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Describing Motion Around Us Class 9 Notes | CBSE Science Chapter 4

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Describing Motion Around Us Class 9 Notes | CBSE Science Chapter 4

Describing Motion Around Us is Chapter 4 of CBSE Class 9 Science (Exploration, 2026-27). It teaches you to describe motion in a straight line with numbers, equations and graphs. You start with position and a reference point, then move to distance travelled and displacement, average speed and average velocity, and average acceleration. The chapter then covers position-time and velocity-time graphs, the three kinematic equations for constant acceleration, and uniform circular motion.

This chapter is heavy on numericals. School exams set questions on distance versus displacement, unit conversion from km/h to m/s, slope and area of motion graphs, and braking-distance problems solved with $v^2 = u^2 + 2as$. The same ideas return in Class 10 and in every later physics course, so the habits you build here (choosing an origin, fixing a positive direction, writing units at every step) pay off for years.

Quick Answer - Describing Motion Around Us in 30 Seconds

Distance travelled is the full path length; displacement is the net change in position, with a direction. Average speed = total distance / time interval, average velocity = displacement / time interval, and average acceleration = $(v - u) / t$. The slope of a position-time graph gives velocity, the slope of a velocity-time graph gives acceleration, and the area under a velocity-time graph gives displacement. For constant acceleration: $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$. Uniform circular motion is accelerated because the direction of velocity keeps changing.

All Key Formulas at a Glance

Quantity	Formula	SI Unit
Average speed	total distance travelled / time interval	m/s (m s^{-1})
Average velocity	$v_{av} = s / t$ (displacement / time interval)	m/s, with direction
Average acceleration	$a = (v - u) / (t_2 - t_1)$	m/s^2 (m s^{-2})
First kinematic equation	$v = u + at$	m/s
Second kinematic equation	$s = ut + \frac{1}{2}at^2$	m
Third kinematic equation	$v^2 = u^2 + 2as$	m^2/s^2
Displacement from average of velocities	$s = \frac{1}{2}(u + v)t$	m
Slope of position-time graph	$(s_2 - s_1) / (t_2 - t_1) = \text{velocity}$	m/s
Slope and area of velocity-time graph	slope = acceleration; area under line = displacement	m/s^2 ; m
Average speed in one revolution	$v_{av} = 2\pi R / T$	m/s
Unit conversion	1 km/h = 5/18 m/s (so 36 km/h = 10 m/s)	-

Key Concepts

1. Position, Distance and Displacement

To study the many motions in nature, scientists begin with idealised simple forms. This chapter takes two of them: **linear motion** (motion in a straight line, the simplest kind, such as a ball falling vertically or a train on a straight track) and **uniform circular motion**.

To say where an object is, you first fix a **reference point**. The **position** of an object at an instant is its distance and direction from the reference point at that instant. An object is in **motion** if its position with respect to the reference point changes with time, and at **rest** if it does not. Rest and motion depend on the reference point: a book on your desk is at rest with respect to the room and moves with the Earth around the Sun.

Direction on a straight line: mark the reference point as the origin O on a number line. Positions to the right of O are generally taken as positive (+) and to the left as negative (-). You may choose the origin and the positive direction to suit the problem, but once chosen they must not change until the problem is finished.

Instant and time interval: an instant is a single clock reading, such as $t = 4$ s. A time interval is the duration between two instants, such as $t = 4$ s to $t = 10$ s, which is 6 s.

Distance travelled and displacement

NCERT follows an athlete on a straight track. She starts at O at $t = 0$ s, passes B (40 m from O) at $t = 4$ s, reaches A (100 m) at $t = 10$ s, then runs back to B, reaching it at $t = 16$ s.

- **Total distance travelled** = $OA + AB = 100 \text{ m} + 60 \text{ m} = 160 \text{ m}$, the full length of the path. It needs only a number with a unit.
- **Displacement** = $OB = 40 \text{ m}$ in the positive direction.

Displacement is the net change in position of an object between two given instants. Its **magnitude** (numerical value with unit) is the distance between the two positions, and its direction points from the first position towards the second. The SI unit of both distance and displacement is the **metre (m)**. Quantities given by a numerical value alone are **scalars** (distance, speed); quantities that also need a direction are **vectors** (displacement, velocity, acceleration).

Key rule: magnitude of displacement $\leq$ distance travelled. For straight-line motion the two are equal only if the object moves in one direction without turning back.

Activity 4.1 (ball thrown up): a ball is thrown vertically upward from O on the ground. It rises in a straight line to its highest point B, then falls back along the same line to O, so this is motion in a straight line. At point A, 40 cm above O on the way up, the distance travelled is 40 cm and the displacement is 40 cm upward.

- **Going up to B:** the ball moves in one direction, so distance travelled and magnitude of displacement stay equal, both equal to the height OB at B.
- **Coming down from B:** distance travelled keeps increasing, while the upward displacement decreases, so the two become unequal.
- **Back at O:** distance travelled = $2 \times OB$, and displacement = 0.

