FORCE and LAWS of MOTION

Point Mass

An object can be considered as a point object if during motion in a given time, it covers distance much greater than its own size.

Object with negligibly small dimension considered as a point mass.

Inertia

Inherent property of all the bodies by virtue of which they cannot change their state of rest or uniform motion along a straight line by their own is called inertia.

Inertia is not a physical quantity, it is only a property of the body which depends on mass of the body.

Inertia has no units and no dimensions

Two bodies of equal mass, one in motion and another is at rest, possess same inertia because it is a factor of mass only and does not depend upon the velocity.

Linear Momentum

Linear momentum of a body is the quantity of motion contained in the body.

It is measured in terms of the force required to stop the body in unit time.

It is also measured as the product of the mass of the body and its velocity *i.e.*, Momentum = mass × velocity.

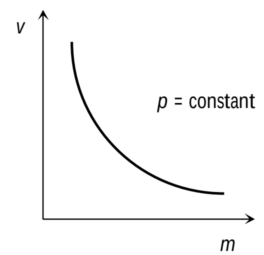
If a body of mass m is moving with velocity $\vec{v}$ then its linear momentum $\vec{p}$ is given by $\vec{p} = m\vec{v}$

It is a vector quantity and it's direction is the same as the direction of velocity of the body.

Units : *kg-m/sec* [S.I.], *g-cm/sec* [C.G.S.]

Dimension : $[MLT^{-1}]$

If two objects of different masses have same momentum, the lighter body possesses greater velocity.



$p = m_1 v_1 = m_2 v_2$ = constant $\quad \therefore$

$\frac{v_1}{v_2} = \frac{m_2}{m_1}$

i.e. $v \propto \frac{1}{m}$

[As p is constant]

For a given body $p \propto v$

For different bodies moving with same velocities $p \propto m$

Force

(1) Force is an external effect in the form of a push or pull which

(i) Produces or tries to produce motion in a body at rest.

(ii) Stops or tries to stop a moving body.

(iii) Changes or tries to change the direction of motion of the body.

Units : Absolute units : (i) *Newton* (S.I.) (ii) *Dyne* (C.G.S)

Gravitational units : (i) Kilogram-force (M.K.S.) (ii) Gram-force (C.G.S)

Newton : One Newton is that force which produces an acceleration of $1 m/s^2$ in a body of mass 1 *Kilogram*.

$\therefore 1$ *Newton* $= 1 kg-m/s^2$

Dyne : One dyne is that force which produces an acceleration of $1 cm/s^2$ in a body of mass 1 *gram*.

$\therefore$ 1 *Dyne* $= 1 gm\ cm/\sec^2$

Relation between absolute units of force 1 *Newton* $= 10^5$ *Dyne*

Kilogram-force : It is that force which produces an acceleration of $9.8 m/s^2$ in a body of mass 1 *kg*.

$\therefore$ 1 *kg-f* = 9.80 *Newton*

Gram-force : It is that force which produces an acceleration of $980 cm/s^2$ in a body of mass 1*gm*.

$\therefore$ 1 *gm-f* = 980 *Dyne*

$\vec{F} = m\vec{a}$ formula is valid only if force is changing the state of rest or motion and the mass of the body is constant and finite.

If *m* is not constant $\vec{F} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}$

If force and acceleration have three component along *x*, *y* and *z* axis, then

$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$ and $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$

From above it is clear that $F_x = ma_x,\ F_y = ma_y, F_z = ma_z$

No force is required to move a body uniformly along a straight line with constant speed.

$\vec{F} = m\vec{a}$ $\quad\quad$ $\therefore \vec{F} = 0$ (As $\vec{a} = 0$)

When force is written without direction then positive force means repulsive while negative force means attractive.

Example : *Positive force* – Force between two similar charges

Negative force – Force between two opposite charges

Out of so many natural forces, for distance 10^{-15} *metre*, nuclear force is strongest while gravitational force weakest. $F_{\text{nuclear}} > F_{\text{electromagnetic}} > F_{\text{gravitational}}$

Constant force : If the direction and magnitude of a force is constant. It is said to be a constant force.

Variable or dependent force :

(i) ***Time dependent force*** : In case of impulse or motion of a charged particle in an alternating electric field force is time dependent.

(ii) ***Position dependent force*** : Gravitational force between two bodies $\frac{Gm_1m_2}{r^2}$

or Force between two charged particles $= \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$.

(iii) ***Velocity dependent force*** : Viscous force $(6\pi\eta rv)$

Force on charged particle in a magnetic field $(qvB\sin\theta)$

Central force : If a position dependent force is directed towards or away from a fixed point it is said to be central otherwise non-central.

Example : Motion of Earth around the Sun. Motion of electron in an atom. Scattering of α-particles from a nucleus.

Conservative or non conservative force : If under the action of a force the work done in a round trip is zero or the work is path independent, the force is said to be conservative otherwise non conservative.

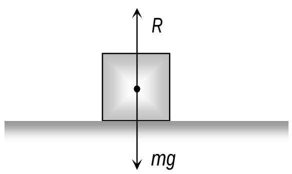
Example : Conservative force : Gravitational force, electric force, elastic force.

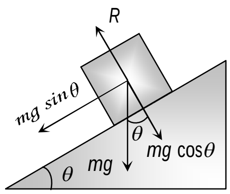
Non conservative force : Frictional force, viscous force.

Common forces in mechanics :

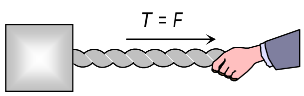
(i) *Weight* : Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

(ii) *Reaction or Normal force :* When a body is placed on a rigid surface, the body experiences a force which is perpendicular to the surfaces in contact. Then force is called 'Normal force' or 'Reaction'.





(iii) ***Tension*** : The force exerted by the end of taut string, rope or chain against pulling (applied) force is called the tension. The direction of tension is so as to pull the body.



(iv) ***Spring force*** *:* Every spring resists any attempt to change its length. This resistive force increases with change in length. Spring force is given by $F = -Kx$; where x is the change in length and K is the spring constant (unit N/m).