KINEMATICS

MOTION IN ONE DIMENSION

IMPORTANT TERMS

1. MECHANICS

It is the branch of Physics, which deals with the study of motion of physical bodies.

Mechanics can be broadly classified into following branches

1.1 Statics

It is the branch of mechanics, which deals with the study of physical bodies at **rest.**

1.2 Kinematics

It is the branch of mechanics, which deals with study of motion of physical bodies without taking into account the factors, which causes motion.

1.3 Dynamics

It is the branch of mechanics, which deals with the study of motion of physical bodies taking into account the factors which causes motion.

2. REST AND MOTION

2.1 Rest

- An object is said to be at rest if it does not changes its position with respect to the surrounding.
- The white board in the classroom is at rest with respect to the classroom

2.2 Motion

- An object is said to be in motion if it changes its position with respect to the surrounding.
- When we walk, run or ride a bike we are in motion with respect to the ground.

2.3 Rest and Motion are relative

Rest and motion depends upon the **observer**. The object in one situation may be at rest whereas the same object in another situation may be in motion.

The driver of a moving car is in motion with respect to an observer standing on the ground whereas, the same driver is at rest with respect to the man(observer) in the passengers seat.

3. WHILE STUDYING THIS CHAPTER

- We will treat the objects as **Point mass** object
  - An object can be considered as a point mass object if during the course of motion it covers distances much greater than its own size.
- We shall confine ourselves to the study of rectilinear motion
  - Rectilinear motion is the study of motion of objects along a straight line.

4. POSITION, DISTANCE, DISPLACEMENT

4.1 Position

- Position of an object is always defined with respect to some reference point which we generally refer to as origin.
- To define the change in position we have two physical quantities

4.2 Distance

- It is the actual path traversed by the body during the course of motion
- SI unit is ‘m’
- Dimensions $[M^0L^1T^0]$

4.3 Displacement

- It is the difference between the final and initial positions of the object during the course of motion
- SI unit is ‘m’
- Dimensions $[M^0L^1T^0]$

Difference between Distance and Displacement

Distance	Displacement
It is the actual path traversed by the object during the course of motion	It is the difference between the initial and the final positions $\Delta x = x_2 - x_1$ where, x_2 and x_1 are final and initial position respectively
It is a **scalar** quantity	It is a **vector** quantity
The distance travelled by an object during the course of motion is never negative or zero and is always positive	The displacement of an object may be positive, negative or, zero during the course of motion
The distance travelled is either equal or greater than displacement and is never less than magnitude of displacement Distance $\geq$ |Displacement|	The magnitude of displacement is less than or equal to the distance travelled during the course of motion
The distance depends upon the path travelled	The magnitude of displacement is independent of the path taken by an object during the course of motion

Difference between Speed and Velocity

Speed	Velocity
It is defined as the total path length travelled divided by the total time interval during which the motion has taken place	It is defined as the change in position or displacement divided by the time intervals, in which displacement occurs of
It is a scalar quantity	It is a vector quantity
It is always positive during the course of the motion	It may be positive, negative or zero during the course of the motion
It is greater than or equal to the magnitude of velocity	It is less than or equal to the speed

NOTE

If the motion of an object is along a straight line and in the same direction, the magnitude of displacement is equal to the total path length. **In that case, the magnitude of average velocity is equal to the average speed.** This is not always the case. **The average velocity tells us how fast an object has been moving over a given interval but does not tell us how fast it moves at different instants of time during that interval.**

5. SCALAR AND VECTOR QUANTITIES

5.1 Scalar quantities

The physical quantities which have only magnitude but no direction, are called scalar quantities.

Example:- mass, length, time, distance, speed, work, temperature

5.2 Vector quantities

The physical quantities which have magnitude as well as direction, are called vector quantities.

