

Unit – 2 Force & Motion

Physical quantities can be broadly divided in two classes:

Scalar Quantities	Vector Quantities
The physical quantities which possess only magnitude & no direction.	The physical quantities which possess both magnitude as well as direction.
Examples: Mass, Length, Time, Work, Temp. etc.	Examples: Force, Momentum, Velocity etc.
These are represented by ordinary letters.	They are represented by bold-faced letters/letters having arrow over them.
Scalars change by change in magnitude only.	Vectors change either with the change in magnitude or with the change in direction or both.
Scalars can be added/subtracted acc. to the ordinary rules of algebra.	They cannot be added/subtracted algebraically. They need special rules.

Representation of a Vector:

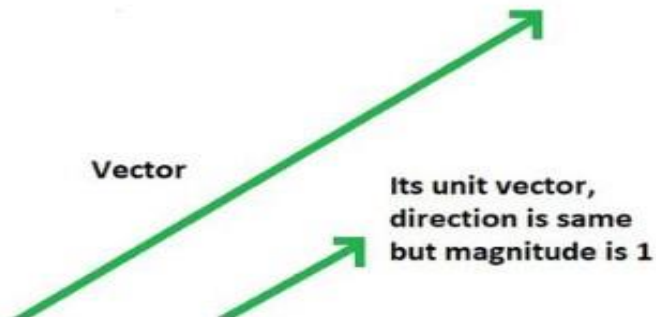


Starting/Initial Point of the vector = **Tail** of the vector

Ending/terminal point of the vector = **Head** of the vector

Types of vectors:

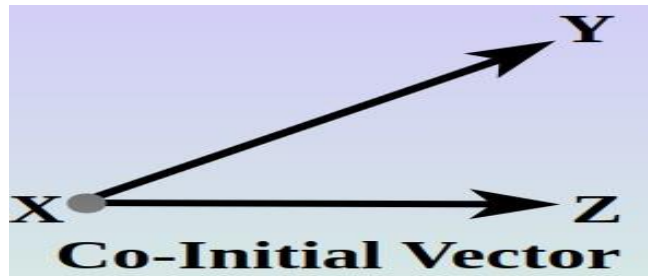
Unit Vector: Vector whose magnitude is 1 unit.



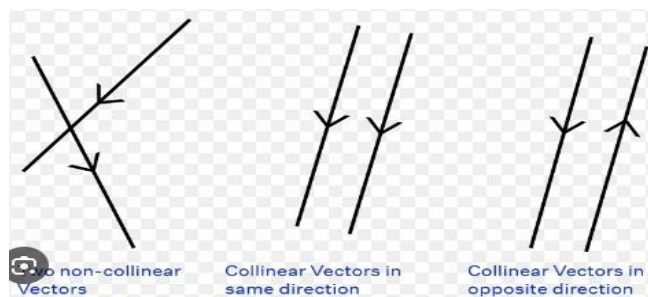
Position Vector: Straight line having one end fixed to a body and the other end attached to a moving point and used to describe the position of the point relative to the body. As the point moves, the position vector will change in length or in direction or in both length and direction.

Co-planar Vector: The vectors which lie on the same plane, in a three-dimensional space. These are vectors which are parallel to the same plane.

Co-Initial Vectors: The vectors are said to be co-initial, if their initial point is common. In other words, the vectors having same tale point.

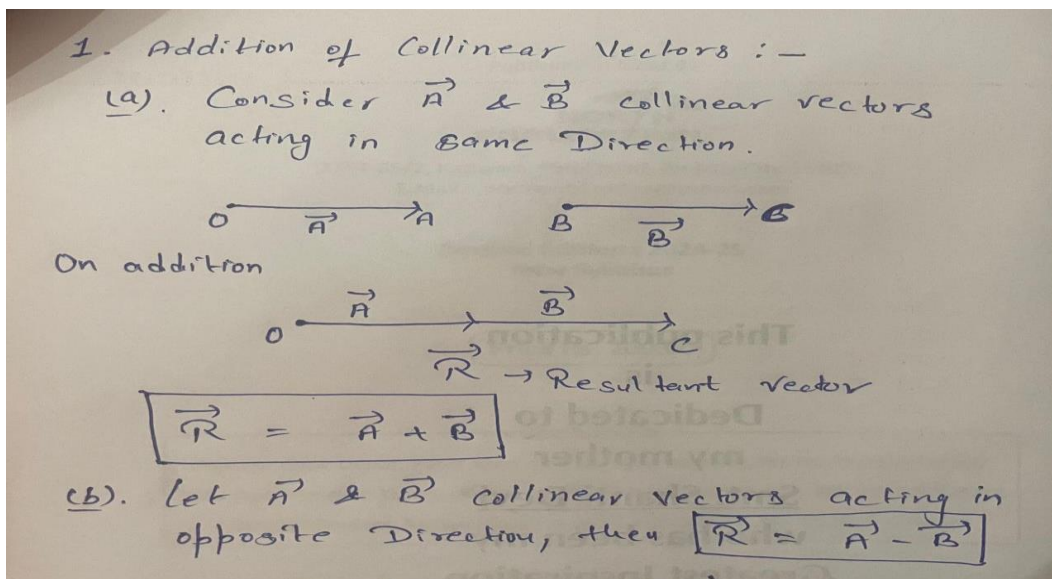


Collinear Vectors: Vectors having equal or unequal magnitude & parallel to each other.



Addition of Vector:

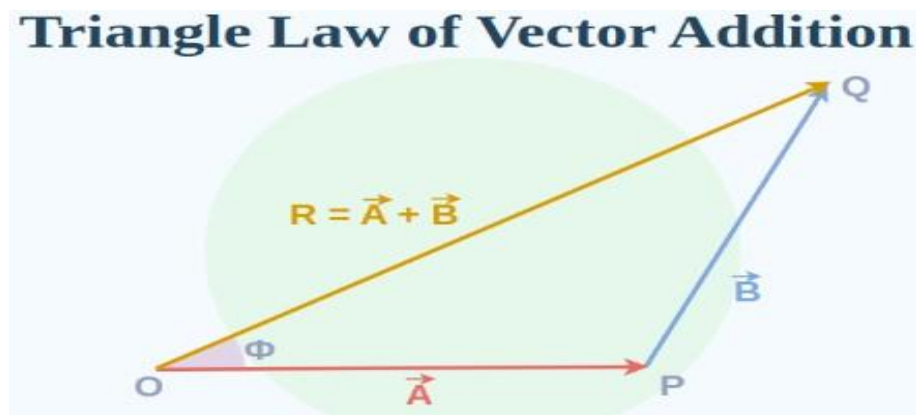
1. Addition of collinear vectors.



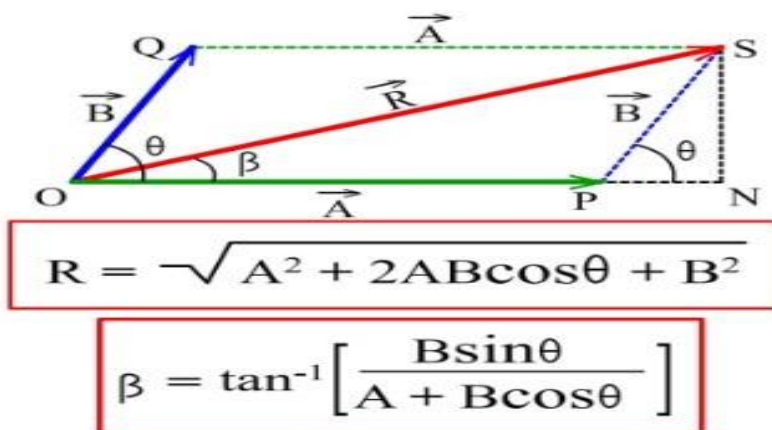
2. Addition of two vectors which are inclined to each other. Following laws are useful for the addition of vectors:
 1. Triangle law of vector addition.
 2. Parallelogram law of vector addition.

