CLASS IX SCIENCE

MOTION

Describing Motion Around Us | Lakshya Smart Notes

Observe → Understand → Visualise → Calculate → Interpret → Apply → Revise → Score

SECTION A · 1st Revision	SECTION B · After 3 Days	SECTION C · After 7 Days
Understand concepts + solved examples	Redo graphs + selected numericals	Formula sheet + Smart Check

Chapter Roadmap

CORE FLOW
Reference point & position → distance & displacement → speed & velocity → acceleration → motion graphs → equations of motion → uniform circular motion

ADVANCED EDGE
Frames of reference → scalars & vectors → graphical vector addition/subtraction → displacement in the nth second

Learning Targets

By the end of this chapter, you should be able to...	
Differentiate distance/displacement and speed/velocity.	Calculate average speed, velocity and acceleration.
Read position-time and velocity-time graphs.	Use slope and area correctly.
Apply the three equations of motion with correct signs.	Explain uniform circular motion and solve numericals.

SECTION A · 1st Revision · Motion Core

1. Motion, rest and reference point

To describe an object, first choose a fixed reference point. Its position is described by both distance and direction from that reference point. If its position changes with time relative to the reference point, it is in motion; if not, it is at rest.

SMART THINKING
Can the same object be at rest for one observer and in motion for another? Yes. A passenger sitting in a moving train is at rest relative to another seated passenger but in motion relative to a person standing on the platform.

REMEMBER
Rest and motion are relative to the chosen reference. Never discuss "moving" or "at rest" without knowing relative to what.

Position on a straight line

Choose an origin O. Usually the right/forward direction is taken as positive (+) and the left/backward direction as negative (-). Any direction may be chosen as positive, but do not change it midway through a problem.

TIME ALERT
An instant of time is one clock reading; a time interval is the duration between two instants.

Quick practice

- A student sits in a bus moving at constant velocity. State one reference relative to which the student is at rest and one relative to which the student is in motion.
- If east is chosen positive, write the sign of the position 12 m west of O.

2. Distance travelled and displacement

Distance travelled is the total length of the actual path covered. Displacement is the net change in position from the initial instant to the final instant; its complete description includes direction.

Feature	Distance travelled	Displacement
Meaning	Total path length	Net change in position
Depends on path?	Yes	Only initial and final positions
Direction needed?	No	Yes
Can be zero after motion?	No, if motion occurred	Yes, after return to start

Feature	Distance travelled	Displacement
Relation	Distance ≥ magnitude of displacement	Magnitude ≤ distance
SI unit	metre (m)	metre (m)

EXAM ALERT
Magnitude of displacement can never exceed total distance travelled.

WHEN ARE THEY EQUAL?
For motion in a straight line, distance = magnitude of displacement when the object moves in one direction without turning back.

SOLVED EXAMPLE | Back-and-forth athlete
GIVEN: O → A = 100 m, then A → B = 60 m back; final B is 40 m from O
FIND: distance and displacement
FORMULA: distance = path length; displacement = final position - initial position
Distance = 100 + 60 = 160 m
Displacement = +40 - 0 = +40 m
ANSWER: Distance = 160 m; displacement = 40 m in the positive direction.

COMMON MISTAKE
“Displacement is the shortest path travelled” is loose wording. Better: magnitude of displacement is the straight-line distance between initial and final positions; displacement also has direction.

3. Average speed and average velocity

Average speed = total distance travelled / total time interval
No direction; SI unit m/s

Average velocity = displacement / time interval
Direction is the same as displacement; SI unit m/s

SOLVED EXAMPLE | Pool round trip
GIVEN: 25 m pool; swimmer goes to the other end and back in 50 s
FIND: average speed and average velocity
FORMULA: avg speed = distance/time; avg velocity = displacement/time
Total distance = 25 + 25 = 50 m
Displacement = 0 m
Average speed = 50/50 = 1 m/s
Average velocity = 0/50 = 0 m/s
ANSWER: Average speed = 1 m/s; average velocity = 0 m/s.

EXAM ALERT
Average speed is not usually the simple average of two speeds. Use total distance ÷ total time unless the situation specifically justifies another method.

Quantity	Formula basis	Direction?	SI unit
Speed / average speed	distance ÷ time	No	m/s
Velocity / average velocity	displacement ÷ time	Yes	m/s

4. Uniform and non-uniform motion

In straight-line uniform motion, the object covers equal distances in equal time intervals for every possible choice of equal intervals; speed is constant. In non-uniform motion, equal time intervals may contain unequal distances; speed changes.

IMPORTANT
For the graph work in this chapter, “constant velocity” means straight-line motion in one direction with unchanged velocity. Then acceleration = 0.

5. Acceleration

Acceleration describes how quickly velocity changes. It can result from a change in the magnitude of velocity, a change in direction, or both.

Average acceleration, $a = (v - u) / t$
u = initial velocity, v = final velocity, t = time interval; SI unit m/s²

Situation (chosen + direction)	Velocity change	Acceleration sign / meaning
Velocity becomes more positive	$v > u$	$a > 0$
Velocity becomes less positive	$v < u$	$a < 0$; opposite to + velocity
Velocity constant	$v = u$	$a = 0$
Motion in negative direction and speed increases	velocity becomes more negative	$a < 0$ but object speeds up

SOLVED EXAMPLE | Bus accelerates then brakes
GIVEN: 10 m/s → 15 m/s in 10 s; then 15 m/s → 0 in 5 s
FIND: average acceleration in both intervals
FORMULA: $a = (v-u)/t$
Accelerating: $a = (15-10)/10 = 0.5\ m/s^2$
Braking: $a = (0-15)/5 = -3\ m/s^2$
ANSWER: $+0.5\ m/s^2$ while speeding up; $-3\ m/s^2$ while braking.