Example:- displacement, velocity, acceleration, force, momentum, torque

6. AVERAGE VELOCITY AND AVERAGE SPEED

6.1 Average velocity

- It is defined as the change in position or displacement divided by the time intervals, in which displacement occurs

- SI unit of velocity is m/s, although km/hr is used in many everyday applications
- Dimensions $[M^0L^1T^{-1}]$

6.2 Average speed

- It is defined as the total path length travelled divided by the total time interval during which the motion has taken place
- SI unit m/s
- Dimensions $[M^0L^1T^{-1}]$

7. INSTANTANEOUS VELOCITY AND INSTANTANEOUS SPEED

7.1 Instantaneous velocity

- It is velocity at an instant t. The velocity at an instant is defined as the limit of the average velocity as the time interval Δt becomes infinitesimally small.
- Instantaneous velocity = Lt $(\Delta x/\Delta t) = dx/dt$
- The quantity on the right hand side of Eq is the differential coefficient of x with respect to t and is denoted by dx/dt.
- It is the rate of change of position with respect to time at that instant.
- SI unit is m/s
- Dimensions $[M^0L^1T^{-1}]$

7.2 Instantaneous Speed

- Instantaneous speed or speed is the magnitude of velocity
- SI unit is m/s
- Dimensions $[M^0L^1T^{-1}]$

8. ACCELERATION

8.1 Average Acceleration

- The average acceleration over a time interval is defined as the change of velocity divided by the time interval :

  $a = (v_2 - v_1)/(t_2 - t_1)$

  where, v_2 and v_1 are velocities at time t_2 and t_1.
- It is the average change of velocity per unit time.
- SI unit m/s^2
- Dimensions $[M^0L^1T^{-2}]$

8.2 Instantaneous Acceleration

- Instantaneous acceleration is defined in the same way as the instantaneous velocity :

  $a = \lim_{\Delta t \to 0} (\Delta v/\Delta t) = dv/dt$
- SI unit m/s^2
- Dimensions $[M^0L^1T^{-2}]$

- When the acceleration is uniform, obviously, instantaneous acceleration equals the average acceleration over that period
- Since velocity is a quantity having both magnitude and direction, a change in the velocity may involve either or both of these factors.
- Acceleration, therefore, may result from a change in the speed(magnitude), a change in direction or changes in both.
- Like velocity, acceleration can also be positive, negative or zero.

NOTE

We will restrict ourselves to the study of constant acceleration for this chapter. In this case average acceleration equals the constant value of acceleration during the interval

- If the velocity of an object is v_o at t=0 and v at time t, we have
  - $a = \dfrac{v - v_0}{t - 0}$

  or, $\boxed{v = v_o + at}$ — This is first equation of motion
  - Other equations of motion are :

$$S = v_0 t + \tfrac{1}{2} at^2$$
$$v^2 - v_0^2 = 2aS$$
$$S = v_0 + \frac{a}{2}(2n - 1)$$

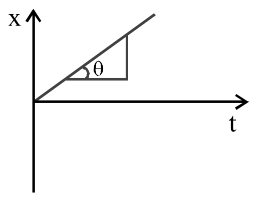
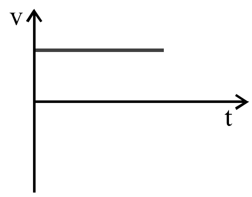
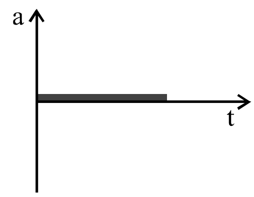
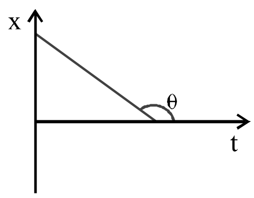
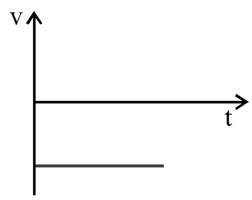
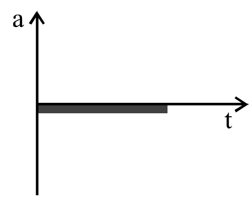
  - In all the above equations acceleration is assumed to be constant

9. GRAPHS

9.1 Uniform motion

- In an uniform motion a body covers equal distance in equal interval of time.
- Velocity is constant during the course of motion
- Acceleration is zero during the course of motion

If we try to represent the same on the number line with x, v, a on the Y-axis and t on the X-axis then we will have

