KSQUARE CAREER INSTITUTE

MOTION IN A STRAIGHT LINE

Class 11 Physics • Kinematics (1D) • NEET Notes

Faculty: Er. Keshav Krishna

Scan to get all notes

Today's Targets

1. Distance & displacement
2. Average speed and average velocity
3. Instantaneous velocity and acceleration (calculus method)
4. Equations of motion for uniform acceleration + important results
5. Graphs — s–t, v–t, a–t • α–β type questions
6. Added: motion under gravity, Galileo's odd-number rule, relative velocity

NEET Point / PYQ Alert

Kinematics (1D + 2D) gives about **2 questions in NEET, at most 3**. Priority: PYQs (39 years) → NCERT line by line → notes → formulas.

DISTANCE & DISPLACEMENT

Distance

Actual path covered by the body.

Scalar quantity (direction not considered). SI unit: **metre (m)**. Dimension: **$[M^0 L^1 T^0]$**.

Always **positive**; can never decrease with time.

Displacement

Shortest possible path (straight line) from initial to final position.

Vector quantity. SI unit: **m**. Dimension: **[L]**.

Can be positive, negative or zero.

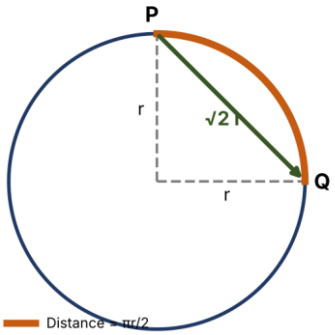
▸ Particle on a Circle (radius r, angle θ at centre)

Formulas

$$\text{Distance (arc)} = r\,\theta \quad (\theta \text{ must be in radian; } \pi \text{ rad} = 180^\circ)$$

$$\text{Displacement (chord)} = 2r\sin(\theta/2)$$

Movement	Angle θ	Distance	Displacement
Quarter circle	90° = π/2	πr/2	√2 r
One-sixth circle	60° = π/3	πr/3	r
Half circle	180° = π	πr	2r
Full circle	360° = 2π	2πr	0



Q1. A particle moves along the circumference of a circle from P to Q (quarter circle) as shown. Find the displacement and distance moved by the particle.

(a) r, πr/6 (b) √2r, πr (c) √2r, πr/2 (d) r, πr/2

Answer: (c) — Displacement = 2r sin 45° = √2 r; Distance = r × π/2 = πr/2.

AVERAGE VELOCITY & AVERAGE SPEED

Definitions

$$\text{Average velocity} = \text{Total displacement} / \text{Total time} \quad \text{(vector)}$$

$$\text{Average speed} = \text{Total distance} / \text{Total time} \quad \text{(scalar)}$$

Remember

1. Displacement ≤ Distance
2. |Average velocity| ≤ Average speed

Equality holds only for motion in a straight line **without turning back** (e.g. A → B, 2 m: distance = displacement = 2 m).

Important Cases

1. n equal distances with speeds $v_1, v_2, v_3 \ldots v_n$

Harmonic mean

$$\langle v \rangle = n / (1/v_1 + 1/v_2 + 1/v_3 + \ldots + 1/v_n)$$

2. Two equal distances (n = 2)

Result

$$\langle v \rangle = 2 / (1/v_1 + 1/v_2) = 2v_1v_2 / (v_1 + v_2)$$

3. Equal time intervals (Added)

Arithmetic mean

$$\langle v \rangle = (v_1 + v_2 + \ldots + v_n) / n \quad \text{for } n = 2: \ \langle v \rangle = (v_1 + v_2)/2$$

NEET Point / PYQ Alert

Equal distance → Harmonic mean. Equal time → Arithmetic mean. A very common trap!

Q2. A person travelling in a straight line moves with a constant velocity v_1 for a certain distance 'x' and with a constant velocity v_2 for the next equal distance. The average velocity v is given by the relation **[NEET 2019]**

(a) $v = \sqrt{(v_1v_2)}$
(b) $1/v = 1/v_1 + 1/v_2$
(c) $2/v = 1/v_1 + 1/v_2$
(d) $v/2 = (v_1 + v_2)/2$

Answer: (c) — $\langle v \rangle = 2/(1/v_1 + 1/v_2) \Rightarrow 2/v = 1/v_1 + 1/v_2$.

