Class 9 Science Notes on Chapter 4 Describing Motion Around Us

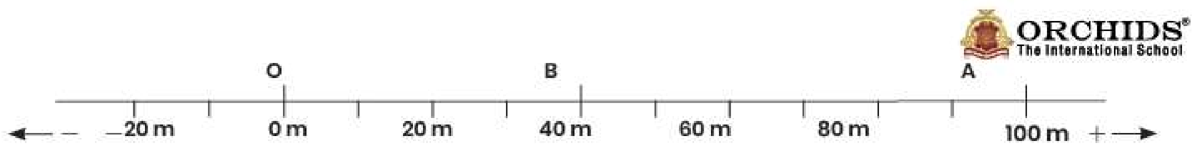
Motion is all around us, and we can observe it. From planets revolving around the Sun to birds flying in the sky, flowing rivers, moving vehicles, and even tiny particles, everything in nature is constantly moving. Motion helps us understand how objects change their position with time and how different types of movement can be described.

Motion in a Straight Line

Motion in a straight line, also called **linear motion**, is the simplest type of motion. It occurs when an object moves along a straight path. Common examples include a car moving on a straight road, a train on a straight track, a ball falling vertically, and athletes running in a straight race.

Describing Position

To describe the position of an object, a **reference point (origin)** is chosen. The position is then expressed by its **distance and direction** from this reference point.



Reference point and positions of the athlete at different instants of time on a straight line

Important Key Points to remember

- A fixed **reference point (origin)** is needed to describe position.
- Positions to the **right of the origin** are generally taken as **positive (+)**.
- Positions to the **left of the origin** are generally taken as **negative (–)**.
- An object is said to be **in motion** if its position changes with time.
- An object is **at rest** if its position remains unchanged with time.

Distance Travelled and Displacement

Although both distance and displacement describe motion, they are different physical quantities.

Distance Travelled: Distance travelled is the **total length of the actual path** covered by an object during its motion.

It depends on the actual path followed. Has only magnitude (scalar quantity).

Displacement: Displacement is the **net change in the position** of an object between its initial and final positions.

It is the shortest straight-line distance between the starting and ending positions. It has both magnitude and direction (vector quantity).

Difference Between Distance and Displacement

Distance Travelled	Displacement
Total length of the actual path travelled.	Shortest straight-line distance between initial and final positions.
Scalar quantity.	Vector quantity.
Depends on the path taken.	Depends only on the initial and final positions.
Always positive or zero.	Can be positive, negative, or zero depending on direction.
Magnitude is always greater than or equal to displacement.	

Average Speed and Average Velocity

Average speed and average velocity help us describe how fast an object moves over a period of time. Although both are measured using time, they are different because average speed depends on distance travelled, while average velocity depends on displacement.

Average Speed

Average speed is the **total distance travelled divided by the total time taken**.

$$\text{Average Speed} = \frac{\text{Total Distance Travelled}}{\text{Time Taken}}$$

Important Key Points to remember,

- Depends on the **total distance travelled**.
- It is a **scalar quantity** (has only magnitude).
- Does **not** indicate the direction of motion.
- SI unit: **metre per second (m/s)**.
- It is also commonly expressed in **kilometre per hour (km/h)**.

Uniform and Non-Uniform Motion

Uniform Motion: An object is said to be in **uniform motion** if it travels **equal distances in equal intervals of time**.

Characteristics:

- Speed remains constant.
- Motion is steady and predictable.

Non-Uniform Motion: An object is said to be in **non-uniform motion** if it travels **unequal distances in equal intervals of time**.

Characteristics:

- Speed changes with time.
- The object may speed up, slow down, or do both.

Average Velocity

Average velocity is the **displacement divided by the total time taken**.

$$v_{\text{avg}} = \frac{\text{Displacement}}{\text{Time Taken}}$$

Important Key Points to Remember

- Depends on **displacement**, not distance.
- It is a **vector quantity** (has both magnitude and direction).
- The direction of average velocity is the **same as the direction of displacement**.
- SI unit: **metre per second (m/s)**.
- It represents the **average rate of change of position** with time.