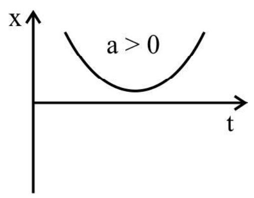
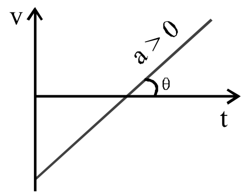
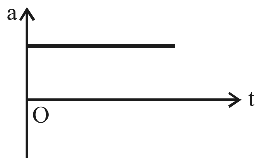
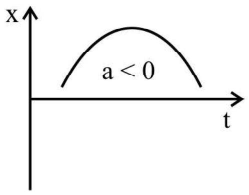
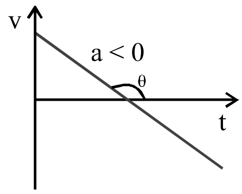
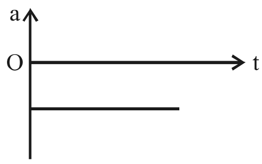
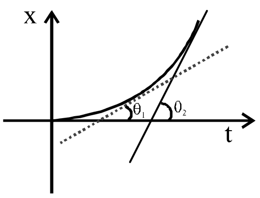
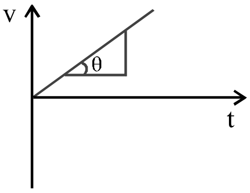
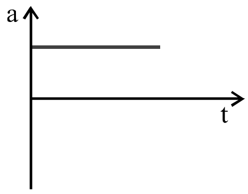
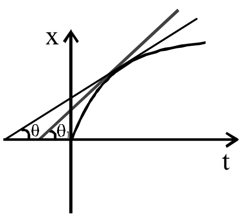
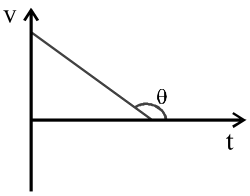
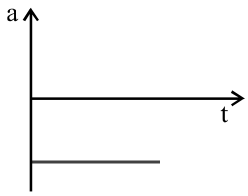
displacement – time graph	**velocity – time graph** **velocity = slope of x – t graph**	**acceleration – time graph** **acc^n = slope of v – t graph**
(i)  Nautre of slope : positive magnitude of slope : constant	 nature of slope : zero magnitude of slope : constant	 nature of slope of a – t
(ii)  nature of slope : negative magnitude of slope : constant	 nature of slope : zero magnitude of slope : constant	

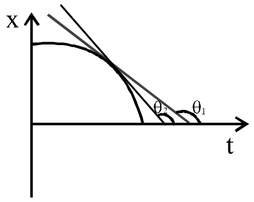
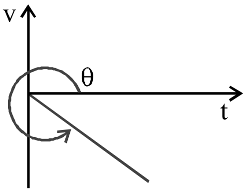
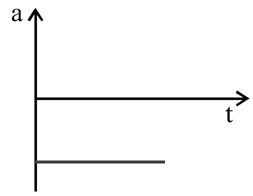
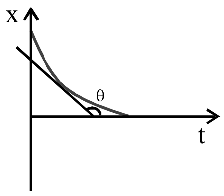
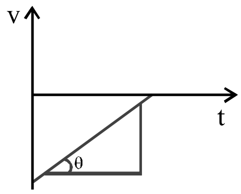
9.2 Non-Uniform motion

Uniformly accelerated motion

Accelerated motion

Magnitude of Velocity increases or decreases with time

displacement – time graph	velocity – time graph velocity = slope of x – t graph	acceleration – time graph acc^n = slope of v – t graph
(i) 		
(ii) 		
(iii)  nature of slope : positive magnitude of slope : Increasing	 nature of slope : positive magnitude of slope : constant	
(iv)  nature of slope : positive magnitude of slope : decreasing	 nature of slope : negative magnitude of slope : constant	

displacement – time graph	velocity – time graph velocity = slope of x – t graph	acceleration – time graph acc^n = slope of v – t graph
(v)  nature of slope : negative magnitude of slope : increasing	 nature of slope : negative magnitude of slope : constant	
(vi)  nature of slope : negative magnitude of slope : decreasing	 nature of slope : positive magnitude of slope : constant