

1 VSAQ + 1 SAQ = 2M + 4M = 6 MARKS

2. MOTION ALONG A STRAIGHT LINE

- Rest & Motion • Distance & Displacement • Types of Speed & Velocity
- Types of Acceleration • Equations of Motion • Graphical Approach

SMART SYNOPSIS

1. Rest and Motion :

A body is said to be **at rest** if it does not change its position with respect to time & surroundings.

Ex : Trees, hills and buildings are in motion with respect to Sun, and are at rest w.r.t. Earth.

A body is said to be **in motion** if it changes its position with respect to time and surroundings.

Ex : A person travelling in a moving train is in motion w.r.t surroundings, but the person is at rest w.r.t co-passengers.

The terms rest and motion are **relative**.

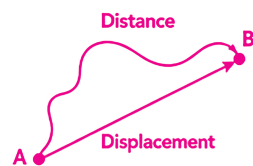
2. Position denotes the location of an object with respect to a chosen origin.

3. Rectilinear motion is the motion of an object along a straight line. [VSAQ]

Ex: A car moving along a straight road. A ball falling vertically downward.

4. Distance & Displacement : [VSAQ]

- **Distance** is the actual path length travelled by an object .
- **Displacement** is the shortest distance between the starting point and the ending point.
- Between two given points, distance $\geq$ |displacement|.
- Distance is a scalar (only magnitude) and displacement is a vector (both magnitude & direction)



5. Average speed, Average velocity & Instantaneous velocity : [VSAQ]

(i) **Average speed** is the ratio of total distance travelled to the total time taken .

(ii) **Average velocity** is the ratio of displacement to the corresponding time interval.

$$\bullet \text{ Average speed} = \frac{\text{Total distance}}{\text{Total time}} \quad \bullet \text{ Average velocity} = \frac{\text{Displacement}}{\text{Time interval}}$$

Note: The **average speed** of an object is greater or equal to the magnitude of the **average velocity** over a given time interval. ($\because$ distance $\geq$ displacement.)

(iii) **Instantaneous velocity** is the velocity of an object at a particular instant. [VSAQ]

If Δx represents a small change in displacement in a very small time Δt then the

$$\text{Instantaneous velocity is } \vec{v} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt} = \text{Slope of the tangent on position-time graph.}$$

Ex: The reading in the speedometer of a Bike reflects the magnitude of instantaneous velocity.

6. Uniform velocity, Non-uniform velocity :

- **Uniform velocity:** A body is said to have uniform velocity, if it covers equal displacements in equal intervals of time, however small the time intervals may be.

Ex : A train moving along a straight track with constant speed.

- **Non-uniform velocity:** A body is said to have non-uniform velocity, if it covers unequal displacements in equal intervals of time (or) the direction of motion of the body changes.

Ex : Motion of a freely falling body, motion of a satellite moving around Earth.

7. Acceleration, Positive and Negative acceleration, Instantaneous Acceleration:

- **Def:** The rate of change of velocity with respect to time is called **acceleration ($\vec{a}$)**.

Ex: A Freely falling body, Motion of a moving train in the beginning.

- **Average acceleration** is the ratio of the change in velocity to the corresponding time interval.

$$\text{Formula: } \vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

SI units: ms^{-2}

[VSAQ]

- **Positive acceleration :** If the velocity of a body is increasing with time, then the body is said to be moving with **positive acceleration**.

Ex : A train starting from a station moves with positive acceleration in the beginning.

- **Negative acceleration :** If the velocity of a body is decreasing with time, then the body is said to be moving with **Negative acceleration** or **Retardation** or **deceleration**.

Ex : A train slows down while approaching a station due to retardation.

- **Instantaneous acceleration :** The acceleration of a body at any instant of time of its motion or at any point along its path is called **Instantaneous acceleration**.

$$\text{Instantaneous acceleration is } \vec{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}, [\Delta v = \text{small change in } v, \Delta t = \text{small change in } t]$$

8. Uniform Acceleration, Non-uniform Acceleration :

- **Uniform Acceleration :** A body is said to have **uniform Acceleration** if it has equal changes in velocity in equal intervals of time, however small the time intervals may be.

Ex : Motion of a freely falling body.

- **Non-uniform Acceleration:** A body is said to have **non-uniform Acceleration**, if the magnitude or direction of the acceleration changes with time.

Ex : The motion of electrons around the nucleus.

9. Free fall: When an object is dropped from a height, it gets accelerated downward due to force of gravity. If **air resistance is neglected**, then the object is said to be in **free fall**.

Here the velocity of the object increases gradually. Acceleration acting downwards is taken as $+g$.

The general value of g is on the surface of Earth is 9.8 ms^{-2} .

