ex: Ball hitting bat, force first increases then decreases.

**Impulse**:- Impulsive force causes change in momentum.

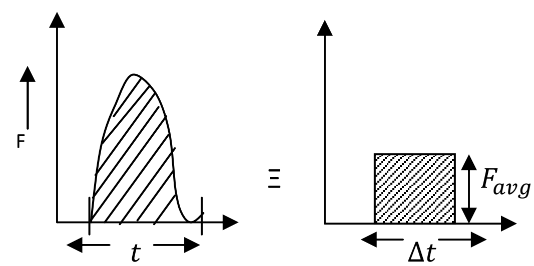
Force = $\frac{dp}{dt}$

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

F.dt = dp

Integrating on both sides $\left[\int F.dt = F_{avg}.\Delta t\right]$

$$\int dp = \int F.dt$$




$|\Delta p|_p^p$ = Area under F-t graph

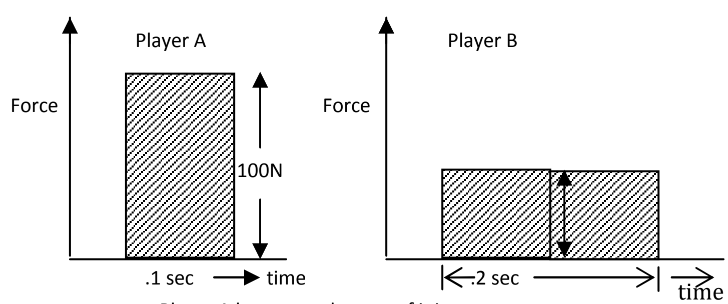
= Area under F-t graph

time

$P_f - P_i$ = Area under F-t graph

b) **Applications of Impulse**:-

(i) A cricket player lowers his hand while catching a cricket ball.




Player A has more chances of injury

(ii) When a person falls from certain height on cemented floor, the floor does not yield.

(iii) The vehicles like car, scooter, truck etc are provided with shockers.

(iv) China wares or glass wares are wrapped in a piece or straw pieces before packing.

**Q9.a) Which Law of Newton (out of 3 Laws of motion) is fundamental Law?**

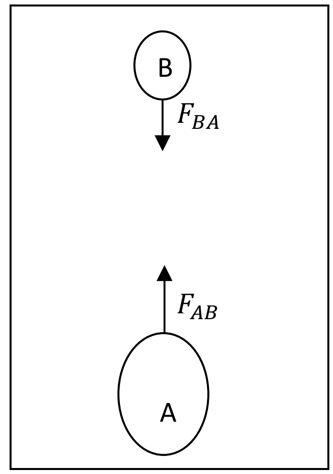
**b) Derive Newton 3rd Law from 2nd Law?**

**c) Derive Newton 1st Law from 2nd Law?**

Ans.a) 2nd Law is fundamental as 1st and 3rd Law can be derived from 2nd Law.

b) **Newton 3rd Law from 2nd Law**

$\vec{p}_{system} = \vec{p}_A + \vec{p}_B$ (Total momentum of system is due to particles only)




Differentiate both sides

$\frac{d}{dt}(p_{syst}) = \frac{d}{dt}(\vec{P}_A) + \frac{d}{dt}(\vec{P}_B)$

$0 = \vec{F}_{AB} + \vec{F}_{BA}$ (No external force applied on the body)

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

Action = Reaction

Action & Reaction are equal & opposite.

c) **Newton 1st Law from 2nd Law**

F = ma

If F = 0 (No external force applied on the body)

ma = 0

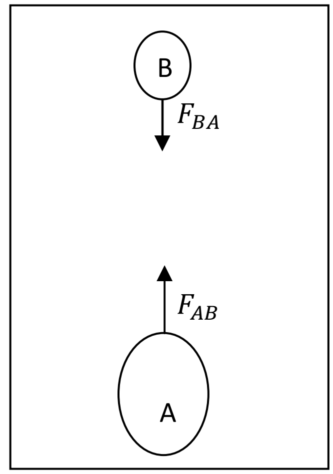
$\Rightarrow a = 0$ (because m is constant)

Acceleration is zero means $\frac{d(velocity)}{dt} = 0$

It means velocity is constant

So, a body in motion will continue to be in motion and if at rest will continue to be at rest.

**Q10.a) State and Explain Newton 3rd Law?**
**b) Examples/Applications of Newton 3rd Law?**



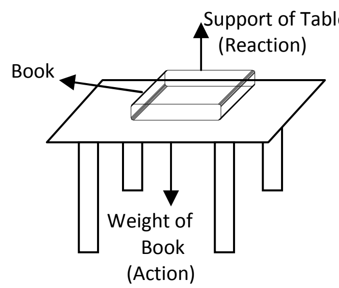

Ans.a) **Statement**:-
'Action and Reaction are always equal / opposite'.

