CBSE CLASS 9 SCIENCE

Chapter 7: Motion

Complete Concept & Question Bank

EXAM BOOSTER EDITION

SECTION 1: Chapter Overview

What is Motion?

Motion is the change in the position of an object with respect to time and a reference point. If an object's position does not change with time, it is said to be at rest.

Importance of Motion in Daily Life

Motion is everywhere—from the movement of vehicles to the orbiting of planets. Understanding motion is fundamental to physics and forms the basis for studying force, energy, and gravitation. Core applications include transportation, sports, and space exploration.

Learning Outcomes

By the end of this chapter, you will be able to:

- Differentiate between distance and displacement, speed and velocity.
- Understand the concept of acceleration and its types.
- Interpret and draw distance-time and velocity-time graphs.
- Apply the three equations of motion to solve numerical problems.
- Understand the concept of uniform circular motion.

Chapter Summary

- **Distance vs Displacement:** Distance is the total path length (scalar); displacement is the shortest path between initial and final positions (vector).
- **Speed vs Velocity:** Speed is distance per unit time (scalar); velocity is displacement per unit time (vector).
- **Acceleration:** Rate of change of velocity; can be positive (speeding up) or negative (slowing down/ retardation).
- **Graphs:** Slope of a distance-time graph gives speed; slope of a velocity-time graph gives acceleration; area under a velocity-time graph gives displacement.
- **Equations of Motion:** $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$.

SECTION 2: Important Concepts

1. Rest and Motion

Rest: An object is said to be at rest if its position does not change with time with respect to a reference point.

Motion: An object is said to be in motion if its position changes with time with respect to a reference point.

Explanation: Motion is relative—an object can be at rest for one observer but in motion for another. For example, a person sitting in a moving train is at rest with respect to the train but in motion with respect to the ground.

2. Distance

The total path length covered by an object during its motion.

- Scalar quantity (has only magnitude)
- Always positive and path-dependent
- **SI Unit:** metre (m)

3. Displacement

The shortest straight-line distance between the initial and final positions of an object.

- Vector quantity (has both magnitude and direction)
- Can be positive, negative, or zero, and is path-independent
- **SI Unit:** metre (m)

4. Scalar and Vector Quantities

Scalar Quantities	Vector Quantities
Have only magnitude	Have both magnitude and direction
Examples: Distance, Speed, Time, Mass	Examples: Displacement, Velocity, Acceleration, Force

5. Uniform Motion

An object is in uniform motion if it covers equal distances in equal intervals of time, regardless of how small the intervals are. It features a constant speed along a straight-line path (e.g., a car moving at a steady speed of 60 km/h on a straight highway).

6. Non-Uniform Motion

An object is in non-uniform motion if it covers unequal distances in equal intervals of time (e.g., a car moving in busy city traffic).

7. Speed & Average Speed

Speed: The distance covered per unit time. $\textit{Speed} = \textit{Distance} / \textit{Time}$ (Scalar, SI Unit: m/s).

Average Speed: The total distance covered divided by the total time taken. $Average\ Speed = Total\ Distance / Total\ Time$.

8. Velocity & Average Velocity

Velocity: The displacement per unit time. $Velocity = Displacement / Time$ (Vector, SI Unit: m/s).

Average Velocity: The total displacement divided by the total time taken.

9. Acceleration

The rate of change of velocity. $a = (v - u) / t$ (Vector, SI Unit: m/s^2).

- **Positive acceleration:** Velocity increasing (speeding up).
- **Negative acceleration (Retardation):** Velocity decreasing (slowing down).
- **Uniform vs Non-Uniform Acceleration:** Velocity changes by equal amounts in equal intervals of time for uniform acceleration (e.g., free fall), and by unequal amounts for non-uniform acceleration.

10. Graphical Representations

- **Distance-Time Graph:** Uniform motion is represented by a straight line inclined to the time axis (slope gives speed). Non-uniform motion is a curved line. An object at rest is a straight horizontal line parallel to the time axis.
- **Velocity-Time Graph:** Uniform acceleration is a straight line inclined to the time axis (slope gives acceleration). Uniform velocity is a horizontal line parallel to the time axis. The area under the graph gives total displacement.