Q3. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2. Its average speed during the complete journey is **[CBSE AIPMT 2011]**

(a) $(v_1 + v_2)/2$
(b) $v_1v_2/(v_1 + v_2)$
(c) $2v_1v_2/(v_1 + v_2)$
(d) $v_1^2v_2^2/(v_1^2 + v_2^2)$

Answer: (c)

INSTANTANEOUS VELOCITY & ACCELERATION

Instantaneous values are found using calculus — **differentiation (d/dt)** to go down from s → v → a, and **integration (∫)** to go up from a → v → s.

Instantaneous velocity

$$v = ds/dt = \tan\theta = \text{slope of s–t curve}$$

$$\text{(vector form: } \vec{v} = d\vec{s}/dt)$$

Instantaneous acceleration

$$a = dv/dt = d^2s/dt^2 = \text{slope of v–t curve}$$

$$\text{Also: } a = v\,(dv/ds) \quad \text{(useful when a is given in terms of position)}$$

▸ Important Points (Calculus Toolkit)

#	Relation	Note
1	$v = ds/dt$	Differentiate position
2	$a = dv/dt$	Differentiate velocity
3	$v_2 - v_1 = \int a\,dt$ $(t_1 \to t_2)$	If $u \neq 0$: **$v = u + \int a\,dt$** (99% cases $u = 0 \Rightarrow v = \int a\,dt$)
4	$s_2 - s_1 = \int v\,dt$	**s~{f} = s~{i} + ∫ v dt** (99% cases $s_i = 0$)

> **2D motion tip**
> If x and y are given separately: $v = \sqrt{(v_x^2 + v_y^2)}$ and $a = \sqrt{(a_x^2 + a_y^2)}$ — find each component by differentiating, then take the resultant.

Q4. Two cars P and Q start from a point at the same time in a straight line and their positions are $X_P(t) = at + bt^2$ and $X_Q(t) = ft - t^2$. At what time do the cars have the same velocity? **[NEET 2016]**

(a) $(a - f)/(1 + b)$
(b) $(a + f)/[2(b - 1)]$
(c) $(a + f)/[2(1 + b)]$
(d) $(f - a)/[2(1 + b)]$

Answer: (d) — $v_P = a + 2bt$, $v_Q = f - 2t$. Equate: $2t(b + 1) = f - a$.

Q5. A particle moves along a straight line OX. At a time t (in s), the distance x (in m) of the particle from O is $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest? **[CBSE AIPMT 2006]**

(a) 24 m
(b) 40 m
(c) 56 m
(d) 16 m

Answer: (d) — $v = 12 - 3t^2 = 0 \Rightarrow t = 2$ s. $x(2) = 56$ m, $x(0) = 40$ m ⇒ distance = 16 m. (Trap: 56 m is the position, not the distance!)

Q6. The x and y co-ordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in metres and t in seconds. The acceleration of the particle at t = 2 s is **[NEET 2017]**

(a) 0
(b) 5 m/s²
(c) –4 m/s²
(d) –8 m/s²

Answer: (c) — $v_x = 5 - 4t \Rightarrow a_x = -4$; $v_y = 10 \Rightarrow a_y = 0$. So $a = -4$ m/s².

AREA UNDER THE CURVE

Graph	Area under curve gives	Formula
v–t graph	Displacement (area with sign) / Distance (all areas positive)	$s = \int v\,dt$
a–t graph	Change in velocity (with sign) / Change in speed (only +ve)	$\Delta v = \int a\,dt$

NEET Point / PYQ Alert

Area with sign → displacement / velocity. Area taken positive → distance / speed.

Graph questions are always about **slope** or **area**.

Q7. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is **[NEET 2016]**

(a) 3A + 7B
(b) (3/2)A + (7/3)B
(c) A/2 + B/3
(d) (3/2)A + 4B

Answer: (b) — $s = \int_1^2 (At + Bt^2)\,dt = (A/2)(2^2 - 1^2) + (B/3)(2^3 - 1^3) = 3A/2 + 7B/3$.

