Imp → Max^m velocity without skidding.

$$F_{cent} \le F_{fric}$$

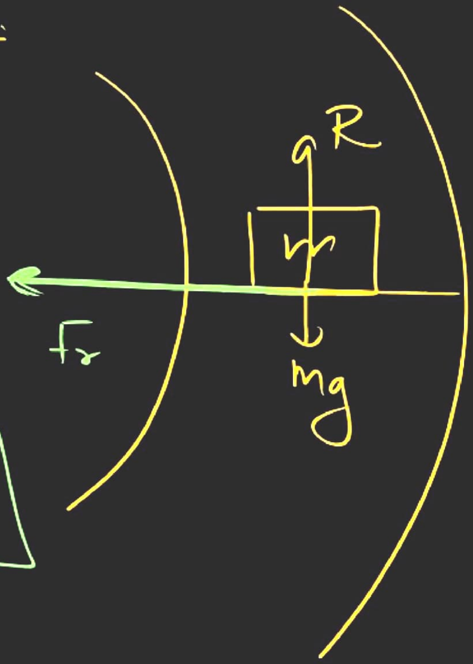
$$\frac{mv^2}{r} \le \mu R$$

$$\frac{mv^2}{r} \le \mu (mg)$$

$$v^2 \le \mu r g$$

$$v \le \sqrt{\mu r g}$$

$$\boxed{v_{max} = \sqrt{\mu r g}}$$



→ Banking of Road:

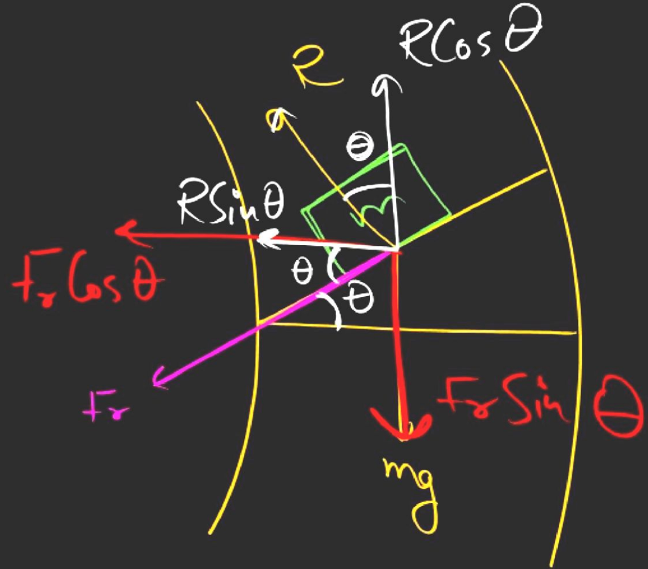
$$R\cos\theta = mg + f_r \sin\theta$$

$$R\cos\theta = mg + \mu R\sin\theta$$

$$R\cos\theta - \mu R\sin\theta = mg$$

$$R(\cos\theta - \mu\sin\theta) = mg$$

$$\boxed{R = \frac{mg}{(\cos\theta - \mu\sin\theta)}} \quad (1)$$



Now, $F_{cent} \leq R\sin\theta + f_r\cos\theta$

$$\frac{mv^2}{r} \leq R\sin\theta + \mu R\cos\theta$$

$$\frac{mv_{max}^2}{r} = R[\sin\theta + \mu\cos\theta]$$

$$\frac{mv_{max}^2}{r} = \frac{mg[\sin\theta + \mu\cos\theta]}{[\cos\theta - \mu\sin\theta]}$$

$$v_{max}^2 = rg\left[\frac{\tan\theta + \mu}{1 - \mu\tan\theta}\right]$$

$$v_{max} = \sqrt{rg\left[\frac{\tan\theta + \mu}{1 - \mu\tan\theta}\right]}$$

→ optimum speed: ($\mu = 0$)

Flat Road

$$V_{max} = \sqrt{\mu r g}$$

$$\boxed{V_{max} = 0}$$

Banked road:

$$V_{max} = \sqrt{rg\left[\frac{\tan\theta + \mu}{1 - \mu\tan\theta}\right]}$$

$$V_{max} = \sqrt{rg\tan\theta}$$

→ Impulse-momentum theorem:

Impulse is also equals change in momentum.