Triangle law of vector addition: If two vectors can be represented in magnitude & direction by two sides of triangle taken in same order, then the resultant is represented in magnitude & direction by third side of triangle taken in opposite order.

i.e. $\vec{R} = \vec{A} + \vec{B}$ and $\text{Magnitude of } \vec{R}: R = \sqrt{A^2 + B^2 + 2AB \cos \theta}$

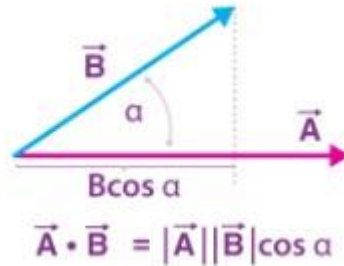


Parallelogram (Ilgm) law of vector addition: It states that if two vectors, acting simultaneously at a point, can be represented both magnitude & direction by two adjacent side of Ilgm, the resultant is represented in magnitude & direction by diagonal of Ilgm passing through that point.



Multiplication of Vectors:

1. **Scalar Product (Dot Product):** It may be defined as product of magnitude of two vectors & cosine of smaller angle between them. Diagram & formula given below:



Dot Product is commutative i.e.

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$$

2. **Vector Product (Cross Product):** It may be defined as the product of magnitude of two vectors & sine of smaller angle between them with a direction perpendicular to both vectors.

$$\vec{A} \times \vec{B} = |\vec{A}| |\vec{B}| \sin \theta \hat{n}$$

Direction of $\vec{A} \times \vec{B}$ is perpendicular to the plane containing the original vectors.

Cross Product is not commutative, meaning $\vec{A} \times \vec{B}$ is not equal to $\vec{B} \times \vec{A}$.

where \hat{n} is the unit vector in the direction of new vector.

Some parameters of Linear Motion:

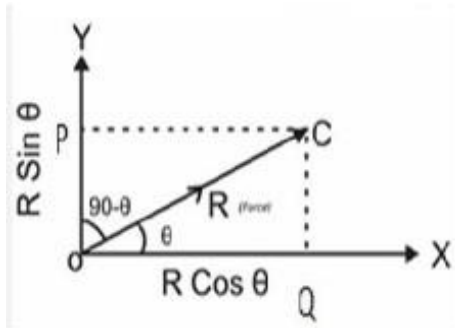
1. **Distance:** Length of path between two points. It is denoted by 'd'.
2. **Displacement:** The shortest distance between initial & final point.
3. **Speed:** The rate at which an object moves. Speed = Distance/time.
4. **Velocity:** The speed of object in a given direction. Velocity = Displacement/time.
5. **Acceleration:** The rate of change of velocity. It is denoted by 'a'.
 $a = (v-u)/t$, where v = final velocity, u = initial velocity, t = time.

Force: Force is a push or pull which tends to change the position of object.

Unit or Force: SI Unit – Newton, CGS Unit – Dyne.

Resolution of Force: The phenomenon of breaking a given force into two or more forces in different direction is called 'resolution of force'.

The force obtained on splitting the given force are called resolved component of given force. Let a Force R represented by a line OC. Resolve it into two components R_x & R_y along x-axis & y-axis.



In Right angle $\triangle OCQ$,

$$\frac{CQ}{OC} = \sin \theta$$

$$CQ = OC \sin \theta$$

$$R_y = R \sin \theta$$

$$\frac{OQ}{OC} = \cos \theta$$

$$OQ = OC \cos \theta$$

$$R_x = R \cos \theta$$

Motion: If a body continuously changes its position w.r.t. an fixed point is called Motion.

Newton's Laws of Motion:

Newton's 1st Law of Motion: It states that if a body is at rest remains at rest or if a body is in motion remains in motion unless external force is applied on it.

For example: A chair is at rest remains at rest until external force is applied on it.

Newton's 2nd Law of Motion: It states that the rate of change of momentum is directly proportional to applied force. i.e. $F = ma$

For example: A cricket player has to lower his hand while catching a ball.

Newton's 3rd Law of Motion: It states that 'To every action there is equal & opposite reaction'.

For example: Bouncing back of ball, Recoiling of Gun.

Linear Momentum: It is defined as the product of mass & velocity. It is denoted by 'p'.

$$p = mv$$

SI Unit of linear momentum = **kg m/s.**

Law of Conservation of Linear Momentum: It states that in absence of external force, the total momentum of system is constant. Acc. to Newton's 2nd Law of Motion:

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

$$\text{or } \vec{F} = \frac{d}{dt}(m \vec{v}) = \frac{d\vec{p}}{dt}$$

$$\text{Thus, } \vec{F} = \frac{d\vec{p}}{dt}$$

Considering external force on the particle (or a body) = zero

$$\text{we have } \vec{F} = \frac{d\vec{p}}{dt} = 0$$

$$\Rightarrow \vec{p} = \text{constant} \quad \dots(1)$$

Impulse: In some cases large force acting on a body acts for a very short time. Such force is called Impulsive Force. It is denoted by 'J'. **For example:** A kick is given to Football.

$$\text{Impulse} = \text{Force} \times \text{Time} = f \times t$$

$$J = ma \times t = m(v-u)$$

$$(\because a = (v-u)/t)$$

$$J = mv - mu$$

$$J = \text{Total change in Momentum}$$

Hence the impulse of a force is measured by the total change in momentum.

SI Unit – Newton/sec.

Circular Motion: Some definitions related to circular motion discussed below:-

Angular Displacement: It is defined as the angle subtended by any point of rotating body with its axis. It is denoted by 'theta' (θ).

$$\theta = \frac{\text{ArcLength}}{\text{Radius}}$$

Angular Velocity: It is defined as the rate of change of angular displacement. It is denoted by omega symbol (ω). Its SI Unit is radian/sec.

$$\omega = \frac{\theta}{t}$$

Angular Acceleration: It is defined as the rate of change of angular velocity. It is denoted by alpha (α). Its SI Unit is radian/sec².

Time Period: The total time taken to complete one cycle is known as time period. It is denoted by T.

Its SI Unit is second.

Frequency: The number of cycles completed in one second is called frequency. It is denoted by 'f' or 'ν'. Its **SI Unit** is Hertz.

$$\nu = \frac{1}{\text{timeperiod}}$$

Relation between Linear & Angular Velocity: Let us consider a particle moving along a circular path & let

r = radius of circular path, S = distance travelled by particle, v = Linear velocity of particle, ω = Angular velocity of particle

Now we know that $\theta = \frac{S}{r} \Rightarrow S = r\theta$

Dividing by 'time' i.e. by 't' both sides, then

$$\frac{S}{t} = r \frac{\theta}{t} \Rightarrow \mathbf{v = r \omega} \quad [\because \frac{S}{t} = v \text{ and } \frac{\theta}{t} = \omega]$$

Centripetal Force: The force which is required to move a body in circular path with uniform speed is called centripetal force. This force acts towards the centre.

$$F = \frac{mv^2}{r}$$

Where m = mass of body, v = velocity of body and r = radius of path.

