

Motion In a Straight Line

Introduction - Motion in a Straight Line

- Motion is everywhere around us. We walk, run, or ride a bicycle.
- Even when we sleep, air moves in and out of our lungs, and blood flows through our veins.
- Leaves fall from trees, rivers flow, and vehicles carry people from place to place.
- The Earth rotates once every 24 hours and revolves around the Sun once every year.
- Even the Sun is moving through our galaxy, and the galaxy itself is moving in space!

What is Motion?

- Motion is simply a change in position of an object with time.
- In this chapter, we will learn how to describe motion, especially when an object moves in a straight line (also called rectilinear motion).
- To describe motion, we will use terms like:
 - **Displacement**
 - **Velocity**
 - **Acceleration**
- For motion with uniform acceleration (acceleration that doesn't change), we can use simple equations to describe the motion.
- We will also study relative velocity, which helps us understand how different observers see the motion.

Point Object Assumption

- In our study, we will treat objects as point objects, meaning we ignore their size.
- This is okay if the size of the object is much smaller than the distance it moves.

What is Kinematics?

- This part of physics is called Kinematics, which means the study of motion without considering what causes the motion (forces).
- The causes of motion are studied later, in Chapter 4.

Instantaneous Velocity and Speed

- **Average velocity** tells us how fast something moved over a certain period. But it doesn't tell us how fast it was moving at every moment.

- For that, we need **instantaneous velocity**.

Instantaneous Velocity

- It is the velocity at a particular moment in time. It is calculated by finding the limit of average velocity as the time interval becomes extremely small.

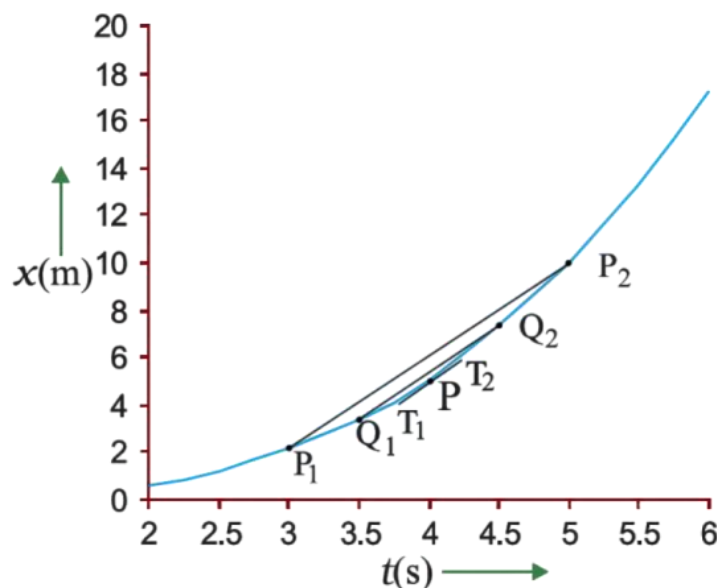
Mathematically:

$$v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Here,

- Δx = change in position
- Δt = change in time
- $\frac{dx}{dt}$ = rate of change of position with respect to time
- We can find instantaneous velocity:
 - **Graphically** (by finding the slope of a position-time graph)
 - **Numerically** (by calculating values for smaller and smaller time intervals)

Example from Graph



- Let's find the velocity at **t = 4 seconds** from the graph shown in the book.
- If we take a time interval of $\Delta t = 2$ seconds around $t = 4$ s, then the average velocity is:
- From $t = 3$ s to $t = 5$ s, the average velocity is the slope of the line connecting these two points on the graph.
- Table:** Velocity at **t = 4 s** for different Δt

Δt (s)	t_1 (s)	t_2 (s)	$x(t_1)$ (m)	$x(t_2)$ (m)	Δx (m)	Average Velocity (m/s)
2.0	3.0	5.0	2.16	10.0	7.84	3.92
1.0	3.5	4.5	3.43	7.86	4.43	4.43
0.5	3.75	4.25	4.22	6.14	1.92	3.85
0.2	3.9	4.1	4.90	5.69	0.79	3.92
0.1	3.95	4.05	5.10	5.52	0.42	4.18
0.01	3.995	4.005	5.10	5.14	0.038	3.84

- As Δt becomes smaller, the average velocity gets closer to 3.84 m/s. So, the instantaneous velocity at $t = 4$ s is 3.84 m/s.

Instantaneous Speed

- Instantaneous speed** is simply the magnitude (absolute value) of instantaneous velocity.
- For example, both +24 m/s and -24 m/s have the same speed: **24 m/s**.
- For **uniform motion**, speed is equal to average velocity at all times.