Of the options in the activity, the true one is: the magnitude of displacement is less than or equal to the total distance travelled.

So displacement can be zero, and its magnitude never exceeds the distance travelled. Fuel used by a vehicle depends on the total distance travelled: a trip to a market 10 km away and back burns fuel for 20 km though the displacement is zero.

2. Average Speed and Average Velocity

Average speed = **total distance travelled / time interval** (Eq. 4.1). Distance has no direction, so average speed has only a numerical value.

- **Uniform motion in a straight line:** equal distances in equal intervals of time, for all possible choices of intervals. The speed is constant. The vehicle of Table 4.3 covers 20 m every second (0, 20, 40 ... 120 m at 0 to 6 s).
- **Non-uniform motion:** unequal distances in equal intervals. If the distances in successive equal intervals keep increasing, the speed is increasing.

India's scientific contribution: speed as distance divided by time appears in the Aryabhatiya (5th century CE). The Ganitakaumudi (14th century CE) asks when two postmen 210 yojanas apart, walking towards each other at 9 and 5 yojanas per day, will meet. They close 14 yojanas a day, so they meet after $210/14 = 15$ days, having walked 135 and 75 yojanas.

Average velocity tells how fast the position changes and in which direction. It is the displacement divided by the time interval in which it occurs.

Average velocity = displacement / time interval, $v_{av} = s / t$ (Eq. 4.2a, 4.2b)

- Its direction is the direction of displacement, shown on a straight line by a + or – sign.
- SI unit of both average speed and average velocity: **$m\ s^{-1}$ (m/s)**; $km\ h^{-1}$ is also common.
- **Rate of change** is the change in a quantity divided by the corresponding change in time. Average velocity is the average rate of change of position.

km/h to m/s: $1\ km/h = 1000\ m / 3600\ s = 5/18\ m/s$.

km/h	18	36	54	72	90	108
m/s	5	10	15	20	25	30

NCERT Example 4.2: Sarang swims to the far end of a 25 m pool and back in 50 s. Average speed = $50\ m / 50\ s = 1\ m/s$. Displacement is 0, so average velocity = $0\ m/s$.

For straight-line motion, average speed equals the magnitude of average velocity if the object moves in one direction. The average velocity is zero while the average speed is not whenever the object returns to its start.

Velocity at an instant: in this chapter “velocity” alone means the velocity at an instant. As the time interval around an instant is made smaller and smaller, the average velocity approaches a fixed value, the **instantaneous velocity**. A speedometer reads nearly its magnitude, and the direction of the tyres gives its direction.

3. Average Acceleration

The jolt you feel when a vehicle suddenly starts or stops is the feeling of a change in velocity. The **average acceleration** of an object over a time interval is the change in its velocity divided by the time interval. If the velocity changes from u at time t_1 to v at time t_2 :

$a = (v - u) / (t_2 - t_1)$ (Eq. 4.3c)

- SI unit: **$m\ s^{-2}$ (m/s²)**. Acceleration has magnitude and direction.
- If the magnitude of velocity is **increasing**, the acceleration is **along** the velocity.
- If the magnitude of velocity is **decreasing**, the acceleration is **opposite** to the velocity; with velocity taken positive, a comes out negative.
- Acceleration can come from a change in the magnitude of velocity, its direction, or both.

Fast motion with zero acceleration: acceleration measures how quickly velocity changes. A bus on a straight highway at a steady 90 km/h has zero acceleration.

NCERT Example 4.3: a bus speeds up from 36 km/h (10 m/s) to 54 km/h (15 m/s) in 10 s: $a = (15 - 10)/10 = 0.5 \text{ m/s}^2$, along the velocity. It then brakes from 15 m/s to rest in 5 s: $a = (0 - 15)/5 = -3 \text{ m/s}^2$, opposite to the velocity.

Constant acceleration: for motion in a straight line in one direction, if velocity changes by equal amounts in equal intervals of time (for all choices of intervals), the acceleration is constant. This chapter treats only constant acceleration.

NCERT Example 4.4 (falling object): an object dropped from rest (origin at the release point, downward positive) has velocities 0, 9.8, 19.6, 29.4 and 39.2 m/s at $t = 0, 1, 2, 3$ and 4 s. In every 1 s interval the velocity rises by 9.8 m/s, so the average acceleration is 9.8 m/s^2 in each interval. This constant downward acceleration is the **acceleration due to the gravitational force of the Earth**, written **g**. Acceleration at a single instant is called instantaneous acceleration.

4. Position-Time Graphs

Graphs show how position or velocity changes with time, help compare two motions, and separate uniform from non-uniform motion. All graphs in this chapter are for straight-line motion in one direction, where distance equals the magnitude of displacement and speed equals the magnitude of velocity.