Difference Between Average Speed and Average Velocity

Average Speed	Average Velocity
Total distance travelled divided by total time.	Displacement divided by total time.
Depends on distance travelled.	Depends on displacement.
Scalar quantity.	Vector quantity.
Has only magnitude.	Has both magnitude and direction.
Always positive or zero.	Can be positive, negative, or zero depending on displacement.

For motion in a straight line, average speed and the magnitude of average velocity are equal only when the object moves continuously in the same direction.

Average Acceleration

Average acceleration is the **change in velocity divided by the time taken for that change**.

$$\text{Average Acceleration} = \frac{\text{Change in Velocity}}{\text{Time Taken}}$$

Or

$$a = \frac{v-u}{t}$$

Where **a** is average acceleration (m/s²), **u** is initial velocity, **v** is final velocity and **t** is time taken.

Important Key Points to remember,

- Average acceleration measures the rate of change of velocity.
- It depends on both the change in velocity and the time interval.
- It is a vector quantity because it has both magnitude and direction.
- SI unit: metre per second squared (m/s^2).

Direction of Average Acceleration

The direction of acceleration depends on how the velocity changes.

- **When the speed increases**, acceleration acts in the **same direction** as the velocity.
- **When the speed decreases**, acceleration acts in the **opposite direction** to the velocity (called **deceleration or retardation**).

A change in velocity can occur due to:

- A change in the speed of an object.
- A change in the direction of motion.
- A change in both speed and direction.

Graphical Representation of Motion

Graphs provide a simple and clear way to study motion. They help us understand how **position, velocity, and acceleration change with time**. By looking at a graph, we can compare the motion of different objects, identify whether the motion is uniform or non-uniform, and calculate important physical quantities.

Plotting a Graph

A graph is plotted by showing one physical quantity on the **X-axis (horizontal axis)** and another on the **Y-axis (vertical axis)**.

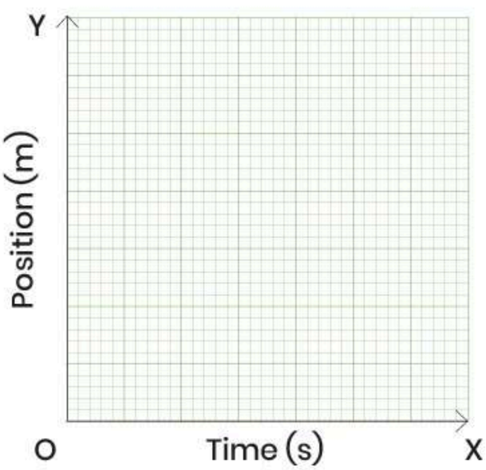
To plot a graph, let us use the data given in the table for a vehicle moving on a straight road.

