Horizontal Motion

1. An object is said to be at rest, if the position of the object does not change with time with respect to its surroundings.
2. An object is said to be in motion, if its position changes with time with respect to its surroundings.
3. Rest and motion are relative.

   Ex: A person travelling in a bus is at rest w.r.t. the co-passenger and he is in motion w.r.t. the person on the road.
4. **Distance and Displacement**
   a) The difference between the final and initial positions of a particle is known as displacement.

      Displacement $\Delta x = x_f - x_i$
   b) Displacement of a particle is the shortest distance between its initial and final position and directed form initial position to final position.
   c) The length of the actual path covered by a particle in a time interval is called distance.
   d) Distance is a scalar quantity and displacement is a vector quantity.

5. **Speed**
   a) Speed of a body is the rate at which it describes its path. Its SI unit is $ms^{\tilde{}1}$.It is a scalar quantity.

      $\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$.
   b) A body is said to move with uniform speed, if it has equal distances in equal intervals of time, however small the intervals may be.
   c) A body is said to move with non uniform speed, if it has unequal distances in equal intervals of time or equal distances in unequal intervals of time, however small the intervals may be.

d) Average speed $= \frac{\text{Total distance}}{\text{Total time}}$

e) Instantaneous speed $= \underset{\Delta t \to 0}{Lt} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$.

f) If a particle covers the 1st half of the total distance with a speed 'v_1' and the second half with a speed 'v_2'.

Average speed $= \frac{2v_1v_2}{v_1 + v_2}$.

g) If a particle covers 1st 1/3rd of a distance with a speed 'v_1', 2nd 1/3rd of the distance with speed 'v_2'and 3rd 1/3rd of the distance with speed 'v_3'.

Average speed $= \frac{3v_1v_2v_3}{v_1 + v_2 + v_3}$.

6. Velocity

a) The rate of change of displacement of a body is called velocity. Its SI unit is ms^{-1}.It is a vector quantity.

b) A body is said to move with uniform velocity, if it has equal displacements in equal intervals of time, however small these intervals may be.

c) If the direction or magnitude or both of the velocity of a body change, then the body is said to be moving with non-uniform velocity.

d) The velocity of a particle at any instant of time or at any point of its path is called instantaneous velocity. $\vec{V} = \underset{\Delta t \to 0}{Lt} \frac{\Delta \vec{s}}{\Delta t} = \frac{\vec{ds}}{dt}$

7. Average velocity

a) Average speed $= \frac{\text{Total distance}}{\text{Total time}}$

b) If a particle under goes a displacement s_1 along a straight line t_1 and a displacement s_2 in time t_2 in the same direction, then

Average velocity$= \frac{s_1 + s_2}{t_1 + t_2}$

c) If a particle undergoes a displacement s_1 along a straight line with velocity v_1 and a displacement s_2 with velocity v_2 in the same direction, then

Average velocity $= \frac{(s_1 + s_2)v_1v_2}{s_1v_2 + s_2v_1}$

d) If a particle travels first half of the displacement along a straight line with velocity v_1 and the next half of the displacement with velocity v_2 in the same direction, then

Average velocity $= \frac{2v_1v_2}{v_1 + v_2}$

e) If a particle travels for a time t_1 with velocity v_1 and for a time t_2 with velocity v_2 in the same direction, then

Average velocity $= \frac{v_1t_1 + v_2t_2}{t_1 + t_2}$

f) If a particle travels first half of the time with velocity v_1 and the next half of the time with velocity v_2 in the same direction, then

Average velocity $= \frac{v_1 + v_2}{2}$

8. Acceleration

a. The acceleration is defined as the time rate of change of velocity.

b. The acceleration and velocity of a body need not be in the same direction. eg : A body thrown vertically upwards.

c. If equal changes of velocity take place in equal intervals of time, however small these intervals may be, then the body is said to be in uniform acceleration.

d. Negative acceleration is called retardation or deceleration.

e. The acceleration of a particle at any instant or at any point is called instantaneous acceleration.

$\vec{a} = \underset{\Delta t \to 0}{Lt} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$

f. A body can have zero velocity and non-zero acceleration. Eg: for a body projected vertically up, at the highest point velocity is zero, but acceleration is ‘g’.

g. If a body has a uniform speed, it may have acceleration. Eg : uniform circular motion

h. If a body has uniform velocity, it has no acceleration.

i. Acceleration of free fall is called acceleration due to gravity (g) and it is equal to 980 cms^{-2} or 9.8 ms^{-2}.

9. The equations of motion for uniform acceleration

1) $v = u + at$

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

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

4) $s_n = u + \frac{a}{2}(2n - 1)$

5) $s = \left(\frac{u+v}{2}\right)t$

10. One dimensional motion (uniform acceleration)

a) If a body starting from rest travels a distance S_m in m^{th} second and S_n is in n^{th} second, then $a = \frac{S_n - S_m}{n - m}$.

b) If a particle travels along a straight line with uniform acceleration and travels distances S_n and S_{n+1} in two successive seconds, the acceleration of the particle is

$a = S_{n+1} - S_n$

c) If a particle travels along a straight line travels distances S_1 and S_2 in two successive intervals of n seconds each, the acceleration of the particle is

$a = \frac{S_2 - S_1}{n^2}$

d) If a body starting from rest, attains a velocity 'v' after a displacement 'x', then its velocity becomes 'nv' after a further displacement $(n^2 - 1)x$.

e) If a bullet loses $(1/n)^{th}$ of its velocity while passing through a plank, then the number of such planks required to just stop the bullet is = $\frac{n^2}{2n-1}$

f) The first compartment of a train crosses a pole with a speed u and the last compartment of the train crosses the pole with a speed v , the speed with which the middle compartment of the train crosses the pole with a speed $V = \sqrt{\frac{u^2 + v^2}{2}}$

g) Starting from rest a body travels with an acceleration 'α' for some time and then with deceleration 'β' and finally comes to rest. If the total time of journey is 't', then the maximum velocity and displacement are given by

$$V_{max} = \left(\frac{\alpha\beta}{\alpha+\beta}\right)t \quad and \quad s = \frac{1}{2}\left(\frac{\alpha\beta}{\alpha+\beta}\right)t^2$$

Also, average velocity = $\left(\frac{V_{max}}{2}\right)$

h) A body is projected vertically up from a topless car relative to the car which is moving horizontally relative to earth.

i. If the velocity of the car is constant, ball will be caught by the thrower.

ii. If the velocity of the car is constant, path of ball relative to the ground is a parabola and relative to the car is straight up and then straight down.

iii. If the car accelerates, ball falls back relative to the car.

iv. If acceleration or retardation of the car is constant path relative to car is a straight line and relative to ground is a parabola.