Plotting (Activity 4.3): draw the X-axis (time) and Y-axis (position) meeting at origin O; choose a scale that uses the paper well (for Table 4.3: 5 divisions = 1 s on X, 5 divisions = 20 m on Y); plot each (time, position) pair; join the points. Table 4.3 gives a straight line. A graph shows how the position changes with time with respect to the origin. It does not show the route.

Example 4.5 data: a vehicle starting from rest has positions 0, 1, 4, 9, 16, 25 and 36 m at 0, 2, 4, 6, 8, 10 and 12 s. These points lie on a curve that bends upward. (They fit $s = \frac{1}{2} \times 0.5 \times t^2$, a constant acceleration of 0.5 m/s^2 .)

Shape of position-time graph	Meaning
Straight line parallel to the time axis	At rest (NCERT Example 4.6: a vehicle resting 40 m from the origin)
Straight sloping line	Constant velocity, zero acceleration
Curve getting steeper	Velocity increasing: accelerated motion
Steeper of two straight lines	Higher velocity (NCERT Example 4.7: B covers more displacement than A in the same interval)

Velocity from slope (Activity 4.4): take points A and B on the line. Draw a line from A parallel to the X-axis and from B parallel to the Y-axis, meeting at C. BC is the change in position ($s_2 - s_1$) and CA the change in time ($t_2 - t_1$).

$$v = (s_2 - s_1) / (t_2 - t_1) = BC / CA$$

With A at (2 s, 40 m) and B at (4 s, 80 m): $v = 40/2 = 20 \text{ m/s}$. BC/CA is the **slope** (steepness) of AB. The slope of a graph gives the rate of change of the Y-axis quantity with respect to the X-axis quantity, so the slope of a position-time graph is velocity.

5. Velocity-Time Graphs

A velocity-time graph has time on the X-axis and velocity on the Y-axis. NCERT uses three cars on a straight highway:

Time (s)	0	5	10	15	20	25	30
Car 1: steady 72 km/h (m/s)	20	20	20	20	20	20	20
Car 2: Table 4.5 (m/s)	0	2.5	5.0	7.5	10.0	12.5	15.0
Car 3: Table 4.6 (m/s)	15.0	12.5	10.0	7.5	5.0	2.5	0

- **Car 1:** line parallel to the X-axis. Constant velocity, zero acceleration.
- **Car 2:** straight line sloping up. Velocity rises by equal amounts, so acceleration is constant and along the velocity.
- **Car 3:** straight line sloping down. Acceleration is constant and opposite to the velocity.

Slope gives acceleration: with A (t_1 , u) and B (t_2 , v) on the line, $a = (v - u)/(t_2 - t_1) = BC/CA$. Car 2 from 10 s to 20 s: $a = (10 - 5)/10 = 0.5 \text{ m/s}^2$. Car 3 over the same interval: $a = (5 - 10)/10 = -0.5 \text{ m/s}^2$.

Area gives displacement: for Car 1 from 0 to 6 s the region under the line is a rectangle of height 20 m/s and width 6 s. Area = velocity $\times$ time = $20 \times 6 = 120 \text{ m}$, the displacement. In general, **the area enclosed by the velocity-time graph and the time axis over an interval equals the displacement in that interval.**

For Car 2 from 10 s to 20 s, split the region into a rectangle ($5 \text{ m/s} \times 10 \text{ s}$) and a triangle above it (base 10 s, height 5 m/s): displacement = $50 + \frac{1}{2} \times 10 \times 5 = 50 + 25 = 75 \text{ m}$. As a trapezium: $\frac{1}{2} \times (5 + 10) \times 10 = 75 \text{ m}$, a useful cross-check.

6. Kinematic Equations for Constant Acceleration

With constant acceleration, the acceleration at every instant equals the average acceleration. Let u be the velocity at $t = 0$, v the velocity at time t , a the acceleration and s the displacement in time t .

First equation: from $a = (v - u)/t$, $at = v - u$, so **$v = u + at$** (Eq. 4.4a).

Second equation (graphical): the velocity-time graph is a straight line from A on the velocity axis ($OA = u$) to B at time t ($BD = v$, where D is on the time axis and $OD = t$). Draw AC parallel to the time axis, meeting BD at C. Displacement = area OABD:

$$s = \text{area of rectangle OACD} + \text{area of triangle ABC} = (OA \times OD) + \frac{1}{2} \times CA \times BC$$

With $OA = u$, $OD = CA = t$ and $BC = BD - CD = v - u$: $s = ut + \frac{1}{2} \times t \times (v - u)$. Since $v - u = at$, $s = ut + \frac{1}{2} \times t \times at$, so **$s = ut + \frac{1}{2}at^2$** (Eq. 4.4b).