As, $\boxed{I = F \times \Delta t}$ — (1)

Also, from Newton's 2nd law:

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

$$\boxed{\Delta p = F \Delta t} \text{ — (2)}$$

from (1) & (2)

$$\boxed{I = \Delta p}$$

↳ S.I unit = $kg\,m\,s^{-1}$.

→ Impulse:

It is product of force and time when force is applied for a very short interval of time.

$\therefore$ Impulse = force × Δt

$$\boxed{I = F\Delta t}$$

↳ S.I unit = N sec.

Dividing ① & ②

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

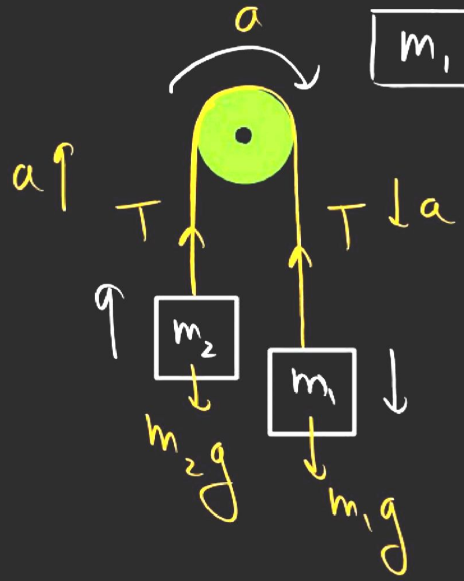
$$\frac{m_1}{m_2} = \frac{m_1 g - T}{T - m_2 g}$$

$$m_1 T - m_1 m_2 g = m_1 m_2 g - m_2 T$$

$$m_1 T + m_2 T = 2 m_1 m_2 g$$

$$\therefore \boxed{T = \frac{2 m_1 m_2 g}{m_1 + m_2}}$$

→ Connected motion:



$$\boxed{m_1 > m_2}$$

for mass m_1:

$$F_n = m_1g - T$$

$$\boxed{m_1a = m_1g - T} \quad (1)$$

Also, for mass m_2:

$$F_n = T - m_2g$$

$$\boxed{m_2a = T - m_2g} \quad (2)$$

Adding (1) & (2)

$$m_1a + m_2a = m_1g - m_2g$$

$$a(m_1 + m_2) = g(m_1 - m_2)$$

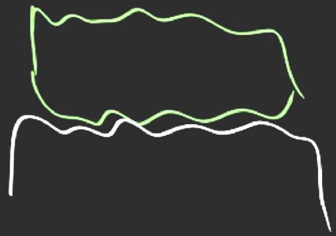
$$\boxed{a = g\frac{(m_1 - m_2)}{m_1 + m_2}}$$

→ **Friction:**

- opposing force which opposes the motion of object in contact.
- friction is present b/w two bodies which are moving or tends to move w.r.t each other.

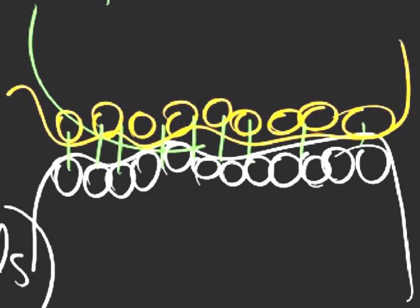
→ Concept of irregular surface: (old View)

Interlocking b/w these irregular surface cause friction.



→ **Modern View:**

friction is caused due to Vander Waal force of attraction b/w the particles.