Centrifugal Force: The force is equal to centripetal force but acting radially outward.

$$F = \frac{mv^2}{r}$$

Where m = mass of body, v = velocity of body and r = radius of path.

Application of Centripetal Force in Banking of Road: The process of raising outer edge of the circular track slightly above its inner edge is called Banking of Road.

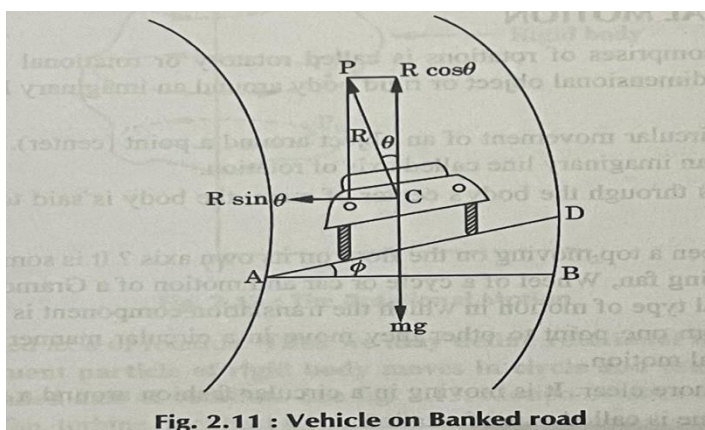


Fig. 2.11 : Vehicle on Banked road

When a vehicle moves on curved road, it performs circular motion. For circular, centripetal force is necessary. To provide this force, vehicle needs to bend towards centre of circular path so that normal reactions get splitted into two parts.

To calculate angle of Banking, Let us suppose m = mass of vehicle, v = uniform speed of vehicle, r = radius of circular track, θ = angle of Banking.

Let us consider two forces acting at point 'O'.

- (i). Weight (mg) of vehicle acting vertically downward.
- (ii). Normal Reaction (R) acting along 'OP'.

Now Resolve Normal reaction into two components:

- (i). $R \cos \theta$ which balance the weight.
- (ii). $R \sin \theta$ which provide necessary centripetal force.

For Equilibrium, $R \sin \theta = \frac{mv^2}{r}$ (1), $R \cos \theta = mg$ (2)

Dividing equation (1) by (2), we get

$$\frac{R \sin \theta}{R \cos \theta} = \frac{mv^2/r}{mg} \Rightarrow \tan \theta = v^2/r g \quad \text{where } g = \text{acc. due to gravity.}$$

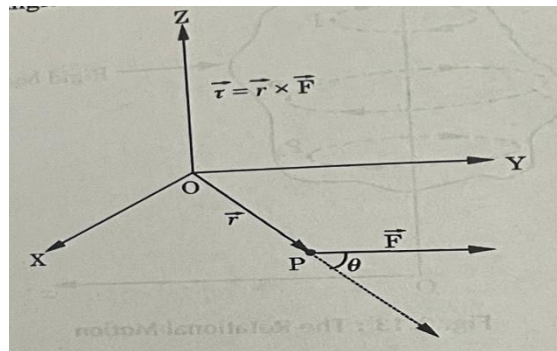
Rotational Motion: The rotation of a body about a fixed axis is called rotational motion.

In this case, the body turns around a fixed axis. The different particles of a body describe concentric circles. A body may pass both translational as well as Rotational motion.

Examples of Rotational Motion:

1. Motion of wheel about its axle.
2. Rotation of earth about its axis.

Torque: It may be defined as the product of magnitude of force & perpendicular distance of the line of action of force from the axis of rotation. It is denoted by τ .



Torque = Force × Perpendicular distance

$$\tau = r \times F \Rightarrow \tau = r F \sin \theta \quad \text{where } \theta \text{ is the angle between 'r' \& 'F'.$$

Here 'r' is the position vector of particle experiencing force.

Torque is a **vector** quantity. Its **SI Unit is Newton-metre (N-m)**.

Examples of Torque: (1). Hinged Doors (2). See Saw

Angular Momentum: It may be defined as product of linear momentum & perpendicular distance of the line of action of momentum from the axis of rotation. It is denoted by 'L'.

Angular Momentum = Linear Momentum × Perpendicular distance

$$\mathbf{L} = \mathbf{r} \times \mathbf{p} \quad \Rightarrow \quad L = rp \sin \theta \text{ where 'r' is the position vector.}$$

Here 'p' is the linear momentum & θ is angle between 'r' & 'p'.

L is a **vector** quantity. Its **SI Unit is Kg m²/s**.

Moment of Inertia: Moment of inertia of a body about a given axis is equal to the sum of product of masses of constituent's particles and square of their respective perpendicular distance from the axis of rotation.

It is denoted by 'I'. Its **SI Unit is Kg-m²**.

$$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \dots$$

$$I = \sum mr^2$$

Physical Significance of Moment of Inertia: It has some physical significance in rotator motion as is of mass in linear motion. In Linear Motion, we have **F = ma & p = mv**.

Similarly, in circular motion, we have **L = I ω** and **τ = I α**

The inertia of a body depends only upon its mass where moment of inertia depends upon

(1). Mass (2). Position & Direction of axis of rotation (3). Shape of the body.

Temperature °

Temperature of a body is defined as degree of hotness & coldness of body

-∴ According to kinetic Theory temperature of body defined as average kinetic energy of its molecule. S.I unit of temperature is kelvin.

$$\text{Temperature} = \frac{\text{Total kinetic energy of all molecule}}{\text{No. of molecule}}$$

Heat: Heat is a form of energy which produces in us the sensation of warmth & hotness

-∴ According to kinetic theory heat of a body is the total kinetic energy possessed by its molecule.

$$\text{Heat} = \text{Total kinetic energy of all molecule.}$$

S.I unit of energy is Joule.

Difference between heat & Temperature.

HEAT	TEMPERATURE
(i) Heat is the total kinetic energy possessed by all the molecule of substance	(i) Temperature is the measure of average kinetic energy of all molecules of substance
(ii) Heat energy depends on speed of particle, No. of particle, size and type of particle.	(ii) Temperature is the measure of average kinetic energy (iii) Temperature of a substance does not depend on size of particle
(iii) Heat is a form of energy	(iii) Temperature is not energy but measure of it.
(iv) The S.I unit of Heat is Joule	(iv) S.I unit of temperature is kelvin

Principle of measurement of temperature:

There are three types of principle of measurement of temperature

- (i) Thermal Expansion
- (ii) change in electric properties with change in temperature
- (iii) change in optical properties with change in temperature

Thermal expansion:

The increase in any ~~temperature~~ in any dimension of an object with rise in temperature is called thermal expansion

There are three types of thermal expansion:

- (i) Linear expansion
- (ii) Superficial expansion
- (iii) Cubical expansion.

Change in electric properties with change in temperature:

Some metals and material change in electric properties like resistance, EMF, current with small change in temperature

This is used in thermometers as a basic principle

Change in optical properties with change in temperature:

This principle is used in pyrometers that change colour of radiation with rise in temperature.

Mode of Transfer of Heat:

Motion of heat energy from one body to another or from one part of body to another is called transfer of the heat

There are three modes of transfer of heat:

(i) Conduction

(ii) convection

(iii) Radiation

Conduction:

The process of transfer of heat in a material in which heat energy is transferred from molecule to molecule without the actual motion of molecule is called conduction.