Third equation (eliminate t): put $t = (v - u)/a$ into Eq. 4.4b:

$$s = u(v - u)/a + \frac{1}{2}a(v - u)^2/a^2 = (uv - u^2)/a + (u^2 + v^2 - 2uv)/(2a)$$

$$s = (2uv - 2u^2 + u^2 + v^2 - 2uv)/(2a) = (v^2 - u^2)/(2a), \text{ so } 2as = v^2 - u^2 \text{ and } \mathbf{v^2 = u^2 + 2as} \quad (\text{Eq. 4.4c}).$$

Two more (“The Journey Beyond”): region OABD is a trapezium with parallel sides u and v and width t , so $\mathbf{s = \frac{1}{2}(u + v)t}$. Putting $u = v - at$ into Eq. 4.4b gives $s = (v - at)t + \frac{1}{2}at^2$, so $\mathbf{s = vt - \frac{1}{2}at^2}$.

Quantity not given and not asked	Use
s	$v = u + at$
v	$s = ut + \frac{1}{2}at^2$
t	$v^2 = u^2 + 2as$
a	$s = \frac{1}{2}(u + v)t$

Rules: use these only when acceleration is constant. Convert to SI units first. “Starts from rest” means $u = 0$; “comes to a stop” means $v = 0$. For motion in both directions, the signs of u , v , a and s give their directions, so fix the positive direction at the start.

Braking (NCERT Example 4.8): brakes give a car $a = -4 \text{ m/s}^2$. With $v = 0$, $0 = u^2 - 8s$, so $s = u^2/8$. At 54 km/h (15 m/s), $s = 225/8 = 28.1 \text{ m}$; at 108 km/h (30 m/s), $s = 900/8 = 112.5 \text{ m}$. Doubling the speed makes the braking distance four times as long. The real stopping distance also depends on the road surface, the braking capacity of the vehicle and the driver’s **reaction time**, during which the vehicle keeps moving at its original speed. That is why drivers keep a safe gap from the vehicle ahead and widen it at higher speed. Vehicle-to-vehicle (V2V) communication, being developed in many countries including India, lets vehicles exchange signals and warn drivers of possible collisions.

7. Motion in a Plane and Uniform Circular Motion

Straight-line motion is motion in one dimension. Motion in a plane (a vehicle overtaking another, a kicked ball, a satellite in a circular orbit) is motion in two dimensions. Motion in space, like a bird flying, is three-dimensional.

When an object moves along a circular path, its motion is **circular motion**. A child on a merry-go-round moving from A to B to C covers the arc ABC as distance, while the displacement is the straight line AC.

- One revolution on a circle of radius R : distance = circumference = $\mathbf{2\pi R}$; displacement = $\mathbf{0}$, so the average velocity is 0.
- If one revolution takes time T : $\mathbf{v_{av} = 2\pi R / T}$ (Eq. 4.5).
- Half a revolution: distance πR , displacement $2R$ (the diameter).

Uniform circular motion is motion along a circular path with constant (uniform) speed. The speed is the same at every point, so $2\pi R/T$ also gives the speed at each point.

Direction changes continuously. An athlete on a rectangular track runs straight along each side and changes direction 4 times per round; on a hexagonal track, 6 times. As the number of sides grows, the turns come more often and the track approaches a circle, where the direction of velocity changes at every point.

Activity 4.5 (marble in a ring): a marble rolls along the inside of a ring placed flat on a smooth surface. When the ring is lifted, the marble moves off in a straight line, in the direction it had at that instant. That direction is along the **tangent**, a

straight line that meets the circle at one and only one point. In circular motion the velocity at any point is along the tangent there, in the direction of motion.

Uniform circular motion is accelerated. Velocity changes if its magnitude, its direction, or both change. Here the direction changes all the time, so the velocity changes and the acceleration is non-zero, even at constant speed. A car going round a bend at a steady 40 km/h is accelerating. Uniform circular motion is an idealised model, and it forms the base for studying planets revolving around the Sun and vehicles taking circular turns.

Formula and Reaction Sheet

Quantity	Formula	SI unit	When to use it
Average speed	total distance / time interval	m/s	Direction ignored
Average velocity	$v_{av} = s / t$	m/s	Displacement known; state direction
Average acceleration	$a = (v - u) / (t_2 - t_1)$	m/s^2	Two velocities and the interval
First equation	$v = u + at$	m/s	No s involved
Second equation	$s = ut + \frac{1}{2}at^2$	m	No v involved
Third equation	$v^2 = u^2 + 2as$	-	No t involved
Mean-velocity form	$s = \frac{1}{2}(u + v)t$	m	No a involved
Braking distance	$s = u^2 / (2 \times \text{magnitude of } a)$	m	$v = 0$; grows as u^2
Slope of position-time graph	$(s_2 - s_1)/(t_2 - t_1)$	m/s	Gives velocity
Slope of velocity-time graph	$(v - u)/(t_2 - t_1)$	m/s^2	Gives acceleration
Area under velocity-time graph	rectangle + triangle, or trapezium	m	Gives displacement
Circular motion, one revolution	distance $2\pi R$; displacement 0; $v_{av} = 2\pi R/T$	m; m/s	Radius R, time T
Free fall	$g = 9.8 \text{ m/s}^2$ downward	m/s^2	Dropped objects
Unit conversion	$km/h \times 5/18 = m/s$	-	Before any equation