→ **Types of friction:**

a) Internal friction (for fluids)

b) External friction

→ External friction:

a) Static friction:

- friction b/w two bodies which tends to move w.r.t each other but not moving actually.
- Static friction is also called self adjusting friction

b) Limiting friction: Max^m value of static friction

c) Kinetic friction: friction b/w two bodies when bodies are moving w.r.t each other.

Rolling   Sliding

→ Law of friction:

Frictional force $\propto$ Normal Reaction

$$F_r \propto R$$

$$\boxed{F_r = \mu R}$$

μ = Coefficient of friction.

= Nature of material

= Unitless quantity.

Newton's Second Law of Motion

Newton's second Law of Motion states that: The rate of change of momentum is directly proportional to the force applied in the direction of force.

$\therefore$ Force $\propto$ Rate of change of momentum

$$\text{force} \propto \frac{\text{change in momentum}}{\text{time}}$$

Also, $F \propto \frac{\text{final } p - \text{initial } p}{t}$

$F \propto \frac{mv - mu}{t}$

$F \propto m\left[\frac{v-u}{t}\right]$

$F \propto m[a]$

$\boxed{F \propto ma}$ — ①

$F = kma$

where $\boxed{k \simeq 1}$

$\therefore \boxed{F = ma}$

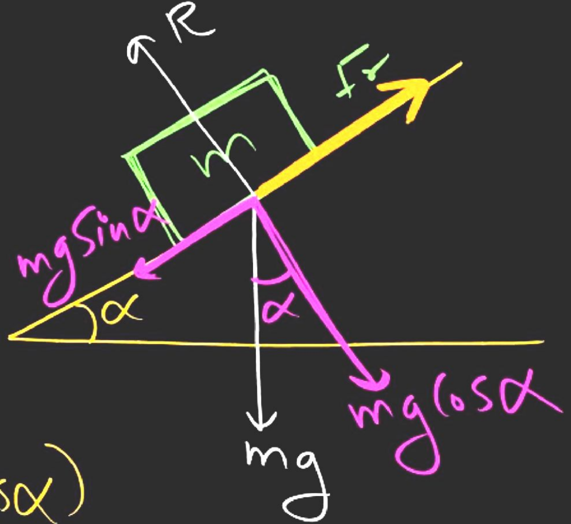
$\mu = \tan\alpha$

$$\boxed{\alpha = \tan^{-1}(\mu)}$$

Note: $\boxed{\text{Angle of repose} = \text{Angle of friction}}$

→ Angle of repose (α)

- It is an angle above which object will slide when kept on inclined plane.



$$\boxed{R = mg\cos\alpha} \quad (1)$$

$$F_r = mg\sin\alpha$$

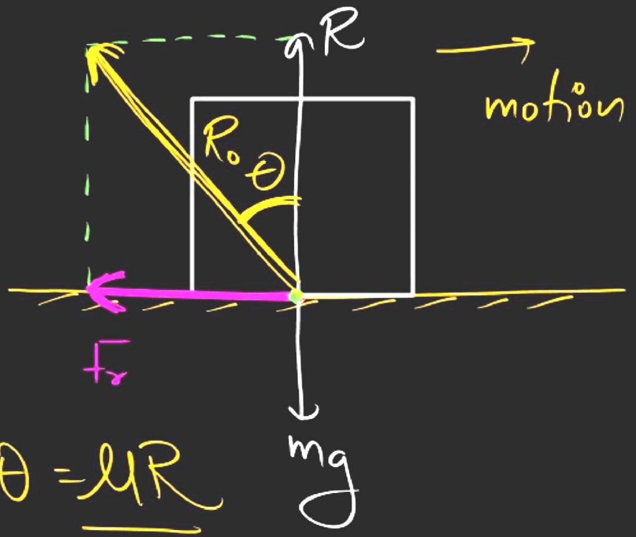
$$\mu R = mg\sin\alpha$$

$$\mu(mg\cos\alpha) = mg\sin\alpha$$

$$\mu = \frac{\sin\alpha}{\cos\alpha}$$

→ Angle of friction: (θ)