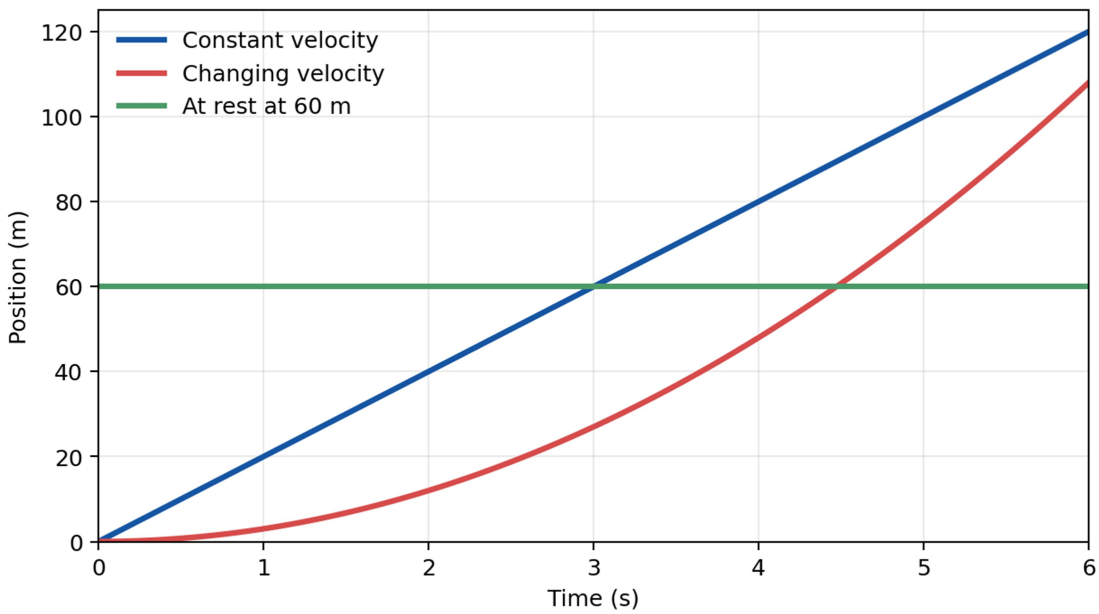
COMMON MISTAKE
Negative acceleration does not automatically mean “slowing down”. Compare the direction of velocity and acceleration. Opposite directions → speed decreases; same direction → speed increases.

CONCEPT EXAMPLE
A freely falling object provides a familiar example of nearly constant acceleration of about $9.8\ m/s^2$ downward. Detailed gravitation is studied separately.

SECTION B · Graph Mastery · Read the Story Hidden in the Line

6. Motion Graphs

GRAPH TERMINOLOGY
Use POSITION-TIME and VELOCITY-TIME as the main graph names. In one-direction motion starting from position zero, these may numerically match distance-time and speed-time graphs.



Position-time: constant velocity, changing velocity, and rest

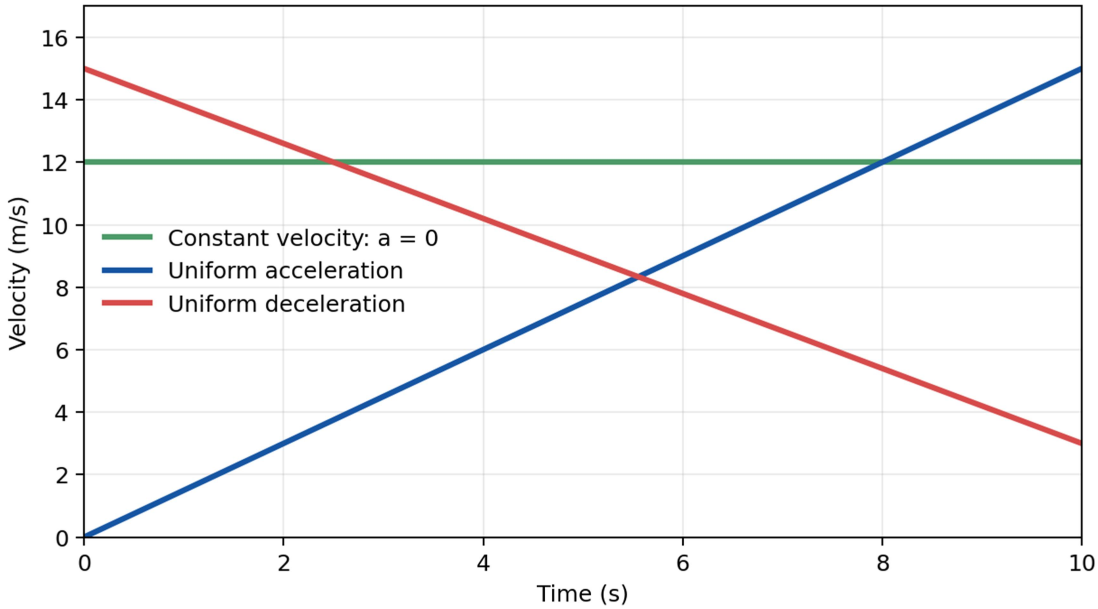
Position-time graph

- X-axis: time; Y-axis: position.
- Straight sloping line → constant velocity.
- Curved line → velocity changes; motion is accelerated.
- Horizontal line → position constant → object is at rest.
- Slope between two points = change in position / change in time = average velocity over that interval.

Slope of position-time graph = Δposition / Δtime = average velocity

SOLVED EXAMPLE | Velocity from p-t slope
GIVEN: position changes from 40 m at 2 s to 80 m at 4 s
FIND: average velocity
FORMULA: $\bar{v} = \Delta s/\Delta t$
$\Delta s = 80 - 40 = 40$ m
$\Delta t = 4 - 2 = 2$ s
$\bar{v} = 40/2 = 20$ m/s
ANSWER: Average velocity = 20 m/s in the positive direction.

GRAPH ALERT
A graph is not the physical path. A horizontal position-time line at 40 m means the object remains 40 m from the origin; it does not mean the object “moves horizontally”.