Important Definitions

Term	Definition
Position	Distance and direction of an object from the reference point at an instant of time
Motion and rest	In motion if the position with respect to the reference point changes with time; at rest if it does not
Instant and time interval	An instant is a single clock reading; a time interval is the duration between two instants
Total distance travelled	Total length of the path covered; numerical value only; SI unit metre
Displacement	Net change in position between two given instants; has magnitude and direction; SI unit metre
Scalar and vector	A scalar needs only a numerical value; a vector needs magnitude and direction
Average speed	Total distance travelled divided by the time interval
Uniform motion	Equal distances in equal intervals of time, for all choices of intervals
Average velocity	Displacement divided by the time interval; $v_{av} = s/t$
Rate of change	Change in a quantity divided by the corresponding change in time
Average acceleration	Change in velocity divided by the time interval; SI unit m/s^2
Acceleration due to gravity (g)	Constant acceleration of a freely falling object, $9.8 m/s^2$ downward
Slope	Steepness of a line; rate of change of the Y-axis quantity with respect to the X-axis quantity
Kinematic equations	Equations relating s , t , u , v and a for straight-line motion with constant acceleration
Uniform circular motion	Motion along a circular path with constant (uniform) speed
Tangent	A straight line that meets a circle at one and only one point

Solved Examples (NCERT-Based)

Example 1: Athlete on a straight track (NCERT Fig. 4.4)

An athlete starts at O at $t = 0$ s, reaches A (100 m from O) at $t = 10$ s, then runs back to B (40 m from O), reaching it at $t = 16$ s. Find the distance, displacement, average speed and average velocity from $t = 0$ to $t = 16$ s.

Solution: Distance = OA + AB = 100 + 60 = **160 m**. Displacement = 40 – 0 = **40 m in the positive direction**.

Average speed = $160/16 = 10 \text{ m/s}$. Average velocity = $40/16 = 2.5 \text{ m/s}$ in the positive direction. From 0 to 10 s she runs one way only, so both come to $100/10 = 10 \text{ m/s}$.

Example 2: A family road trip (NCERT Pause and Ponder)

You drive 200 km north in 3 hours, then 200 km south in 2 hours. Find the average speed and average velocity for the trip.

Solution: Distance = 400 km, time = 5 h. Average speed = $400/5 = 80 \text{ km/h}$. You end where you started, so displacement = 0 and average velocity = **0 km/h**. Averaging 66.7 km/h and 100 km/h to get 83.3 km/h is wrong: use total distance over total time.

Example 3: Bus speeding up and braking (NCERT Example 4.3)

A bus at 36 km/h speeds up to 54 km/h in 10 s. Later it brakes and stops in 5 s. Find the average acceleration in both intervals.

Solution: $36 \text{ km/h} = 36 \times 1000/3600 = 10 \text{ m/s}$; $54 \text{ km/h} = 15 \text{ m/s}$.

(i) $a = (15 - 10)/10 = 0.5 \text{ m/s}^2$, along the velocity. (ii) $a = (0 - 15)/5 = -3 \text{ m/s}^2$, opposite to the velocity.

Example 4: Braking distance at two speeds (NCERT Example 4.8)

Brakes give a car an acceleration of -4 m/s^2 . How far does it travel before stopping if its speed was (i) 54 km/h, (ii) 108 km/h?

Solution: $v = 0$; (i) $u = 15 \text{ m/s}$, (ii) $u = 30 \text{ m/s}$. Time is not involved, so use $v^2 = u^2 + 2as$: $0 = u^2 - 8s$, so $s = u^2/8$.

(i) $s = 225/8 = 28.1 \text{ m}$. (ii) $s = 900/8 = 112.5 \text{ m}$. Double the speed, four times the distance.

Example 5: Motorbike coming to a stop (NCERT Exercise)

A motorbike at 28 m/s with constant acceleration stops after 98 m. Find the acceleration and the time to stop.

Solution: $u = 28 \text{ m/s}$, $v = 0$, $s = 98 \text{ m}$. $v^2 = u^2 + 2as$: $0 = 784 + 196a$, so $a = -4 \text{ m/s}^2$.

$v = u + at$: $0 = 28 - 4t$, so $t = 7 \text{ s}$. Check: $s = \frac{1}{2}(28 + 0) \times 7 = 98 \text{ m}$.

Example 6: Car starting from rest (NCERT Exercise)

A car starts from rest and reaches 24 m/s in 6 s. Find the average acceleration and the distance travelled.

Solution: $a = (24 - 0)/6 = 4 \text{ m/s}^2$. $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 4 \times 36 = 72 \text{ m}$.

