

Motion

Motion:- The change of the position of an object with respect to a point object is called motion.

Point object:- The object is said to be a point object if its dimensions i.e. length, breadth and height are very small as compared to the distance travelled by the object.

Distance (s):- The difference between two places irrespective of any direction is called distance. It is a scalar quantity with S.I unit m.

Displacement (s):- The shortest distance between two places in a particular direction is called displacement. It is a vector quantity with S.I unit m.

Speed:- The distance travelled by a moving object in unit time is called speed. It is a scalar quantity.

$$\text{speed} = \frac{\text{Distance}}{\text{time}} \quad \text{with S.I unit}$$

m/sec

Average speed:- The total distance travelled by an object with the total time taken to cover the distance

Mathematically, Average speed = $\frac{\text{total distance}}{\text{total time}}$

Velocity :- The total distance travelled by an object in a particular direction per unit time is known as velocity.

$$V = \frac{s}{t}$$

where, v = velocity
 s = displacement
 t = time

Uniform/constant velocity :- An object is said to have uniform velocity, if it travels in a straight line and covers equal distance in equal time interval.

Average velocity :- The ratio of total displacement to the total time taken is known as average velocity.

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time}}$$

$$\Rightarrow \text{average velocity} = \frac{u+v}{2}$$

where, u = initial velocity
 v = final velocity.

Acceleration :- The rate of change of velocity with time is known as acceleration, denoted by a .

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

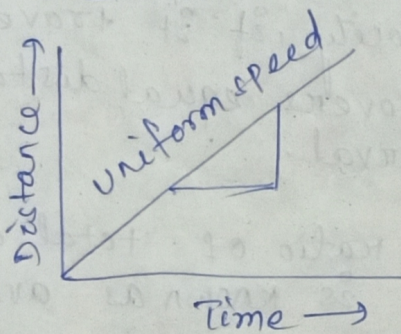
$$\Rightarrow a = \frac{v-u}{t}$$

(change in velocity = $v-u$)

Uniform Acceleration :- If the rate of change of velocity remains same throughout the motion.

Non-uniform acceleration :- If the rate of change of velocity is unequal in equal interval of time.

1. Distance-time Graph for uniform speed

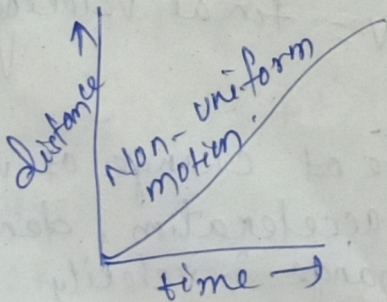


slope of the Graph indicates speed.

$$\text{slope} = \frac{\text{Perpendicular}}{\text{Base}}$$

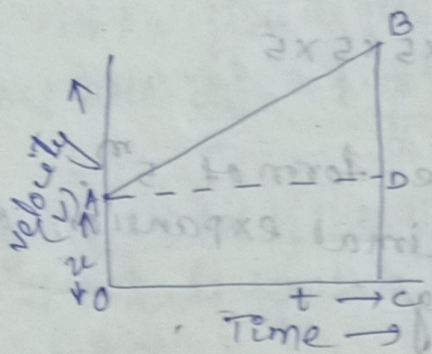
$$\Rightarrow \frac{s}{t} = v.$$

2. Distance-time graph for non-uniform motion



Equation of motion by Graphical Method

Consider an object having an initial velocity 'u' at A, then its velocity changes with uniform rate from A to B. So there is a uniform acceleration from A to B.



(i) Equation for velocity - time relation -

$$v = u + at$$

from the graph,

initial velocity, $u = OA$

final velocity, $v = BC$

$OC = AD = t$

But from the graph, $BC = BD + CD$

$$\Rightarrow BC = BD + OA \quad (\because CD = OA)$$

$$\Rightarrow v = BD + u \rightarrow \text{①}$$

Acceleration 'a' = slope of line AB

$$\Rightarrow a = \frac{BD}{AD} = \frac{BD}{t}$$

$$\Rightarrow BD = at \rightarrow \text{②}$$

Putting BD in eq ① we get,

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

- Newton's 1st equation.

(ii) Equation for position-time relation

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

Let the object travels a distance 's' in time 't'.

So the distance travelled = area below the graph AB.

$$\Rightarrow s = \text{area OABC}$$

$$= \text{area of } \square \text{OACD} + \text{area of } \triangle \text{ABC}$$

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

$$= u \times t + \frac{1}{2} t \times at \quad (\text{As } BD = at)$$

$$\Rightarrow \boxed{s = ut + \frac{1}{2}at^2} \text{ - 2nd equation of motion.}$$

(iii) Equation for position-velocity relation

$$v^2 = u^2 + 2as$$

The distance covered by the object is equal to the area of trapezium OABC.

$$s = \frac{1}{2} (OA + BC) \times OC$$

$$= \frac{1}{2} (u + v) \times t \quad \rightarrow \textcircled{1}$$

from Newton's 1st equation $v = u + at$

$$\Rightarrow at = v - u$$

$$\Rightarrow t = \frac{v - u}{a}$$

Putting the value of 't' in eqⁿ ① we get.

$$s = \frac{1}{2}(u + v) \left(\frac{v - u}{a} \right)$$

$$\left[a^2 - b^2 = (a + b)(a - b) \right]$$

$$= \frac{1}{2} \left(\frac{v^2 - u^2}{a} \right)$$

$$\Rightarrow 2as = v^2 - u^2$$

$$\Rightarrow \boxed{v^2 = u^2 + 2as} \text{ - 3rd equation of motion.}$$