Chapter 8: - Motion

- An object is said to be in motion when its position changes with time.
- We describe the location of an object by specifying a reference point. Motion is relative. The total path covered by an object is said to be the distance travelled by it.
- The shortest path/distance measured from the initial to the final position of an object is known as the displacement.

Rest: A body is said to be in a state of rest when its position does not change with respect to a reference point.

Motion: A body is said to be in a state of motion when its position change continuously with reference to a point.

→ Motion can be of different types depending upon the type of path by which the object is going through.

(i) Circulatory motion/Circular motion – In a circular path.

(ii) Linear motion – In a straight line path.

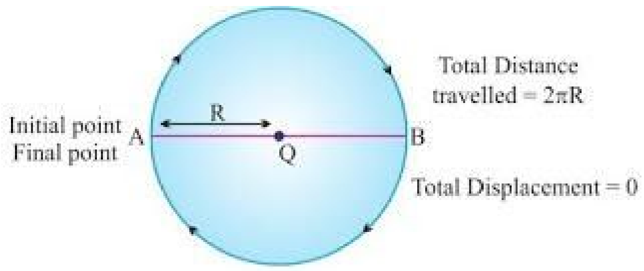
(iii) Oscillatory/Vibratory motion – To and fro path with respect to origin.

Scalar quantity: It is the physical quantity having its own magnitude but no direction. Example: distance, speed.

Vector quantity: It is the physical quantity that requires both magnitude and direction.

Example: displacement, velocity.

Distance and Displacement



Distance	Displacement
Length of actual path travelled by an object.	Shortest length between initial point and far point of an object.
It is a scalar quantity.	It is a vector quantity.
It remains positive, can't be '0' or negative.	It can be positive (+ve), negative (-ve) or zero.
Distance can be equal to displacement (in linear path).	Displacement can be equal to distance or its lesser than distance.

Uniform motion: When an object covers equal distances in equal intervals of time, it is said to be in uniform motion.

Non-uniform motion: Motions where objects cover unequal distances in equal intervals of time.

Speed: The distance travelled by an object in unit time is referred to as speed. Its unit is m/s.

Average speed: For non-uniform motion, the average speed of an object is obtained by dividing the total distance travelled by an object by the total time taken.

$$\text{Average speed } (v) = \frac{\text{Total distance travelled} (s)}{\text{Total time taken } (t)}$$

Velocity: Velocity is the speed of an object moving indefinite direction. S.I. unit is m/s.

$$\text{Average velocity} = \frac{\text{initial velocity} + \text{final velocity}}{2}$$

$$\therefore \qquad V_{av} = \frac{u+v}{2} \qquad u = \text{initial velocity}$$

$$v = \text{final velocity}$$

Acceleration: Change in the velocity of an object per unit time.

$$\text{Acceleration } a = \frac{v-u}{t} \quad \text{S.I. unit is m/s}^2$$

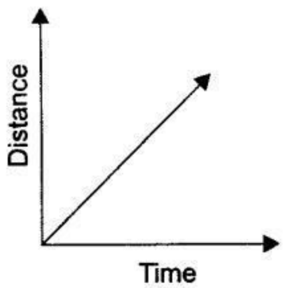
Retardation/Deceleration

→ Deceleration is seen in non-uniform motion during decrease in velocity with time. It has the same definition as acceleration.

• Deceleration (a') = Change in velocity/Time = (v-u)/t
Here, v < u, ‘a’ = negative (-ve).

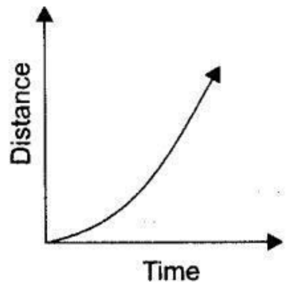
Graphical representation of motions

(i) Distance-time graph
For a distance-time graph, time is taken on x-axis and distance is taken on the y-axis. [**Note:** All independent quantities are taken along the x-axis and dependent quantities are taken along the y-axis.]

