SHORT NOTES: CLASS 9
CHAPTER 7: MOTION

Reference Point: A fixed point or a fixed object w.r.t. in which the given body changes its position is known as a reference point.

Rest: If an object does not change its position w.r.t. a fixed point taken as a reference point in its surroundings with the passage of time, it is said to be at rest.

Motion: An object is said to be in motion if its position changes w.r.t. a reference point in its surroundings with the passage of time.

Motion is a relative term: Motion is a combined property of an object under study and the observer. *Nothing is in absolute rest or in absolute motion.* An object may appear to be moving for one person and stationary for another person. Rest and motion are not significant without the viewer.

Types of motion:

(i) **Rectilinear Motion:** The motion of an object along a straight line is termed as rectilinear motion. For example: A car moving on a straight road, the motion of an aeroplane flying in the sky, and a freely falling object.

(ii) **Circular Motion-Rotational Motion:** *Circular motion* is the movement of the object along the circumference of the circle. Centre of mass of the object moves about a fixed point. The point lies outside the body. *The rotational motion* of the object is the motion of the object about its centre of mass. It is the motion about the point which lies inside the body.

(iii) **Oscillatory Motion-Vibratory Motion:** *Oscillatory motion* is the to and fro movement of the body about its mean position. For example The movement of a simple pendulum.
Vibratory motion can be in all directions. For example: the movement of the string of guitar.

Point Object: Size of the object << Distance covered by the object.

Physical Quantities- The quantities which can be measured are known as physical quantities.
Examples: length, mass, time, temperature, intensity, area, volume
Physical quantities are of two types: (i) Scalar Quantities and (ii) Vector Quantities

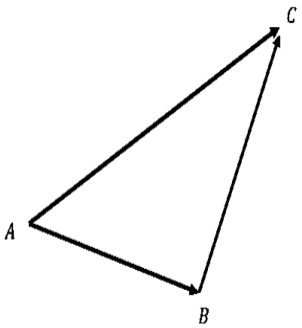
Scalar Quantities- The physical quantities that are fully described by magnitude (numerical value) alone.
Examples: Mass, Length, Time, Distance, Speed, Temperature

Vector Quantities- The physical quantities that are fully described by both the magnitude and direction.
Examples: Displacement, Velocity, Acceleration, Force etc.

Distance- The length of the actual path traversed by an object is called distance. Distance is a Scalar Quantity. Its value can never be zero or negative during its motion.
S.I. Unit of Distance is m.

Displacement- The shortest distance measured from the initial position to the final position of an object is called its displacement. It is a Vector Quantity. Its value can be positive, negative, or zero.
S. I. Unit of Displacement is m.

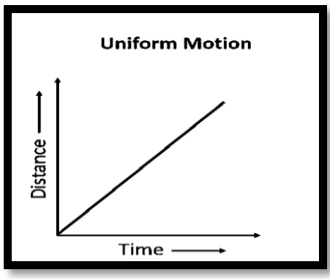
Example: If a person moves a distance of 5 km from A to B and then 10 km from B to C such that the distance between A and C is 13 km.
Total Distance traveled: Actual path traversed
= AB + BC = 5 km + 10 km = 15 km
Displacement: distance between the initial and final position of the object.
= AC (Initial Position = A, Final Position = B = 13 km



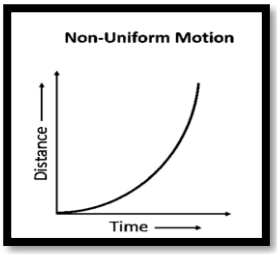
Note: *The odometer in automobiles measures the distance traveled by it in kilometers.*

Uniform Motion-

- An object is said to be in Uniform Motion if it travels equal distance in equal intervals of time. However, small these intervals may be e.g., a vehicle running at constant speed.
- No Force is required for an object in Uniform Motion.
- The object moves with constant speed in Uniform Motion.
- The Distance-Time graph for an object in uniform motion is a straight line.



Non-Uniform Motion-



- An object is said to be in Non-Uniform Motion if it travels unequal distance in equal intervals of time; the motion of a freely falling object is Non Uniform Motion.
- The object moves with variable speed in Non Uniform Motion.
- The Distance-Time graph for an object in Non Uniform Motion is a curved line.

Speed- The speed of an object is the distance travelled in any direction in a unit time.i.e,

$$\textbf{Speed} = \frac{\textbf{Distance Travelled}}{\textbf{Time}}$$

S.I.Unit of speed is m/s. It is a Scalar Quantity.

