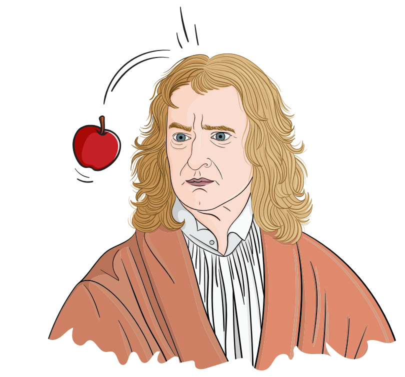
NEWTON'S LAWS OF MOTION



INERTIA OF REST

The property of a body due to which it cannot change its state of rest by itself.

INERTIA OF DIRECTION

The property due to which a body cannot change its direction of motion by itself.

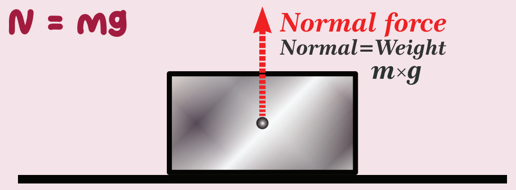
INERTIA OF MOTION

The tendency of a body to remain in a state of uniform motion in a straight line.

FORCES

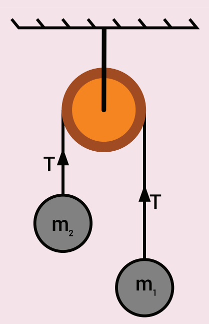
(i) Normal Contact force

(1) always acts along the common normal of two surface in contact.
(2) Always directed towards the system.
(3) It is an electromagnetic type of force. Normal force on block is N. N = mg



(ii) Tension Force

(1) Acts along the string and away from the system on which it acts.
(2) Tension in a massless string remains constant throughout the string if no tangential force acts along the string.
(3) This is force applied by a string on an object or force applied by one part of string on the remaining part of string.
(4) It is an electromagnetic type of force.



(iii) Friction Force

(1) Rolling friction:- The force of friction which comes into play when one body Rolls or tends to roll on the surface of a norther body.

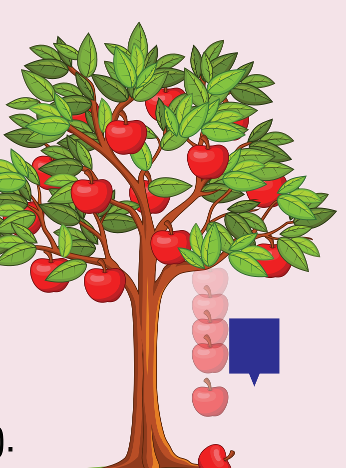
(iv) Sliding friction

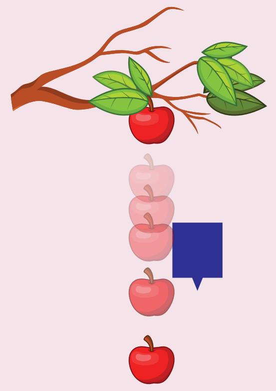
Resistance offered to the relative motion between the surface of two bodies in contact.

The frictional force f is directly proportional to the normal force N exerted by the surface on the body.

(F ∝ N or f/N = Constant = μ).

The friction force depends upon the nature of surfaces in contact and independent of the area of contact.





Types of friction

- **Static friction** — acts when a body is at rest on application of a force. $f_s = \mu_s N$.
- **Limiting friction** — acts when a body is just at the verge of movement. $F_l = \mu_s N$.
- **Kinetic friction** — acts when a body is actually sliding. $f_k = \mu_K N$

Newton's 1st law

A body continues its sate of rest or motion until unless an external force is acted on it.

$$\text{If } \vec{F}_{ext} = 0 ;\ \vec{a} = 0$$

Newton's 3rd law

To every action there is always on equal and opposite reaction.

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

Action & Reaction act on different bodies and not on the same body. - action – reaction forces are of same type.

We cannot produce a single isolated force in nature force are always produce in action – reaction pair.

due to no time gap, any one force can be action, and other reaction.

applicable for all the interactive forces eg. Gravitational, electrostatic, electromagnetic, Tension, friction, viscous forces, etc.

For Non – inertial frame

$$\vec{F}_{ext} + \vec{F}_{Pseudo} = m\vec{a}$$

$$\vec{F}_{pseudo} = -M\vec{a}_{frame}$$

SOLVING PROBLEMS IN MECHANICS

- Draw FBD of bodies in the system.
- Choose a convenient part of the assembly as one system.
- Identify the unknown force and accelerations.
- Resolve forces into their components.