It is the angle b/w Normal reaction and resultant of normal Rxn and friction



$$\therefore \tan\theta = \frac{Perp}{Base}$$

$$\tan\theta = \frac{f_r}{R}$$

$$\tan\theta = \frac{\mu R}{R}$$

$$\tan\theta = \mu \Rightarrow \boxed{\theta = \tan^{-1}(\mu)}$$

Newton's Second Law of Motion in everyday life:

(a) A fielder pulls his hand backward; while catching a cricket ball coming with a great speed to reduce the momentum of the ball with a little delay. According to Newton's Second Law of Me rate of change of momentum is directly proportional to the force applied in the direction. While catching cricket ball the momentum of ball is reduced to zero when it is stopped after coming in the hands of fielder e ball is stopped suddenly, its momentum will be reduced to zero instantly. The rate of change in momentum is very quick and as a result, the player's hand may get injured. Therefore, by pulling the hand backward a fielder gives more time to the change of momentum to become zero. This prevents the hands of fielder from getting hurt

Law of Conservation of Momentum: The sum of momenta of two objects before collision and sum of momenta of two objects after collision are equal.

Mathematical Formulation of Conservation of Momentum:

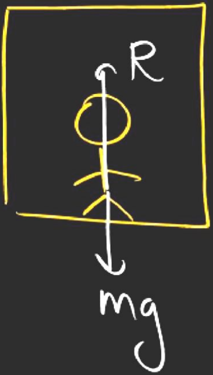
Total momentum before collision = Total momentum after collision.

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

Proof: Acc. to 2nd law:

→ Lift cases:

① Lift at rest :-



$$F_n = R - mg$$

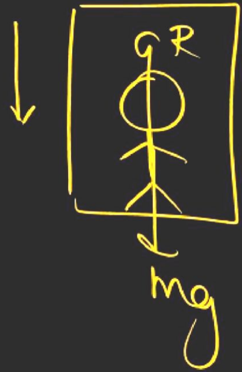
$$ma = R - mg$$

$$m(0) = R - mg$$

$$\boxed{R = mg}$$

② Lift is moving up/down with Uniform velocity :

$a = 0$



$$F_n = mg - R$$

$$m(0) = mg - R$$

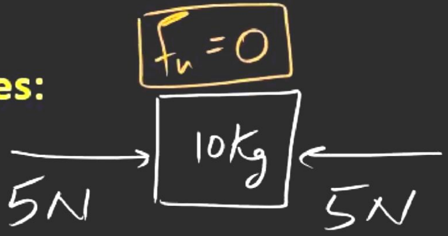
$$\boxed{R = mg}$$

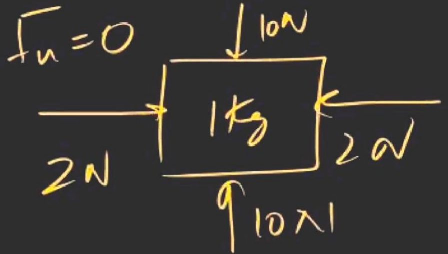
Effect of Force:

1. Force can make a stationary body in motion. For example a football can be set to move by kicking it is applying a force.
2. Force can stop a moving body. For example by applying brakes, a running cycle canning vehicle can be stopped.
3. Force can change the direction of a moving of For example; By applying force, i.e. by moving is handle the direction on a running bicycle can be changed.
4. Force can change the speed of a moving body For example: By accelerating, the speed running vehicle can increased or by applying bikes the speed of a running vehicle can be decreased.
5. Force can change the shape and object. For example: Hammering an iron rod hammer.

Forces are mainly of two types:

1. Balanced Forces
2. Unbalanced Forces





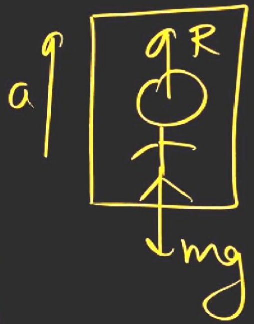
1.Balanced Forces

If the resultant of applied forces is equal to zero ibis called balanced forces.