[VSAQ]

10. Vertically projected object :

[VSAQ]

When an object is projected vertically up from the ground then it moves against gravity.

Its velocity decreases gradually. At the **highest point** its **velocity becomes zero**.

The height at which the velocity becomes zero, is called **maximum height**.

Here, acceleration is taken as $-g$.

11. Derivations of the Equations of Motion in a straight line :**11.1 Derive the equation $v=v_0+at$, with usual notation.**

[SAQ]

Proof: Consider a body starting with initial velocity ' v_0 ' and moving with uniform acceleration ' a '.After time ' t ', let its final velocity be ' v '.

From the definition of acceleration,



$$a = \frac{\text{Change in velocity}}{\text{time}} = \frac{v - v_0}{t} \Rightarrow v - v_0 = at$$

$$\therefore v = v_0 + at$$

11.2 Derive the equation $x = v_0t + \frac{1}{2}at^2$

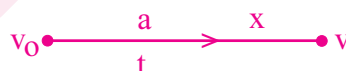
[VSAQ] [TS 16]

Proof: Consider a body starting with initial velocity ' v_0 ' and moving with uniform acceleration ' a '.After time ' t ', let its final velocity be ' v '. Let ' x ' be the distance travelled by the body in time ' t '.Distance travelled x = Average velocity $\times$ Time

$$x = \left(\frac{v_0 + v}{2} \right) t = \left(\frac{v_0 + (v_0 + at)}{2} \right) t, [\because v = v_0 + at]$$

$$= \left(\frac{2v_0t + at^2}{2} \right) = v_0t + \frac{1}{2}at^2$$

$$\therefore x = v_0t + \frac{1}{2}at^2$$

**11.3 Derive the equation $v^2 = v_0^2 + 2ax$**

[SAQ]

Proof: Consider a body starting with initial velocity ' v_0 ' and moving with uniform acceleration ' a '.After time ' t ', let its final velocity be ' v '. Let ' x ' be the distance travelled by the body in time ' t '.Distance travelled x = Average of velocity $\times$ time

$$x = \left(\frac{v_0 + v}{2} \right) t = \left(\frac{v_0 + v}{2} \right) \left(\frac{v - v_0}{a} \right), \quad \left(\because a = \frac{v - v_0}{t} \Rightarrow t = \frac{v - v_0}{a} \right)$$

$$= \left(\frac{v^2 - v_0^2}{2a} \right) \quad \therefore v^2 - v_0^2 = 2ax \Rightarrow v^2 = v_0^2 + 2ax$$

12. Equations of motion for a freely falling body (Here , $v_0 = 0$, $a = +g$, $x = h$) :

(i) $v = gt$ (From $v = v_0 + at$)

(ii) $h = \frac{1}{2}gt^2$, [From $x = v_0t + \frac{1}{2}at^2$]

(iii) $v^2 = 2gh \Rightarrow v = \sqrt{2gh}$ [From $v^2 = v_0^2 + 2ax$]

13. Second Equation of Motion (or Position Equation): Position (or displacement) of an objectafter time t when it is moving with constant (uniform) **acceleration**. $y = y_0 + v_0t + \frac{1}{2}at^2$ Here y = Final position of the object , y_0 = Initial position, v_0 = Initial velocity

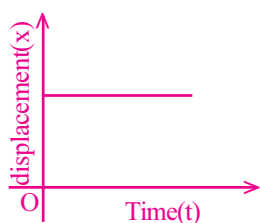
14. GRAPHICAL REPRESENTATION OF LINEAR MOTION:

14.1 Position - time graph or displacement–time graph is obtained by plotting displacement on the Y-axis against time on the X-axis.

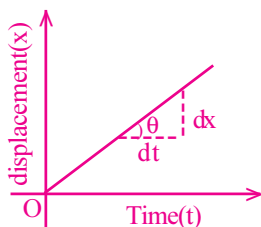
The ‘Slope’ of the tangent at a point on this curve gives ‘velocity’ at that point.

$$\text{Slope} = \tan \theta = \frac{dx}{dt} = \text{Velocity (v)}$$

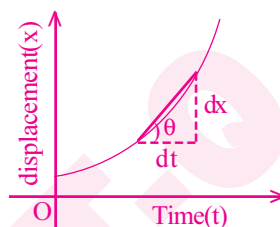
Various cases:



(i) Body at rest
(Slope=0)



(ii) Body moving with
constant velocity



(iii) Body moving with
increasing velocity
(acceleration)

14.2 Velocity-time Graph is a graph drawn taking ‘time (t)’ on the X-axis and ‘velocity(v)’ of a moving body on the Y-axis.