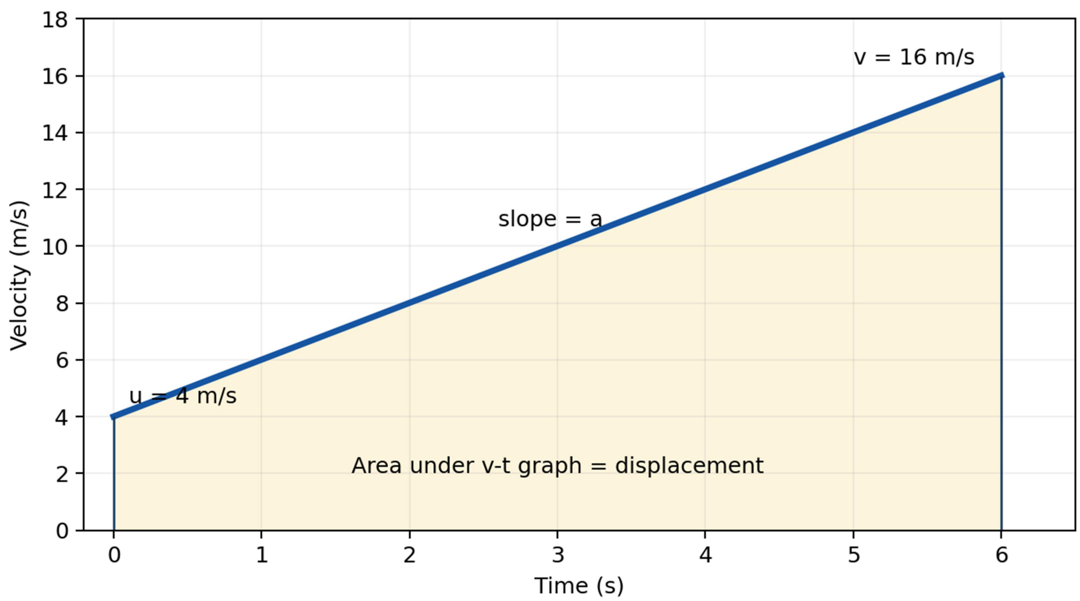
Velocity-time: constant velocity, uniform acceleration and uniform deceleration

Velocity-time graph

- X-axis: time; Y-axis: velocity.
- Horizontal line above time axis → constant non-zero velocity; acceleration = 0.
- Upward straight line → velocity increases by equal amounts in equal times; constant acceleration.
- Downward straight line → velocity decreases by equal amounts in equal times; constant acceleration opposite to the chosen positive direction.
- Slope = acceleration.
- Area between the velocity-time line and time axis over an interval = displacement in that interval.

Slope of velocity-time graph = Δvelocity / Δtime = acceleration

Area under velocity-time graph = displacement



A trapezoidal area under a v-t line represents displacement

SOLVED EXAMPLE | Displacement from constant velocity
GIVEN: v = 20 m/s for 6 s
FIND: displacement
FORMULA: area under v-t graph = rectangle
s = 20 × 6 = 120 m
ANSWER: Displacement = 120 m.

SOLVED EXAMPLE | Displacement from accelerating v-t graph
GIVEN: u = 4 m/s, v = 16 m/s, t = 6 s, constant acceleration

FIND: displacement
FORMULA: area of trapezium = 1/2(u+v)t
$s = 1/2(4+16)\times 6$
$s = 10\times 6 = 60$ m
ANSWER: Displacement = 60 m.

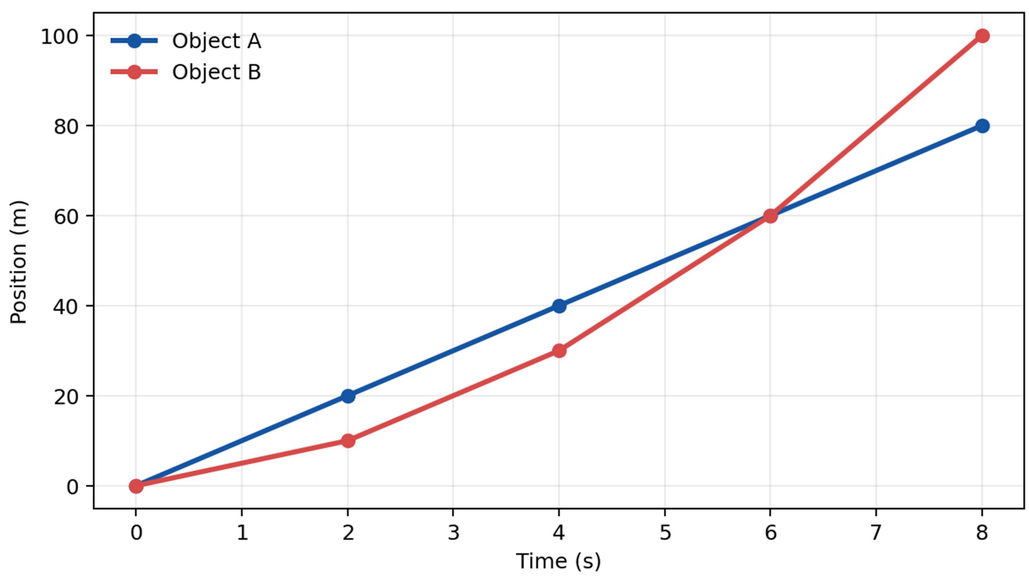
7. Read a graph in 5 steps

1. Check the X-axis quantity and unit.
2. Check the Y-axis quantity and unit.
3. Read the scale carefully.
4. Observe slope/shape and divide the graph into intervals if needed.
5. Translate each interval into physics: rest/constant velocity/acceleration/deceleration, then calculate slope or area only if asked.

DON'T CONFUSE
Steeper line means a larger rate of change, but what that rate means depends on the axes. On a position-time graph slope is velocity; on a velocity-time graph slope is acceleration.

Graph feature	Position-time meaning	Velocity-time meaning
Horizontal line	At rest at a fixed position	Constant velocity; not necessarily rest
Positive straight slope	Constant positive velocity	Constant positive acceleration
Curved line	Changing velocity	Outside the chapter's simple constant-acceleration line cases unless interpreted qualitatively
Area under graph	No standard Motion meaning here	Displacement

Graph practice



Practice: compare slopes and average velocities of A and B

- From 0-8 s, which object has the larger average velocity?
- At which time do A and B have the same position?
- Between 6-8 s, which graph is steeper? What does that tell you?

SECTION C · Equations of Motion · Constant Acceleration Only

8. Conditions before using kinematic equations

USE ONLY WHEN
Motion is treated along a straight line and acceleration is constant over the interval. Choose one positive direction and keep signs consistent.