11. Equations of Motion

For uniformly accelerated motion along a straight line:

1. $v = u + at$ (First equation)
2. $s = ut + \frac{1}{2}at^2$ (Second equation)
3. $v^2 = u^2 + 2as$ (Third equation)

Where: u = initial velocity, v = final velocity, a = acceleration, t = time, s = displacement.

12. Uniform Circular Motion

Motion of an object in a circular path with constant speed. While the speed remains constant, the velocity changes continuously because the direction of motion changes at every point. Hence, it is an accelerated motion (e.g., a satellite orbiting Earth).

SECTION 3: Important Formula Sheet

Formula	Description	SI Unit
$Speed = Distance / Time$	Basic Speed Formula	m/s
$Avg\ Speed = Total\ Distance / Total\ Time$	Average Speed across journeys	m/s
$Velocity = Displacement / Time$	Velocity Formula	m/s
$a = (v - u) / t$	Acceleration Formula	m/s^2
$v = u + at$	First Equation of Motion	m/s
$s = ut + \frac{1}{2}at^2$	Second Equation of Motion	m
$v^2 = u^2 + 2as$	Third Equation of Motion	m^2/s^2

Crucial Unit Conversions

- To convert **km/h to m/s**: Multiply by $5/18$
- To convert **m/s to km/h**: Multiply by $18/5$

SECTION 4: Top 30 Frequently Repeated Questions

Very Short Answer Type (1 Mark)

Q1. What is motion?

Ans: Motion is the change in position of an object with time relative to a reference point.

Q2. What is the SI unit of speed?

Ans: Metre per second (m/s).

Q3. Define acceleration.

Ans: Acceleration is defined as the rate of change of velocity per unit time.

Q4. What type of quantity is displacement?

Ans: Displacement is a vector quantity as it requires both magnitude and direction.

Q5. What is the slope of a distance-time graph?

Ans: The slope of a distance-time graph represents the speed of the object.

Q6. What does the area under a velocity-time graph represent?

Ans: It represents the total displacement covered by the object.

Q7. What is uniform motion?

Ans: An object is in uniform motion when it covers equal distances in equal intervals of time.

Q8. What is the acceleration of a body moving with uniform velocity?

Ans: Zero, because the change in velocity is zero.

Q9. What is the nature of a distance-time graph for uniform motion?

Ans: A straight line inclined to the time axis.

Q10. What is a scalar quantity?

Ans: A physical quantity that has only magnitude but no direction, e.g., distance.

Short Answer Type (2-3 Marks)

Q11. Distinguish between distance and displacement.

Ans: Distance is the total actual path length covered, is a scalar quantity, and is always positive. Displacement is the shortest path between the initial and final positions, is a vector quantity, and can be positive, negative, or zero.

Q12. Distinguish between speed and velocity.

Ans: Speed is distance covered per unit time (scalar, always positive). Velocity is displacement per unit time (vector, can be positive, negative, or zero).

Q13. What is uniform acceleration? Give an example.

Ans: When an object's velocity changes by equal amounts in equal intervals of time, it has uniform acceleration. Example: A freely falling stone under gravity.

Q14. What is the difference between uniform and non-uniform motion?

Ans: Uniform motion involves covering equal distances in equal time intervals (constant velocity). Non-uniform motion involves covering unequal distances in equal intervals of time (variable velocity).

Q15. Why is circular motion called accelerated motion?

Ans: In circular motion, even if the speed is constant, the direction of motion changes continuously at every point. Since velocity depends on direction, velocity changes, making it an accelerated motion.

Q16. What is the SI unit of acceleration?

Ans: Metre per second squared (m/s^2).

Q17. Write the three equations of motion.

Ans: (1) $v = u + at$, (2) $s = ut + \frac{1}{2}at^2$, (3) $v^2 = u^2 + 2as$.

Q18. What is the slope of a velocity-time graph?

Ans: The slope of a velocity-time graph gives the acceleration of the body.

Q19. What is average speed?

Ans: Average speed is calculated as the total distance travelled divided by the total time taken.

Q20. What does the odometer of an automobile measure?

Ans: The total actual distance covered by the automobile.

SECTION 5: Top 20 Most Expected Questions

Q1. Derive the first equation of motion v = u + at.

