Physics Notes Class 11 CHAPTER 3 MOTION IN A STRAIGHT LINE

Motion

If an object changes its position with respect to its surroundings with time, then it is called in motion.

Rest

If an object does not change its position with respect to its surroundings with time, then it is called at rest.

[Rest and motion are relative states. It means an object which is at rest in one frame of reference can be in motion in another frame of reference at the same time.]

Point Mass Object An object can be considered as a point mass object, if the distance travelled by it in motion is very large in comparison to its dimensions.

Types of Motion

1. One Dimensional Motion

If only one out of three coordinates specifying the position of the object changes with respect to time, then the motion is called one dimensional motion.

For instance, motion of a block in a straight line motion of a train along a straight track a man walking on a level and narrow road and object falling under gravity etc.

2. Two Dimensional Motion

If only two out of three coordinates specifying the position of the object changes with respect to time, then the motion is called two dimensional motion.

A circular motion is an instance of two dimensional motion.

3. Three Dimensional Motion

If all the three coordinates specifying the position of the object changes with respect to time, then the motion is called three dimensional motion.

A few instances of three dimension are flying bird, a flying kite, a flying aeroplane, the random motion of gas molecule etc.

Distance

The length of the actual path traversed by an object is called the distance.

It is a scalar quantity and it can never be zero or negative during the motion of an object.

Its unit is metre.

Displacement

The shortest distance between the initial and final positions of any object during motion is called displacement. The displacement of an object in a given time can be positive, zero or negative.

It is a vector quantity.

Its unit is metre.

Speed

The time rate of change of position of the object in any direction is called speed of the object.

Speed (v) = Distance travelled (s) / Time taken (t)

Its unit is m/s.

It is a scalar quantity.

Its dimensional formula is $[M^oT^{-1}]$.

Uniform Speed

If an object covers equal distances in equal intervals of time, then its speed is called uniform speed.

Non-uniform or Variable Speed

If an object covers unequal distances in equal intervals of time, then its speed is called non-uniform or variable speed.

Average Speed

The ratio of the total distance travelled by the object to the total time taken is called average speed of the object.

Average speed = Total distanced travelled / Total time taken

If a particle travels distances s_1, s_2, s_3 , … with speeds v_1, v_2, v_3, …, then

Average speed = $s_1 + s_2 + s_3 +$ ….. / $(s_1 / v_1 + s_2 / v_2 + s_3 / v_3 +$ …..)

If particle travels equal distances ($s_1 = s_2 = s$) with velocities v_1 and v_2, then

Average speed = $2 v_1 v_2 / (v_1 + v_2)$

If a particle travels with speeds v_1, v_2, v_3, …, during time intervals t_1, t_2, t_3,…, then

Average speed = $v_1t_1 + v_2t_2 + v_3t_3 +$… / $t_1 + t_2 + t_3 +$….

If particle travels with speeds v_1, and v_2 for equal time intervals, i.e., $t_1 = t_2 = t_3$, then

Average speed = $v_1 + v_2 / 2$

When a body travels equal distance with speeds V_1 and V_2, the average speed (v) is the harmonic mean of two speeds.

$2 / v = 1 / v_1 + 1 / v_2$

Instantaneous Speed

When an object is travelling with variable speed, then its speed at a given instant of time is called its instantaneous speed.

Instantaneous speed = $\lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$

Velocity

Tlie rate of change of displacement of an object in a particular direction is called its velocity.

Velocity = Displacement / Time taken

Its unit is m/s.

Its dimensional formula is $[M^o T^{-1}]$.

It is a vector quantity, as it has both, the magnitude and direction.

The velocity of an object can be positive, zero and negative.

Uniform Velocity

If an object undergoes equal displacements in equal intervals of time, then it is said to be moving with a uniform velocity.

Non-uniform or Variable Velocity

If an object undergoes unequal displacements in equal intervals of time, then it is said to be moving with a non-uniform or variable velocity.

Relative Velocity

Relative velocity of one object with respect to another object is the time rate of change of relative position of one object with respect to another object.

Relative velocity of object A with respect to object B
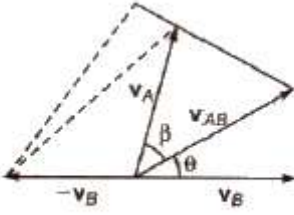
$$V_{AB} = V_A - V_B$$

When two objects are moving in the same direction, then

When two objects are moving in opposite direction, then

When two objects are moving at an angle, then

$$v_{AB} = \sqrt{v_A^2 + v_B^2 - 2v_A v_B \cos \theta}$$

and $\tan \beta = v_B \sin \theta \, / \, v_A - v_B \cos \theta$

Average Velocity

The ratio of the total displacement to the total time taken is called average velocity.