Symbol	Meaning	SI unit
u	initial velocity	m/s
v	final velocity	m/s
a	constant acceleration	m/s²
t	time interval	s
s	displacement	m

$$v = u + at$$

Connects u, v, a and t
$s = ut + \frac{1}{2}at^2$ Connects s, u, a and t
$v^2 = u^2 + 2as$ Useful when time t is absent

Need v?	Need s?	No time t?
Know u, a, t	Know u, a, t	Know u, v, a/s
$v = u + at$	**$s = ut + 1/2\ at^2$**	**$v^2 = u^2 + 2as$**

First list u, v, a, t, s. Then choose the equation with only one unknown.

9. Graphical / logical derivation

Equation 1: $v = u + at$

For a straight velocity-time line, slope = acceleration: $a = (v-u)/t$. Therefore $at = v-u$, giving $v = u + at$.

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

Displacement equals the area under the velocity-time graph. Split the area into a rectangle and a triangle:

$$s = ut + \tfrac{1}{2}(v-u)t$$

From $v-u = at$, substitute to obtain:

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

Equation 3: $v^2 = u^2 + 2as$

Eliminate t using $t = (v-u)/a$ in the second equation, simplify, and obtain:

$$v^2 = u^2 + 2as$$

EXTRA USEFUL FORMS

Two equivalent forms are useful in some problems: $s = vt - \frac{1}{2}at^2$ and $s = \frac{1}{2}(u+v)t$. Master the three main equations first, then use these as shortcuts when suitable.

10. Which equation should I use?

Known quantities	Unknown wanted	Most direct choice
u, a, t	v	$v = u + at$
u, a, t	s	$s = ut + \frac{1}{2}at^2$
u, v, a	s	$v^2 = u^2 + 2as$
u, v, t	s	$s = \frac{1}{2}(u+v)t$ (constant acceleration)
v, a, t	s	$s = vt - \frac{1}{2}at^2$ (constant acceleration)

11. Numerical Smart Method

GIVEN → FIND → FORMULA → SUBSTITUTE → SOLVE → UNIT → CHECK

- First list u, v, a, t and s with units.
- Convert km/h to m/s before mixing with seconds and metres.
- Choose one equation with only one unknown.
- Keep signs: braking acceleration is negative if forward is positive.
- Check the final unit and whether the numerical size makes physical sense.

12. Unit conversion

$$1\ \text{km/h} = 5/18\ \text{m/s} \quad | \quad 1\ \text{m/s} = 18/5\ \text{km/h}$$

Logic: 1 km/h = 1000 m / 3600 s = 5/18 m/s. The reverse factor is its reciprocal.

SOLVED EXAMPLE | Convert 54 km/h

GIVEN: 54 km/h
FIND: m/s
FORMULA: multiply by 5/18
$54 \times 5/18 = 3 \times 5 = 15$
ANSWER: 54 km/h = 15 m/s.

NUMERICAL ALERT
Never use 54 km/h directly with time in seconds in SI equations. Convert first.

Solved Numerical & Graph Bank

LEVEL 1 · Foundation

SOLVED EXAMPLE | Average speed on two legs
GIVEN: 16 m in 4 s, then 16 m in 2 s
FIND: average speed
FORMULA: total distance / total time
Total distance = 32 m
Total time = 6 s
Average speed = 32/6 = 5.33 m/s
ANSWER: 5.33 m/s.

SOLVED EXAMPLE | Direct acceleration
GIVEN: $u = 6$ m/s, $v = 18$ m/s, $t = 4$ s
FIND: a
FORMULA: $a = (v-u)/t$
$a = (18-6)/4 = 12/4$
ANSWER: 3 m/s².

SOLVED EXAMPLE | Distance from rest
GIVEN: $u = 0$, $a = 3$ m/s², $t = 8$ s
FIND: s
FORMULA: $s = ut + \frac{1}{2}at^2$
$s = 0 + \frac{1}{2}\times3\times8^2$
$s = 1.5\times64 = 96$
ANSWER: 96 m.

LEVEL 2 · CBSE Exam Standard

SOLVED EXAMPLE | Car reaches 24 m/s
GIVEN: $u = 0$, $v = 24$ m/s, $t = 6$ s
FIND: a and s
FORMULA: $a=(v-u)/t$; $s=ut+\frac{1}{2}at^2$
$a = 24/6 = 4$ m/s²
$s = 0 + \frac{1}{2}\times4\times6^2 = 72$ m
ANSWER: Acceleration = 4 m/s²; displacement = 72 m.

SOLVED EXAMPLE | Motorbike braking
GIVEN: $u = 28$ m/s, $v = 0$, $s = 98$ m
FIND: a and t
FORMULA: $v^2=u^2+2as$; $v=u+at$
$0 = 28^2 + 2a(98) \rightarrow a = -784/196 = -4$ m/s²
$0 = 28 - 4t \rightarrow t = 7$ s
ANSWER: Acceleration = -4 m/s²; stopping time = 7 s.

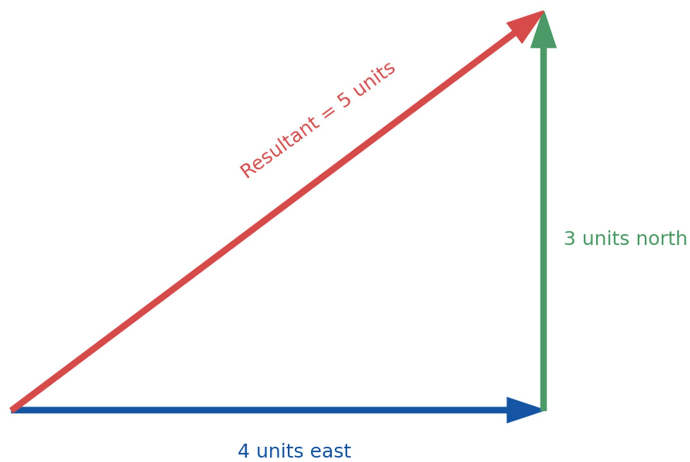
SOLVED EXAMPLE | Truck slows from 54 to 36 km/h
GIVEN: $u = 54$ km/h = 15 m/s, $v = 36$ km/h = 10 m/s, $t = 36$ s
FIND: distance
FORMULA: $s = \frac{1}{2}(u+v)t$
$s = \frac{1}{2}(15+10)\times36$
$s = 12.5\times36 = 450$
ANSWER: 450 m.

