CLASS 9 SCIENCE

Chapter 4 Notes

Describing Motion Around Us

Chapter focus
Motion can be described using position, distance, displacement, speed, velocity and acceleration. The chapter develops graphical methods, kinematic equations for constant acceleration and uniform circular motion.

1. Motion and Reference Point

- Motion means change in the position of an object with time relative to a chosen reference point.
- Position is described by both distance and direction from the reference point.
- If position relative to the reference point does not change with time, the object is at rest.
- Straight-line motion is also called linear motion and is the simplest form of motion.

Sign convention
For straight-line motion, one direction may be chosen positive (+) and the opposite direction negative (−). The chosen origin and positive direction should remain unchanged while solving a problem.

2. Distance and Displacement

Distance travelled	Displacement
Total length of the actual path travelled.	Net change in position between two instants.
Needs numerical value and unit; direction is not required.	Needs magnitude, direction and unit.
Can be non-zero even when an object returns to its starting point.	Becomes zero if final and initial positions are the same.
SI unit: metre (m).	SI unit: metre (m).

- Magnitude of displacement is always less than or equal to the total distance travelled.
- For straight-line motion without turning back, distance travelled equals the magnitude of displacement.

Important distinction
An instant of time is a single clock reading. A time interval is the duration between two instants.

3. Average Speed and Average Velocity

Average speed
Average speed = Total distance travelled ÷ Time interval

Average velocity
Average velocity = Displacement ÷ Time interval

- Average speed has no direction; average velocity requires direction.
- SI unit of both average speed and average velocity: metre per second (m/s or m s^{-1}).
- Kilometre per hour (km/h or km h^{-1}) is also commonly used.
- For straight-line motion in one direction, average speed equals the magnitude of average velocity.
- If an object returns to its starting point, displacement and average velocity may be zero even though distance and average speed are not zero.

4. Uniform and Non-Uniform Motion

Uniform motion in a straight line	Non-uniform motion in a straight line
Equal distances in equal intervals of time.	Unequal distances in equal intervals of time.
Speed remains constant.	Speed may increase, decrease or do both.
Velocity remains constant when direction also remains unchanged.	Velocity changes.

5. Average Acceleration

Definition
Average acceleration = Change in velocity ÷ Time interval
If velocity changes from u at t_1 to v at t_2:
$a = (v - u)/(t_2 - t_1)$

- SI unit: m/s^2 or m s^{-2}.
- Acceleration depends on how quickly velocity changes, not simply on how fast an object is moving.
- If velocity increases in a straight line, acceleration is in the direction of velocity.
- If velocity decreases, acceleration is opposite to the direction of velocity.
- A fast-moving object at constant velocity has zero acceleration.
- Acceleration may result from change in the magnitude of velocity, direction of velocity, or both.
- For a freely falling object, the acceleration due to Earth's gravity, $g \approx 9.8\ m/s^2$.

6. Graphical Representation of Motion

- Graphs show how position, velocity or acceleration changes with time.
- They help compare motions, calculate physical quantities and identify uniform or non-uniform motion.
- Time is generally plotted on the x-axis; the changing motion quantity is plotted on the y-axis.
- A graph is not a route map. It represents how a physical quantity changes with another quantity.

7. Position-Time Graph

Graph feature	Meaning
Straight sloping line	Constant velocity.
Curved line	Changing velocity; accelerated motion.
Horizontal line parallel to time axis	Object is at rest at a fixed position.
Steeper straight line	Greater magnitude of velocity.

Slope of position-time graph
Average velocity = Change in position ÷ Change in time = slope of the line joining two points.

8. Velocity-Time Graph

Graph feature	Meaning
Horizontal straight line	Constant velocity; acceleration = 0.
Straight line sloping upward	Velocity increases uniformly; constant positive acceleration relative to the chosen direction.
Straight line sloping downward	Velocity decreases uniformly; acceleration is opposite to the velocity.

Slope and area
Slope of a velocity-time graph gives acceleration. The area enclosed by the velocity-time graph and the time axis over a chosen interval gives displacement.

9. Kinematic Equations

- For motion in a straight line with constant acceleration, five quantities are related: displacement s, time t, initial velocity u, final velocity v and acceleration a.

Three main equations
1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$

- These equations are valid only for constant acceleration.
- Signs of u, v, a and s represent direction according to the chosen positive direction.
- For motion in one direction, distance equals magnitude of displacement and speed equals magnitude of velocity.

Two additional forms
$s = vt - \frac{1}{2}at^2$
$s = \frac{1}{2}(u + v)t$

10. Choosing a Kinematic Equation

Known / required information	Useful equation
u, a, t; find v	$v = u + at$
u, a, t; find s	$s = ut + \frac{1}{2}at^2$
u, v, a; find s	$v^2 = u^2 + 2as$
v, a, t; find s	$s = vt - \frac{1}{2}at^2$
u, v, t; find s	$s = \frac{1}{2}(u + v)t$

- Convert all quantities to compatible units before substitution, especially km/h to m/s.

Useful conversion
1 km/h = 5/18 m/s and 1 m/s = 18/5 km/h.