Average Speed: It is defined as the total distance travelled by an object divided by the total time taken to cover this distance. It is a scalar quantity.

$$\text{i.e., } \textbf{Average speed} = \frac{\textbf{Total distance travelled by the object}}{\textbf{Total time taken}}$$

If an object covers a distance s_1 in time t_1 and a distance s_2 in time t_2, then the average speed of the object during the whole journey is:

$$V_{av} = \frac{s_1 + s_2}{t_1 + t_2}$$

Uniform Speed (Constant Speed): If an object covers equal distances in equal intervals of time, no matter how small these intervals may be, then its speed is said to be uniform.

For example: A car running at a constant speed of 20 m/min will cover 20 m in every minute.

Non-Uniform Speed (Variable Speed): If an object covers unequal distances in equal intervals of time, no matter how small these intervals may be, then its speed is said to be non-uniform speed.

For example:

(i) The motion of a car on a crowded road. (ii) The motion of a freely falling body.

Velocity- The velocity of an object is defined as the distance travelled in a given direction in a Unit time.i.e,

$$\textbf{Velocity} = \frac{\textbf{Distance travelled (in a given direction)}}{\textbf{Time Taken}}$$

S.I. Unit of velocity is m/s. It is a Vector Quantity.

$$\textbf{Velocity} = \textbf{Speed} + \textbf{Direction}$$

The velocity of an object can be changed by changing its speed, direction of motion, or both.

Average Velocity: it is defined by the total displacement of a body divided by the total time taken to cover that displacement.

$$\textbf{Average Velocity} = \frac{\textbf{Total displacement}}{\textbf{Total time taken}}$$

Uniform Velocity: An object is said to have uniform velocity, if it covers equal distances in equal intervals of time in a particular direction, no matter how small these intervals may be. An object travelling with uniform velocity is said to have uniform motion along a straight line.

Variable/Non-uniform Velocity: An object is said to have variable velocity if

- It has a non-uniform speed.
- Its direction of motion keeps on changing.
- Both its speed and direction change with time.

Example:

(i) A person running on a circular track.
(ii) A car moving on a crowded road.

Instantaneous Speed and Velocity: The speed/velocity at an instant is called instantaneous speed/Instantaneous velocity.

Note:

- ❖ If an object moves along a straight line without changing its direction, then the magnitude of average velocity is equal to the average speed.
- ❖ If an object is moving with constant velocity, then the average velocity and instantaneous velocity are equal.
- ❖ The speedometer shows the instantaneous speed of the automobile.

Acceleration- Acceleration of an object is defined as the rate of change of its velocity with time.

Suppose, the initial velocity of an object is 'u' and it attains a final velocity 'v' in time't'.

Then, **Acceleration, a = Final Velocity – Initial Velocity / Time Taken**

i.e, $\mathbf{a = \frac{v-u}{t}}$

Its S.I.Unit is m/s^2. It is a Vector Quantity.

- Retardation/Deceleration- Negative acceleration.
- For an object in uniform motion, acceleration is zero because, in this case, the change in velocity (final velocity-initial velocity) is zero.

Uniform Acceleration: An object is said to have uniform acceleration if it travels in a straight line and its velocity increases or decreases by equal magnitude in equal intervals of time.

For example:

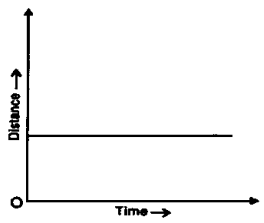
(i) The motion of a freely falling body.
(ii) The motion of a bicycle going down the slope of a road (when the rider is not pedaling and air resistance is negligible).

Non-uniform Acceleration: An object is said to have non-uniform acceleration if its velocity changes by unequal magnitude in equal intervals of time.

For example: The motion of a car on a crowded road.

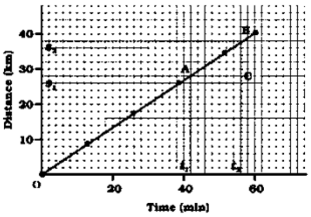
Graphical representation of motion: A Graph is a pictorial representation of the relation between two sets of data of which one set is of dependent variables and the other set is of independent variables. Quantities that can be calculated using a graph: one by finding the slope of the curve and the other by finding the area under the curve.

(i) For a stationary body- The graph is always a straight line parallel to the time axis.