For example:

When one end of an iron rod is placed in fire and other end is held in hand then the heat reaches the other end in some times. It means heat has passed from one end to other end. The particles of the rod does not move but heat is ended from particle to particle. This mode of transfer of heat is slowest among all.

Other Examples of conduction:

- 1) For cooking in utensils, conduction process is used
- 2) In heat exchanger
- 3) Used in laser cooling
- 4) In medical treatment of humans.

Convection:

The process of transfer of heat in which heat is transferred from one point to another by the actual motion of particles away from source of heat is called convection.

For example:

When a flask filled with water is heated on a burner then water is seen to move upward from the centre and downward along the sides. This is because water at bottom lighter and rises up. Cold water from the top being heavy move downward.

→ Other examples of convection:

- 1) Fan or AC used to cool a room in summer make use of process of convection.

- (ii) Ventilators used in room used the process of convection
- (iii) Radiators used in vehicles make use of convection
- (iv) In Refrigerators.

Radiation: Radiation is the process of heat transfer in which heat is transferred from one place to another in straight line in the form of heat wave with velocity of light without heating the medium through which it is passed.

For example:

- (i) Heat from sun comes to us on earth by radiation.
- (ii) When we sit near an open fire then heat comes to us by radiation.

Properties of Heat Radiation:

- (i) Heat Radiation travels in straight lines
- (ii) Heat Radiation travels in velocity of light ($3 \times 10^8 \text{ m/s}$)
- (iii) Heat Radiation requires no material medium for their propagation.
- (iv) Heat Radiation obey the laws of reflection
- (v) Heat radiation don't heat the medium through which they pass

Different scales of temperature:

For quantitative measurement of temperature, we must select standard temperature scale between two fixed temperature. The two fixed temperature selected are melting point of ice & boiling point of water. The interval between them is divided into equal parts. Each part is called a degree of temperature and a scale is obtained is called scale of temperature

(i) Celsius Scale:

On this scale, freezing point of water (0°C) is taken as lower

fixed point & boiling point of water 100°C as upper fixed point. The interval between them is divided into 100 equal parts. Each part is called 1°C

(ii) Fahrenheit Scale°

On this scale, freezing point of water (32°) is taken as lower fixed point & boiling point of water (212°) as upper fixed point the interval between them is divided into 180 equal parts. Each part is called 1°F

(iii) Kelvin Scale°

On this scale freezing point of water (273K) and boiling point of water 373K . The interval between them is divided into 100 equal parts. Each part is called (1K)

(iv) Reumar Scale°

on this scale, freezing point of water (0°R) is taken as lower fixed point & boiling point of water (80°R) as upper fixed point. The interval between them is divided into 80 equal parts. Each part is called 1°R

Relation between different scales of temperature°

Temperature of body can be converted from one scale to other such that scale does not effect the magnitude of physical quantity. Therefore, on any one scale of temperature, we write in terms of reference point

L = lower reference point (Ice point)

H = upper reference point (Steam point)

T = Temperature read on given scale

Now $\left(\frac{T-L}{H-L} \right) = \text{Relative temperature with respect to both reference points.}$

Let us take a body whose temperature is to be determined by using different thermometers in $^{\circ}\text{C}$, $^{\circ}\text{F}$, $^{\circ}\text{K}$, $^{\circ}\text{R}$ respectively

- Let $T_1 = C$ = Temperature read in $^{\circ}\text{C}$
 $T_2 = F$ = Temperature read in $^{\circ}\text{F}$
 $T_3 = K$ = Temperature read in $^{\circ}\text{K}$
 $T_4 = R$ = Temperature read in $^{\circ}\text{R}$

To develop a formula of conversion of temperature from one scale to other, we select ice point as lower reference & Steam point as upper fixed point

$L_1 = 0^{\circ}\text{C}$	$L_2 = 32^{\circ}\text{F}$	$L_3 = 273\text{K}$	$L_4 = 0^{\circ}\text{R}$
$H_1 = 100^{\circ}\text{C}$	$H_2 = 212^{\circ}\text{F}$	$H_3 = 373\text{K}$	$H_4 = 80^{\circ}\text{R}$

Now, $\frac{T_1 - L_1}{H_1 - L_1} = \frac{T_2 - L_2}{H_2 - L_2} = \frac{T_3 - L_3}{H_3 - L_3} = \frac{T_4 - L_4}{H_4 - L_4}$

$$\frac{C - 0}{100 - 0} = \frac{F - 32}{212 - 32} = \frac{K - 273}{373 - 273} = \frac{R - 0}{80 - 0}$$

$$\frac{C}{100} = \frac{F - 32}{180} = \frac{K - 273}{100} = \frac{R}{80}$$

Sum

$$\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5} = \frac{R}{4}$$

x x x,

Properties of Matter

Deforming force :-

The deforming force is a force which when applied on a body it change the Configuration (length, volume and shape) of a body. This force is known as deforming force.

ELASTICITY :-

(प्रत्यास्ति) The tendency of a body to regain it's original configuration after remove deforming force is known as elasticity.

* elastic body :-

A body which completely regain it's original shape and size after removal of deforming force is said to be perfectly elastic body.

Note:- Steel is more elastic than Rubber

* Plastic body :-

A body which do not regain it's original shape and size after remove deforming force is said to be perfectly plastic body.

Note:-

ELASTICITY depend on two factor

1. Stress
2. Strain

* Stress (यत्न) :->

When a deforming force is applied on a body, then it develops equal and opposite force known as restoring force. Restoring force help to bring the body back to it's original configuration.

⇒ Defination:-

The restoring force acting per unit area of the body is called stress.

$$\text{Stress} = \frac{\text{Restoring force}}{\text{area}}$$

$$\text{Stress} = \frac{F}{A}$$

Unit → N/m^2

D.F → $[\text{M}^1 \text{L}^{-1} \text{T}^{-2}]$

Type of Stress

1. Normal stress
2. Tangential stress
3. Volumetric stress

⇒ Normal stress :-

It is defined as the restoring force acting per unit area perpendicular to the surface of the body.

2. Tangential stress :-

It is defined as the restoring force acting per unit area tangential to the surface of the body.

3. Volumetric stress :-

When a body is immersed in a fluid then a body acted upon by force acting everywhere on the surface normal to it.

* Strain (Deformation)

It is the ratio of change in configuration to the original configuration.

$$\text{Strain} = \frac{\text{change in Dimension / configuration}}{\text{original Dimension / configuration}}$$

Unit \Rightarrow Unitless

Dimension \Rightarrow Dimensionless

Type of strain

1. Longitudinal strain.
2. Volumetric strain.
3. Shearing strain.

1 Longitudinal strain :-

if the deforming force produces a change in length alone, the strain produced in body is known as longitudinal strain.

⇒ It is defined as the ratio of change in length to the original length.

$$\text{Longitudinal Strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta L}{L}$$

2 Volumetric strain :-

It is defined as the ratio of change in volume to the original volume.

$$\text{Volumetric strain} = \frac{\text{change in volume}}{\text{original volume}} = \frac{\Delta V}{V}$$

3 Shearing strain :-

if a tangential force is applied on the top face of a rectangular block whose bottom face is rigid, change the shape of rectangular block, without changing its volume.

