Unit 3
Motion in a Straight Line

Introduction

Motion is a fundamental concept in physics and is part of our everyday experiences. This unit will introduce you to the basic concepts of motion including position, distance, displacement, speed, velocity, and acceleration. We will explore how these concepts describe different types of motion, especially linear or one-dimensional motion.

1. Position, Distance, and Displacement

- **Position:** The location of an object in space at a given time is called its position. For example, your home and school are positions on a map.
- **Distance:** Distance is the total length of the path traveled by an object. It does not depend on direction and is a scalar quantity. For example, if you walk 3 km to the west and then 2 km to the east, the total distance traveled is 5 km.
- **Displacement:** Displacement is the change in position of an object and is a vector quantity. It considers both magnitude and direction. For example, if you travel 3 km west and then 2 km east, your displacement is 1 km to the west. Displacement can be zero if you return to your starting point.

2. Speed and Velocity

- **Speed:** Speed is the rate at which an object covers distance. It is a scalar quantity with only magnitude and is given by the formula:

  $$\text{Speed} = \frac{Distance}{\text{Time}}$$

  For example, if you travel 80 km in 1.5 hours, your average speed is calculated as 53.33 km/h or 14.81 m/s.

- **Instantaneous Speed:** The speed of an object at a specific moment in time. It is what is shown on a speedometer of a car.

3. Average Speed vs. Instantaneous Speed

- **Average Speed:** Total distance traveled divided by the total time taken. It is calculated using:

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

- **Instantaneous Speed:** The speed of an object at a specific point in time, which can vary throughout the motion.

Example Problems

1. **Cyclist's Motion:**
   - A cyclist rides 3 km west and then 2 km east.
     - **Displacement:** 1 km west (calculated as final position minus initial position).
     - **Distance:** 5 km (sum of all distances traveled).
     - **Magnitude of Displacement:** 1 km.
2. **Car Travel:**
   - A car covers 80 km in 1.5 hours.

   Average Speed: $\frac{80\ km}{1.5\ \text{hr}}$ =53.33 km/hr=14.81 m/s

3. **Walking Distance:**
   - A student walks for 1.5 hours at an average speed of 5 m/s.
     - **Distance:** Speed×Time=5 m/s×5400 s=27,000 m or 27 km.

Understanding these concepts will help you analyze and describe motion in various scenarios, both in theoretical problems and practical situations.

Average Velocity and Instantaneous Velocity

Velocity is a vector quantity, meaning it has both magnitude and direction. Unlike speed, which only measures how fast an object is moving, velocity also tells us the direction of movement. The SI unit for velocity is meters per second (m/s), though it can also be expressed in kilometers per hour (km/h) or miles per hour (mi/h).

1. Average Velocity

To describe an object's motion over a period, we use **average velocity**. It is calculated by dividing the total displacement by the total time taken. Displacement is the straight-line distance in a specific direction from the starting point to the end point.

Formula:

$\vec{v}_{avg}=\frac{\Delta \vec{X}}{\Delta t}$

- **ΔX** is the displacement (final position minus initial position).
- **Δt** is the total time taken.

Example 1:

A student moves 360 meters north in 180 seconds. To find the average velocity:

$\vec{v}_{avg} = \frac{360\ m}{180\ s} = 2$ m/s north

Example 2:

A girl jogs east with an average velocity of 2.4 m/s for 40 seconds. The displacement is:

Displacement $= \vec{v}_{avg} \times \Delta t = 2.4\ m/s \times 40\ s = 96$ m east

Example 3:

A bus covers different distances over specific time intervals:

- From 20 km to 60 km in 1 hour: $\vec{v}_{avg} = \frac{60\ km - 20\ km}{1\ hr} = 40$ km/hr
- The same calculation applies to subsequent intervals.

2. Instantaneous Velocity

Instantaneous velocity is the velocity of an object at a specific instant in time. It can be found by considering a very small time interval around the instant in question. For uniform motion, the average velocity equals the instantaneous velocity.

Example 4:

A car accelerates from rest to 36 km/h in 20 seconds. The average acceleration is:

$\text{Acceleration} = \frac{\Delta v}{\Delta t} = \frac{36\ km/h - 0}{20\ s}$

Converting 36 km/h to m/s:

36 km/h = 10 m/s

Thus:

Acceleration=$\frac{10\,m/s}{20\,s}$ =0.5 m/s^2

Summary

- **Average Velocity** is calculated over a period and reflects the overall change in position.
- **Instantaneous Velocity** is the velocity at a particular moment and can be obtained by analyzing small time intervals.

Understanding both average and instantaneous velocity helps in accurately describing and analyzing the motion of objects.