Table 4.3: Positions of vehicle at different instants of time

Time	0 s	1 s	2 s	3 s	4 s	5 s	6 s
Position	0 m	20 m	40 m	60 m	80 m	100 m	120 m

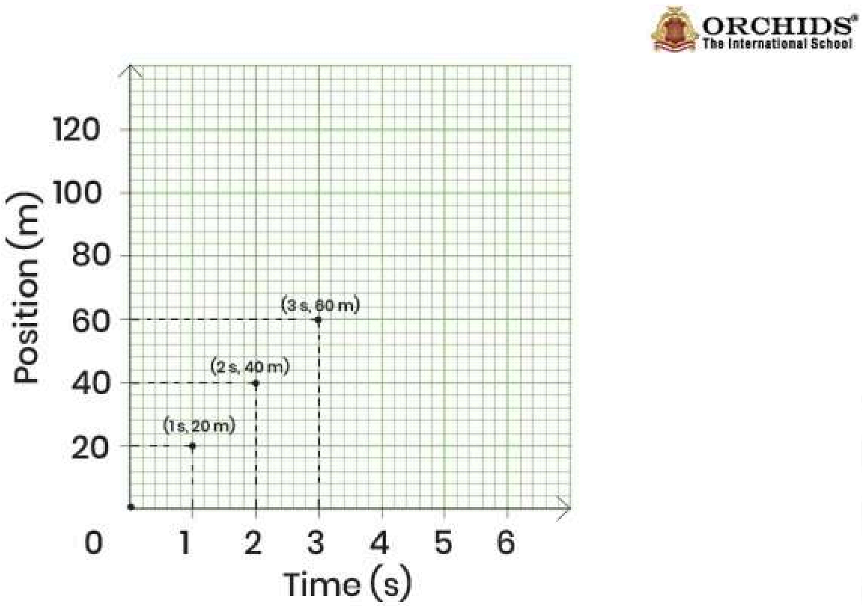
Steps to Plot a Position-Time Graph

1. Draw two perpendicular lines to form the **X-axis** and **Y-axis** with the **origin (O)**.



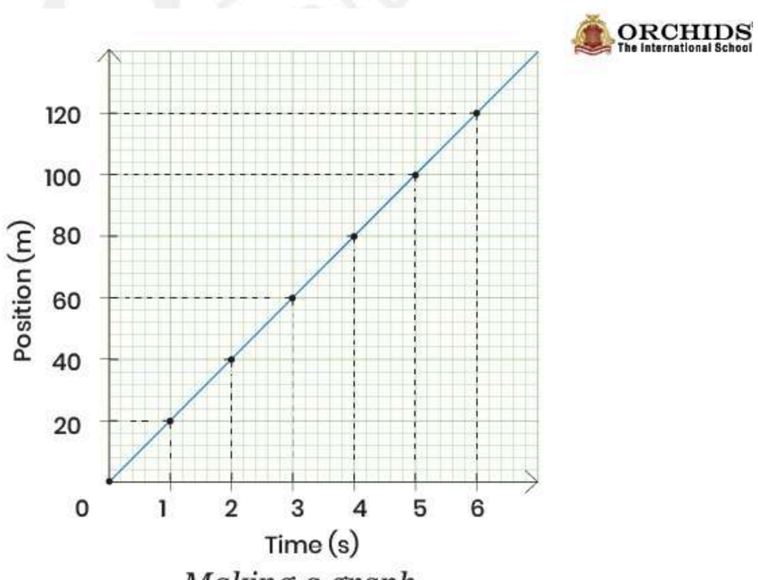
Marking origin, X and Y axes on graph paper

2. Plot **time** on the X-axis and **position** on the Y-axis.



Plotting points on the graph

3. Choose a suitable scale for both axes.
4. Mark the values on each axis according to the selected scale.
5. Plot each point using the given time and position values.
6. Join the plotted points to obtain the **position-time graph**.



Making a graph

Position-Time Graphs

Position-time graphs show how the position of an object changes with time. By studying the shape and slope of the graph, we can understand the nature of an object's motion. **X-axis:** Time and **Y-axis:** Position