⇒ It is defined as the ratio of displacement of a surface under the tangential force to perpendicular distance between surfaces.

$$\text{Shearing stress} = \frac{\text{Lateral Displacement}}{\text{Distance between surface}}$$
$$= \frac{\Delta L}{L} = \tan \phi$$

Hook's Law :-

The stress developed in a solid is directly proportional to the strain produced in it.

$$\text{Stress} \propto \text{Strain}$$

$$\text{Stress} = E \times \text{Strain}$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

where E is constant and is known as modulus of elasticity.

Note:- Hook's law is only valid for small strain

- ⇒ Modulus of elasticity depends on
1. Nature of material
 2. Temperature
 3. Dimension/Area

Type of Modulus of elasticity:

1. young's modulus of elasticity
2. Bulk modulus of elasticity
3. shear modulus (modulus of rigidity)

1. Young's Modulus of elasticity :-

It is defined as the ratio of longitudinal stress to longitudinal strain.

$$\text{Young's modulus } (\gamma) = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}}$$

$$\Rightarrow \frac{F/A}{\Delta L/L} \Rightarrow \frac{F \cdot L}{A \cdot \Delta L}$$

$$\gamma = \frac{F \cdot L}{A \cdot \Delta L}$$

Note:-

- * It is present in solids only.
- * Young's modulus for gas is zero.

2. Bulk modulus of elasticity :-

It is defined as the ratio of Volumetric stress to the Volumetric strain.

$$\text{Bulk Modulus } (\beta) = \frac{\text{Volumetric stress}}{\text{Volumetric strain}}$$

$$= \frac{F/A}{\Delta V/V} \Rightarrow \frac{F \cdot V}{A \cdot \Delta V}$$

$$\beta = \frac{F \cdot V}{A \cdot \Delta V}$$

3 Shear Modulus (Modulus of Rigidity)

It is defined as the ratio of shear stress to the shear strain.

$$\text{Shear Modulus } (\eta) = \frac{\text{shear stress}}{\text{shear strain}}$$

$$\eta = \frac{F/A}{\tan \phi} = \frac{F/A}{\phi} \quad \because \tan \phi = \phi$$

$$\eta = \frac{F}{A \phi}$$

* It is present in solid ~~at~~ only.

FLUIDS

FLUIDS \rightarrow Substance that can flow

\Rightarrow Hence Fluids can be liquid and gas.

\Rightarrow Here we discuss liquid only. We know that liquid has a definite volume but not definite shape.

* Pressure :

A basic property of every fluid is that it exerts a pressure.

\Rightarrow The "Thrust" exerted by a fluid at rest per unit area of the surface in contact with it is called pressure.

$$P = \frac{F}{A}$$

unit \Rightarrow N/m^2 or Pascal.

Dimension $\Rightarrow [M L^{-1} T^{-2}]$

It is a scalar quantity.

* Atmospheric Pressure :

The envelope of gas surrounding the earth is called ~~atm~~ atmosphere.

The atmosphere exerts pressure on earth's surface is known as atmospheric pressure.

$$P = h \rho g$$
$$= 76 \times 13.6 \times 9.80$$
$$= 1.013 \times 10^6 \text{ dyne/cm}^2$$

Where $h \Rightarrow$ height at sea level

ρ = density of Mercury

g = acc. due to gravity.

Absolute Pressure:

Total Pressure inside a liquid at any point is called absolute pressure

$$\text{absolute pressure} = \text{atmospheric pressure} + h \rho g$$

Gauge Pressure :

The pressure at any point inside a liquid due to the liquid above it is called Gauge Pressure.

\Rightarrow It is excess pressure

Hence, Difference in absolute pressure and ~~atm~~ atmospheric pressure is known as gauge pressure.

* Pascal's Law :-

According to Pascal Law, when liquid is at rest, pressure is same from everywhere if the effect of gravity is neglected.

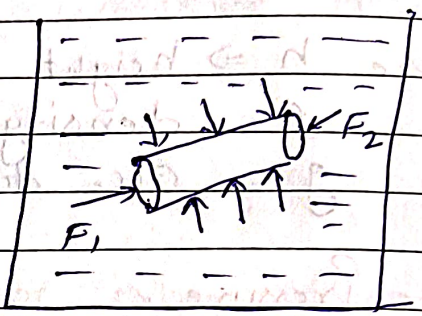
$$F_1 = F_2$$

$$F_1 = P_1 A \quad \text{--- (1)}$$

$$F_2 = P_2 A \quad \text{--- (2)}$$

from eqⁿ (1) & (2),

$$P_1 = P_2$$



Application of Pascal's law

1. Hydraulic Lift
2. Hydraulic Brakes

Intermolecular Forces :-

The force between the molecule of the substances are called intermolecular forces.

- ⇒ Solid → Strong intermolecular force → Less Distance b/w Molecule
- ⇒ Liquid → Weak intermolecular force →
- ⇒ Gas → Very weak intermolecular force → Large Distance b/w Molecule.

* Cohesive force :- (ससजक बल)

The force of attraction between the molecules of the same substance is known as Cohesive force.

Solid → Cohesive force is very large

Liquid → Cohesive force is weaker than that of solid.

Gas → Cohesive force is very weak.

Example:- It is difficult to separate two strictly plate of glass wetted with water.

* Adhesive force :- (असजक बल)

The force of attraction between the molecule of the different substance is called force of adhesive.

Example:-

1. Adhesive force enable us to write on the blackboard with chalk.

2. Water wets the glass surface.

* Molecular Range :-

It is the distance up to which a molecule can exert some measurable attraction on other molecule.

OR

The maximum distance upto which the force of attraction between two molecule is measurable is called molecular range.

⇒ Range of order $= 10^{-9}m$. (in solid & liquid)

* Sphere of Influence :-

It is an imaginary sphere drawn with a molecule as center and molecular range as radius.

Surface Tension (956 ताला)

"It is a property of a liquid by which free surface of liquid at rest tends to have minimum surface area."

⇒ It is defined as force per unit length.

$$\text{Surface Tension } (T) = \frac{F}{l}$$

Unit $\rightarrow N/m$, It is a scalar quantity.
Dimension $\rightarrow [M^1 L^{-1} T^{-2}]$

Application of Surface Tension:-

1. When we increase the temp, Surface Tension will decrease.
2. oil, grease etc. will decrease the surface tension.
3. If electricity is supplied through the liquid then surface Tension will be decrease.
4. Antiseptics, like detol have low surface Tension so they spread faster.
5. Soap & Detergents have the ability to reduce the surface Tension. Hence it can wash clothes more effectively.

* effect of Temperature on surface Tension :-

Surface Tension of liquid decrease with rise in temp.

Temperature $\uparrow \Rightarrow$ surface Tension \downarrow

Surface Tension is zero at its boiling point.

* effect of impurity on surface Tension:

When impurity are added to the liquid, the surface Tension of liquid may decrease or increase depending on the substance added to the liquid.

⇒ if highly soluble substance like NaCl dissolve in water then surface Tension of water will increase.

⇒ if slightly soluble substance like phenol, oil are dissolve in the water, then surface Tension will decrease.

* Viscosity:

As we know that surface Tension is a property of liquid at rest, but here Viscosity is a property of fluid in motion.

"

Internal friction of liquid is known as Viscosity?

definition:

Hence, Viscosity is a property of fluid (liquid or gas) by virtue of which an internal frictional force comes into play when fluid is in motion.