- Apply $\sum \vec{F} = m\vec{a}$ in the direction of motion.
- Apply $\sum \vec{F} = 0$ in the direction of equilibrium
- Write constraint relation if exists.
- Solve the equation $\sum \vec{F} = m\vec{a}$ & $\sum \vec{F} = 0$.

Newton's 2nd Law

The rate of change of linear momentum of a body is directly proportional to the external force applied on the body in the direction of force.

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

S.I. Unit of force = Newton (N)

if m = const $\vec{F} = \frac{md\vec{v}}{dt} = m\vec{a} \Rightarrow$ dimensional formula = $[M^1L^1T^{-2}]$

if $\vec{V}$ = Cost = $\vec{F} = \vec{V}\frac{dm}{dt}$

convey or belt & rocket propulsion

Conservation of linear momentum:- if there is no external force acting on it, total momentum of an isolated system of interacting particles is conserved

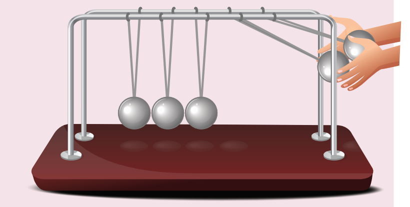
$$\vec{F}_{ext} = 0 = \frac{d\vec{p}}{dt} \text{ or } P_{initial} = P_{final}$$

Impulse

$$\vec{I} = \vec{F}_{avg}\ \Delta t = \Delta\vec{P}$$

$\Rightarrow I = \Delta P = \int F.dt$ = area under f – t curve

Horizontal Circular motion (Conical Pendulum):-

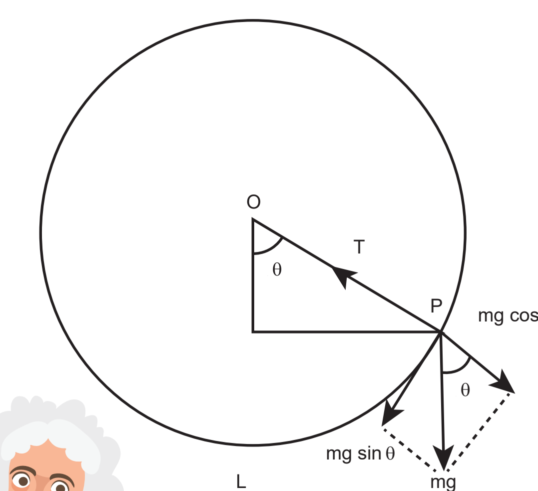


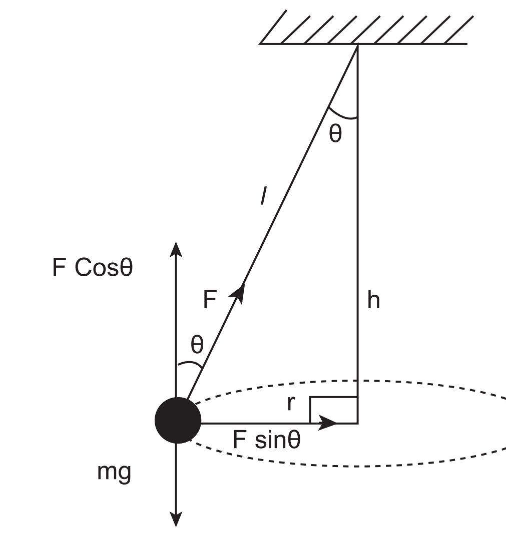
$$T_{Sin\theta} = \frac{mv^2}{r} \ \&\ T_{cos\theta} = mg$$

$$V = \sqrt{rg\tan\theta}$$

Angular Speed, ω = $W = \frac{v}{r} = \sqrt{\frac{g\tan\theta}{r}}$

Time Period $T = \frac{2\pi}{w}\ \ 2\pi\sqrt{\frac{r}{g\tan\theta}} = 2\pi\sqrt{\frac{L\cos\theta}{g}}$



