Displacement, Velocity and Acceleration

Displacement:

The displacement of a moving particle is the change in its position, during which the particle remains in motion. It is a vector quantity, has both magnitude and sense of direction. It is denoted by the letter S.

Speed

It is the distance travelled by the particle or body along its path per unit time. It is a scalar quantity, it has magnitude only. It is measured in m/s, km/her etc.

$$\textbf{Speed} = \frac{\textbf{Distance travelled}}{\textbf{Time taken}}$$

Velocity :

It is the rate of change of displacement. It is a vector quantity.

$$\text{Velocity} = \frac{Distance\ \ travelled\ \ in\ particular\ \ direction}{Time\ \ taken}$$

In S.I. system, it is measured in m/s.

When a particle moves in one direction, and it covers equal distance in equal intervals of time, then the velocity of the particle is known as uniform velocity.

When there is a change in direction or change in magnitude, or change in magnitude and direction, then the velocity is known as variable velocity.

Acceleration :

It is the rate of change of velocity. It is denoted by 'a'. In S.I. system, it is measured in m/s^2. It is a vector quantity.

$$\therefore \text{acceleration, a} = \frac{Change\ \ of\ \ velocity}{Time\ \ taken}$$

$$= \frac{Final\ \ velcotiy\ -Initial\ \ velocitiy}{Time\ \ taken}$$

Negative acceleration is called as retardation (when final velocity < Initial velocity)

Average velocity:

It is the ratio of displacement and time interval.

$$\text{i.e. Average velocity} = \frac{Change\ \ in\ position}{Change\ \ in\ time}$$

$$= \frac{\Delta x}{\Delta t}$$

It can be either positive or negative.

Average speed:

It is the ratio of total distance to total distance to total time it takes to travel that distance.

$$\text{Average Speed} = \frac{Total\ \ distance\ \ travelled}{Total\ \ time\ \ takne}$$

Note :

If a particle starts from a point and then if it returns to the same point, average velocity is zero. But average speed is not zero.

Instantaneous Velocity :

For any particle, the instantaneous velocity at any instant of time is the limit of average velocity as the increment of time approaches zero.

$$\text{i.e. V} = \text{Lim}_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

It can be either positive or negative. Similarly, average acceleration and instantaneous acceleration can be defined.

Mathematical expressions for velocity and acceleration :

Let S = Distance travelled by a particle in a straight line.

t = time taken by the particle to travel this distance 's' then mathematical.

Velocity , $V = \frac{ds}{dt}$

and acceleration, $a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{ds}{dt}\right) = \frac{d^2s}{dt^2}$

Types of Rectilinear motion :

In a rectilinear motion, the particle travels along a straight line. On the straight line, the motion of particle can be with.

i) Uniform acceleration

ii) Variable acceleration

Equations of motion in a straight line :

Consider a particle, moving with uniform acceleration in a straight line,

Let

u = Initial velocity (m/s)

v = Final velocity (m/s)

s = Distance travelled by the particle (m)

t = time taken by the particle, to change from u to v (sec)

a = acceleration of the particle $(m/s)^2$

$V = u + at$ ..... (1)

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

$V^2 = u^2 + 2as$ ..... (3)

The equation (1), (2) & (3) are known as the equations of motion.

Q. A car is moving with a velocity of 20 m/s. The car is brought to rest by applying brakes in 6 seconds.

Find : i) retardation

ii) Distance travelled by the car after applying the brakes.

Answer :

i) Retardation is the negative acceleration

Using the equation of motion,

$V = U + at$

i.e. $O = 20 + a \times 6$

$\therefore a = -3.33\ m/s^2$

$\therefore$ retardation $= 3.33\ m/s^2$

ii) Distance travelled

Let S = Distance travelled by the car after applying the brakes.

Using the equation, $s = ut + \frac{1}{2}at^2$

$S = (20 \times 6) + \frac{1}{2}(-3.3) \times 6^2$

$= 60$ m

Distance travelled in n^{th} second.

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

Motion of a particle under gravity:

The motion of a particle under gravity is the special case of rectilinear motion under constant acceleration, known as the acceleration due to gravity. It is denoted by the letter 'g'. The value of acceleration due to gravity is constant, equal to $9.81\ m/s^2$.

When a body is dropped vertically downwards, from a height, the earth attracts it, hence the velocity of the particle will go on increasing as it comes nearer to the earth and hence it will be maximum when it strikes the surface of the earth. So in downward motion of particles, acceleration due to gravity 'g' is + ve.

On the otherhand, if the particle is projected vertically upwards, it travels against the gravitational force and hence the velocity of the particle will go on decreasing and the velocity becomes zero, when it reaches the maximum height, so in upward motion of particles acceleration due to gravity 'g' is –ve.

The motion under gravity is similar to the rectilinear motion in horizontal direction, with the difference of, the acceleration 'a' is replaced by the acceleration due to gravity 'g' and the distances, replaced by the height 'h'.

Laws of Motion:

When a particle / body is at rest, or moving in a straight line (rectilinear motion) or in a curved line (curvilinear motion), the particle / body obeys certain laws of motion. These laws are called the principles of motion or the principles of dynamics.

First Law:

Every body continues to be in its state of rest or of uniform motion in a straight line unless and until it is acted upon some external force to change that state.

Second law:

The rate of change of momentum of a moving body is directly proportional to the impressed force and takes place in the direction of the force applied.

Third Law:

To every action, there is always an equal and opposite reaction.