11. Braking and Safe Distance

- A moving vehicle travels some distance after brakes are applied before coming to rest.
- Stopping behaviour depends on initial velocity, road surface, braking capacity and driver reaction time.
- With the same braking acceleration, doubling initial speed from 15 m/s to 30 m/s increases the calculated braking distance from about 28.1 m to 112.5 m.
- This explains why greater following distance is necessary at higher speeds.
- The vehicle-to-vehicle (V2V) communication being developed to warn drivers of possible collisions.

12. Motion in a Plane

- Motion in a plane is motion in two dimensions.
- A vehicle overtaking another, a kicked ball and a satellite moving along a circular path.
- Motion in space is three-dimensional; a mountain road, a flying bird and an aircraft as examples for higher-grade study.

13. Circular and Uniform Circular Motion

- Circular motion occurs when an object moves along a circular path.
- For one complete revolution of a circle of radius R, distance travelled = circumference = $2\pi R$.
- After one complete revolution, displacement = 0 because the final position is the initial position.

Average speed for one revolution
If time for one revolution is T:
Average speed = $2\pi R/T$

- Uniform circular motion is circular motion with constant speed.
- Although speed remains constant, velocity changes continuously because its direction changes.
- Therefore, uniform circular motion is accelerated motion.
- At any point on the circular path, the instantaneous velocity is along the tangent to the circle in the direction of motion.

Key idea
Constant speed does NOT always mean zero acceleration. In uniform circular motion, acceleration exists because the direction of velocity continuously changes.

14. Formula Sheet

Quantity	Formula / relation	SI unit
Average speed	Total distance / time interval	m/s
Average velocity	Displacement / time interval	m/s
Average acceleration	$(v - u)/(t_2 - t_1)$	m/s^2
First kinematic equation	$v = u + at$	—
Second kinematic equation	$s = ut + \frac{1}{2}at^2$	—
Third kinematic equation	$v^2 = u^2 + 2as$	—
Circular path, one revolution	Distance = $2\pi R$	m
Uniform circular motion	Speed = $2\pi R/T$	m/s

15. Important Graph Results

Graph	What slope gives	What area gives
Position-time	Velocity	Not used here for a standard motion quantity.
Velocity-time	Acceleration	Displacement.

- For a position-time graph, a larger slope means a larger magnitude of velocity.
- For a velocity-time graph with constant velocity, displacement is the rectangular area under the graph.
- For changing velocity with constant acceleration, displacement can be found by adding rectangular and triangular areas.

16. Common Misconceptions

Misconception	Correct idea
Distance and displacement are always equal.	They are equal in magnitude only for straight-line motion without turning back.
Speed and velocity mean exactly the same thing.	Velocity includes direction; speed does not.
If speed is constant, acceleration must be zero.	Not in circular motion; changing direction changes velocity.
An object moving very fast must have high acceleration.	Acceleration depends on change in velocity, not the velocity alone.
A graph of motion shows the actual path of the object.	A motion graph shows how one physical quantity varies with another.
Negative acceleration always means an object is slowing down.	Its meaning depends on the chosen positive direction; signs indicate direction.

17. Key Terms

Term	Meaning
Reference point	Fixed point relative to which position is described.
Position	Distance and direction of an object from a reference point.
Distance	Total path length travelled.
Displacement	Net change in position, with direction.
Average speed	Total distance divided by time interval.
Average velocity	Displacement divided by time interval.
Acceleration	Rate of change of velocity.
Slope	Steepness of a graph; represents rate of change of y-axis quantity with x-axis quantity.
Kinematic equations	Equations relating s, t, u, v and a for constant acceleration.
Circular motion	Motion along a circular path.
Uniform circular motion	Circular motion at constant speed.
Tangent	Straight line touching a circle at only one point.

18. Exam-Oriented Self-Check Questions

1. Why is a reference point necessary to describe motion?
2. Differentiate between distance travelled and displacement with an example.
3. Under what condition are distance and magnitude of displacement equal?
4. Define average speed and average velocity. State their SI units.
5. When can average velocity be zero while average speed is non-zero?
6. Differentiate uniform and non-uniform motion in a straight line.
7. Define average acceleration and write its SI unit.
8. Can an object have high velocity and zero acceleration? Explain.
9. What does the slope of a position-time graph represent?
10. What does a horizontal line on a position-time graph indicate?
11. What information is obtained from the slope of a velocity-time graph?
12. What does the area under a velocity-time graph represent?
13. Write the three kinematic equations for constant acceleration.
14. Why must a sign convention remain unchanged while solving a motion problem?
15. Explain why stopping distance generally increases strongly with initial speed.
16. Define uniform circular motion.
17. Why is an object in uniform circular motion accelerated even though its speed is constant?
18. What are distance and displacement after one complete circular revolution?
19. Write the expression for average speed in one complete revolution of radius R and time period T.
20. Explain why a motion graph should not be interpreted as a route map.

One-Minute Chapter Summary

Revision paragraph

Motion is described relative to a reference point. Distance measures total path length, while displacement measures net change in position. Average speed equals total distance divided by time, whereas average velocity equals displacement divided by time. Acceleration describes change in velocity with time. Position-time graphs reveal velocity through slope; velocity-time graphs reveal acceleration through slope and displacement through area. For constant acceleration in a straight line, $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$. In uniform circular motion, speed remains constant but velocity changes direction continuously, so the motion is accelerated.

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