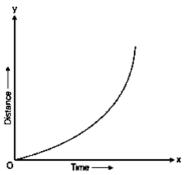
(ii) For Uniform Motion- The slope of the graph is a straight line.

Speed = slope of distance-time graph = $\frac{s_2-s_1}{t_2-t_1}$

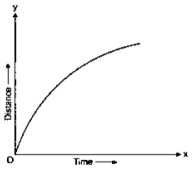


(iii) For Non-Uniform Motion- Curved line.

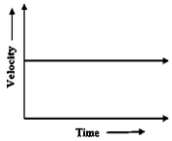
(a) When the speed increases with time- increasing slope

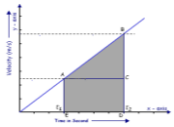


(b) When the speed decreases with time- decreasing slope



Velocity-Time Graph:





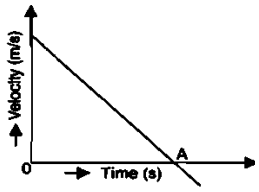
(i) For the object moving with constant velocity- a straight line parallel t the time axis.

(ii) (a) For Uniform Acceleration- The slope of the graph is a straight line

Acceleration = slope of velocity -time graph = $\frac{v_2-v_1}{t_2-t_1}$

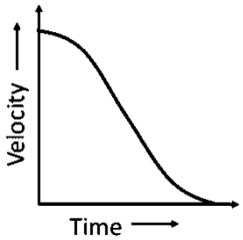
Displacement = Area under velocity – time graph = ar (ABCDEA)

(b) For Uniform Retardation- The slope of the graph is a straight line



(iii) (a) For Non-Uniform/Variable Acceleration: the graph is a curve.

(b) For Non-Uniform/Variable Retardation: the graph is a curve.



Equations of motion: When a body moves along a straight line under uniform acceleration, the relation between its velocity, acceleration, distance covered & time taken can be found by equations known as "Equations of motion".

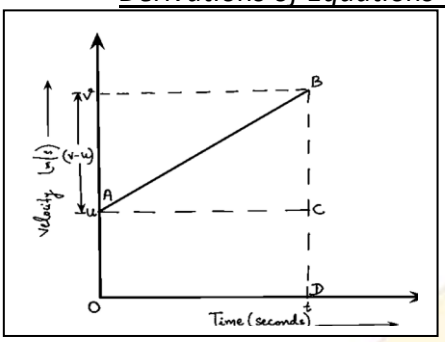
Ist Eq^{n} of Motion **Velocity – Time Relation** **V = u + at**

2nd Eqn of Motion **Position – Time Relation** **$S = ut + \frac{1}{2} at^2$**

3rd Eqn of Motion **Position – Velocity Relation** **$V^2 - u^2 = 2as$**

Where, u = Initial Velocity, V = Final Velocity, t = time taken, s = distance covered, a = acceleration
Let, at time t= 0, the given object is moving uniformly with velocity, u, and after time t, its velocity changes to let's say v.

Derivations of Equations of Motion:



First Equation of Motion:

$a = (v - u)/t;$

$v = u + at$

From graph:

a = Slope of AB = BC/AC = (BD-CD)/AC

= (v-u)/t

$a = (v-u)/t$

$v = u + at.$

Second Equation of Motion:

S = Area under v-t graph

= ar (ABCDOA)

= ar (□ ACDO) + ar (Δ ABC)

= OA .OD + ½ AC.BC

$=ut + \frac{1}{2} t(v-u)$

$=ut + \frac{1}{2} t.at$

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

Third Equation of Motion:

S = Area under v-t graph

= ar(trapezium ABDO)

$= \frac{1}{2} (v+u)\, t$

$= \frac{1}{2} (v+u) \{(v-u)/a\}$

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

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

Uniform Circular Motion:

- Uniform Circular Motion can be described as the motion of an object in a circle at constant speed.
- When an object moves in a circle, it constantly changes its direction, and therefore, its velocity changes at every point due to a change in direction.
- An object moving in a circle is accelerating due to a change in velocity/change in direction.
- The net force acting upon such an object is directed towards the centre of the circle. The net force is said to be a centripetal force.
- The centripetal force acting upon the object is perpendicular to the velocity vector, and the object is always changing its direction and undergoing an inward acceleration.

Let r be the radius of a circular path, then its circumference= 2πr.

If an object takes t sec to go once around the circular path, then

Velocity, v = Circumference (distance moved by the object) / Time taken

$$v = \frac{2\pi r}{t}$$