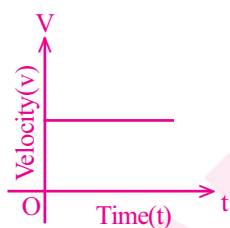
The ‘Slope’ of the tangent at a point on this curve gives ‘acceleration’.

$$\text{Slope} = \tan \theta = \frac{dv}{dt} = \text{acceleration (a)}$$

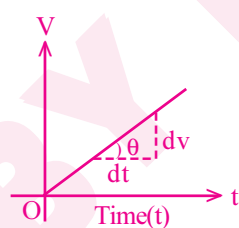
☞ Area under the **velocity-time graph** gives **displacement**.

[VSAQ]

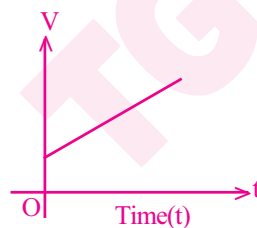
Various cases:



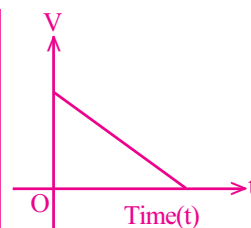
(i) Uniform velocity



(ii) Uniform acceleration
starting from Rest



(iii) Uniform acceleration
with some initial velocity



(iv) Uniform retardation

15. Relative velocity: The velocity of object B relative to object A is $v_{BA} = v_B - v_A$

Similarly, velocity of object A relative to object B is $v_{AB} = v_A - v_B$

16. Reaction time (t_r) is the time a person takes to perceive, process and respond to a situation.

Formula: Reaction time $t_r = \sqrt{\frac{2d}{g}}$

1 REST AND MOTION

- A body is at rest if it does not change its position with respect to time and surroundings.

Ex : Trees, hills and buildings are in motion w.r.t. Sun, and at rest w.r.t. Earth.

- A body is in motion if it changes its position with respect to time and surroundings.

Ex : A person travelling in a moving train is in motion w.r.t. surroundings.

The terms rest and motion are relative.

2 RECTILINEAR MOTION

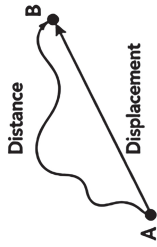
Rectilinear motion is the motion of an object along a straight line.

Ex :

- A car moving along a straight road.
- A ball falling vertically downward.

3 DISTANCE & DISPLACEMENT

- Distance is the actual path length travelled by an object.
- Displacement is the shortest distance between the starting point and the ending point.
- Between two given points, distance $\geq$ displacement.
- Distance is a scalar (only magnitude) and displacement is a vector (both magnitude & direction).



Distance $\geq$ Displacement

4 AVERAGE SPEED, AVERAGE VELOCITY & INSTANTANEOUS VELOCITY

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

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time interval}}$$

$$\text{Instantaneous velocity } \vec{v} = \frac{dx}{dt}$$

6 UNIFORM ACCELERATION

A body is said to have uniform acceleration if it has equal changes in velocity in equal intervals of time.

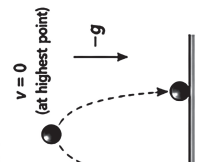
Ex : Motion of a freely falling body.

- $-v_1$
- $-v_2$
- $-v_3$
- $-v_4$
- ...

8 VERTICALLY PROJECTED OBJECT

When an object is projected vertically up

- Its velocity decreases.
- At the highest point, velocity is zero.
- Acceleration is taken as $-g$ (downward direction is positive).

**2. MOTION ALONG A STRAIGHT LINE****CONCEPTS AND FORMULAS****5 ACCELERATION (a)**

The rate of change of velocity with respect to time.

Ex :

- A freely falling body
- Motion of a moving train in the beginning.

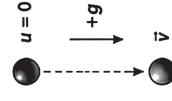
Average acceleration is the ratio of the change in velocity to the corresponding time interval.

$$\text{Formula : } a = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} \quad \text{SI units : ms}^{-2}$$

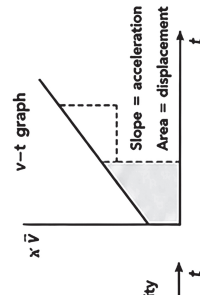
7 FREE FALL

When an object is dropped from a height, and air resistance is neglected, then the object is in free fall.

- Velocity increases gradually.
- Acceleration is taken as $+g$ (downward direction is positive).

**10 GRAPHICAL APPROACH**

- Slope of $x-t$ graph = velocity
- Slope of $v-t$ graph = acceleration
- Area under $v-t$ graph = displacement

**9 EQUATIONS OF MOTION IN A STRAIGHT LINE**

- $v = v_0 + at$
- $x = v_0 t + \frac{1}{2} at^2$
- $v^2 = v_0^2 + 2ax$

Where,

v = final velocity, v_0 = initial velocity
 a = acceleration, t = time, x = displacement