Motion In a Straight Line

For Quick Revision and Smart Practice

NEET

FAST FORWARD

An Innovation of **NEET Experts** with **30+ years** of Blissful Teaching Experience and Inspiration of **Lakh+ successful MEDICO professionals**

India's First e - Magazine with Live Testing

Motion in a Straight Line

1. 'Kinematics' deals with description of motion, without referring to cause of motion.
2. Motion in one dimension is also called motion along a straight line and rectilinear motion.
3. Particle: The 'particle' is a physical concept represented by a mathematical concept 'point'. A particle ideally means a point mass. But in practice, a particle need not be a tiny object. For example, in a journey of a bus from Kurnool to Hyderabad, the bus can comfortably be considered as a point as its size is much smaller when compared to the distance between Kurnool and Hyderabad. (i.e., 210 km)
4. Frame of reference: To describe motion, the observer must define a 'frame of reference' relative to which the motion is analyzed. A set of coordinate axes (and a clock) attached to the object(s) at rest relative to the observer is called 'a reference frame'. In our discussion in this chapter, our frame of reference is the earth unless otherwise mentioned.
   Inertial and non-inertial frames of reference: A reference frame at rest or moving with constant velocity (with respect to objects of motion) is called an 'inertial frame of reference'. A frame of reference which and x_2 = final position.
5. Distance travelled – The length of actual path traversed by a particle is called distance travelled. It is a scalar.
6. Displacement – The magnitude straight line path from initial point to final point is called 'displacement'. It is a vector quantity. Its direction is from initial point to final point.
   If we consider a particle moving on X-axis its displacement is given by
   $$S = (x_2 - x_1)$$
   where x_1 = initial position and x_2 = final position.
   If a particle moves along a straight line in one direction, then distance travelled and magnitude of displacement are equal. In all other cases, distance travelled is more than the magnitude of displacement. Displacement of a particle can be zero positive or negative. But distance travelled cannot be zero (once the motion starts) or negative i.e., distance travelled is always positive.
7. The average velocity during a certain time interval is given by the ratio of its displacement to the time interval. Consider a particle moving on X-axis. Say, it is at x_1 (when $t = t_1$) and at x_2 (when $t = t_2$) then average velocity is given by
   $$v_{avg} = \frac{(x_2 - x_1)}{(t_2 - t_1)} = \frac{\Delta x}{\Delta t}$$
   The instantaneous velocity at a certain time is given by $V = \underset{\Delta t \to 0}{Lt} \frac{(x_2 - x_1)}{(t_2 - t_1)} = \underset{\Delta t \to 0}{Lt} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$
   So, 'the instantaneous velocity is the time rate of change of displacement'. Velocity is a vector and its SI unit is metre per second (= m s^{-1}).
8. If the velocity remains constant (both in magnitude and in direction) the motion is said to be 'uniform'. In uniform motion the instantaneous velocity and average velocity are equal. In uniform motion the distance travelled and magnitude of displacement are equal. If the direction of velocity or magnitude of velocity or both change, we say that the particle has variable velocity and is in 'non-uniform motion'. Whenever you come across the term 'velocity' in our discussion, it indicates 'instantaneous velocity'.
9. The average speed during a certain time interval is the ratio of distance travelled by the particle to that time interval.
   So, $\text{Average speed} = \frac{\text{total distance travelled}}{\text{time taken to cover that distance}}$
   In uniform motion, the speed and magnitude of velocity are equal. If a particle has constant speed, it does not imply that its velocity is constant. But if we say a particle has constant velocity, it implies that it has constant speed also. Speed is a scalar. Speed cannot be negative.
10. The average acceleration during a certain time interval is given by the ratio of the change in velocity to the time interval.
    $$a_{avg} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$
    Instantaneous acceleration is the time rate of change of velocity. It is given by

$$a = \frac{dv}{dt}$$

Acceleration is a vector. Its SI unit is m s^{-2}. In uniform motion, acceleration is zero.