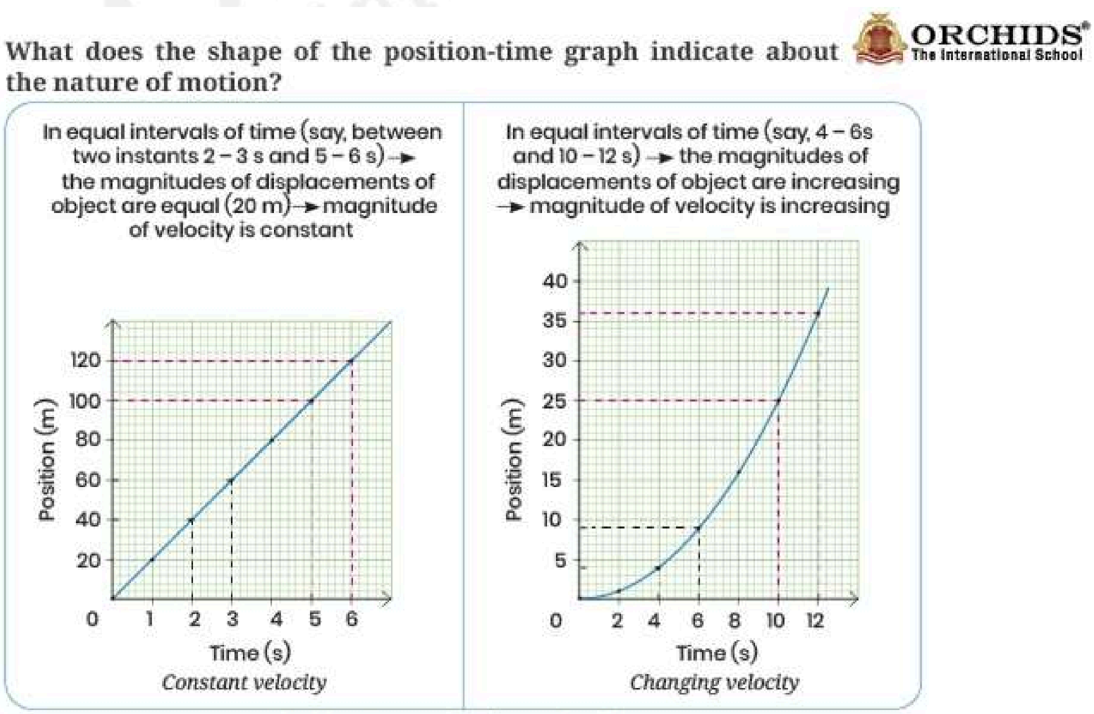
It helps us determine how an object's position changes as time passes.

What Does the Shape of a Position-Time Graph Tell Us?

The shape of the graph indicates the type of motion.

Graph Shape	Nature of Motion
Straight line	Constant (uniform) velocity
Curved line	Changing velocity (accelerated or non-uniform motion)

- A **straight-line graph** means the object covers equal distances in equal intervals of time.
- A **curved graph** means the object's velocity is changing with time.



Position-time graph of a moving object

Information Obtained from a Position-Time Graph

A position-time graph helps us find:

- Position of the object at any instant of time.
- Nature of motion (uniform or non-uniform).
- Average velocity between two points using the graph's slope.

Slope of a Position-Time Graph

The **slope** of a position-time graph gives the **average velocity** of the object.

$$\text{Average Velocity} = \frac{\text{Change in Position}}{\text{Change in Time}}$$

or

$$v = \frac{\Delta s}{\Delta t}$$

Where **Δs** is the change in position, and **Δt** is the change in time. A steeper slope indicates a higher velocity.

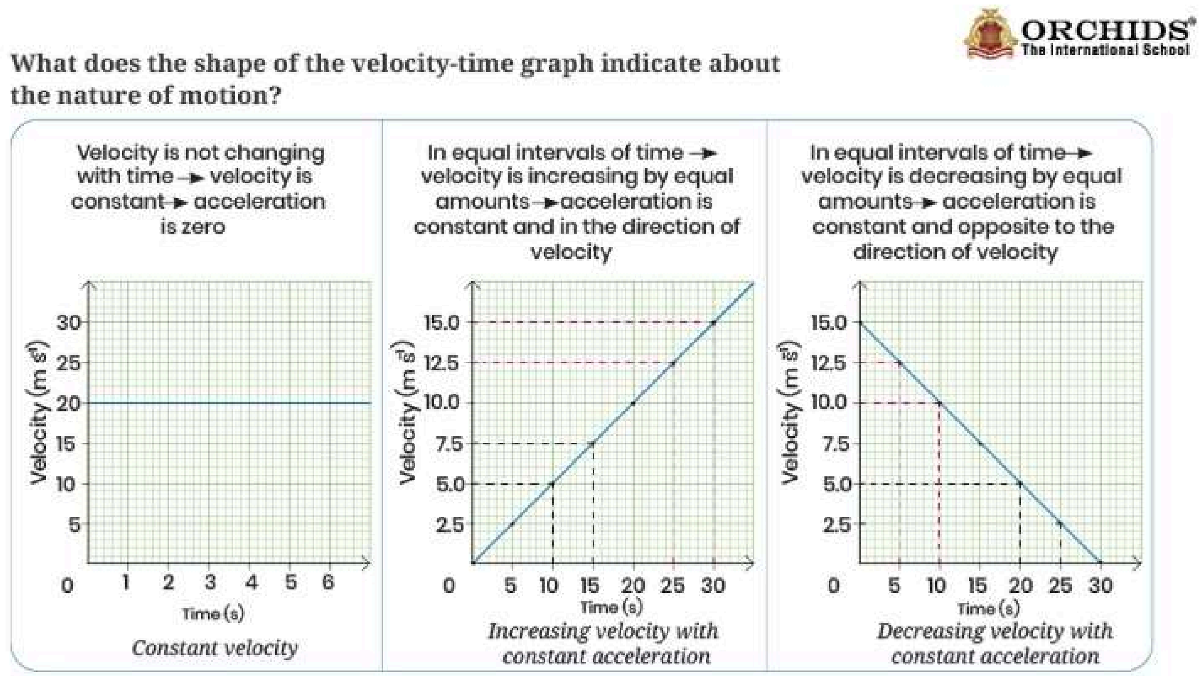
How to Find Average Velocity from the Graph