Ans: Acceleration (a) is the rate of change of velocity:

$a = (v - u) / t$

Cross-multiplying: $at = v - u$

Rearranging terms: $v = u + at$.

Q2. Derive the second equation of motion $s = ut + \frac{1}{2}at^2$.

Ans: Distance (s) = Average velocity × Time

$s = [(u + v) / 2] \times t$

Substitute the first equation $v = u + at$:

$s = [(u + u + at) / 2] \times t$

$s = [(2u + at) / 2] \times t = (u + \frac{1}{2}at)t$

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

Q3. Derive the third equation of motion $v^2 = u^2 + 2as$.

Ans: From the first equation, $t = (v - u) / a$.

Substitute this into the second equation ($s = ut + \frac{1}{2}at^2$):

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

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

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

Simplifying gives: $v^2 = u^2 + 2as$.

Q4. What is the difference between uniform velocity and uniform acceleration?

Ans: Uniform velocity means covering equal displacements in equal intervals of time (acceleration is zero). Uniform acceleration means the velocity changes by equal amounts in equal intervals of time.

Q5. A car travels 30 km at 40 km/h and the next 30 km at 20 km/h. Find its average speed.

Ans: Total distance = 30 + 30 = 60 km.

Time 1 = 30 / 40 = 0.75 h. Time 2 = 30 / 20 = 1.5 h.

Total time = 0.75 + 1.5 = 2.25 h.

Average speed = 60 / 2.25 = 26.67 km/h.

Q6. A train 200 m long passes over a bridge 800 m long. Find the time it takes to cross the bridge moving with uniform velocity of 36 km/h.

Ans: Total distance = 200 m + 800 m = 1000 m.
Speed = 36 km/h = 36 × (5/18) = 10 m/s.
Time = Distance / Speed = 1000 / 10 = 100 seconds.

Q7. A body moving with a speed of 36 km/h is brought to rest in 10 s. What is the negative acceleration and distance travelled?

Ans: $u = 36 \times (5/18) = 10\ m/s$, $v = 0$, $t = 10\ s$.
$a = (0 - 10) / 10 = -1\ m/s^2$ (Retardation = 1 m/s²).
$s = ut + \frac{1}{2}at^2 = (10 \times 10) + \frac{1}{2}(-1)(10)^2 = 100 - 50 = 50\ m$.

Q8. Why can the displacement of an object be equal to its distance?

Ans: It happens only when the object moves along a perfectly straight line without changing its direction.

Q9. What is the acceleration of an object moving with constant velocity?

Ans: Zero, because velocity is not changing.

Q10. A car starts from rest and moves with constant acceleration of 5 m/s² for 8 s. What distance will it cover in 12 s?

Ans: First 8 s: $s_1 = 0 + \frac{1}{2}(5)(8)^2 = 160\ m$. Velocity at 8 s: $v = 0 + 5(8) = 40\ m/s$.
Next 4 s (constant velocity): $s_2 = v \times t = 40 \times 4 = 160\ m$.
Total distance covered in 12 s = 160 + 160 = 320 m.

Q11. What is the displacement of a particle after half a circle of radius r?

Ans: The straight line distance between initial and final points is the diameter, which is $2r$.

Q12. When is average velocity equal to average speed?

Ans: When the body moves along a straight line in a fixed direction, such that actual distance equals displacement.

SECTION 6: NCERT-Based Questions

Q1. An object has moved through a distance. Can it have zero displacement?

Ans: Yes, if it returns to its initial position. Example: A circular lap where the starting and ending points are identical.

Q2. A bus decreases its speed from 80 km/h to 60 km/h in 5 s. Find the acceleration.

Ans: $u = 80 \times (5/18) = 22.22\ m/s$, $v = 60 \times (5/18) = 16.67\ m/s$, $t = 5\ s$.

$a = (16.67 - 22.22) / 5 = -1.11\ m/s^2$.

Q3. A train starting from a railway station and moving with uniform acceleration attains a speed 40 km/h in 10 minutes. Find its acceleration.

Ans: $u = 0$, $v = 40 \times (5/18) = 11.11\ m/s$, $t = 10 \times 60 = 600\ s$.

$a = (11.11 - 0) / 600 = 0.0185\ m/s^2$.