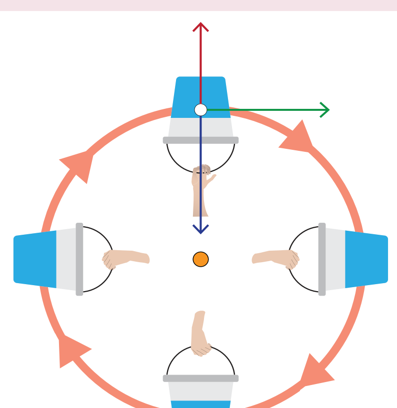


Vertical Circular motion

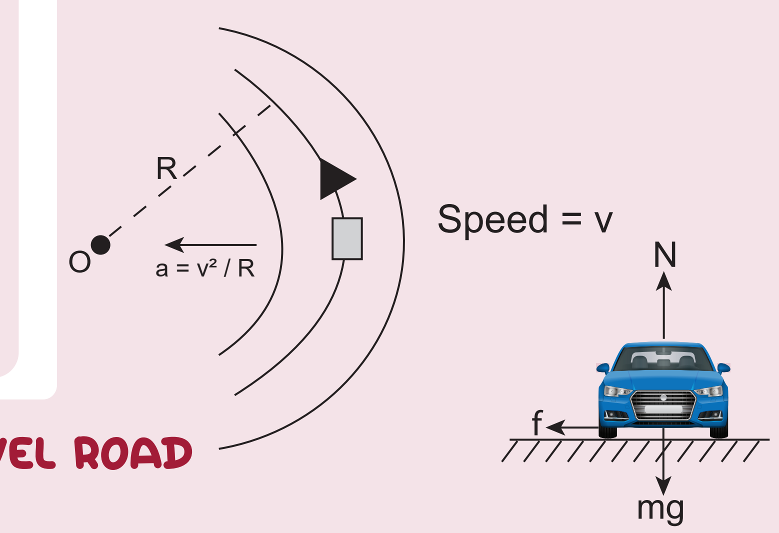
1. Particle ossillates in lower half circle.
Condition of ossillation $(0 < u \le \sqrt{2gR})$

2. Particles moves to upper half circle but not able to complete the loop. Condition of leaving the circle: $(\sqrt{2gR} < u < \sqrt{5gR})$

3. Particle completes loop. Condition of looping the loop $(u \ge \sqrt{5gR})$



Circular motion



Kinematics of Uniform Circular motion

1. A particle moves in a circle at a constant speed
2. Angular displacement (θ) SI Unit: rad or degree.
3. Angular velocity (w):

$$W_{avg} = \frac{\Delta\theta}{\Delta t}[\text{Unit. rad / sec}] \quad W_{ins} = \frac{d\theta}{dt}$$

Centripetal Force

$$F_c = ma_c = \frac{mv^2}{r} = mrw^2$$

$$\Delta S = r\Delta O \quad v = wr$$

$$\vec{V} = \vec{w} \times \vec{r}$$

$\vec{V}$ is linear velocity (tangential vector)
$\vec{w}$ (axial vector)
$\vec{r}$ = radius vector

Kinematics of Non – Uniform circular motion

Speed of the particle in a horizontal circular motion changes with respect to time.

Tangential acceleration:

$$\vec{a}_t = \vec{\alpha} \times \vec{r}$$

Centripetal force

$$F_c = ma_c = \frac{mv^2}{r} = mrw^2$$

Tangential force $F_t = ma_t$

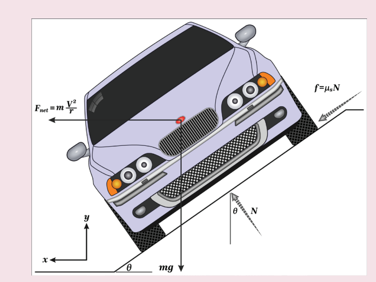
Net force $F_{net} = m\sqrt{a_c^2 + a_t^2}$

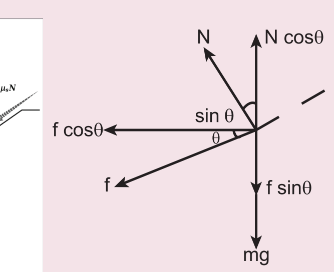
a_c responsible for change in direction of movement of particle

MOTION OF A CAR IN LEVEL ROAD (by friction only):-

$$\text{Vmax} \le \sqrt{\mu_s Rg}$$

MOTION OF A CAR ON BANKED ROAD





(i) Optimum speed of a vehicle on a banked road. $V = \sqrt{rg\tan\theta}$

maximum safe speed on a banked frictional road. $V_{max} = \sqrt{\frac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}}$

minimum safe speed on a banked frictional road $V_{min} = \sqrt{\frac{Rg(\tan\theta - \mu)}{(1 + \mu\tan\theta)}}$