Example: In the tug of war if both the teams apply similar magnitude of forces in opposite directions, rope does not move in either side. This happens because of balanced forces in which resultant of applied forces become zero. Balanced forces do not cause any change of state of an object. Balanced forces are equal in magnitude and opposite in direction.

③ Upward with acceleration:

$F_n = R - mg$



$ma = R - mg$

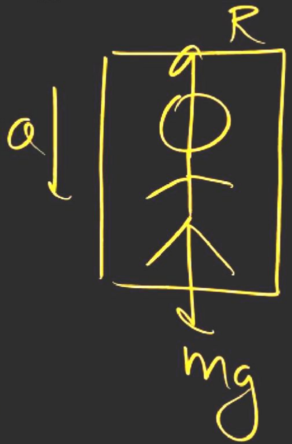
$$\boxed{R = ma + mg}$$

$$\therefore \boxed{R > mg}$$

Person will feel heavier.

④ Downward with acceleration:

$F_n = mg - R$



$ma = mg - R$

$$\boxed{R = mg - ma}$$

$$\therefore \boxed{R < mg}$$

Person will feel lighter.

$$F_1 = \frac{\Delta p_1}{\Delta t}$$

$$\boxed{F_1 = \frac{m_1 v_1 - m_1 u_1}{\Delta t}} \quad (1)$$

Illy $F_2 = \dfrac{\Delta p_2}{\Delta t}$

$$\boxed{F_2 = \frac{m_2 v_2 - m_1 u_1}{\Delta t}} \quad (2)$$

from 3rd law:

$$F_1 = -F_2$$

$$\frac{m_1 v_1 - m_1 u_1}{\cancel{\Delta t}} = -\frac{\left[m_2 v_2 - m_2 u_2\right]}{\cancel{\Delta t}}$$

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

$$\boxed{m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2}$$

H.P

(b) For athletes of long and high jump sand bed or cushioned bed is provided to allow a delayed change of momentum to zero because of jumping of athlete. When an athlete falls on the ground after performing a high or long jump, the momentum because of the velocity and mass of the athlete is reduced to zero. If the momentum of an athlete will be reduced to zero instantly, the force because of momentum may hurt the player. By providing a cushioned bed, the reduction of the momentum of the athlete to zero is delayed. This prevents the athlete from getting hurt.

(c) Seat belts in car - Seat belts in the vehicles prevent the passenger from getting thrown in the direction of motion. In case of emergency, such as accidents or sudden braking, passengers may be thrown in the direction of motion of vehicle and may get fatal injuries. The stretchable seat belts increase the time of the rate of momentum to be reduced to zero. The delayed reduction of momentum to zero prevents passengers from such fatal injury.

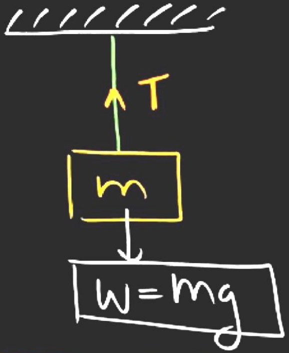
Newton's Third Law of Motion: It states that there is always reaction for every action in opposite direction and of equal magnitude.

Explanation:

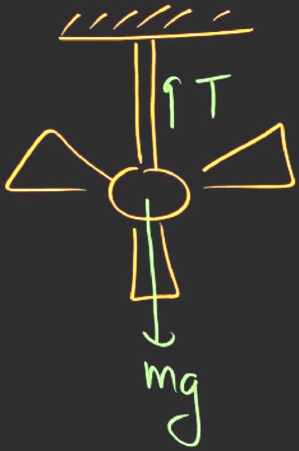
If we apply any force on an object then object will also apply equal but opposite force on us.