SOLVED EXAMPLE | Three-stage car journey
GIVEN: 0→20 m/s in 5 s; then 20 m/s for 10 s; then 20→0 m/s in 6 s
FIND: total distance
FORMULA: area under v-t graph
Stage 1 triangle = $\frac{1}{2}\times5\times20 = 50$ m

Stage 2 rectangle = 10×20 = 200 m
Stage 3 triangle = ½×6×20 = 60 m
Total = 50+200+60 = 310 m
ANSWER: Total distance/displacement in one direction = 310 m.

SOLVED EXAMPLE | Will the bus stop in time?
GIVEN: u = 36 km/h = 10 m/s; obstacle 30 m ahead; reaction time 0.5 s; braking a = -2.5 m/s²
FIND: total stopping distance
FORMULA: reaction distance = ut; braking: $v^2=u^2+2as$
Reaction distance = 10×0.5 = 5 m
Braking: 0 = 100 + 2(-2.5)s → s = 20 m
Total stopping distance = 25 m
ANSWER: Yes. It stops 5 m before the obstacle (30 - 25 = 5 m).

LEVEL 3 · Advanced Edge



Advanced Edge: triangle method of vector addition

ADVANCED EDGE | Resultant displacement
GIVEN: 4 units east, then 3 units north
FIND: resultant displacement
FORMULA: Pythagoras for the right-triangle resultant
$R = \sqrt{(4^2+3^2)} = \sqrt{25}$
ANSWER: 5 units, directed from the starting point toward the final point (north-east).

ADVANCED EDGE | Sita: coordinates
GIVEN: A(1,1) house; B(3,1) bus stop; C(3,5) signal; D(4,5) school; distances in km
FIND: foot distance, bus distance, total displacement
FORMULA: path lengths + coordinate separation
AB = 2 km
BC = 4 km, CD = 1 km → bus distance = 5 km
$AD = \sqrt{[(4-1)^2+(5-1)^2]} = \sqrt{(9+16)} = 5$ km
ANSWER: On foot = 2 km; by bus = 5 km; displacement house→school = 5 km.

ADVANCED EDGE | Distance/displacement in 6th second
GIVEN: u = 0, a = 4 m/s², n = 6
FIND: displacement during 6th second
FORMULA: $s_n = u + (a/2)(2n-1)$
$s_n = 0 + (4/2)(12-1)$
$s_n = 2×11 = 22$ m
ANSWER: 22 m during the 6th second (same as distance here because motion remains in one direction).

ADVANCED EDGE | 5th second
GIVEN: u = 8 m/s, a = 2 m/s², n = 5
FIND: displacement during 5th second
FORMULA: $s_n = u + (a/2)(2n-1)$
$s_n = 8 + (2/2)(10-1)$
$s_n = 8+9 = 17$ m
ANSWER: 17 m during the 5th second.

13. Graph problem bank

Graph Q1
A position-time line goes from (2 s, 20 m) to (7 s, 70 m). Find average velocity. Answer: (70-20)/(7-2) = 10 m/s.

Graph Q2
A v-t line rises from 5 m/s at 0 s to 17 m/s at 6 s. Find acceleration and displacement. Answer: a = 2 m/s²; s = area trapezium = ½(5+17)×6 = 66 m.

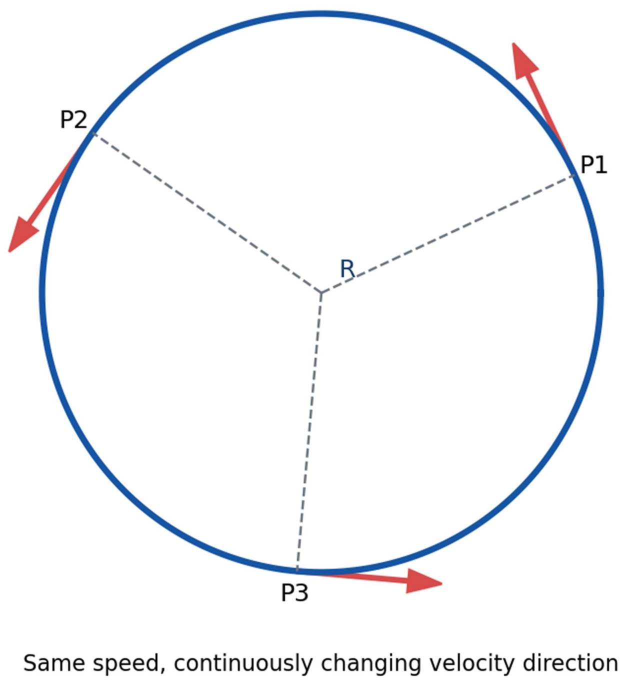
Graph Q3
A horizontal p-t line is at 35 m from t = 2 s to t = 9 s. What is the velocity? Answer: 0 m/s; the object is at rest at position 35 m.

Graph Q4
A horizontal v-t line is at 12 m/s for 8 s. Is the object at rest? No. It moves with constant velocity; acceleration is zero and displacement is 96 m.

SECTION D · Uniform Circular Motion

14. Uniform circular motion

Circular motion is motion along a circular path. If speed is constant on that circular path, the motion is called uniform circular motion.



Velocity is tangent to the circle; its direction changes continuously

- Distance in one complete revolution = circumference = 2πR.
- Displacement after one complete revolution = 0.
- If one revolution takes time T, average speed for the revolution = 2πR/T.
- In uniform circular motion, speed is constant but velocity changes because its direction changes continuously.
- Therefore, the motion is accelerated even though speed does not change.

$$v = 2\pi R / T$$

Speed in uniform circular motion; R = radius, T = time for one revolution

KEEP THE FOCUS
At this level, focus on constant speed + changing velocity direction and v = 2πR/T. Detailed centripetal-force and centripetal-acceleration formulae come later.

SOLVED EXAMPLE | Minute-hand tip over 90 min
GIVEN: radius R = 7 cm; time = 90 min = 1.5 revolutions
FIND: distance and displacement
FORMULA: distance = revolutions × 2πR; displacement after 1.5 rev = diameter
Distance = 1.5×2π×7 = 21π cm ≈ 66.0 cm
After 1.5 revolutions the tip is opposite the starting point
Displacement magnitude = 2R = 14 cm
ANSWER: Distance ≈ 66.0 cm; displacement = 14 cm toward the point opposite the start.