Q4. A bus starting from rest moves with uniform acceleration of 0.1 m/s² for 2 minutes. Find speed acquired and distance travelled.

Ans: $u = 0$, $a = 0.1\ m/s^2$, $t = 120\ s$.

(a) Speed acquired: $v = u + at = 0 + 0.1 \times 120 = 12\ m/s$.

(b) Distance: $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(0.1)(120)^2 = 720\ m$.

SECTION 7: Most Important Numericals

Q1. A motorcyclist drives from A to B with uniform speed of 30 km/h and returns with speed of 20 km/h. Find average speed.

Ans: Let distance AB = x. Total distance = $2x$.

Time to go (t_1) = $x / 30$, Time to return (t_2) = $x / 20$.

Total time = $x/30 + x/20 = 5x / 60 = x / 12$.

Average speed = Total Distance / Total Time = $2x / (x / 12) = 24\ km/h$.

Q2. A stone is dropped from a height of 10 m. Find time to reach ground. (g = 10 m/s²)

Ans: $u = 0$, $s = 10\ m$, $a = 10\ m/s^2$.

$s = ut + \frac{1}{2}at^2 \rightarrow 10 = 0 + \frac{1}{2}(10)t^2 \rightarrow 5t^2 = 10 \rightarrow t^2 = 2$.

$t = \&sqrt;2 \approx 1.41\ s$.

Q3. A train is travelling at 90 km/h. If brakes apply with retardation of 0.5 m/s², find distance before stopping.

Ans: $u = 90 \times (5/18) = 25\ m/s$, $v = 0$, $a = -0.5\ m/s^2$.

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

$0 = 25^2 + 2(-0.5)s \rightarrow 0 = 625 - 1s \rightarrow s = 625\ m$.

SECTION 8: Assertion & Reason Questions

Directions: Choose (a) if both Assertion and Reason are true and Reason is the correct explanation.

Q1. Assertion: Distance is a scalar quantity.
Reason: It does not require direction for its complete description.

Ans: (a) Both true, Reason is correct explanation.

Q2. Assertion: In uniform circular motion, speed is constant.
Reason: Direction changes continuously, so velocity changes.

Ans: (a) Both true, Reason explains why velocity changes despite constant speed, making it accelerated motion.

SECTION 9: Case Study Questions

Case Study 1: Distance-Time Graph Analysis

The distance-time graph of two trains A and B shows their motion. Train B starts 100 km ahead of Train A. Both trains move at uniform speeds.

- **Q1:** How much ahead of A is B when the motion starts? **Ans:** 100 km.
- **Q2:** What is the speed of B? **Ans:** $Slope = (150-100)/(2-0) = 25\ km/h$.
- **Q3:** When and where will A catch B? **Ans:** After 2 hours at a distance of 150 km.

SECTION 10 & 11: Graph-Based Qs & Common Mistakes

Common Mistake	Correct Concept Reminder
Confusing distance & displacement	Distance is total path length; displacement is the shortest straight line.
Incorrect unit conversion errors	Always convert to standard units: $1\ km/h = 5/18\ m/s$.
Misinterpreting graph slopes	Slope of D-T graph = Speed. Slope of V-T graph = Acceleration.

SECTION 14: High-Probability Exam Numericals

Q1. A train 150 m long is travelling at 54 km/h. How long will it take to cross a telegraph post?

Ans: Distance to cross the post = length of train = 150 m.

Speed = $54 \times (5/18) = 15\ m/s$.

Time = Distance / Speed = $150 / 15 = 10\ seconds$.

Q2. A bus decreases its speed from 72 km/h to 54 km/h in 5 s. Find acceleration.

Ans: $u = 72 \times (5/18) = 20\ m/s$, $v = 54 \times (5/18) = 15\ m/s$, $t = 5\ s$.

$a = (15 - 20) / 5 = -1\ m/s^2$.

Top Exam Tips for Physics Numericals

1. Always check the units first. Convert everything into SI units (m, s, m/s, m/s²) before using formulae.
2. Pay attention to terms like "starts from rest" (→ $u = 0$) and "brought to rest/brakes applied" (→ $v = 0$).
3. Assign correct signs: negative for retardation/brakes.