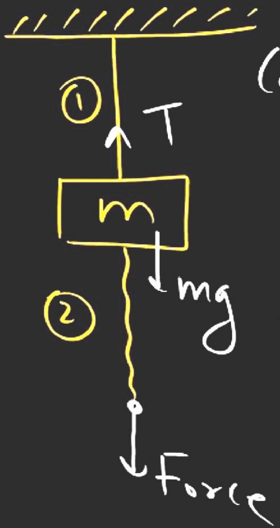
$$\boxed{F_1 = -F_2}$$

Concept of tension:-



$\boxed{T = mg}$

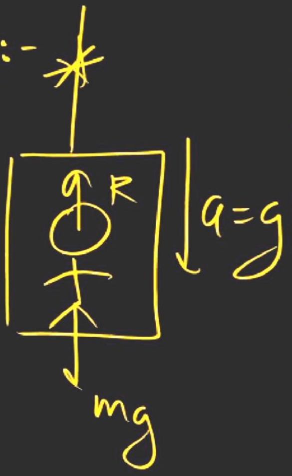




Case I Force
↓
suddenly
↓
String 2

Case II Force
↓
gradually
↓
String 1

⑤ free fall of lift :-



$F_n = mg - R$

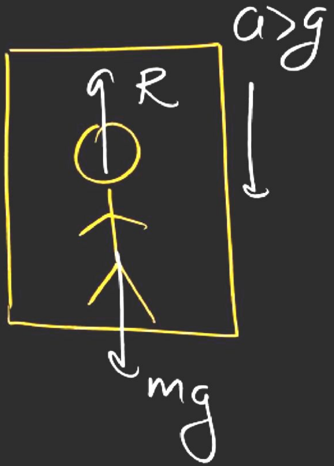
$ma = mg - R$

$mg = mg - R$

$\boxed{R = 0}$

↳ Weightlessness

⑥ when lift moves downward with $\boxed{a > g}$:-



$F_n = mg - R$

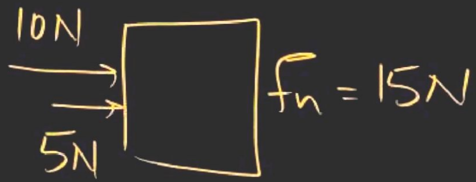
$ma = mg - R$

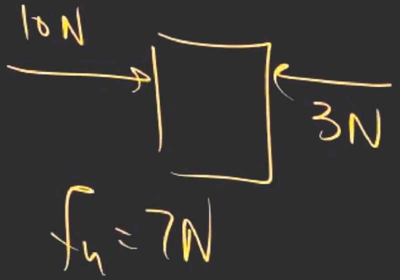
$R = mg - ma$

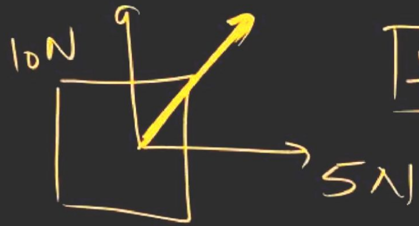
$\boxed{R = -ve}$

2.Unbalanced Forces

If the resultant of applied forces are greater than zero the forces are called unbalanced forces. An object in rest can be moved because of applying balanced forces.







$$\boxed{f_n \neq 0}$$

Note: Unbalanced force can change state, shape and size.
but balanced force can only change shape and size.

1. Newton's First Law of Motion:

- Any object remains in the state of rest or in uniform motion along a straight line, until it is compelled to change the state by applying external force.

→ Inertia :- A property of substance by which it do not allow any change in state.

