CHAPTER NOTES

Motion in a Straight Line Class 11 Notes | CBSE Physics Chapter 2

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CHAPTER SUMMARY

Motion in a Straight Line is the kinematics chapter that describes one-dimensional motion using position, distance, displacement, speed, velocity and acceleration, and the graphs and equations that connect them. It teaches the three equations of uniformly accelerated motion, free fall under...

... see more

CHAPTER NOTES

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Key Concepts

1. Position, Path Length and Displacement

To describe motion we first fix a **reference point (origin)** and a set of axes — together these form a **frame of reference**. The **position** of an object is its location measured from the origin along the chosen axis.

Path length (distance) is the total length of the actual path covered by the object. It is a **scalar**, is always positive, and can never be zero for a moving body.

Displacement (Δx) is the change in position: the straight-line distance from the start point to the end point, with direction. It is a **vector** and can be positive, negative, or zero.

$$\Delta x = x_2 - x_1$$

- If you walk 4 m east and 3 m back west, path length = 7 m but displacement = 1 m east.
- For a round trip, displacement is zero but path length is not.
- Magnitude of displacement ≤ path length, always.

2. Average Velocity and Average Speed

Average velocity is the displacement divided by the time interval. It is a vector, in the direction of displacement.

$$\bar{v} = \Delta x/\Delta t = (x_2 - x_1)/(t_2 - t_1)$$

Average speed is the total path length divided by the total time taken. It is a scalar and is always positive for a moving body.

Average speed = total path length / total time

- **SI unit:** m/s for both.
- Average speed ≥ magnitude of average velocity (they are equal only when motion is along a straight line in one direction).

3. Instantaneous Velocity and Speed

Instantaneous velocity is the velocity of a body at a particular instant of time. It is the limit of average velocity as the time interval approaches zero.

$v = \lim_{\Delta t \to 0} \Delta x/\Delta t = dx/dt$

- It is the slope of the tangent to the position-time graph at that instant.
- The magnitude of instantaneous velocity equals the **instantaneous speed**.
- The speedometer of a car shows instantaneous speed.

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4. Acceleration

Acceleration is the rate of change of velocity with time. It is a vector and tells us how quickly velocity changes.

Average acceleration $\bar{a} = \Delta v/\Delta t$ and **instantaneous acceleration $a = dv/dt = d^2x/dt^2$**

- **SI unit:** m/s^2.
- If velocity and acceleration point the same way, the body speeds up; if opposite, it slows down (retardation/deceleration).
- Acceleration is the slope of the velocity-time graph.

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5. Kinematic Equations for Uniformly Accelerated Motion

When acceleration **a** is constant, the motion is called **uniformly accelerated motion**, and three standard equations connect initial velocity u, final velocity v, acceleration a, time t, and displacement s.

Equation	What it connects
$v = u + at$	velocity and time (no s)
$s = ut + \frac{1}{2}at^2$	displacement and time (no v)
$v^2 = u^2 + 2as$	velocity and displacement (no t)

A useful fourth result — the distance covered in the **nth second**:

$s_n = u + \frac{1}{2}a(2n - 1)$

Note: These equations are valid only when acceleration is constant. Take care with signs — choose one direction as positive and stick to it throughout the problem.

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6. Position-Time Graphs

A **position-time (x–t) graph** plots position on the y-axis against time on the x-axis. Its slope at any point gives the instantaneous velocity.

[DIAGRAM: x–t graph — a horizontal line means the body is at rest; a straight slanted line means uniform velocity; an upward curve (increasing slope) means acceleration.]

- **Straight horizontal line:** object at rest (velocity = 0).
- **Straight slanted line:** uniform velocity (constant slope).
- **Curved line:** non-uniform velocity — accelerated motion.
- A steeper slope means a greater speed.

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7. Velocity-Time Graphs

A **velocity-time (v–t) graph** plots velocity against time. It is one of the most powerful tools in kinematics because both its slope and its area carry meaning.

- **Slope** of the v–t graph = acceleration.
- **Area** under the v–t graph = displacement.
- A straight slanted line means uniform acceleration; a horizontal line means uniform velocity (zero acceleration).

[DIAGRAM: v–t graph for uniform acceleration — a straight line rising from u to v; the area under it (a trapezium) equals the displacement $s = ut + \frac{1}{2}at^2$.]

The kinematic equations can actually be **derived** from the v–t graph: v = u + at comes from the slope, and s = ut + ½at² comes from the area.

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8. Relative Velocity in One Dimension

The **relative velocity** of object A with respect to object B is the velocity of A as seen by an observer moving with B.

v(AB) = v(A) − v(B)

- **Same direction:** relative velocity = v(A) − v(B) (small if speeds are close — two trains moving alongside seem slow relative to each other).
- **Opposite directions:** relative velocity = v(A) + v(B) (they approach quickly).
- The time to meet = relative displacement / relative velocity.