Example 7: Three stages of a journey (NCERT Exercise)

A car starts from rest, accelerates uniformly to 20 m/s in 5 s, travels at 20 m/s for 10 s, then brakes uniformly to stop in 6 s. Find the total distance.

Solution: Use the area under the velocity-time graph.

- Stage 1 (triangle): $\frac{1}{2} \times 5 \times 20 = 50$ m
- Stage 2 (rectangle): $20 \times 10 = 200$ m
- Stage 3 (triangle): $\frac{1}{2} \times 6 \times 20 = 60$ m

Total = **310 m** in 21 s.

Example 8: Reaction time and an obstacle (NCERT Exercise)

A bus at 36 km/h sees an obstacle 30 m ahead. The driver takes 0.5 s to react, and the brakes then give a constant acceleration of magnitude 2.5 m/s^2 . Will the bus stop in time?

Solution: $u = 10 \text{ m/s}$. Reaction distance = $10 \times 0.5 = 5$ m. Braking: $0 = 100 - 2 \times 2.5 \times s$, so $s = 20$ m. Total = $25 \text{ m} < 30$ m, so **the bus stops 5 m short of the obstacle**.

Example 9: Tip of a minute hand (NCERT Exercise)

Rohan studies from 6 PM to 7:30 PM. The minute hand of the wall clock is 7 cm long. For its tip, during this interval, find (i) distance travelled, (ii) displacement, (iii) speed, (iv) velocity. Take $\pi = 22/7$.

Solution: 90 min = 5400 s = 1.5 revolutions. The tip moves from the 12 mark to the 6 mark.

(i) Distance = $1.5 \times 2 \times (22/7) \times 7 = \mathbf{66 \text{ cm}}$. (ii) Displacement = diameter = **14 cm**, from the 12 mark towards the 6 mark. (iii) Speed is constant: $2\pi R/T = 44 \text{ cm} / 3600 \text{ s} = \mathbf{0.0122 \text{ cm/s}}$ (the same as $66/5400$). (iv) In this chapter, velocity means the velocity at an instant. Its magnitude equals the speed, **0.0122 cm/s**, and its direction is along the tangent to the circle at the tip's position, so the direction changes continuously. Over the whole interval, average velocity = displacement / time = $14/5400 \approx \mathbf{0.0026 \text{ cm/s}}$, directed from the 12 mark towards the 6 mark.

Competency-Based Questions (with answers)

1. Case-based: Keeping a safe distance

A driving instructor explains that stopping distance = reaction distance (at constant speed while the driver reacts) + braking distance. A learner has a reaction time of 0.8 s and the brakes give an acceleration of magnitude 5 m/s^2 .

(a) Stopping distance at 72 km/h? $u = 20 \text{ m/s}$. Reaction: $20 \times 0.8 = 16$ m. Braking: $400/10 = 40$ m. Total **56 m**.

(b) Stopping distance at 36 km/h? $u = 10 \text{ m/s}$. Reaction 8 m, braking $100/10 = 10$ m. Total **18 m**.

(c) Why did halving the speed cut the braking distance to one-fourth but the reaction distance only to one-half?

Reaction distance = $u \times \text{reaction time}$, proportional to u . Braking distance = $u^2/(2a)$, proportional to u^2 .

2. Data-based: Two cyclists

Cyclists P and Q start together and ride the same way on a straight road.

Time (s)	0	2	4	6	8
P (m)	0	8	16	24	32
Q (m)	0	2	8	18	32

(a) Shape of each position-time graph? P: straight line, uniform motion at 4 m/s. Q: curve getting steeper (2, 6, 10, 14 m in successive 2 s), so Q is accelerating.

(b) Q's acceleration, if constant? From rest, $s = \frac{1}{2}at^2$: $2 = \frac{1}{2} \times a \times 4$, $a = 1 \text{ m/s}^2$. Check at 8 s: $\frac{1}{2} \times 64 = 32 \text{ m}$.

(c) Average velocities over 0 to 8 s, and when are their velocities equal? Both $32/8 = 4 \text{ m/s}$. Q's velocity is $v = 0 + 1 \times t$, which equals 4 m/s at $t = 4 \text{ s}$.

3. Source-based: Travellers in the Ganitakaumudi

The Ganitakaumudi (14th century CE) has a problem of two postmen, 210 yojanas apart, walking towards each other at 9 and 5 yojanas per day; they meet after 15 days. A problem in the same style: two messengers start 280 yojanas apart and walk towards each other at 8 and 6 yojanas per day.

(a) When do they meet? They close 14 yojanas a day: $280/14 = 20 \text{ days}$.

(b) How far does each walk? 160 and 120 yojanas; together 280.

4. Assertion-Reason

Assertion (A): An object moving with constant speed can have an acceleration. **Reason (R):** Velocity changes when the direction of motion changes, even at constant speed.

Answer: (a) Both true, and R correctly explains A. Uniform circular motion is the example.

5. Assertion-Reason

Assertion (A): The magnitude of displacement can be greater than the distance travelled. **Reason (R):** The magnitude of displacement is the straight-line distance between the initial and final positions.