S.I unit \Rightarrow Pl (Poiseuille)
 \Rightarrow $\text{N m}^{-2} \cdot \text{s}$ (Pascal second)

Dimension = $[\text{M L}^{-1} \text{T}^{-1}]$

effect of temperature on Viscosity:

1. With increase in temperature, the viscosity of liquid decrease.

2. With increase in temperature, the viscosity of gases increase.

~~3. Viscosity play~~

Applications of Viscosity:

1. As viscosity of liquid vary with temperature, proper choice of lubricant is made up.

2. Viscosity play an important role in circulation of blood through veins.

3. At railway terminal, liquid of High ~~Visc~~ viscosity are used as buffers.

UNIT-1 UNITS AND DIMENSIONS

Physics: It is a branch of science which deals with the Quantitative studies and laws about nature like motion of matter, energy and force.

Basically, Physics is a science of measurements. It tells us all about quantities whether they can be measured or not, if measured then how they can be measured.

Physical Quantities: Those quantities which can be measured are called physical quantities. For example: Length of a table, volume of milk, height of tower etc.

Types of Physical Quantities: 1. Fundamental Quantities 2. Derived Quantities

1. **Fundamental Quantities:** Those physical quantities which are independent of others & can be measured directly. For example: Mass, Length & Time.
2. **Derived Quantities:** Those quantities which depend on one or more fundamental quantities or derived from fundamental quantities. For example: Area, Volume, Speed, Force etc.

Units: Unit is a standard quantity which is used for measurement. To measure a quantity, a unit is must.

Properties of Unit:

- (i) It should be well defined.
- (ii) It should have proper size.
- (iii) It should not change with time, place/physical conditions.

Types of Units: 1. Fundamental Units 2. Derived Units

1. **Fundamental Units:** The units selected for the measurement of three basic quantities i.e. mass, length & time. For example: meter, km, cm, foot, second, minute, kg, gm all are fundamental units.
Units of length, mass & time are independent of each other.
2. **Derived Units:** Which are derived from one or more fundamental units. For example: Velocity = Distance /Time, if the units of distance & time are well defined, unit of velocity can be obtained.

System of Units: It is a set and contains the definitions of fundamental & derived units. There are four system of unit in which every physical quantity is measured in terms of mass, length & time.

Types: 1. CGS System 2. MKS System 3. FPS System 4. International System of Units (S.I. Units)

<u>CGS System</u>	<u>MKS System</u>	<u>FPS System</u>	<u>S.I. Units</u>
Developed by French People. CGS System uses a centimeter, gram & second as the fundamental units.	MKS System uses metre, kilogram & second as the fundamental units.	Developed by Britishers. FPS System uses foot for length, pound for mass & second as the fundamental units.	This system is the modification over MKS System.
It is based on decimal	It is slightly improvement	These units are less	It is based on

number system and the size of basic unit is too small.	over CGS System. The size of units was made more practical of course.	in use & system was based in the customary units in English.	seven basic units & two supplementary units.
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Basic Units in SI:

<u>Sr. No.</u>	<u>Physical Quantity</u>	<u>Unit Name</u>	<u>Symbol</u>
1.	Mass	Kilogram	Kg
2.	Length	Metre	m
3.	Time	Second	S
4.	Temperature	Kelvin	K
5.	Electric Current	Ampere	A
6.	Luminous Intensity	Candela	Cd
7.	Amount of substance (or quantity of matter)	Mole	mol

Supplementary Units:

1.	Plane Angle	Radian	rad
2.	Solid Angle	Steradian	sr

SI Units of Some Physical Quantities:

<u>Sr. No.</u>	<u>Physical Quantity</u>	<u>Unit Name</u>	<u>Symbol</u>	<u>Equivalent</u>
1.	Distance	Metre	m	
2.	Displacement	Metre	m	
3.	Area	Square metre	m ²	
4.	Volume	Cubic metre	m ³	
5.	Density	Kilogram per cubic metre	Kg m ⁻³	
6.	Velocity	Metre per second	ms ⁻¹	
7.	Linear Momentum	Kilogram metre per second	Kgm s ⁻¹	
8.	Acceleration	Metre per second square	ms ⁻²	
9.	Force	Newton	N	kgms ⁻²
10.	Work, Energy & Heat	Joule	J	Nm
11.	Power	Watt	W	Js ⁻¹
12.	Pressure, Elasticity	Pascal	Pa	Nm ⁻²
13.	Surface Tension	Newton per metre	Nm ⁻¹	
14.	Stress	Pascal	Pa	Nm ⁻²
15.	Strain	-	-	-
16.	Impulse	Newton second	Ns	kgms ⁻¹

Dimension: The dimensions of a physical quantity are the powers to which the fundamental units of mass, length & time must be raised to represent a derived unit of the quantity. For example:

(i) **Area (A)** = Length × breadth

$A = [L^1] \times [L^1] = [L^2]$ i.e. area has two dimensions (power raised) in length and has zero dimensions in mass & time & is represented by $[M^0L^2T^0]$.

(ii) **Volume (V)** = Length × breadth × height

$V = [L^1] \times [L^1] \times [L^1] = [L^3]$ i.e. $[M^0L^3T^0]$.

Dimensional Formula: An expression showing how & which of the fundamental units are required to represent the unit of a physical quantity.

Dimensional Equation: The equation obtained by equating a physical quantity to its dimensional formula.

$$V = [M^0L^3T^0]$$

Dimensional Formulas of Some Physical Quantities:

1. **Dimensional formula of area:**

Area (A) = Length × breadth = $[M^0L^1T^0] \times [M^0L^1T^0] = [M^0L^2T^0]$.

2. **Dimensional Formula of Volume:**

Volume (V) = Length × breadth × height = $[M^0L^1T^0] \times [M^0L^1T^0] \times [M^0L^1T^0] = [M^0L^3T^0]$.

3. **Dimensional Formula of Distance:** $[M^0L^1T^0]$.

4. **Dimensional Formula of Displacement:** $[M^0L^1T^0]$.

5. **Dimensional Formula of Density:**

Density = Mass / Volume then Density = $[M^1L^0T^0] / [M^0L^3T^0] = [M^1L^{-3}T^0]$.

6. **Dimensional Formula of Velocity:**

Velocity = Displacement / Time = $[M^0L^1T^0] / [M^0L^0T^1] = [M^0L^1T^{-1}]$.

7. **Dimensional Formula of Acceleration:**

Acceleration = Velocity / Time = $[M^0L^1T^{-1}] / [M^0L^0T^1] = [M^0L^1T^{-2}]$.

8. **Dimensional Formula of Linear Momentum:**

Linear Momentum (p) = Mass × Velocity = $[M^1L^0T^0] \times [M^0L^1T^{-1}] = [M^1L^1T^{-1}]$.

9. **Dimensional Formula of Force:**

Force (F) = Mass × Acceleration = $[M^1L^0T^0] \times [M^0L^1T^{-2}] = [M^1L^1T^{-2}]$.

10. **Dimensional Formula of Impulse:**

Impulse = Force × Time = $[M^1L^1T^{-2}] \times [M^0L^0T^1] = [M^1L^1T^{-1}]$.

11. Dimensional Formula of Work & Energy:

Work (W) = Force × Displacement = $[M^1L^1T^{-2}] \times [M^0L^1T^0] = [M^1L^2T^{-2}]$.
Work = P.E. = K.E. = $[M^1L^2T^{-2}]$.

12. Dimensional Formula of Power:

Power = Work done/Time taken = $[M^1L^2T^{-2}] / [M^0L^0T^1] = [M^1L^2T^{-3}]$.

13. Dimensional Formula of Pressure & Stress:

Pressure & Stress = Force/Area = $[M^1L^1T^{-2}] / [M^0L^2T^0] = [M^1L^{-1}T^{-2}]$.

