MOTION IN ONE DIMENSION

Rest : When a body does not change its position with respect to time, then it is said to be at rest. Rest is of two types : *(i)* Absolute rest *(ii)* Relative rest.

Absolute rest : Complete absence of motion is called absolute rest. It is impossible to obtain.

Relative rest : When a body does not change its position with respect to another one, then it is said to be in relative rest.

Motion : Whenever an object changes its position continuously with respect to the position of other objects around it, it is said to be in motion. Motion is of two types : *(i)* Absolute motion *(ii)* Relative motion.

Absolute motion : Motion with respect to body which is at absolute rest is called absolute motion. It is impossible.

Relative motion : Motion with respect to a body which is at relative rest is called relative motion. e.g., a person sitting in a moving train is at relative rest with respect to the train but it is in relative motion with respect to a person on the platform.

Displacement : The change of position of an object in a particular direction is called its displacement. If $x(t_2)$ and $x(t_1)$ are two position coordinates of a moving particle at times t_2 and t_1 respectively, then the displacement of the particle in the time interval t_1 to t_2 is

$$x(t_2) - x(t_1)$$

Following are the important results regarding displacement :

(i) Displacement is represented by the difference of two position coordination, like $x(t_2) - x(t_1)$.

(ii) It may be positive, negative or zero.

(iii) It does not depend upon the choice of origin of position coordinates.

(iv) It does not tell the actual distance travelled by the object.

Speed : The distance covered by an object in one second is called as the speed of that object.

$$\therefore \quad \text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

$$\text{or} \qquad V = \frac{s}{t}$$

If an object covers equal distance in equal time intervals, its speed is said to be *uniform speed*. If it covers unequal distance in equal time intervals, its speed is said to be non-uniform speed.

Average speed : The average speed of an object is calculated by dividing the total distance travelled by the total time taken by it, i.e.,

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

Velocity : Velocity is defined as the distance moved by a moving object in unit time in a given direction, i.e.,

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}}$$

$$\text{or } \vec{v} = \frac{\vec{s}}{t}$$

Its SI unit is ms^{-1}. It is a vector quantity.

Difference between Speed and Velocity:

Speed	Velocity
• It is the rate of change of position of an object.	• It is the rate of change of position of an object in a particular direction.
• Speed $= \dfrac{\text{distance travelled}}{\text{time taken}}$	• Velocity $= \dfrac{\text{displacement}}{\text{time}}$
• It is scalar quantity.	• It is vector quantity.

Instantaneous speed and instantaneous velocity : The actual speed (or velocity) at any moment is called as instantaneous speed (or instantaneous velocity). If an object travels a distance Δx in an infinitesimally small time Δt, then,

$$\text{Instantaneous speed, } V = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

And if an object covers a displacement $\Delta\vec{x}$ during infinitesimally small time interval Δt,

$$\text{then Instantaneous velocity } \vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$$

The magnitude of instantaneous velocity always equals the instantaneous speed.

Acceleration : Acceleration of an object is defined as the rate of change of velocity, i.e.,

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

or $$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

Instantaneous acceleration,

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

$$= \frac{d}{dt}\left(\frac{d\vec{x}}{dt}\right) = \frac{d^2\vec{x}}{dt^2}$$

i.e., acceleration is the second derivative of the position with respect to time.

A particle is said to be moving with *uniform acceleration* if its velocity varies equally in equal intervals of time.

Deceleration or Retardation or Negative acceleration : If the velocity of an object decreases without change in direction, acceleration is directed opposite to the direction of velocity and the object is said to be moving with negative acceleration or deceleration or retardation.

Equation for uniformly accelerated motion :

(a) $V = u + at$

(b) $s = ut + \frac{1}{2}at^2$

(c) $v^2 = u^2 + 2as$

where

u = initial velocity

v = final velocity

a = uniform acceleration

t = time-interval

s = displacement in time-interval t.

Equation for free fall under gravity alone :

(a) $v = u + gt$

(b) $s = ut + \frac{1}{2}gt^2$

(c) $v^2 = u^2 + 2as$

where g = acceleration due to gravity

Displacement in nth second of motion (S_{nth})

$$S_{nth} = u + \frac{1}{2}a(2n - 1)$$

Variable acceleration : If the change in velocity in equal intervals of time is not the same, the object is said to be moving with variable acceleration.

Important Deduction

- If a body starts from rest or falls freely or is dropped then, $u = 0$.
- If a body is thrown upwards then it will rise until its vertical velocity becomes zero. Maximum height attained is $h = u^2/2g$.
- If air resistance is negligible, then the time of rise is equal to time of fall, each is equal to $t = u/g$.
- The body returns to the starting point with the same velocity with which it was thrown.
- The velocity and acceleration of a body need not be in same direction.
- A body in equilibrium has *zero acceleration* only. All other quantities need not be zero.