SECTION E · Advanced Edge · Enrichment

15. Frame of reference

A frame of reference provides the viewpoint or coordinate system from which motion is described. Two useful frame types are:

Frame	Meaning at this level	Key idea
Inertial frame	At rest or moving with constant velocity	Newton's laws work without special correction.
Non-inertial frame	Accelerating frame	Additional apparent-effect reasoning is needed; detailed pseudo-force treatment belongs with the laws-of-motion chapter.

MOTION IS RELATIVE
Two students walking side-by-side with the same velocity are at rest relative to each other but moving relative to the classroom/ground.

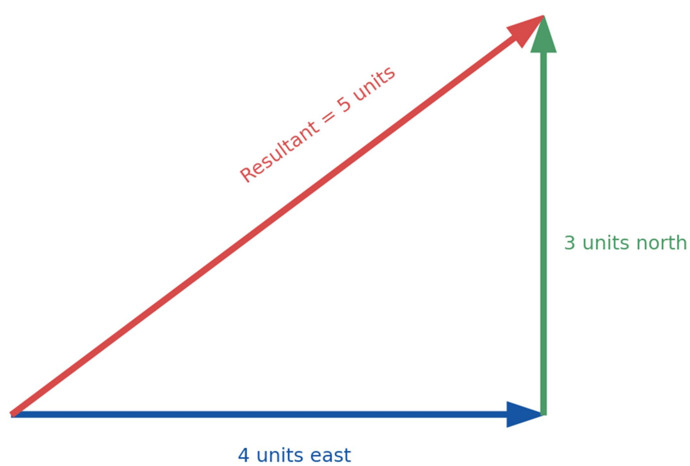
16. Scalars and vectors

Scalar (magnitude only)	Vector (magnitude + direction)
distance	displacement
time	velocity
mass	acceleration
speed	force

CORE vs ADVANCED EDGE
For the core chapter, focus first on whether direction matters. The formal scalar/vector labels and graphical vector operations are enrichment.

17. Graphical vector addition and subtraction

- Triangle method: draw the second vector from the head of the first; resultant joins the tail of the first to the head of the second.
- Parallelogram method: draw both vectors from the same point and complete the parallelogram; the diagonal from the common tail is the resultant.
- Vector subtraction A - B can be treated graphically as A + (-B), where -B has the same magnitude as B but opposite direction.
- Two equal and opposite vectors have zero resultant.



18. Displacement during the nth second

For constant acceleration, total displacement after n seconds is $S(n) = un + \frac{1}{2}an^2$. The displacement during the nth second is S(n) - S(n-1):

$$s_n = u + (a/2)(2n - 1)$$

n is a positive integer. This is for the single interval from (n-1) s to n s.

SIGN ALERT
This relation gives displacement during the nth one-second interval. If direction reverses within an interval, actual distance requires separate path analysis.

19. High-Value Exam Memory Pages

Important definitions

Term	Student-friendly definition	Exam words / unit
Position	Location relative to a chosen reference point	distance + direction from reference
Motion	Position changes with time relative to reference	relative to reference point
Distance	Total path length travelled	m
Displacement	Net change in position	m + direction

Term	Student-friendly definition	Exam words / unit
Average speed	Total distance / total time	m/s
Average velocity	Displacement / time interval	m/s + direction
Average acceleration	Change in velocity / time interval	m/s^2 + direction
Uniform motion in straight line	Equal distances in equal time intervals; constant speed	one-direction simplified case
Uniform circular motion	Circular path with constant speed	velocity direction changes

Formula sheet

What	Formula	Condition / reminder
Average speed	distance / time	Use total distance and total time
Average velocity	displacement / time	Direction required
Acceleration	$(v-u)/t$	Average; straight-line sign convention
Equation 1	$v = u + at$	constant acceleration
Equation 2	$s = ut + \frac{1}{2}at^2$	constant acceleration
Equation 3	$v^2 = u^2 + 2as$	constant acceleration; no t needed
p-t slope	Δposition/Δtime	average velocity
v-t slope	Δvelocity/Δtime	acceleration
v-t area	displacement	signed area if graph crosses axis
UCM speed	$2\pi R/T$	one revolution, constant speed
Conversion	km/h × 5/18 = m/s	reverse ×18/5
Nth-second relation	$u + a/2(2n-1)$	single nth-second interval

Don’t confuse

Confusion	One-line correction
Distance vs displacement	Path length vs net change in position.
Speed vs velocity	Distance-rate without direction vs displacement-rate with direction.
Average speed vs average velocity	Use total distance for speed; displacement for velocity.
Uniform speed vs uniform velocity	Constant speed can still have changing direction; uniform velocity cannot.
Acceleration vs velocity	Acceleration is rate of change of velocity, not “how fast” the object is.
Negative acceleration vs slowing	Negative sign states direction; slowing depends on relation between v and a.
Position-time vs velocity-time slope	p-t slope → velocity; v-t slope → acceleration.
Graph slope vs graph area	Slope is rate of change; v-t area is displacement.
u vs v	u is initial, v is final velocity for the chosen interval.
hours vs seconds	Convert to a single consistent unit system before substitution.
km/h vs m/s	Use ×5/18 or ×18/5 as appropriate.
Horizontal graph line	p-t: rest; v-t: constant velocity.

20. Activities → Exam Connections

Activity / idea	Observation	Concept learned	Exam connection
Ball up and back along a line	Distance keeps increasing; final displacement can become zero	distance vs displacement	round-trip questions
Compare car 0-100 km/h times	same velocity change over different time gives different acceleration	average acceleration	$a=(v-u)/t$
Plot position data	points form straight line or curve	constant vs changing velocity	interpret p-t graphs
Find slope on p-t graph	Δposition/Δtime	average velocity	graph numerical
Find slope/area on v-t graph	slope gives a; area gives s	graph calculus idea at Class IX level	graph numerical / derivation
Marble released from circular ring	moves along tangent direction	instantaneous velocity direction in circle	UCM concept
Smartphone accelerometer	small accelerations can be measured	real-life sensing and data	inquiry / activity

Conceptual WHY questions with model answers

WHY? Why can distance not be negative?
Distance is total path length; path length is a non-negative magnitude.

WHY? Why can displacement be zero after motion?
If final position equals initial position, net change in position is zero even though a path was travelled.

WHY? Why can constant speed still mean changing velocity?
Velocity includes direction. In circular motion direction changes continuously.