14. Dimensional Formula of Surface Tension:

Surface Tension = Force/Length = $[M^1L^1T^{-2}] / [M^0L^1T^0] = [M^1L^0T^{-2}]$.

15. Dimensional Formula of Strain:

Strain = Change in length/Original Length = **Dimensionless**.

Principle of Homogeneity of Dimensions: It states that dimensions of all the terms on the both side of equation must be same.

Applications of Dimensional Equations and analysis:

- (i) Checking the correctness of the given physical relation.
- (ii) To drive the relationship between different physical quantities.
- (iii) Conversion of one system into the other.

Example 1: Check the correctness of physical equation $S = ut + \frac{1}{2}at^2$. In the equation, s is the displacement, u is the initial velocity, v is the final velocity, a is the acceleration and t is the time in which change occurs.

Solution: We know that L.H.S = S
R.H.S = $ut + \frac{1}{2}at^2$

Dimensional formula for S = $[M^0 L^1 T^0]$ (1)

Simplifying R.H.S as $[u][t] + [a] [t]^2$ and $\frac{1}{2}$ dimensionless being a number.

$[M^0 L^1 T^{-1}][M^0 L^0 T^1] + [M^0 L^1 T^{-2}][M^0 L^0 T^2] = [M^0 L^1 T^0]$(2)

From (1) and (2), we have [L.H.S] = [R.H.S]

Example 2: Using Dimensional Analysis, Check the correctness of physical equation $T = 2\pi l/g$ where T = Time Period, l = Length of pendulum, g = acceleration due to gravity.

Solution: We know that L.H.S = T

$$\text{R.H.S} = 2\pi v/g$$

Dimensional formula for T = $[M^0 L^0 T^1]$ (1)

Simplifying R.H.S as v/g and 2π dimensionless being a number.

$$\sqrt{[M^0 L^1 T^0]/[M^0 L^1 T^{-2}]} = v [M^0 L^0 T^2] = [M^0 L^0 T^1] \dots\dots\dots(2)$$

From (1) and (2), we have [L.H.S] = [R.H.S].

Example 3: Using Dimensional Analysis, Check the correctness of physical equation $F = ma$, where F = Force, m = mass and a = acceleration.

Example 4: Using Dimensional Analysis, Check the correctness of physical equation $S = ut + at^2$, where S = Distance, u = initial velocity, a = acceleration and t = time.

Conversion of One system into the other:

Consider a physical quantity 'X' having its dimensional formula $[X] = [M^a L^b T^c]$.

In 1st System, $u_1 = M_1^a L_1^b T_1^c$

In 2nd System, $u_2 = M_2^a L_2^b T_2^c$ where a, b & c are dimensions.

Now the concept "change of unit does not affect the magnitude" is applied i.e. $n_1 u_1 = n_2 u_2$ where n_1 & n_2 are dimensionless numbers.

Therefore, $n_1 \times M_1^a L_1^b T_1^c = n_2 \times M_2^a L_2^b T_2^c$

$n_2 = n_1 \times (M_1/M_2)^a \times (L_1/L_2)^b \times (T_1/T_2)^c$ is the required formula for conversion.

Note: This formula is applied when units are absolute only.

Example 1: Convert one Newton into dynes using the method of dimensions.

Solution:

Newton is unit of force in S.I., then $u_1 = N$

Dyne is unit of force in C.G.S., then $u_2 = \text{dyne}$

Both are units of force, whose dimensional formula is

Force = $[M^1 L^1 T^{-2}] = [M^a L^b T^c]$ (say), therefore a =1, b = 1 and c = -2

<u>In S.I.</u>	<u>In C.G.S.</u>
----------------	------------------

$$M_1 = 1\text{kg}$$

$$M_2 = 1\text{gm}$$

$$L_1 = 1\text{m}$$

$$L_2 = \text{cm}$$

$$T_1 = 1\text{s}$$

$$T_2 = 1\text{s}$$

$$n_1 = 1$$

$$n_2 = ?$$

$$u_1 = \text{N}$$

$$u_2 = \text{dyne}$$

The relation $n_1 u_1 = n_2 u_2$, Therefore $n_2 = n_1 \times (M_1/M_2)^a \times (L_1/L_2)^b \times (T_1/T_2)^c$

$$n_2 = 1 \times (1\text{kg/g})^1 \times (1\text{m}/1\text{cm})^1 \times (1\text{s}/1\text{s})^{-2}$$

$$n_2 = 1 \times (K)^1 \times (1/c)^1 \times (-1)^{-2}$$

$$n_2 = 1 \times 10^3 \times 10^2 \times 1$$

$$n_2 = 10^5$$

Hence by using $n_1 u_1 = n_2 u_2$

$$1\text{N} = 10^5 \text{ dyne.}$$

Example 2: Convert one Joule into erg using the method of dimensions.

Example 3: Convert an acceleration of 100m/s^2 into km/hr^2 using the method of dimensions.

Solution:

Dimensional formula of Acceleration = $[M^0 L^1 T^{-2}] = [M^a L^b T^c]$ (say), therefore $a = 0$, $b = 1$ and $c = -2$

<u>In S.I.</u>	<u>In C.G.S.</u>
----------------	------------------

$$M_1 = 1\text{kg}$$

$$M_2 = 1\text{kg}$$

$$L_1 = 1\text{m}$$

$$L_2 = 1\text{km}$$

$$T_1 = 1\text{s}$$

$$T_2 = 1\text{hr}$$

$$n_1 = 100$$

$$n_2 = ?$$

$$u_1 = \text{m/s}^2$$

$$u_2 = \text{km/hr}^2$$

The relation $n_1 u_1 = n_2 u_2$, Therefore $n_2 = n_1 \times (M_1/M_2)^a \times (L_1/L_2)^b \times (T_1/T_2)^c$

$$n_2 = 100 \times (1\text{kg}/1\text{kg})^0 \times (1\text{m}/1\text{km})^1 \times (1\text{s}/1\text{hr})^{-2}$$

$$n_2 = 100 \times (1/1000)^1 \times (1/3600)^{-2}$$

$$n_2 = 12.96 \times 10^5$$

Hence by using $n_1 u_1 = n_2 u_2$

$$100 \text{ m/s}^2 = 12.96 \times 10^5 \text{ km/hr}^2$$

Limitations of method of Dimensions:

- (i) It gives no information about dimensionless constants & pure numbers.
- (ii) This method does not make any difference between scalar & vector quantities.

UNIT-3 WORK, POWER & ENERGY

Work

Work: Work is said to be done whenever a force is applied on a body & displacement occurs. It is denoted by 'W'. Its SI unit is **Joule (J)**. Work is a **Scalar** quantity.

$$\text{Work} = \text{Force} \times \text{Displacement} \Rightarrow W = F.S$$

OR

$$W = FS \cos \theta$$

$$1 \text{ J} = 1 \text{ NEWTON} \times 1 \text{ m}$$

1 Joule: Work is said to be one joule if force of 1 Newton produces displacement of 1 m.

Types of Work: (i). Zero Work (ii). Positive Work (iii). Negative Work

Zero Work: Whenever force & displacement stand perpendicular to one another or when neither force nor displacement occurs. **Example:** If you push a wall & it doesn't move, you haven't accomplished anything.

Positive Work: Occurs when the force & displacement of an object are in the same direction.

Example: A girl pulling a box towards herself. In this case force & displacement have the same direction.