Answer: (d) A is false, R is true. The straight line is the shortest path, so magnitude of displacement $\leq$ distance.

6. Assertion-Reason

Assertion (A): The kinematic equations can be used for a car in city traffic whose acceleration keeps changing. **Reason (R):** They were derived assuming constant acceleration.

Answer: (d) A is false, R is true.

7. Graph reasoning: A lift

A lift moving up has a velocity-time graph that rises in a straight line from 0 to 2 m/s in 2 s, stays at 2 m/s for 6 s, then falls in a straight line to 0 in 2 s.

(a) Acceleration in each stage? 1 m/s^2 upward, 0, and -1 m/s^2 (1 m/s^2 downward, opposite to the velocity).

(b) Height risen? Area = $\frac{1}{2} \times 2 \times 2 + 2 \times 6 + \frac{1}{2} \times 2 \times 2 = 2 + 12 + 2 = 16 \text{ m}$, which is the fourth floor if each floor is 4 m high. Average velocity = $16/10 = 1.6 \text{ m/s}$ upward.

8. Competency MCQ: Circular track

An athlete runs one lap of a circular track of radius 49 m at constant speed in 44 s. Which is correct? (A) Average velocity for the lap is 7 m/s. (B) Displacement after half a lap is 154 m. (C) Average speed for the lap is 7 m/s. (D) Acceleration is zero because the speed is constant.

Answer: (C). Distance = $2 \times (22/7) \times 49 = 308 \text{ m}$, and $308/44 = 7 \text{ m/s}$. (A) fails because displacement for a lap is zero. (B) fails because the half-lap displacement is the diameter, 98 m. (D) fails because the direction of velocity keeps changing.

Important Questions for Exams

1-Mark Questions

- Define displacement.** The net change in position of an object between two given instants, with magnitude and direction.
- SI unit of average acceleration?** m s^{-2} (m/s^2).
- What does the area under a velocity-time graph give?** Displacement in that interval.
- Convert 72 km/h to m/s.** $72 \times 5/18 = 20 \text{ m/s}$.
- A scooter's speedometer reading is constant. Can it be accelerating?** Yes, when it turns, because the direction of velocity changes.

2-Mark Questions

- My father walked to a shop 250 m away on a straight road, came home for a bag, went to the shop again and returned home. Find distance and displacement.** Distance = $4 \times 250 = 1000 \text{ m}$. Displacement = 0 (he ends at home).

2. **A student runs from the ground floor to the fourth floor, then down to the second floor. Each floor is 3 m. Find vertical distance and displacement.** 12 m up + 6 m down = 18 m. Displacement = 6 m upward.
3. **When is (i) average speed equal to the magnitude of average velocity, (ii) average velocity zero while average speed is not?** (i) Straight-line motion in one direction. (ii) When the object returns to its starting point.
4. **"The Earth moves around the Sun." Can an object kept on the Earth be at rest?** Yes, with respect to a reference point on the Earth, since its position relative to that point does not change. With respect to the Sun it moves with the Earth. Rest and motion depend on the reference point.

3-Mark Questions

1. **A truck slows uniformly from 54 km/h to 36 km/h in 36 s. Find the distance travelled.** $u = 15 \text{ m/s}$, $v = 10 \text{ m/s}$. $s = \frac{1}{2}(u + v)t = \frac{1}{2} \times 25 \times 36 = 450 \text{ m}$.
2. **A car moves at 6 m/s for 2 min, then accelerates at 1 m/s^2 for 6 s. Describe the velocity-time graph and find the displacement.** A flat line at 6 m/s up to 120 s, then a line rising to 12 m/s at 126 s. Area = $6 \times 120 + \frac{1}{2} \times (6 + 12) \times 6 = 720 + 54 = 774 \text{ m}$.
3. **Cars A and B start from rest. A reaches 5 m/s in 5 s; B reaches 3 m/s in 10 s. Find their displacements.** $a_A = 1 \text{ m/s}^2$, $a_B = 0.3 \text{ m/s}^2$. Triangle areas: $s_A = \frac{1}{2} \times 5 \times 5 = 12.5 \text{ m}$; $s_B = \frac{1}{2} \times 10 \times 3 = 15 \text{ m}$.
4. **Explain why uniform circular motion is accelerated, using rectangular, hexagonal and circular tracks.** The athlete turns 4 times per round on a rectangle and 6 times on a hexagon. As sides increase the track approaches a circle, where the direction changes at every point. Changing direction means changing velocity, which means acceleration even at constant speed.