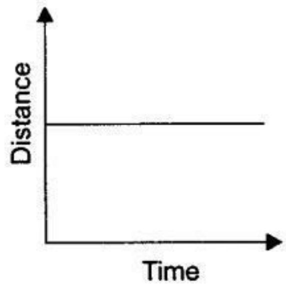


Uniform speed

$$\left(\text{speed} = \frac{\text{distance}}{\text{time}}\right)$$

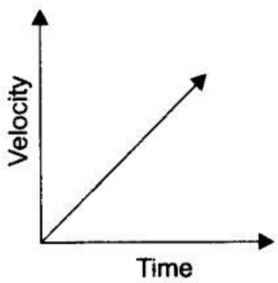


Non-uniform speed



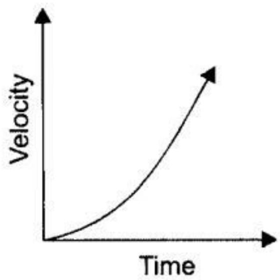
Stationary

(ii) Velocity-time graph

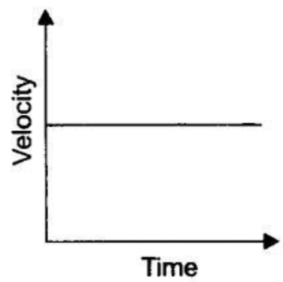


Uniform acceleration

$$\left(a = \frac{v}{t}\right)$$



Non-uniform acceleration

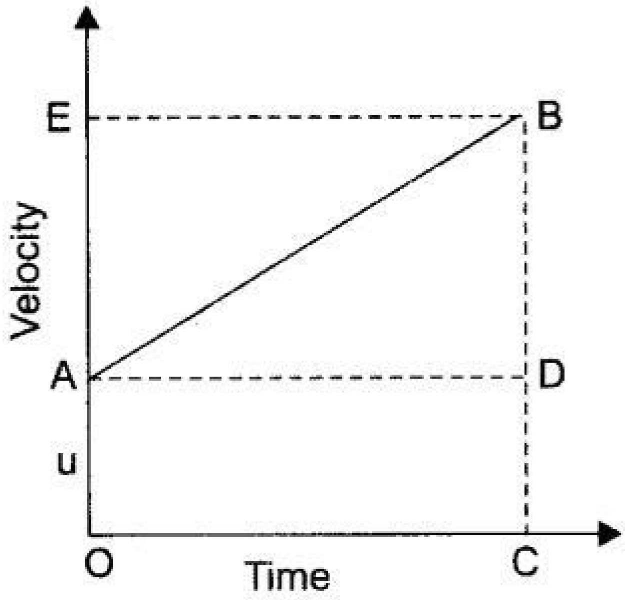


Uniform motion or no acceleration

Equation of motion by graphical methods

(i)velocity-time relation:

$$v = u + at$$



$OA = CD = u$

$OE = CB = v$

$OC = AD = t$

$BD = BC - DC$ (Change in velocity)

AD is parallel to OC.

$\therefore$ $BC = BD + DC = BD + OA$

$\therefore$ $BC = v$ and $OA = u$

We get $v = BD + u$

$\therefore$ $BD = v - u$ ...(1)

In velocity-time graph, slope gives acceleration.

$$\therefore \quad a = \frac{BD}{AD} = \frac{BD}{OC}$$

$\because$ $OC = t$ we get $a = \dfrac{BD}{t}$

$\therefore$ $BD = at$ ...(2)

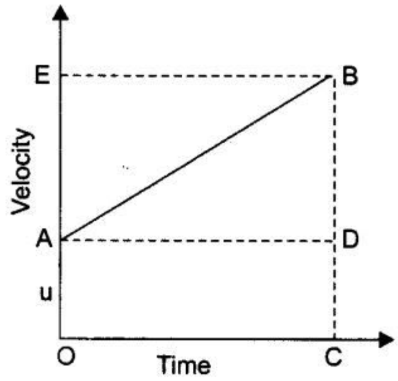
Substituting (2) in (1) we get

$$BD = v - u$$

$$at = v - u$$

$$\therefore \quad \boxed{v = u + at}$$

(ii) The equation for position-time relation:



Let us assume,

s = distance travelled by the object

t = in time t

a = with uniform acceleration.

$\therefore$ Distance travelled by the object is given by area enclosed with $OABC$ in the graph.

$\therefore$ $s = OABC$

= (area of rectangle $OADC$) + (area of ΔABD)

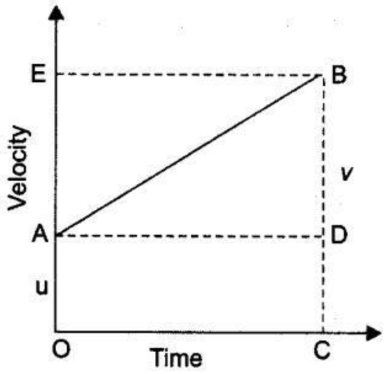
$$= (OA \times OC) = \frac{1}{2}(AD \times BD)$$

Substituting $OA = u$, $OC = AD = t$ and $BD = at$

We get $s = ut + \frac{1}{2}(t \times at)$

$$\therefore \quad \boxed{s = ut + \frac{1}{2}at^2}$$

(iii) Equation for position-velocity relation:



s = distance travelled by the object

t = in time t

a = moving with uniform acceleration

$\therefore$ s = area enclosed by trapezium $OABC$

$$\therefore \quad s = \frac{(OA + BC) \times OC}{2}$$

$$\therefore \quad OA = u, \quad BC = v \quad \text{and} \quad OC = t.$$

$$\therefore \quad s = \frac{(u+v)\,t}{2} \qquad \text{...(1)}$$

Slope $$t = \frac{v-u}{a} \text{ from the graph} \qquad \text{...(2)}$$

Substitute value of 't' in (1)

$$\therefore \quad s = \frac{u+v}{2} \times \frac{(v-u)}{a}$$

$$s = \frac{v^2 - u^2}{2a}$$

$$\therefore \quad \boxed{v^2 - u^2 = 2as}$$

Uniform circular motion: When a body moves in a circular path with uniform speed, its . motion is called uniform circular motion.