Motion in a Straight Line

Introduction

Motion in a straight line or **one-dimensional motion** is the motion of an object along a straight path. In this chapter, we study the basic concepts of **position, distance, displacement, speed, velocity, acceleration, and equations of motion**. Graphs are also used to understand the motion of objects.

Position and Reference Point

Position

The location of an object with respect to a fixed point is called its **position**. The fixed point is called the **origin** or reference point.

The position of an object can be positive or negative depending on the chosen direction.

Reference Frame

A **reference frame** is a coordinate system with respect to which the position and motion of an object are described.

Distance and Displacement

Distance

Distance is the total length of the actual path travelled by an object.

It is a **scalar quantity** and is always positive or zero.

SI Unit: **metre (m)**

Displacement

Displacement is the change in position of an object.

Displacement = Final Position − Initial Position

It is a **vector quantity** and can be positive, negative, or zero.

The magnitude of displacement is always less than or equal to the distance travelled.

Speed and Velocity

Speed

Speed is the rate of change of distance with time.

Speed = Distance/Time

Average speed:

Average Speed = Total Distance/Total Time

Speed is a scalar quantity.

SI Unit: **m/s**

Velocity

Velocity is the rate of change of displacement with time.

v = Displacement/Time

Average velocity:

vavg = Total Displacement/Total Time

Velocity is a vector quantity and has both magnitude and direction.

Uniform and Non-Uniform Motion

Uniform Motion

An object is said to be in **uniform motion** when it covers equal distances in equal intervals of time.

Its velocity remains constant if its direction does not change.

Non-Uniform Motion

An object is in **non-uniform motion** when it covers unequal distances in equal intervals of time.

Its velocity changes with time.

Acceleration

Definition

Acceleration is the rate of change of velocity with time.

$a = \Delta v/\Delta t$

where:

- **a** = Acceleration
- **Δv** = Change in velocity
- **Δt** = Time interval

SI Unit: **m/s^2**

Types of Acceleration

- **Positive acceleration:** Velocity increases with time.
- **Negative acceleration:** Velocity decreases with time. It is also called retardation.
- **Zero acceleration:** Velocity remains constant.

Equations of Motion

First Equation

The first equation of motion is:

$v = u + at$

where:

- **u** = Initial velocity
- **v** = Final velocity
- **a** = Acceleration
- **t** = Time

Second Equation

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

where **s** is displacement.

Third Equation

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

These equations are valid for motion with **constant acceleration**.

Graphical Representation of Motion

Position-Time Graph

A graph showing the position of an object with time is called a **position-time graph**.

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

Slope = Δx/Δt = Velocity

- Straight line with constant slope → Uniform velocity
- Changing slope → Non-uniform velocity

Velocity-Time Graph

The slope of a velocity-time graph gives **acceleration**.

Slope = Δv/Δt = Acceleration

The area under a velocity-time graph gives the **displacement**.

Acceleration-Time Graph

The area under an acceleration-time graph gives the **change in velocity**.

Relative Velocity

Definition

The velocity of one object as observed from another moving object is called **relative velocity**.

For two objects moving in the same direction:

vAB = vA − vB

For objects moving in opposite directions:

vAB = vA + vB

Relative velocity is useful for studying the motion of two objects with respect to each other.

Free Fall

Definition

The motion of an object under the influence of gravity alone is called **free fall**.

The acceleration due to gravity is represented by **g**.

Near the surface of Earth:

$g \approx 9.8\ m/s^2$

For a freely falling object, the equations of motion can be written by replacing **a** with **g**.

Key Points

- Motion in a straight line is one-dimensional motion.
- Distance is a scalar, while displacement is a vector.
- Distance is always greater than or equal to the magnitude of displacement.
- Speed is the rate of change of distance.
- Velocity is the rate of change of displacement.
- Acceleration is the rate of change of velocity.
- The three equations of motion apply to uniformly accelerated motion.
- The slope of a position-time graph gives velocity.
- The slope of a velocity-time graph gives acceleration.
- The area under a velocity-time graph gives displacement.
- The area under an acceleration-time graph gives change in velocity.
- Free fall is motion under gravity alone.

Chapter Summary

This chapter introduces the fundamental concepts of one-dimensional motion. It explains position, reference frame, distance, displacement, speed, velocity, acceleration, uniform and non-uniform motion, equations of motion, graphical representation of motion, relative velocity, and free fall. These concepts form the foundation for understanding more advanced topics in mechanics and physics.