Choose any two points on the graph.

1. Find the change in position (Δs).
2. Find the change in time (Δt).
3. Divide the change in position by the change in time.

Velocity-Time Graphs

A velocity-time graph shows how the velocity of an object changes with time. It helps us understand whether an object is moving with constant velocity, accelerating, or slowing down. The graph is plotted by taking time on the X-axis and velocity on the Y-axis.



Velocity-time graph of a moving car

Types of Velocity-Time Graphs

Constant Velocity: When an object moves with the same velocity throughout its motion, the velocity-time graph is a **horizontal straight line** parallel to the time axis.

- Velocity remains constant.
- Acceleration is zero.
- The object covers equal distances in equal intervals of time.

Increasing Velocity (Uniform Acceleration): If the velocity increases by equal amounts in equal intervals of time, the graph is a **straight line sloping upward**.

- Velocity increases uniformly.
- Acceleration is constant and positive.
- The object speeds up with time.

Decreasing Velocity (Uniform Deceleration)

If the velocity decreases by equal amounts in equal intervals of time, the graph is a **straight line sloping downward**.

- Velocity decreases uniformly.
- Acceleration is constant but acts opposite to the direction of motion (negative acceleration or deceleration).
- The object slows down with time.

Information Obtained from a Velocity-Time Graph

A velocity-time graph helps us determine,

- Velocity of the object at any instant.
- Whether the object is moving with constant velocity, accelerating, or decelerating.
- The acceleration of the object from the slope of the graph.
- The distance travelled by finding the area under the graph (covered later in higher classes).

Slope of a Velocity-Time Graph

The **slope (gradient)** of a velocity-time graph represents the **acceleration** of the object.

$$\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Time Taken}}$$

or

$$a = \frac{v-u}{t}$$

Where u is the initial velocity, v is the final velocity, and t is the time interval

- A **horizontal line** has zero slope, so the acceleration is **zero**.
- An **upward sloping line** indicates **positive (constant) acceleration**.
- A **downward sloping line** indicates **negative acceleration (deceleration)**.

Area Under the Velocity-Time Graph

The **area enclosed between the velocity-time graph and the time axis** gives the **displacement** of the object during that time interval.

$$\text{Displacement} = \text{Area under the velocity-time graph}$$

For Constant Velocity

When velocity remains constant, the graph forms a rectangle.

$$\text{Displacement} = \text{Velocity} \times \text{Time}$$

For Uniformly Accelerated Motion

When velocity changes uniformly, the graph forms a combination of a rectangle and a triangle.

$$\text{Displacement} = \text{Area of Rectangle} + \text{Area of Triangle}$$

Important Key Points to Remember

- Slope of a velocity-time graph = Acceleration
- Area under a velocity-time graph = Displacement
- A horizontal graph represents constant velocity and zero acceleration.
- A positive slope indicates increasing velocity.
- A negative slope indicates decreasing velocity (deceleration).
- The greater the area under the graph, the greater the displacement.