WHY? Why does p-t slope represent velocity?
Slope is change in position divided by change in time, exactly the definition of average velocity over the interval.

WHY? Why does a horizontal p-t line mean rest?
Position does not change while time passes, so displacement over every interval is zero.

WHY? Why are kinematic equations not valid for every motion?
These equations assume constant acceleration over the chosen straight-line interval.

WHY? Can a very fast object have zero acceleration?
Yes. If its velocity stays constant, acceleration is zero regardless of how large that velocity is.

WHY? Why is area under v-t graph displacement?
velocity × time has unit metre, and geometrically summing velocity×small-time intervals gives net change in position.

Error-detection practice

ERROR DETECTION
A student writes average velocity = total distance / total time. Correction: Error: that is average speed. Average velocity uses displacement.

ERROR DETECTION
A student uses u = 54 km/h, t = 10 s directly in s = ut. Correction: Error: units are inconsistent. Convert 54 km/h to 15 m/s first.

ERROR DETECTION
A student says a horizontal v-t graph means the object is at rest. Correction: Not always. It means constant velocity; rest only if that constant velocity is zero.

ERROR DETECTION
A student says negative acceleration always means slowing down. Correction: False. If velocity is also negative, negative acceleration can increase speed.

ERROR DETECTION
A student finds “distance” from signed area under a v-t graph that crosses below zero. Correction: Signed area gives displacement. Distance requires adding path magnitudes interval by interval.

21. Topic-wise Practice, HOTS & Case-Based Questions

Short practice after major topics

Reference, distance & displacement

- 1 mark: Define displacement.
- 2 mark: Give one situation where distance is non-zero but displacement is zero.
- 3 mark: A student walks 60 m east and 25 m west. Find distance and displacement.
- Assertion-Reason: A full lap on a circular track can have zero displacement although distance is non-zero. Explain.

Speed, velocity & acceleration

- 1 mark: State the SI unit of acceleration.
- 2 mark: A runner covers 200 m north in 40 s. Find average velocity.
- 3 mark: A car changes velocity from 8 m/s to 20 m/s in 6 s. Find acceleration.
- Reasoning: Can speed be constant while acceleration is non-zero? Give the chapter example.

Graphs

- 1 mark: What does slope of a velocity-time graph represent?
- 2 mark: What does a horizontal position-time graph represent?
- 3 mark: A v-t line is constant at 15 m/s for 8 s. Find displacement.
- Graph reasoning: Two p-t lines start together; B is steeper. Which has larger velocity and why?

Kinematic equations

- 1 mark: State one condition for using the equations of motion.
- 2 mark: Choose the most direct equation if u, v and a are known but t is not given.
- 3 mark: A car starts from rest at 2 m/s² for 5 s. Find final velocity and displacement.
- Error check: A student uses a = +4 m/s² for a braking car when forward is positive. What should be reconsidered?

Uniform circular motion

- 1 mark: Define uniform circular motion.
- 2 mark: Why is velocity not constant in UCM?
- 3 mark: A point moves on a circle of radius 3.5 m and takes 11 s per revolution. Find speed using π = 22/7.

HOTS / application

HOTS
A car doubles its initial braking speed while the braking acceleration magnitude remains the same. From $v^2=u^2+2as$, how does ideal braking distance change? Answer: With v=0, stopping distance □ u^2. Doubling u makes braking distance 4 times, ignoring reaction distance.

HOTS
Two objects have the same average velocity over 10 s. Must they have the same average speed? Answer: No. They may have different path lengths but the same net displacement.

HOTS
A p-t graph bends upward and becomes steeper with time. What does this indicate? Answer: Velocity magnitude is increasing; the motion is accelerated.

HOTS
A vehicle’s speedometer remains constant while it turns around a circular roundabout. Is acceleration zero? Answer: No. Velocity direction changes, so acceleration is non-zero.

HOTS
Why should safe following distance increase at higher speed? Answer: Reaction distance increases with speed, and for a similar braking acceleration the braking distance grows roughly with speed squared.

CBSE-style case-based sets

CASE 1 · School bus
A bus moves at 36 km/h. The driver sees a barrier 30 m ahead, reacts after 0.5 s, then brakes with constant acceleration -2.5 m/s^2. (i) Convert speed to m/s. (ii) Find reaction distance. (iii) Find braking distance. (iv) Decide whether it stops safely.

CASE 2 · Racing track
An athlete completes one full circular lap at constant speed. (i) Compare distance and displacement for one lap. (ii) Compare average speed and magnitude of average velocity. (iii) Explain why instantaneous velocity changes.

CASE 3 · Train graph
A train’s v-t graph rises linearly from 0 to 18 m/s in 6 s, stays at 18 m/s for 10 s, then falls linearly to zero in 4 s. (i) Identify each type of motion. (ii) Find acceleration in stage 1. (iii) Find total displacement by area.

CASE 4 · Position-time comparison
Objects A and B start at the origin. A has a straight p-t line; B has an upward-curving p-t graph. (i) Which has constant velocity? (ii) Which is accelerated? (iii) What does increasing steepness of B mean?

1-Page Formula + Graph Revision Sheet

LAKSHYA QUICK SHEET · Formula + Graph

Item	Must remember
Distance	Total path length; m; no direction.
Displacement	Net change in position; m + direction; |displacement| ≤ distance.
Average speed	total distance / total time.
Average velocity	displacement / time interval.
Acceleration	$a=(v-u)/t$; m/s^2.
p-t slope	average velocity.
v-t slope	acceleration.
v-t area	displacement.
Equation 1	$v=u+at$.
Equation 2	$s=ut+\frac{1}{2}at^2$.
Equation 3	$v^2=u^2+2as$.
UCM	constant speed + changing velocity direction; $v=2\pi R/T$.
Conversion	km/h×5/18=m/s; m/s×18/5=km/h.

GRAPH SHAPES
p-t horizontal → rest | p-t straight slope → constant velocity | p-t curve → changing velocity | v-t horizontal → constant velocity & zero acceleration | v-t straight rising/falling → constant acceleration.

KEY CONDITIONS
Kinematic equations: straight-line interval + constant acceleration. Keep signs consistent. Graph axes must include quantity and unit.