Q8. If acceleration of a particle is given by $a = 3t^2$, find velocity of the particle at t = 3 s, if initially the particle was at rest.

(a) 9 m/s
(b) 18 m/s
(c) 27 m/s
(d) 30 m/s

Answer: (c) — $v = \int 3t^2\,dt = t^3 \Rightarrow v(3) = 27$ m/s.

Extension: if initial velocity u = 3 m/s

$v = u + \int a\,dt = 3 + 27 =$ **30 m/s**

Q8(b). Consider a particle moving along a straight line whose position is $s(t) = \alpha t^2 - \beta t + \gamma$, where $\alpha = 1$ m s^{-2}, $\beta = 6$ m s^{-1} and $\gamma = 5$ m. The average speed of the particle from t = 0 to t = 6 s is

(a) 0
(b) 12
(c) 6
(d) 3

Answer: (d) — $v = 2\alpha t - \beta = 0$ at t = 3 s (turns back). s(0) = 5, s(3) = –4, s(6) = 5 m. Distance = 9 + 9 = 18 m ⇒ speed = 18/6 = 3 m/s. (Average velocity = 0.)

EQUATIONS OF MOTION (UNIFORM ACCELERATION)

Valid ONLY for constant acceleration

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$
4. $s = [(u + v)/2] \times t$ (Added)
5. $S_{nth} = u + (a/2)(2n - 1)$

Symbol	Meaning
u	Initial velocity

Symbol	Meaning
v	Final velocity
a	Acceleration (constant)
t	Time period of acceleration
s	Displacement

Sign convention (Added)

Choose one direction as positive. Quantities along it are +ve, opposite are –ve.

Retardation (slowing down) → a is opposite to v, so put a as negative.

Q9. A particle has initial velocity $(3\hat{i} + 4\hat{j})$ and has acceleration $(0.4\hat{i} + 0.3\hat{j})$. Its speed after 10 s is **[CBSE AIPMT 2010]**

(a) 7 unit
(b) 7√2 unit
(c) 8.5 unit
(d) 10 unit

Answer: (b) — $v_x = 3 + 0.4\times10 = 7$; $v_y = 4 + 0.3\times10 = 7 \Rightarrow$ speed $= \sqrt{(49 + 49)} = 7\sqrt{2}$.

IMPORTANT RESULTS FOR UNIFORM ACCELERATION

Result 1 — Velocity at the mid-point

A particle moving with uniform acceleration from A to B has velocities v_1 and v_2 at A and B. If C is the mid-point of AB:

Mid-point velocity

$$v_C = \sqrt{((v_1^2 + v_2^2) / 2)}$$

Result 2 — Stopping distance

A body moving with velocity u stops after distance s on braking. With velocity nu and the same braking force, it stops after:

Stopping distance ∝ u²

$$s' = n^2 s \quad (\text{from } v^2 = u^2 - 2as \Rightarrow s = u^2/2a)$$

Result 3 — Average velocity

For uniform acceleration

$$\text{Average velocity} = (u + v)/2$$

$$\text{Displacement} = \text{average velocity} \times \text{time} = [(u + v)/2] \times t$$

Q10. A particle moves in a straight line with a constant acceleration. It changes its velocity from 10 m/s to 20 m/s while passing through a distance 135 m in t seconds. The value of t is **[CBSE AIPMT 2008]**

(a) 10
(b) 1.8
(c) 12
(d) 9

Answer: (d) — $135 = [(10 + 20)/2] \times t = 15t \Rightarrow t = 9$ s.

DISTANCE COVERED IN THE Nth SECOND

- Distance in 5th second = S(5) – S(4); in general $\mathbf{S_{nth} = S(n) - S(n-1)}$.

For uniform acceleration

$$S_{nth} = u + (a/2)(2n - 1)$$

Galileo's law of odd numbers (Added)

For a body starting from rest (u = 0) with uniform a, distances in successive equal intervals are in the ratio **1 : 3 : 5 : 7 : …**

Distances in first 1 s, 2 s, 3 s … are in ratio **1 : 4 : 9 : …** ($s \propto t^2$).

