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MOTION IN STRAIGHT LINE

KEY CONCEPTS AT A GLANCE

WHY IT MATTERS

- Foundation for all of mechanics and physics.
- Essential in daily life applications like vehicles, sports, projectiles etc.
- Important for NEET, JEE & Board Exams.

KEY TAKEAWAYS

- ✓ Motion is described relative to a frame of reference.
- ✓ Displacement is a vector, distance is a scalar.
- ✓ Speed tells how fast, velocity tells how fast in a direction.
- ✓ Acceleration describes the rate of change of velocity.
- ✓ Equations of motion hold for constant acceleration.

COMMON SYMBOLS

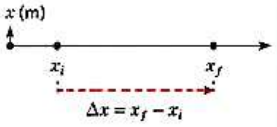
x	Position / Displacement (m)
s	Displacement (m)
u	Initial velocity (m s^{-1})
v	Final velocity (m s^{-1})
a	Acceleration (m s^{-2})
t	Time (s)
Δx	Change in position (m)
Δv	Change in velocity (m s^{-1})
$\bar{v}$	Average velocity (m s^{-1})
$\bar{s}$	Average speed (m s^{-1})

1 POSITION, DISTANCE & DISPLACEMENT

Position : Location of object on a straight line at an instant.

Distance (d) : Total length of path travelled. (Scalar)

Displacement (Δx) : Shortest distance from initial to final position with direction. (Vector)



Key Relation

$$\Delta x = x_f - x_i$$

2 SPEED & VELOCITY

Speed (v) : Rate of change of distance.

$$\bar{v}_{speed} = \frac{\text{Total distance}}{\text{Total time}}$$

Velocity (v) : Rate of change of displacement.

$$\bar{v} = \frac{\text{Displacement}}{\text{Time}}$$

Instantaneous velocity : Velocity at a particular instant.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

3 ACCELERATION

Acceleration : Rate of change of velocity.

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v-u}{t}$$

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Types

- **Positive acceleration :** Speed increases.
- **Negative acceleration (Retardation) :** Speed decreases.
- **Zero acceleration :** Velocity is constant.

4 EQUATIONS OF MOTION

(For constant acceleration)

(i) $v = u + at$

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

(iii) $v^2 = u^2 + 2as$

(iv) $s = \frac{(u+v)}{2}t$

Where,

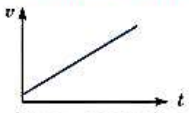
u = Initial velocity
v = Final velocity
a = Acceleration
t = Time
s = Displacement

5 GRAPHICAL REPRESENTATION

(i) Position–Time Graph

Slope = velocity

(ii) Velocity–Time Graph

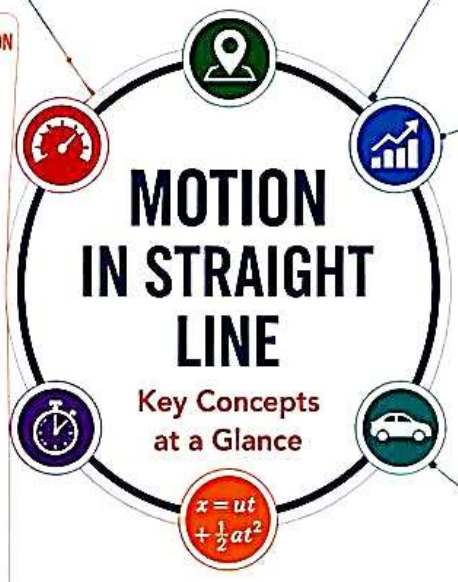


Slope = acceleration

Area under curve = displacement

(iii) Acceleration–Time Graph

Area under curve = change in velocity



6 SPECIAL CASES

- Uniform motion ($a = 0$)
  v = constant, $s = vt$
- Uniformly accelerated motion ($a = +ve$)
  Speed increases uniformly.
- Uniformly retarded motion ($a = -ve$)
  Speed decreases uniformly.
- Free fall (near Earth, ignoring air resistance)
  $a = g = 9.8\ m\ s^{-2}$ (downward)

$$v = u + gt, \quad s = ut + \frac{1}{2}gt^2$$

7 RELATIONS BETWEEN QUANTITIES

- If $a > 0$, graph of v–t is a straight line with positive slope.
- If $a < 0$, graph of v–t is a straight line with negative slope.
- If $v = 0$, object is momentarily at rest.
- If $s = 0$, final and initial positions coincide.

8 AVERAGE SPEED & AVERAGE VELOCITY

Average speed:

$$\bar{v}_{speed} = \frac{\text{Total distance}}{\text{Total time}}$$

Average velocity:

$$\bar{v} = \frac{\text{Displacement}}{\text{Total time}}$$

Note: For motion in a straight line, $|\bar{v}| \leq \bar{v}_{speed}$, equality holds only for motion in one direction without reversal.

9 RELATIVE SPEED

When two bodies move in same line, relative speed = $|v_1 - v_2|$

Case	Relative Speed
Same direction	$\lvert v_1 - v_2 \rvert$
Opposite direction	$v_1 + v_2$
One at rest	v (of moving body)

10 IMPORTANT POINTS

- Equations of motion are valid only for constant acceleration.
- Displacement can be positive, negative or zero.
- Scalar quantities : distance, speed, time, mass.
- Vector quantities : displacement, velocity, acceleration.
- Units : $[s]$ = m, $[v]$ = m s^{-1}, $[a]$ = m s^{-2}

11 EXAMPLE APPLICATIONS

- Motion of vehicles starting, stopping or overtaking.
- Objects in free fall.
- Motion in lifts.
- Projectiles (in one dimension).
- Sports: running, cycling, car racing.

IMPORTANT FORMULAS AT A GLANCE

Average velocity	Average speed	Acceleration (avg.)	Velocity (instantaneous)	Acceleration (instantaneous)	Equations of motion
$\bar{v} = \frac{\Delta x}{\Delta t}$	$\bar{v}_{speed} = \frac{\text{Total distance}}{\text{Total time}}$	$a_{avg} = \frac{v-u}{t}$	$v = \frac{dx}{dt}$	$a = \frac{dv}{dt}$	1. $v = u + at$ 2. $s = ut + \frac{1}{2}at^2$ 3. $v^2 = u^2 + 2as$ 4. $s = \frac{(u+v)}{2}t$

PRO TIPS

- ✓ Draw diagrams for better understanding.
- ✓ Always write units.
- ✓ Practice numerical problems regularly.
- ✓ Check signs of velocity and acceleration carefully.

★ ★ CONCEPT CLEAR • PRACTICE MORE • SCORE HIGH ★ ★

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REMEMBER

Understanding motion in a straight line builds the base for all complex motion!