Kinematic Equations for Motion in a Straight Line with Constant Acceleration

Kinematic equations describe the motion of an object moving in a straight line with constant acceleration. These equations help calculate displacement, velocity, acceleration, and time without repeatedly using definitions.

These equations are valid only when the acceleration remains constant throughout the motion.

Kinematic Equations

1. First Equation of Motion

This equation is used to calculate the **final velocity** of an object.

$v = u + at$

Where u is the initial velocity, v is the final velocity, a is constant acceleration, and t is the time taken.

2. Second Equation of Motion

This equation is used to calculate the **displacement** of an object.

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

Where s is displacement, u is initial velocity, a is constant acceleration, and t is time taken.

3. Third Equation of Motion

This equation relates **velocity, acceleration, and displacement** without using time.

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

Where v is final velocity, **u** is Initial velocity, **a** is constant acceleration and **s** is displacement.

Conditions for Using Kinematic Equations

These equations can be applied only when:

- Motion is in a **straight line**.

- Acceleration remains **constant**.
- The object follows **uniformly accelerated motion**.

Real-Life Applications of Kinematic Equations

Kinematic equations are useful for solving problems involving:

- Motion of moving vehicles
- Freely falling objects
- Objects thrown vertically upward or downward
- Motion of trains, buses, and cyclists
- Calculating stopping distance and braking distance

Important Points to Remember

- Kinematic equations apply **only for constant acceleration**.
- The **sign (+ or –)** of displacement, velocity, and acceleration indicates their direction.
- In one-direction motion, **distance equals the magnitude of displacement**, and **speed equals the magnitude of velocity**.
- These equations help predict the **future position and velocity** of an object.

Motion in a Plane

Motion that takes place in **two dimensions** is called **motion in a plane**. In this type of motion, an object moves in both the horizontal and vertical directions or along a curved path.

Examples of Motion in a Plane

- A vehicle overtaking another vehicle.
- The path of a kicked football or thrown ball.
- A satellite moving around the Earth.
- A bird flying through the sky.

Uniform Circular Motion

When an object moves along a **circular path**, its motion is called **circular motion**.

If the object moves with **constant speed** along the circular path, it is said to be in **uniform circular motion**.

Distance and Displacement in Circular Motion

- **Distance travelled** is the actual length of the circular path covered.
- **Displacement** is the shortest straight-line distance between the starting and ending positions.

For one complete revolution:

- Distance travelled = Circumference of the circle

$$\text{Distance} = 2\pi R$$

where **R** is the radius of the circle. And displacement = **0**, because the object returns to its starting point.

Average Speed in Uniform Circular Motion

If an object takes **T** seconds to complete one revolution, then

$$\text{Average Speed} = \frac{2\pi R}{T}$$

Where **R** is the radius of the circular path, and **T** is the time taken for one revolution

Average Velocity in One Complete Revolution

Although the object keeps moving, its **average velocity over one complete revolution is zero** because its displacement is zero.

Direction of Velocity in Circular Motion

In uniform circular motion:

- **Speed remains constant.**
- **Velocity continuously changes** because its **direction changes at every point** on the circular path.
- Therefore, the object is **accelerating even though its speed is constant**.

Velocity is Along the Tangent

At any point on a circular path, the **velocity acts along the tangent to the circle** at that point.

A **tangent** is a straight line that touches the circle at only one point.

This explains why an object released from circular motion moves in a straight line in the direction of the tangent.

Important Key Points to Remember

- Motion in a plane is **two-dimensional motion**.
- Uniform circular motion means **constant speed along a circular path**.
- Distance covered in one revolution = **2πR**.
- Displacement after one complete revolution = **0**.
- Average speed is **distance ÷ time**.
- Average velocity for one complete revolution is **zero**.
- In circular motion, **speed is constant, but velocity changes continuously** because the direction changes.
- The **velocity at any point is always along the tangent** to the circle.