Motion Velocity

Rest and Motion

An object or particle is said to be at rest if it does not change its position with time relative to a fixed reference point. Depending on the observer's position, rest can be absolute or relative.

Motion occurs when an object changes its position with time relative to the same reference point. Motion can be linear, circular, oscillatory, or vibratory.

Types of Motion

Linear Motion: Movement along a straight line where all particles of the body move parallel and cover equal distances in equal time intervals.

Circular Motion: Movement along a circular path where all particles move along concentric circles.

Oscillatory Motion: Back and forth movement about a fixed point in a definite time interval. If the amplitude is very small, it is called vibratory motion.

Dimensions of Motion

One-Dimensional Motion: Movement along a single direction or straight line.

Two-Dimensional Motion: Movement where two coordinates change with time.

Three-Dimensional Motion: Movement where all three coordinates change with time.

Distance and Displacement

Distance: The actual path length traveled by a body. It is a scalar quantity measured in meters (SI unit).

Displacement: The shortest distance between initial and final positions in a specific direction. It is a vector quantity with magnitude and direction, measured in meters.

Displacement can be positive, zero, or negative, but never greater than the distance traveled.

Difference Between Distance and Displacement

Distance is the total path length and always positive, while displacement is the shortest path and can be positive, negative, or zero. Distance depends on the path taken; displacement does not.

Instantaneous Velocity

The velocity of a body at a specific instant of time, especially when velocity varies with time.

Uniform and Non-Uniform Motion

Uniform Motion: Equal displacements in equal time intervals.

Non-Uniform Motion: Unequal displacements in equal time intervals.

Solved Examples

Example 1: A car moves along a straight road covering 100 m in 5 seconds. Calculate its average speed.

Solution:

Distance, D = 100 m

Time, t = 5 s

Speed = Distance / Time = 100 m / 5 s = 20 m/s

Example 2: A particle moves from point A to B, 50 m east, then to point C, 40 m west. Find the displacement.

Solution:

Displacement = Final position - Initial position = 50 m east - 40 m west = 10 m east

Example 3: A body moves with uniform velocity of 15 m/s for 10 seconds. Find the distance covered.

Solution:

Speed = 15 m/s

Time = 10 s

Distance = Speed × Time = 15 × 10 = 150 m

Practice Set

- **Level 1:** Define displacement and state its SI unit.
- **Level 1:** Differentiate between rest and motion.
- **Level 2:** A person walks 30 m north and then 40 m east. Calculate the total distance and displacement.

Answer Key

- **Level 1:** Displacement is the shortest distance between initial and final positions in a specific direction. SI unit is meter (m).
- **Level 1:** Rest means no change in position with time relative to a reference point; motion means change in position with time.
- **Level 2:** Total distance = 30 m + 40 m = 70 m. Displacement = $\sqrt{(30^2 + 40^2)}$ = 50 m.

Uniformly Accelerated Motion

Acceleration and Types

Acceleration is the rate of change of velocity with time. It is a vector quantity measured in meters per second squared (m/s^2).

Types include uniform acceleration (velocity changes equally in equal time intervals) and variable acceleration (velocity changes unequally).

Equations of Motion

For uniformly accelerated motion with initial velocity u, acceleration a, time t, final velocity v, and displacement s:

- $v = u + at$
- $s = ut + \frac{1}{2} at^2$
- $v^2 = u^2 + 2as$

Special Cases Under Gravity

When acceleration is due to gravity g ($\approx 9.8\ m/s^2$):

- $v = u + gt$ (falling down)
- $h = ut + \frac{1}{2} gt^2$ (displacement)
- $v^2 = u^2 + 2gh$
- Maximum height: $h_{max} = u^2 / (2g)$
- Time to reach max height: $t = u / g$
- Total time up and down: $T = 2u / g$

Solved Examples

Example 1: A car starts from rest and accelerates uniformly at 2 m/s² for 5 seconds. Find its final velocity and distance covered.

Solution:

Initial velocity, u = 0 m/s

Acceleration, a = 2 m/s²

Time, t = 5 s

Final velocity, v = u + at = 0 + 2 × 5 = 10 m/s

Distance, s = ut + ½ at² = 0 + ½ × 2 × 25 = 25 m

Example 2: A ball is thrown vertically upwards with velocity 20 m/s. Calculate the maximum height reached.

Solution:

Initial velocity, u = 20 m/s

Acceleration due to gravity, g = 9.8 m/s²

Maximum height, h_max = u² / (2g) = (20)² / (2 × 9.8) = 400 / 19.6 ≈ 20.41 m

Practice Set

- **Level 1:** Define acceleration and state its SI unit.
- **Level 2:** A body moving with initial velocity 5 m/s accelerates uniformly at 3 m/s² for 4 seconds. Find its final velocity.
- **Level 3:** A ball is thrown upwards with velocity 15 m/s. Calculate the time taken to reach maximum height and total time in air.

Answer Key

- **Level 1:** Acceleration is the rate of change of velocity with time. SI unit is m/s².
- **Level 2:** $v = u + at = 5 + 3 \times 4 = 17$ m/s.
- **Level 3:** Time to max height, $t = u / g = 15 / 9.8 \approx 1.53$ s. Total time, $T = 2t \approx 3.06$ s.

Quick Reference Table

Common Mistakes and Misconceptions

Glossary