Explanation:- In a given system of two objects A and B

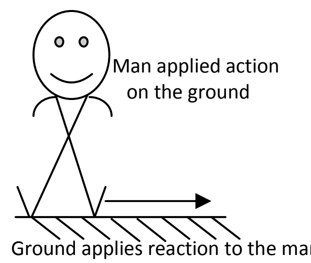
$$F_{AB} = F_{BA}$$

b) Examples:-

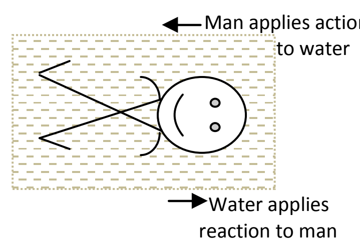
(I) Book kept on table: - A book lying on the table exerts force which is equal to weight of book. The table supports the book, by exerting an equal force.



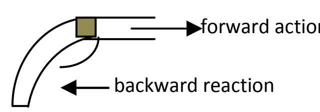

(II) Walking:- while walking ,a person presses the ground backward direction and the ground pushes the person in forward direction.



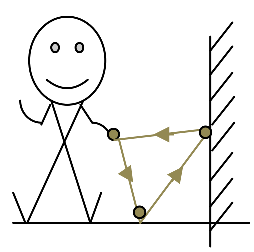

(III) Swimming:- While swimming, a swimmier pushes the water in backward direction and the water pushes the swimmer in foreword direction.



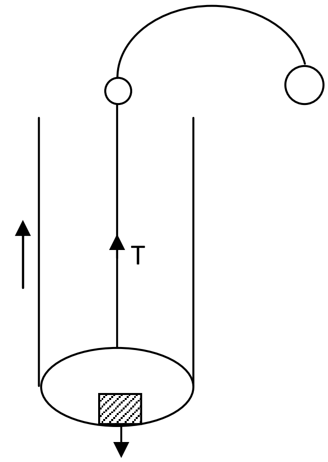

(IV) Firing from a gun:- When a gun is fired, the bullet moves in forward direction and the gun moves in backward direction.




(V) Rebounding of rubber ball:- When a rubber ball is struck against a wall or floor, It exerts a force on the wall. The ball rebounds with an equal force exerts by the wall on the ball.



**Q11. Discuss variation of a weight of a man in a lift for different cases.**




Ans. Case I:- Moving up, accelerating

$T = m.g + m.a$

$= m (g + a)$

Ex $g_{eff} = g + a$

$= 10 + 2$

$= 12$

Case II acc = 0, moving up

$g_{eff} = g \pm a$

$= g \pm 0$

$= g$

Case III Retarding, moving up

$g_{eff} = g - a$

Case IV Moving down, acceleration

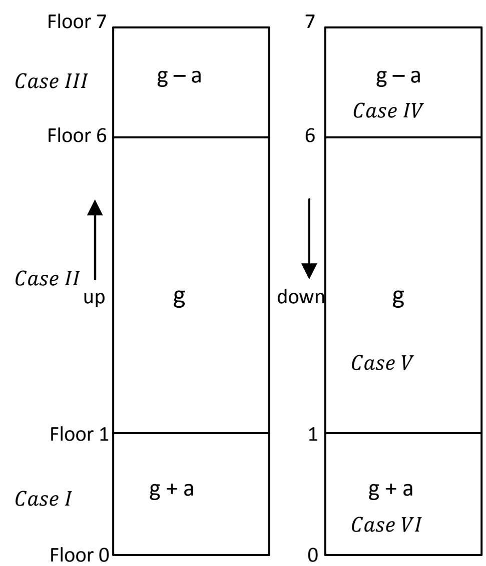
$g_{eff} = g - a$

Case V Moving down with constant speed, acc = 0

$g_{eff} = g \pm 0$

Case VI Moving down, Retarding

$g_{eff} = g + a$

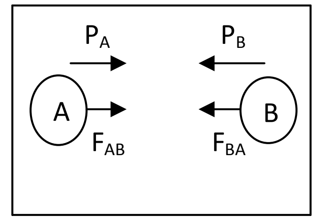


**Q12. State and prove Law of conservation of Linear Momentum?**

Ans. **Law**:-

In an isolated system (No external force acting) total momentum of system remains conserved.

$At\ time = 0$




**Proof**:-

Two objects A and B are under influence of two forces $\vec{F}_{AB}$ and $\vec{F}_{BA}$ as shown

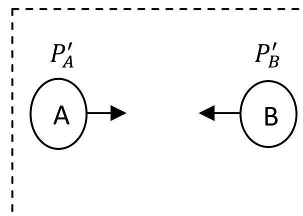
For object A

Momentum of A changes due to force $\vec{F}_{AB}$ for time Δ t

Change in momentum = $p_A$ - $p_A$

? $\vec{F}_{AB}.\Delta$ t = $\vec{P}'_A$- $\vec{P}_A$ --------------- (1)

$At\ time = \Delta$ t




For object B

Momentum of B changes due to force $\vec{F}_{BA}$ for time Δt

change in momentum = $P_B - P_B$

$\vec{F}_{BA}.\Delta$ t = $\vec{P}'_B$- $\vec{P}_B$

$\vec{F}_{BA}.\Delta$ t = $\vec{P}'_B$- $\vec{P}_B$ ------------- (2)