Q11. The distance travelled by a particle starting from rest and moving with an acceleration 4/3 m s^{-2}, in the third second is

(a) 6 m
(b) 4 m
(c) 10/3 m
(d) 19/3 m

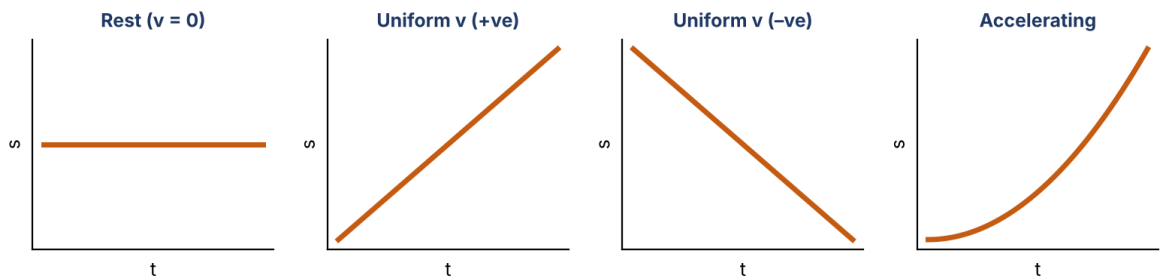
Answer: (c) — $S_3 = 0 + (4/3)/2 \times (2\times3 - 1) = (2/3) \times 5 = 10/3$ m.

GRAPH CONCEPTS

1. s–t (Position–Time) Graphs

Slope

$$\text{slope} = \tan\theta = ds/dt = \text{velocity}$$



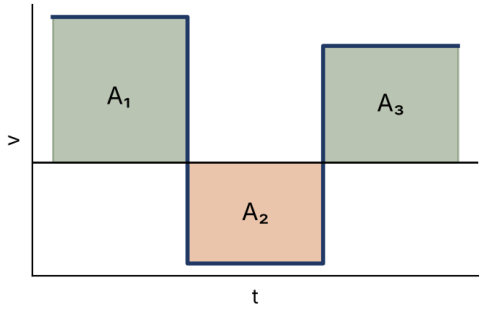
Shape of s–t graph	Meaning
Parallel to time axis (θ = 0)	Slope = 0 ⇒ v = 0, body at **rest**
Straight line, θ < 90°	Constant **positive** velocity (uniform motion)
Straight line, θ > 90°	Constant **negative** velocity
Curve bending upward (slope increasing)	Velocity increasing ⇒ **a positive** (accelerating)
Curve bending downward (slope decreasing)	Velocity decreasing ⇒ **retardation**
Line perpendicular to time axis	Infinite velocity — **not possible**

2. v–t (Velocity–Time) Graphs

Slope & Area

$$\text{slope} = \tan\theta = dv/dt = \text{acceleration}$$

$$\text{Area under curve} = \int v\,dt = \text{displacement}$$



From the graph above

$$\text{Displacement} = A_1 - A_2 + A_3$$

$$\text{Distance} = A_1 + A_2 + A_3$$

3. a–t (Acceleration–Time) Graphs

Area

$$\text{Area under a–t curve} = \int a\,dt = \text{change in velocity } (\Delta v)$$

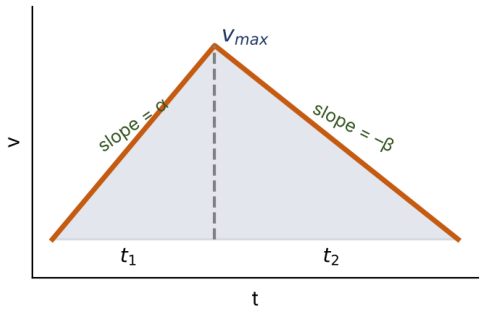
NEET Point / PYQ Alert

Slope of a–t graph = rate of change of acceleration (called **jerk**) — rarely asked.

For uniform acceleration: a–t is a horizontal line, v–t is a straight slanted line, s–t is a **parabola**.

α – β TYPE QUESTIONS

A particle accelerates from rest at a constant rate **α** for time t_1 and then retards at a constant rate **β** for time t_2 and comes to rest. Total time $T = t_1 + t_2$.