11. Acceleration, $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$

Also, $a = v\frac{dv}{dx}\left[\because\ v = \frac{dx}{dt}\right]$

12. Uniformly accelerated rectilinear motion:

A particle is moving along a straight line and its acceleration is constant. Then the following equations can be used.

$$v = u + at$$

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

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

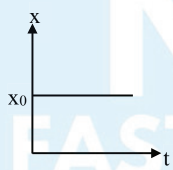
$S_{n^{th}} = u + a\left(n - \frac{1}{2}\right)$ where u = initial velocity, v = final velocity, a = acceleration, t = time, S = displacement and $S_{n^{th}}$ = displacement in n^{th} second.

13. Graphs for rectilinear motion

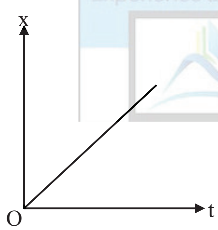
Position-time (x-t) graphs:

Note: The slope of position-time graph gives velocity of particle.

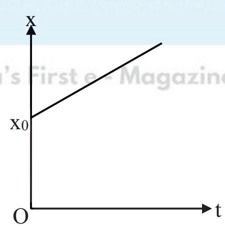
(i) Particle is at rest:



(ii) Particle is in uniform motion i.e., moving with constant velocity.



At t = 0, particle is at x = 0

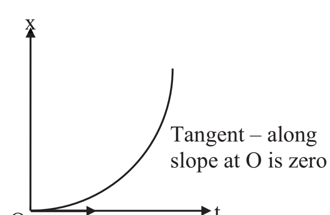


At t = 0, particle is at x = x_0

(iii) Particle is moving with constant acceleration: Here $x = ut + \frac{1}{2}at^2$. So x-t graph is a parabola

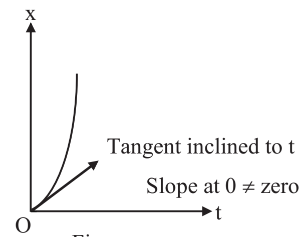
Figure (a) Initial velocity, u = 0 and particle is at x = 0 when t = 0

[The slope of curve at origin is zero]



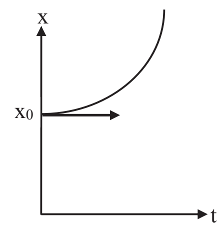
Figure

Figure (b) Initial velocity, $u \neq 0$ and particle is at $x = 0$, when $t = 0$ [Then slope of curve at origin is not zero]



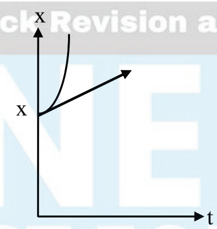
Figure

Figure (c) Initial velocity, $u = 0$ and particle is at $x = x_0$ when $t = 0$ [Slope of curve at $x = x_0$ is zero]



Figure

Figure (d) Initial velocity, $u \neq 0$ and particle is at $x = x_0$ when $t = 0$ [The slope of curve at $x = x_0$ is not zero]



Figure

Velocity-time (v-t) graphs

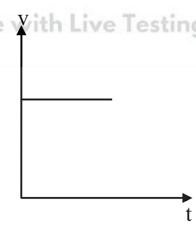
Note: (i) The slope of v-t graph gives acceleration

(ii) The area under v-t graph gives displacement.

(i) Particle is at rest

In this case v-t graph is time axis itself

(ii) Particle is in uniform motion



In this case acceleration of the particle is $a = 0$

(iii) Particle is moving with constant acceleration

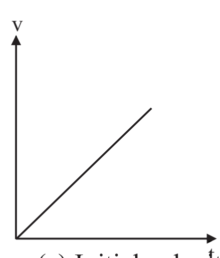


Figure (a) Initial velocity, $u = 0$

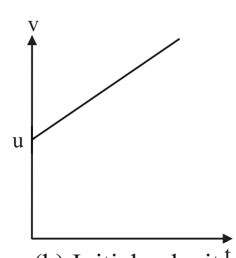


Figure (b) Initial velocity, $u \neq 0$