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9. Motion Under Gravity (Free Fall)

Near the Earth's surface, every freely falling body has a constant downward acceleration called **acceleration due to gravity (g ≈ 9.8 m/s²)**, independent of its mass.

The kinematic equations apply directly, replacing a with g and choosing a sign convention (usually downward positive for a dropped body):

- **v = u + gt**
- **h = ut + ½gt²**
- **v² = u² + 2gh**

For a body **thrown vertically upward** with speed u: it stops momentarily at the top (v = 0), so the maximum height is **H = u²/2g**, the time to reach the top is **t = u/g**, and the total time of flight is **2u/g**.

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Q1 NEET 2021

A small block slides down on a smooth inclined plane, starting from rest at time t = 0. Let s_n be the distance travelled by the block in the interval t = n – 1 to t = n. The ratio s_n/s_{n+1} is

A (2n – 1)/2n

B (2n – 1)/(2n + 1)

C (2n + 1)/(2n – 1)

D 2n/(2n – 1)

Q2 NEET 2020

A person sitting in the ground floor of a building notices through the window of height 1.5 m, a ball dropped from the roof of the building crosses the window in 0.1 s. What is the velocity of the ball when it is at the topmost point of the window? ($g = 10\ m/s^2$)

A 15.5 m/s

B 14.5 m/s

C 4.5 m/s

D 20 m/s

Q3 NEET 2019

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

A $1/v = 1/v_1 + 1/v_2$

B $2/v = 1/v_1 + 1/v_2$

C $v = (v_1 + v_2)/2$

D $v = \sqrt{(v_1 v_2)}$

Q4 NEET 2018

A toy car with charge q moves on a frictionless horizontal plane surface under the influence of a uniform electric field E. Due to the force qE, its velocity increases from 0 to 6 m/s in one second duration. At that instant the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 seconds are respectively

A 1 m/s, 3.5 m/s

B 1 m/s, 3 m/s

C 2 m/s, 4 m/s

D 1.5 m/s, 3 m/s

Q5 NEET 2017

Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be

A $(t_1 + t_2)/2$

B $t_1t_2/(t_2 - t_1)$

C $t_1t_2/(t_2 + t_1)$

D $t_1 - t_2$

Q6 NEET 2015

A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x is given by

A $-2n\beta^2x^{-2n-1}$

B $-2n\beta^2x^{-4n-1}$

C $-2\beta^2x^{-2n+1}$

D $-2n\beta^2e^{-4n+1}$

Q7 NEET 2012

The motion of a particle along a straight line is described by the equation $x = 8 + 12t - t^3$, where x is in metre and t in sec. The retardation of the particle when its velocity becomes zero, is

A 24 m/s²

B zero

C 6 m/s²

D 12 m/s²

Q8 NEET 2010

A particle moves a distance x in time t according to the equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to

A $(\text{velocity})^{3/2}$

B $(\text{distance})^2$

C $(\text{distance})^{-2}$

D (velocity)$^{2/3}$

Q9 NEET 2009

A bus is moving with a speed of 10 m/s on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus?

A 20 m/s

B 40 m/s

C 25 m/s

D 10 m/s

Q10 NEET 1992

A train of 150 m length is going towards North direction at a speed of 10 m/s. A parrot flies at the speed of 5 m/s towards South direction parallel to the railways track. The time taken by the parrot to cross the train is

A 12 s

B 8 s

C 15 s

D 10 s

Frequently Asked Questions

What is the difference between distance and displacement?

Distance is the total path length actually covered and is a scalar that is always positive. Displacement is the straight-line change in position from start to finish and is a vector that can be positive, negative or zero, so an object that returns to its start has zero displacement but non-zero distance.

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What are the three equations of motion in this chapter?

For constant acceleration they are v = u + at, s = ut + half a t squared, and v squared = u squared + 2as, where u is initial velocity, v is final velocity, a is acceleration, s is displacement and t is time. They are valid only when acceleration is constant, and all the quantities must carry signs based on a chos...

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What is the difference between speed and velocity?

Speed is built from distance and is a scalar that is never negative, while velocity is built from displacement and is a vector whose sign shows direction. For a closed loop the average speed is positive but the average velocity is zero because the displacement is zero.

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Can an object have zero velocity but non-zero acceleration?

Yes. A ball thrown straight up has zero velocity for an instant at its highest point, but its acceleration is still g pointing downward the whole time. Acceleration is the rate of change of velocity, so it can be non-zero even when the velocity is momentarily zero.

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Is Motion in a Straight Line important for NEET?

Yes. It is part of the Class 11 Physics NEET syllabus and usually contributes about one to two direct questions, often on the equations of motion, free fall, graphs or relative velocity. Because the questions are formula-based and quick to solve, it is a high-yield scoring chapter.

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