$\boxed{\text{Inertia} \propto \text{mass}}$

- Inertia of rest
- Inertia of motion
- Inertia of direction

Force

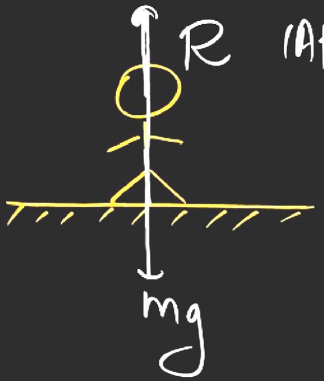
The pull or push on an object is called force. (irrespective to the effect)

Example:

1. To open a door, either we push or pull it.
2. A drawer is pulled to open and pushed to close.

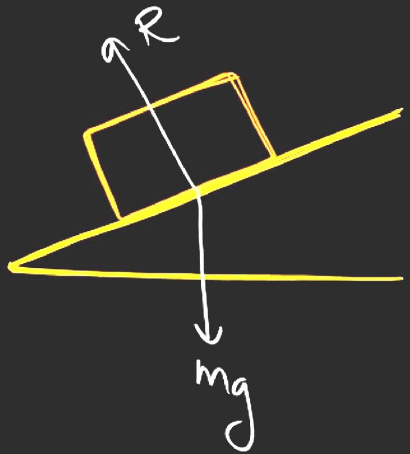
→ Concept of normal Rxn: (Apparent weight)

(1)



(Apparent weight)

(2)



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

Daily life applications:

1. Walking of a person A person is able to walk because of the Newton's Third Law of Motion. During walking, a person pushes the ground in backward direction and in the reaction the ground also pushes the person with equal magnitude of force but in opposite direction. This enables him to move in forward direction against the push.

(b) Recoil of gun When bullet is fired from a gun, the bullet also pushes the gun in opposite direction, with equal magnitude of force. This results in gunman feeling a backward push from the butt of gun.

(c) Propulsion of a boat in forward direction- Sailor pushes water with oar in backward direction; resulting water pushing the car in forward direction. Consequently, the boat is pushed in forward direction. Force applied by oar and water are of equal magnitude but in opposite directions.

Momentum : (p)

It is product of mass and velocity of object.

$\therefore$ Momentum = mass × Velocity

$$\boxed{p = mv}$$

→ S.I unit = $\boxed{kg\,ms^{-1}}$

→ Vector quantity → Direction similar to direction of velocity

e. Seat belts are used in car and other vehicles, to prevent the passengers being thrown in the condition of sudden braking or other emergency. In the condition of sudden braking of the vehicles or any other emergency such as accident, the speed of vehicle would decrease or vehicle may stop suddenly, in that condition passengers maybe thrown in the direction of the motion of vehicle because of the tendency to remain in the state of motion.

f. The head of hammer is tightened on a wooden handle by banging the handle against a hard surface. When handle of the hammer is struck against a surface, handle comes in rest while hammer over it's head has tendency to remaining motion and thus after some jerks it tightens over the handle.

c. Before hanging the wet clothes over laundry line, usually many jerks are given to the cloths to get them dried quickly. Because of jerks droplets of water from the pores of the cloth falls on the ground and reduced amount of water in clothes dred them quickly. This happens because, when suddenly cloth are made in motion by giving jerks, the water droplets in it have tendency to remain in rest and they are separated from cloths and fall on the ground.

d. When the pile of coin on the carom-board hit by a striker; coin only at the bottom moves away leaving rest of the pile of coin at same place. This happens because when the pile is struck with a striker, the coin at the bottom comes in motion while rest of the coin in the pile has tendency to remain in the rest and they vertically falls the carom board and remain at same place.

Newton's First Law of Motion in Everyday Life:

a. A person standing in a bus falls backward when bus is start moving suddenly. This happens because the person and bus both are in rest while bus is not moving, but as the bus starts moving the legs of the person start moving along with bus but rest portion of his body has tendency to remain in rest. Because of this person falls backward; if he is not alert.

b. A person standing in a moving bus falls forward if driver applies brakes suddenly. This happens because when bus is moving the person standing it is also in motion along with bus. But when driver applies brakes the speed of bus decreases suddenly or bus comes in the state of rest suddenly, in this condition the legs of the person which are in the contact with bus come in rest while the test parts of his body have tendency to remain in motion. Because of this person falls forward if he is not alert.