ADVANCED ONLY
Inertial/non-inertial frames; scalars/vectors; graphical vector addition/subtraction; nth-second relation.

Lakshya 10-15 Minute Revision Sheet

10-15 MINUTES · COMPLETE CHAPTER RECALL

MUST REMEMBER
1. Motion is change in position with time relative to a reference point. Position needs distance + direction from that reference.

MUST REMEMBER
2. Distance is path length; displacement is net change in position. |displacement| ≤ distance. A round trip can have displacement = 0.

MUST REMEMBER
3. Average speed = total distance/total time; average velocity = displacement/time.

MUST REMEMBER
4. Uniform straight-line motion: equal distances in equal time intervals; constant velocity → a = 0.

MUST REMEMBER
5. Acceleration = change in velocity/time. A negative sign gives direction; it does not by itself prove slowing.

MUST REMEMBER
6. Graph language: position-time and velocity-time. p-t slope = velocity; v-t slope = acceleration; v-t area = displacement.

MUST REMEMBER
7. Horizontal p-t = rest. Horizontal v-t above zero = motion at constant velocity.

MUST REMEMBER
8. Constant-acceleration equations: $v=u+at$; $s=ut+\frac{1}{2}at^2$; $v^2=u^2+2as$.

MUST REMEMBER
9. Before numerical: list u,v,a,t,s → convert units → choose sign → choose equation → solve → unit check.

MUST REMEMBER
10. 1 km/h = 5/18 m/s. 1 m/s = 18/5 km/h.

MUST REMEMBER
11. Uniform circular motion: speed constant, velocity direction changes, so acceleration is non-zero; speed = $2\pi R/T$.

MUST REMEMBER
12. Advanced Edge: frame of reference, scalar/vector, graphical vector operations, and $s_n=u+a/2(2n-1)$.

Lakshya Smart Check

Do this closed-book. Answers follow separately.

A. MCQs (5)

1. An object returns to its starting point. Which must be zero? (A) distance (B) displacement (C) average speed (D) time
2. The slope of a position-time graph gives: (A) acceleration (B) displacement (C) average velocity (D) distance
3. A horizontal velocity-time line at 12 m/s means: (A) rest (B) zero acceleration (C) negative acceleration (D) increasing speed
4. Which equation does not contain time? (A) $v=u+at$ (B) $s=ut+\frac{1}{2}at^2$ (C) $v^2=u^2+2as$ (D) $a=(v-u)/t$
5. In uniform circular motion: (A) velocity is constant (B) acceleration is zero (C) speed is constant but velocity changes (D) displacement per revolution equals circumference.

B. Very short answer (5)

6. Define displacement.
7. State the SI unit of acceleration.
8. Convert 72 km/h to m/s.
9. What does area under a velocity-time graph represent?
10. When are distance and magnitude of displacement equal in straight-line motion?

C. Conceptual (5)

11. Why can average velocity be zero while average speed is non-zero?
12. Why can a fast car have zero acceleration?
13. Why does a horizontal position-time graph represent rest?

14. Why can constant speed on a circle still involve acceleration?
15. Is negative acceleration always retardation? Explain briefly.

D. Numericals (5)

16. A cyclist covers 300 m in 50 s. Find average speed.
17. Velocity changes from 5 m/s to 17 m/s in 6 s. Find acceleration.
18. A car starts from rest with $a=2$ m/s^2 for 8 s. Find v and s.
19. A train moving at 20 m/s stops uniformly in 5 s. Find acceleration and stopping distance.
20. A circular track has radius 14 m. One round takes 44 s. Find uniform speed using $\pi=22/7$.

E. Graph-based (3)

21. A p-t line goes from (1 s, 10 m) to (5 s, 50 m). Find average velocity.
22. A v-t line is horizontal at 8 m/s for 12 s. Find acceleration and displacement.
23. A v-t line rises from 0 to 12 m/s in 4 s. Find acceleration and displacement in 4 s.

F. Error detection (2)

24. “Average velocity = total distance / total time.” Identify and correct the error.
25. “A horizontal v-t graph means the object is at rest.” Identify and correct the error.

G. HOTS / Application (2)

26. Under the same braking acceleration, a car doubles its speed before braking. How does ideal braking distance change?
27. Two cars have equal average velocity over 10 s. Must they have equal average speed? Explain.

Lakshya Smart Check - Detailed Answer Key

Q	Answer
1	B - displacement.
2	C - average velocity over the chosen interval.
3	B - velocity is constant, so acceleration is zero.
4	C - $v^2=u^2+2as$.
5	C - speed is constant but velocity direction changes.
6	Displacement is the net change in position between two instants, with magnitude and direction.
7	m/s^2.
8	$72\times5/18 = 20$ m/s.
9	Displacement over the interval.
10	When the object moves in one direction along a straight line without turning back.
11	A round trip can have zero displacement but non-zero distance; thus average velocity can be zero while average speed is positive.
12	Acceleration depends on change in velocity. If velocity is constant, acceleration is zero even if velocity is large.
13	Its position does not change as time passes; slope = 0, so velocity = 0.
14	Velocity changes direction continuously on a circle, so velocity changes and acceleration is non-zero.
15	No. Negative acceleration only gives direction relative to the chosen positive axis. If velocity is also negative, speed may increase.
16	Average speed = 300/50 = 6 m/s.
17	$a=(17-5)/6 = 2$ m/s^2.
18	$v=0+2\times8=16$ m/s; $s=\frac{1}{2}\times2\times8^2=64$ m.
19	$a=(0-20)/5=-4$ m/s^2; $s=\frac{1}{2}(20+0)\times5=50$ m.
20	$v=2\pi R/T = 2\times(22/7)\times14/44 = 2$ m/s.
21	$(50-10)/(5-1)=40/4=10$ m/s.
22	$a=0$; $s=8\times12=96$ m.
23	$a=12/4=3$ m/s^2; $s=\frac{1}{2}\times4\times12=24$ m.
24	The formula shown is average speed. Correct: average velocity = displacement / total time interval.
25	Horizontal v-t means constant velocity. It represents rest only if the line lies at $v=0$.
26	Stopping distance $\propto u^2$ for fixed braking acceleration magnitude. Doubling speed makes ideal braking distance 4 times.
27	No. Equal average velocity means equal displacement/time, not equal total path length/time. Their average speeds can differ.