Negative Work: when the force & displacement of an object are in the opposite direction. **Example:** Pulling water from a well. In this case force & displacement have the opposite direction.

Numerical 1: How much work is done at the rate of 40W in 40seconds?

Solution: P = 40W, T = 40 sec [Given]

$$\Rightarrow P = \frac{W}{T} \Rightarrow 40 = \frac{W}{40} \Rightarrow \text{Work done} = 40 \times 40 = 1600 \text{ Joule} \Rightarrow W = 1600 \text{ Joule}$$

Power

Power: Rate of doing work is called power. It is denoted by 'P'. SI unit is **Watt (W)**. $1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ sec}}$

$$\text{Power} = \frac{\text{Workdone}}{\text{Time}} \Rightarrow P = \frac{W}{T}$$

Numerical 2: Calculate Power of motor, which is capable of raising 200kg of water in 5min from a well 120m deep? [g = 9.8 m/s²]

Solution: m = 200kg, T = 5×60 = 300sec, h = 120m [Given]

$$\Rightarrow P = \frac{W}{T} \Rightarrow \frac{mgh}{T} \Rightarrow \frac{200 \times 9.8 \times 120}{300 \times 10} = 78400.$$

Numerical 3: Calculate power of a body doing work of 50J in 20 sec?

Solution: P = 40W, T = 40 sec [Given]

$$\Rightarrow P = \frac{W}{T} \Rightarrow \frac{5}{20} \Rightarrow 2.5 \text{ watt.}$$

Energy

Energy: Capacity of doing work is called as Energy. SI Unit of Energy is **Joule (J)**.

Transformation of Energy: Conversion of one form of energy to another form is called transformation of energy.

Examples of Transformation of Energy:

1. A loudspeaker converts electric energy into sound energy.
2. Solar energy converts into electric energy using solar panel.
3. An electric generator converts mechanical energy into electrical energy.
4. Burning of coal, matchstick converts chemical energy into heat energy.
5. In an electric bulb, electric energy is converted into light energy.

Mechanical Energy: The energy in an object due to its motion, position or both is called mechanical energy. It is the sum of kinetic energy & potential energy of the object.

Kinetic Energy: The energy possessed by a body because of its motion is called kinetic energy.

$$\text{K.E.} = \frac{1}{2} mv^2$$

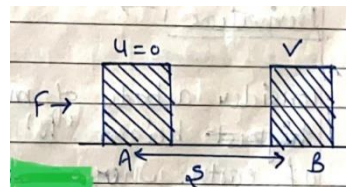
Examples: (i). Flowing water in river (ii). Moving bullet from gun.

Derivation: Consider a body of mass 'm' is at rest at point 'A'. Now apply force on body so that it start move with velocity 'v' & undergone displacement 'S'.

$$v^2 - u^2 = 2aS \quad \Rightarrow \quad v^2 - (0)^2 = 2aS$$

[∵ u = 0 because body is at rest]

$$\Rightarrow S = \frac{v^2}{2a} \dots\dots\dots(1)$$



Work done in displacing a body

$$W = F \times S \quad \Rightarrow \quad W = ma \times S$$

[$\because F = ma$ from Newton's 2nd law of motion]

$$\Rightarrow W = ma \times \frac{v^2}{2a}$$

This work done is stored in the form of K.E.

$$\text{K.E.} = \frac{1}{2} mv^2$$

Potential Energy(U): The energy possessed by a body because of its position is called Potential energy.

$$\text{P.E.} = mgh$$

Examples: (i). Water stored in Dam (ii). Energy stored in spring

Derivation: Consider a body of mass 'm' is at height 'h' from surface of earth where acceleration due to gravity is 'g'.

Gravitational force $F = mg$

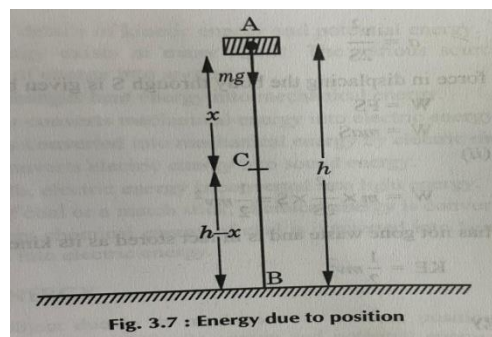
Work done in raising a body vertically upward

$$W = F \times S \quad \Rightarrow \quad W = mg \times h$$

$$\Rightarrow W = mgh$$

This work done is stored in the form of potential energy, then

$$\text{P.E.} = mgh$$



Law of conservation of Energy: It states that energy can neither be created nor be destroyed but can be transformed from one form to another. The total energy of a body remains constant i.e. P.E. + K.E. = Constant

Proof: In case of freely falling body:-

Consider a body of mass 'm' is at height 'h' from surface of earth where acceleration due to gravity is 'g'.

Let x = distance of a point C from A i.e. at a height $(h-x)$ above the ground

v_1 = velocity of body at C

v_2 = velocity of body at point B, just above the ground

At Point A: Body is at rest, so initial velocity ' u ' = 0, \Rightarrow K.E. = 0

P.E. = mgh

\Rightarrow Total Energy = K.E. + P.E. \Rightarrow **mgh**

At Point B: Let the body is allowed to fall freely under gravity with velocity ' v '.

From $v^2 - u^2 = 2aS \Rightarrow v^2 - (0)^2 = 2 \times g \times x$ [$\because u = 0$ from (1) and $S = x$]

$\Rightarrow v^2 = 2gx$

P.E. = $mg \times (h - x) \Rightarrow mgh - mgx$

K.E. = $\frac{1}{2}mv^2 \Rightarrow \frac{1}{2} \times m \times 2gx \Rightarrow mgx$

\Rightarrow Total Energy = K.E. + P.E. $\Rightarrow mgh - mgx + mgx \Rightarrow$ **mgh**

At Point C: When body at point 'C'

P.E. = $mg \times 0 = 0$

K.E. = $\frac{1}{2}mv^2 \Rightarrow \frac{1}{2} \times m \times 2gh \Rightarrow mgh$

Total Energy = K.E. + P.E. $\Rightarrow 0 + mgh \Rightarrow$ **mgh**

Thus the total energy of the body at every point remains the same.

Numerical 4: An object of mass 20 kg is moved to a path with velocity 20 m/s. Find the K.E. in this case?

Solution: $m = 20\text{kg}$, $v = 20 \text{ m/sec}$ [Given]

K.E. = $\frac{1}{2}mv^2 \Rightarrow \frac{1}{2} \times 20 \times 20 \times 20 \Rightarrow 4000\text{J}$

Numerical 5: An Athlete raises a mass of 20kg to a height 8m and drops it. Find P.E. of object at highest point?

Solution: $m = 20\text{kg}$, $g = 9.8 \text{ m/sec}^2$, $h = 8\text{m}$ [Given]

P.E. = $mgh \Rightarrow 20 \times 9.8 \times 8 \Rightarrow 1568\text{J}$

Friction

Friction: It is the force that opposes the motion between any surfaces that are in contact. Opposing force is called friction or force of friction.

Types of Friction: (i) Static Friction (ii). Dynamic Friction

Examples of Friction in our daily life:

1. Walking: Ground provide friction to shoes of person by which we can move forward i.e. friction is necessary for walking.
2. Breaks applied in the vehicles.
3. Lightening of match stick..
4. Skating.
5. Writing: helps in writing on a paper with pen.