Average velocity = Total displacement / Total time taken

Acceleration

The time rate of change of velocity is called acceleration.

Acceleration (a) = Change in velocity (Δv) / Time interval (Δt)

Its unit is m/s^2

Its dimensional formula is $[M^oLT^{-2}]$.

It is a vector quantity.

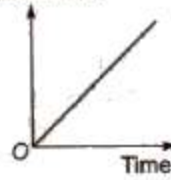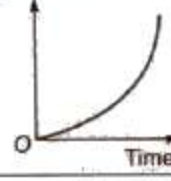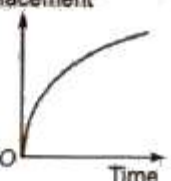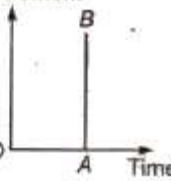Acceleration can be positive, zero or negative. Positive acceleration means velocity increasing with time, zero acceleration means velocity is uniform while negative acceleration (retardation) means velocity is decreasing with time.

If a particle is accelerated for a time t_1 with acceleration a_1 and for a time t_2 with acceleration a_2, then average acceleration

$a_{av} = a_1t_1 + a_2t_2 / t_1 + t_2$

Different Graphs of Motion

Displacement – Time Graph

S. No.	Condition	Graph
(a)	For a stationary body	Displacement vs Time
(b)	Body moving with a constant velocity	Displacement vs Time
(c)	Body moving with a constant acceleration	Displacement vs Time

S. No.	Condition	Graph
(d)	Body moving with a constant retardation	Displacement vs Time
(e)	Body moving with infinite velocity. But such motion of a body is never possible.	Displacement vs Time

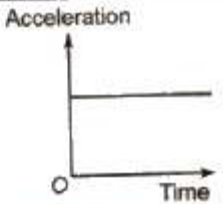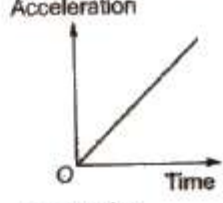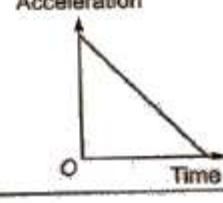**Note** Slope of displacement-time graph gives average velocity.

Velocity – Time Graph

S. No.	Condition	Graph
(a)	Moving with a constant velocity	Velocity vs Time graph: horizontal line
(b)	Moving with a constant acceleration	Velocity vs Time graph: straight line increasing from origin
(c)	Body moving with a constant retardation and its initial velocity is not zero.	Velocity vs Time graph: line from A decreasing to B

S. No.	Condition	Graph
(d)	Moving with a constant retardation	Velocity vs Time graph: line decreasing
(e)	Moving with increasing acceleration	Velocity vs Time graph: curve increasing upward
(f)	Moving with decreasing acceleration	Velocity vs Time graph: curve decreasing

Note Slope of velocity-time graph gives average acceleration.

Acceleration – Time

S. No.	Condition	Graph
(a)	When object is moving with constant acceleration	Acceleration vs Time
(b)	When object is moving with constant increasing acceleration	Acceleration vs Time
(c)	When object is moving with constant decreasing acceleration	Acceleration vs Time

Equations of Uniformly Accelerated Motion

If a body starts with velocity (u) and after time t its velocity changes to v, if the uniform acceleration is a and the distance travelled in time t in s, then the following relations are obtained, which are called equations of uniformly accelerated motion.

(i) $v = u + at$

(ii) $s = ut + at^2$

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

(iv) Distance travelled in nth second.

$S_n = u + a / 2(2n - 1)$

If a body moves with uniform acceleration and velocity changes from u to v in a time interval, then the velocity at the mid point of its path

$\sqrt{u^2 + v^2} / 2$

Motion Under Gravity

If an object is falling freely (u = 0) under gravity, then equations of motion

(i) $v = u + gt$

(ii) $h = ut + gt^2$

(iii) $V^2 = u^2 + 2gh$

Note If an object is thrown upward then g is replaced by – g in above three equations.

It thus follows that

(i) Time taken to reach maximum height

$t_A = u / g = \sqrt{2h} / g$

(ii) Maximum height reached by the body

$h_{max} = u^2 / 2g$

(iii) A ball is dropped from a building of height h and it reaches after t seconds on earth. From the same building if two ball are thrown (one upwards and other downwards) with the same velocity u and they reach the earth surface after t, and t2 seconds respectively, then

$t = \sqrt{t_1 t_2}$

(iv) When a body is dropped freely from the top of the tower and another body is projected horizontally from the same point, both will reach the ground at the same time.