5-Mark Questions

1. **Derive $v = u + at$ and, by the graphical method, $s = ut + \frac{1}{2}at^2$.** From $a = (v - u)/t$, $v = u + at$. On the velocity-time graph from A (0, u) to B (t, v), displacement = area OABD = rectangle OACD + triangle ABC = $ut + \frac{1}{2}t(v - u)$. With $v - u = at$, $s = ut + \frac{1}{2}at^2$. Marks go to the labelled graph, the split of the area and the substitution.
2. **Derive $v^2 = u^2 + 2as$. A car at 108 km/h brakes at -6 m/s^2 . Find the stopping distance and time.** Substitute $t = (v - u)/a$ in $s = ut + \frac{1}{2}at^2$ and simplify to $s = (v^2 - u^2)/(2a)$. Numerical: $u = 30 \text{ m/s}$, $s = 900/12 = 75 \text{ m}$, $t = 30/6 = 5 \text{ s}$. Check: $\frac{1}{2} \times 30 \times 5 = 75 \text{ m}$.
3. **A car's velocity is 0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0 m/s at 0, 5, 10 ... 30 s. Describe the graph, find the acceleration, and the displacement from 10 s to 20 s and from 0 to 30 s.** A straight line through the origin sloping up: constant acceleration. Slope = $(10 - 5)/10 = 0.5 \text{ m/s}^2$. 10 s to 20 s: $50 + 25 = 75 \text{ m}$. 0 to 30 s: $\frac{1}{2} \times 30 \times 15 = 225 \text{ m}$.

Common Mistakes and Examiner Tips

1. **Equating distance and displacement.** They match only for straight-line motion in one direction. Otherwise work them out separately.
2. **Displacement without direction.** Write "40 m in the positive direction" or "6 m upward", never just "40 m".
3. **Averaging two speeds.** Average speed is always total distance / total time.
4. **Skipping unit conversion.** Convert km/h with $\times 5/18$ and minutes to seconds before substituting.

5. **Losing the minus sign when slowing down.** With velocity positive, a is negative while braking; a positive a gives an impossible stopping distance.
 6. **Using the equations when acceleration changes.** Split a multi-stage journey into stages, or use the area of the velocity-time graph.
 7. **Mixing up graph rules.** Position-time slope = velocity; velocity-time slope = acceleration; velocity-time area = displacement. Read the axis labels first.
 8. **Treating a graph as a route map.** A flat position-time line means rest; a flat velocity-time line means constant velocity.
 9. **Forgetting reaction distance.** Stopping distance = speed $\times$ reaction time + braking distance.
 10. **Zero acceleration in uniform circular motion.** The direction of velocity keeps changing, so the motion is accelerated.
 11. **Non-zero average velocity for a full revolution.** Displacement is zero after a whole revolution, so average velocity is zero; average speed is $2\pi R/T$.
-

Quick Revision Points

- Position = distance and direction from a reference point at an instant
- Motion: position changes with time; rest: it does not; both depend on the reference point
- Right of O usually +, left –; keep the choice fixed through a problem
- Distance: path length, no direction; displacement: net change in position, with direction; unit metre
- Magnitude of displacement $\leq$ distance; equal only for one-direction straight-line motion
- Average speed = distance / time; average velocity = displacement / time; unit m/s
- Uniform motion: equal distances in equal intervals, for all intervals
- 36, 54, 72, 108 km/h = 10, 15, 20, 30 m/s (multiply by 5/18)
- $a = (v - u)/(t_2 - t_1)$, unit m/s^2 ; negative when slowing with velocity +
- Steady fast motion in a line has zero acceleration
- Free fall: $g = 9.8 \text{ m/s}^2$ downward
- Position-time: flat = rest, straight = constant velocity, curve = changing velocity; slope = velocity
- Velocity-time: flat = zero acceleration, straight sloping = constant acceleration; slope = acceleration; area = displacement
- $v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$; also $s = \frac{1}{2}(u + v)t$
- Kinematic equations hold only for constant acceleration
- Braking distance = $u^2/(2a)$, with a the magnitude of the braking acceleration: double the speed, four times the distance
- Stopping distance = reaction distance + braking distance
- One revolution: distance $2\pi R$, displacement 0, $v_{av} = 2\pi R/T$

- Uniform circular motion: constant speed, changing direction, so accelerated; velocity along the tangent
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Weightage and Exam Pattern

Class 9 has no board exam. This chapter is assessed in school exams (periodic tests, half-yearly and annual papers), and the NCERT source gives no fixed mark allocation. It is a numerical chapter, so it usually supplies both definitions and calculations.

Question type	What this chapter typically supplies
MCQ and one-word	SI units, km/h to m/s, reading a graph, zero displacement on a round trip
Assertion-Reason	Constant speed with acceleration, displacement versus distance, validity of the equations
Short answer (2 to 3 marks)	Distance and displacement, average speed versus velocity, one-step kinematic numericals
Long answer (5 marks)	Graphical derivation of the equations, multi-stage journeys, braking with reaction time
Case-based	Safe distance on roads, data tables to plot and read, circular tracks and clock hands

This chapter is the foundation for Class 10 physics: fixing an origin, converting units first and reading slope and area from graphs are used in every later numerical chapter.



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