As per Newton's 3rd Law

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

$\frac{P'_A - P_A}{\Delta t} = \frac{(P'_B - P_B)}{\Delta t}$

$P'_A - P_A = (P'_B - P_B)$

$P'_A - P_A = P'_B - P_B$

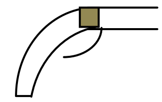
$\vec{P}'_A + \vec{P}'_B = \vec{P}_A + \vec{P}_B$

Total momentum after Δt = Total momentum initially

**Q13. 5 Examples/Applications of Law of conservation of Linear Momentum?**

Ans.(1) <u>Recoiling of a gun</u>:-

When a bullet is fired from a gun, the gun recoils i.e. moves in a direction opposite to the direction of motion of the bullet.

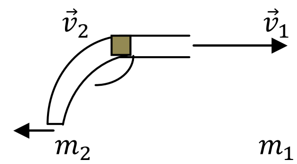


$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$m_1\vec{v}_1 + m_2\vec{v}_2 = 0$$

(2) <u>While firing, the gun must be held tightly to the shoulder</u>:-

This would save hurting the shoulder. When the gun is held tightly, the body of the shooter and gun behaves as one body. Total mass becomes large and therefore, recoil velocity of the body and the gun becomes too small.




$u_1$ = 0, $u_2$ = 0

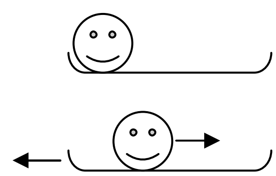
0 = $m_1\vec{v}_1 + m_2\vec{v}_2$

(3) <u>Flight of rockets and jet</u> <u>planes</u>:-

In rockets and jet planes, the fuel is burnt in the presence of some oxidizing agent in combustion chamber. The hot and highly compressed gases escape through the narrow opening with large velocity. As a result of it , the escaping gases acquire a large backward momentum, This in turn ,imparts an equal forward momentum to the rocket in accordance with the law of conservation of linear momentum.

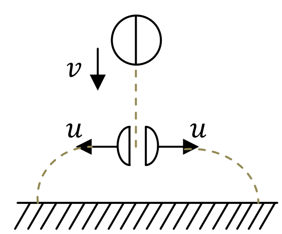
(4) <u>When a man jumps out of a boat to the shore</u>:-

The boat is pushed slightly away from the shore. The momentum of the boat is equal and opposite to that of the man in accordance with the law of conservation of linear momentum.



(5) <u>Explosion of bomb</u>:-

When a bomb falls vertically down wards in its horizontal velocity is zero and hence its horizontal momentum is zero. When bomb explodes, its pieces are scattered horizontal in different directions so that the vector sum of moments of these pieces becomes zero along x-axis.




(6) <u>A person left on a friction less surface</u>:-

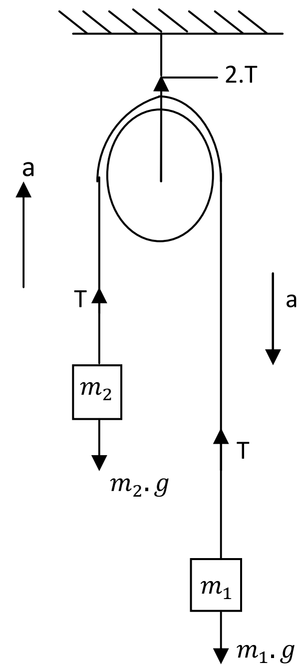
Can get away from it by blowing air out of his mouth or by throwing some object in a direction opposite to the direction in which he wants to move.

**Q14.** **Derive an expression for**

**a) Acc, a**

**b) Tension, T**

**For two masses ($m_1, m_2$) connected by a string passing over a pulley.**




Ans. <u>mass $m_1$</u>

$$a = \frac{m_1 g - T}{m_1} \quad \text{------} (1)$$

<u>mass $m_2$</u>

$$a = \frac{T - m_2 g}{m_2} \quad \text{------} (2)$$

Comparing eq(1) and (2)

$$\frac{m_1 g - T}{m_1} = \frac{T - m_2 g}{m_2}$$

$m_2 (m_1 g - T) = m_1 (T - m_2 g)$

$m_1 m_2 g - Tm_2 = Tm_1 - m_1 m_2 g$

$2m_1 m_2 g = Tm_1 + Tm_2.$

**Tension**

$$\boxed{T = \frac{2m_1 m_2 g}{m_1 + m_2}} \quad \text{------} (3)$$

Put value T in eqt. No.1

$$a = \frac{m_1 g - \frac{2m_1 m_2 g}{m_1 + m_2}}{m_1}$$

$$= \frac{{m_1}^2 g + m_1 m_2 g - 2m_1 m_2 g}{m_1(m_1 + m_2)}$$

**acc**,

$$\boxed{a = \frac{(m_1 - m_2)g}{(m_1 + m_2)}} \quad \text{------} (4)$$