Example

- The position of an object moving along the x-axis is given by the equation:

$$x = a + bt^2$$

- where:

- $a = 8.5\text{m}$
- $b = 2.5\text{m/s}^2$
- t is time in seconds

Questions:

- What is the velocity at $t = 0$ s and $t = 2.0$ s?
- What is the average velocity between $t = 2.0$ s and $t = 4.0$ s?

Solution:

- We know that:

$$v = \frac{dx}{dt} = \frac{d}{dt}(a + bt^2) = 2bt$$

- Given $b = 2.5$, so:

$$v = 2 \times 2.5 \times t = 5t \text{ m/s}$$

1. At $t = 0$:

$$v = 5 \times 0 = 0 \text{ m/s}$$

2. At $t = 2.0$:

$$v = 5 \times 2 = 10 \text{ m/s}$$

Average velocity from $t = 2.0 \text{ s}$ to $t = 4.0 \text{ s}$:

➤ We use the formula:

$$\text{Average velocity} = \frac{x(4.0) - x(2.0)}{4.0 - 2.0}$$

➤ Given $x = a + bt^2$

$$\circ \quad x(4.0) = 8.5 + 2.5 \times 16 = 8.5 + 40 = 48.5 \text{ m}$$

$$\circ \quad x(2.0) = 8.5 + 2.5 \times 4 = 8.5 + 10 = 18.5 \text{ m}$$

$$\text{Average velocity} = \frac{48.5 - 18.5}{2} = \frac{30}{2} = 15 \text{ m/s}$$

Acceleration

What is Acceleration?

- When an object moves, its **velocity** usually changes. So how do we describe this change in velocity?
- Long ago, even during **Galileo's** time, people wondered whether the change in velocity should be measured with respect to **distance** or **time**.
- At first, it was thought that velocity changes with distance.
- But through his experiments with falling objects and motion on inclined planes, **Galileo** discovered something important:
 - **The rate of change of velocity with time is constant for objects in free fall**, not with distance.
- This led to the concept of **acceleration**, which is defined as the **rate of change of velocity with time**.

Average Acceleration

- The **average acceleration** over a time period is calculated using the formula:

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

- Where:

- v_1 and v_2 are the velocities at times t_1 and t_2
- Δv is the change in velocity
- Δt is the change in time

SI unit of acceleration:

- Meters per second squared (m/s^2)
- On a **velocity-time graph**, average acceleration is the **slope of the straight line** joining two points (v_1, t_1) and (v_2, t_2).

Instantaneous Acceleration

- Just like **instantaneous velocity**, we also have **instantaneous acceleration** — which is the acceleration at a specific moment in time.

$$a = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

- This means:

Acceleration = rate of change of velocity with respect to time at that moment.

- Graphically, this is the **slope of the tangent** to the velocity-time ($v-t$) curve at a point.

Direction and Type of Acceleration

- Since velocity has both **magnitude (speed)** and **direction**, any change in either can cause **acceleration**.
- So, acceleration can result from:
 - A change in **speed**
 - A change in **direction**
 - Or **both**
- Just like velocity, **acceleration** can be:
 - **Positive** (speed increasing in a given direction)
 - **Negative** (speed decreasing, also called **deceleration**)
 - **Zero** (no change in velocity)

Position-Time Graphs and Acceleration

- The **shape** of a **position-time ($x-t$) graph** tells us about the acceleration:
 1. **Positive acceleration:** The graph curves **upward**.
 2. **Negative acceleration:** The graph curves **downward**.

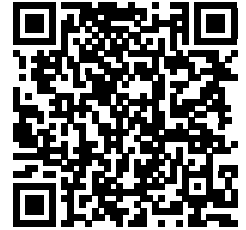


FREE PREVIEW

[Click here to visit our website](#)

SCHOOL NOTES & NCERT SOLUTIONS

Complete notes and
NCERT solutions are
available on
FirstHope app only.



[Scan or click here](#)

Click here to get the app

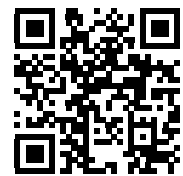


Available on Google Play

JOIN THE FIRSTHOPE COMMUNITY

Join our Telegram channel

Click here to join Telegram



[Scan or click here](#)

@FirstHope_CBSE_Notes

Instagram

@firsthope.school

[Click here to follow >](#)

YouTube channel

@firsthope.school

[Click here to watch >](#)

FirstHope website

firsthope.co.in

[Click here to visit our website >](#)

CBSE / Class 9 / Class 10 / Class 11 / Class 12

Preview notes and NCERT solutions. Full PDFs in the FirstHope app.