Shortcut formulas

$$a_{eff} = \alpha\beta / (\alpha + \beta)$$

1. $v_{max} = a_{eff} \times T = \alpha\beta T / (\alpha + \beta)$
2. $v_{avg} = v_{max} / 2$
3. $S = \frac{1}{2}\, a_{eff}\, T^2$
4. $v_{max} = \alpha\, t_1 = \beta\, t_2$ (to find t_1 and t_2)

Q12. A car accelerates at 6 m/s² from rest, then retards at 3 m/s² and comes to rest. If the total time taken for the journey is 20 s, find (a) v_{max} (b) v_{avg} (c) S in 20 s (d) time for acceleration & retardation.

Quantity	Working	Answer
a_{eff}	(6 × 3)/(6 + 3)	2 m/s²
(a) v_{max}	2 × 20	**40 m/s**
(b) v_{avg}	40/2	**20 m/s**
(c) S	½ × 2 × 20²	**400 m**
(d) t_1, t_2	$40 = 6t_1 = 3t_2$	**t_1 = 20/3 s, t_2 = 40/3 s**

Q13. A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β and comes to rest. If the total time elapsed is t, then the maximum velocity acquired by the car is **[CBSE AIPMT 1994]**

(a) $[(\alpha^2 + \beta^2)/\alpha\beta]\, t$
(b) $[\alpha\beta/(\alpha^2 - \beta^2)]\, t$
(c) $[(\alpha + \beta)/\alpha\beta]\, t$
(d) $\alpha\beta t/(\alpha + \beta)$

Answer: (d) — $v_{max} = a_{eff} \times t = \alpha\beta t/(\alpha + \beta)$.

MOTION UNDER GRAVITY (ADDITIONAL TOPIC)

- A freely falling body moves with constant acceleration **g = 9.8 m/s²** (≈ 10 m/s²) downward, neglecting air resistance.

- Use equations of motion with **a = –g** (taking upward as +ve).

Case	Result
Body dropped from height h (u = 0)	Time t = √(2h/g); velocity on reaching ground v = √(2gh)
Body thrown up with speed u	Max height H = $u^2/2g$; time to reach top = u/g
Total time of flight (back to same point)	T = 2u/g; time of ascent = time of descent
Speed on return	Equal to speed of projection u (opposite direction)
At the highest point	v = 0 but **a = g** (not zero!)

NEET Point / PYQ Alert

A body dropped from rest: distances in successive seconds = 5, 15, 25 … m (g = 10) → ratio 1 : 3 : 5.

All bodies fall with the same acceleration in vacuum, independent of mass.

RELATIVE VELOCITY IN 1D (ADDITIONAL TOPIC)

Relative velocity

$$v_{AB} = v_A - v_B \quad \text{(velocity of A with respect to B)}$$

- **Same direction:** relative speed = $|v_A - v_B|$
- **Opposite direction:** relative speed = $v_A + v_B$
- Time to meet/overtake = relative separation / relative speed.

QUICK REVISION — FORMULA SHEET

- Distance ≥ |displacement|; average speed ≥ |average velocity|.
- Circle: distance = rθ, displacement = 2r sin(θ/2).
- Equal distances: $\langle v \rangle = 2v_1v_2/(v_1 + v_2)$. Equal times: $\langle v \rangle = (v_1 + v_2)/2$.
- v = ds/dt, a = dv/dt = v dv/ds, v = u + ∫a dt, s = s_i + ∫v dt.
- v = u + at; s = ut + ½at^2; $v^2 = u^2 + 2as$; $S_{nth} = u + (a/2)(2n - 1)$.
- Mid-point velocity = $\sqrt{[(v_1^2 + v_2^2)/2]}$; stopping distance ∝ u^2 (s′ = n^2s).
- Slope of s–t = v; slope of v–t = a; area of v–t = displacement; area of a–t = Δv.
- α–β: $v_{max} = \alpha\beta T/(\alpha + \beta)$, $S = \frac{1}{2}[\alpha\beta/(\alpha + \beta)]\,T^2$.
- Free fall: v = √(2gh), H = $u^2/2g$, T = 2u/g.

Stay focused, stay consistent — your white coat is waiting for you.