Table of Contents

"

Motion in a Straight Line

Describing position

To describe the position of an object, we select a fixed reference point. The position is given by the distance and direction of the object from this reference point at any instant. If the position changes with time, the object is said to be in motion; if it remains the same, the object is at rest.

Distance travelled and displacement

Distance travelled is the total length of the path covered by the object, irrespective of direction. Displacement is the net change in position of the object between two instants, having both magnitude and direction. For motion in a straight line, displacement is the straight-line distance from the initial to the final position, with direction specified.

Average speed and average velocity

Average speed is the total distance travelled divided by the time interval. It is a scalar quantity with no direction. Average velocity is the displacement divided by the time interval and is a vector quantity, having both magnitude and direction. The SI unit for both is metre per second (m/s).

Average acceleration

Average acceleration is the change in velocity divided by the time interval over which the change occurs. It is a vector quantity with SI unit metre per second squared (m/s^2). Acceleration can be positive (speeding up) or negative (slowing down), depending on the direction of velocity change.

Graphs of motion

Position-time graphs show how position changes with time. A straight line indicates constant velocity, while a curve indicates changing velocity (acceleration). Velocity-time graphs show how velocity changes with time. The slope of a velocity-time graph gives acceleration, and the area under the graph gives displacement.

Kinematic equations

For motion in a straight line with constant acceleration, the following equations relate displacement (s), time (t), initial velocity (u), final velocity (v), and acceleration (a):

- $v = u + at$
- $s = ut + 1/2\ at^2$
- $v^2 = u^2 + 2as$

Solved Examples

Example 1: Two postmen start walking towards each other from a distance of 210 yojanas. One travels 9 yojanas per day and the other 5 yojanas per day. When will they meet?

Solution: Total distance covered per day = 9 + 5 = 14 yojanas. Time to meet = 210 / 14 = 15 days.

Example 2: Sarang swims 50 m in 50 seconds, going from one end of a pool to the other and back. Find his average speed and average velocity.

Solution: Total distance = 50 m, displacement = 0 m (since he returns to start). Average speed = 50 m / 50 s = 1 m/s. Average velocity = 0 m / 50 s = 0 m/s.

Example 3: A bus accelerates from 36 km/h to 54 km/h in 10 s, then brakes to stop in 5 s. Find average acceleration in both intervals.

Solution: Convert speeds to m/s: 36 km/h = 10 m/s, 54 km/h = 15 m/s.

Acceleration phase: $a = (15 - 10) / 10 = 0.5$ m/s².

Braking phase: $a = (0 - 15) / 5 = -3$ m/s².

Example 4: An object is dropped from rest and its velocity increases by 9.8 m/s every second. Find the average acceleration.

Solution: Average acceleration = change in velocity / time = 9.8 m/s², constant in each interval.

Example 5: A car moving at 54 km/h applies brakes with acceleration -4 m/s². Find stopping distance.

Solution: Convert speed: 54 km/h = 15 m/s. Using $v^2 = u^2 + 2as$, $0 = 15^2 + 2(-4)s$, $s = 225 / 8 = 28.1$ m.

Practice Set

Conceptual Questions

- What is the difference between distance travelled and displacement?
- Why is average velocity a vector quantity while average speed is a scalar?

Application-based Question

- A car accelerates uniformly from 20 m/s to 30 m/s in 5 seconds. Calculate its acceleration and distance travelled during this time.

Numerical Question

- A cyclist travels 100 m north in 20 seconds, then 40 m south in 10 seconds. Find the average speed and average velocity for the entire trip.

Answer Key

Conceptual Questions

- Distance is the total path length covered; displacement is the straight-line change in position with direction.
- Average velocity includes direction (displacement/time), making it a vector; average speed is total distance/time, a scalar.

Application-based Question

Acceleration = (30 - 20) / 5 = 2 m/s².

Distance travelled = ut + 1/2 at² = 20 × 5 + 0.5 × 2 × 25 = 100 + 25 = 125 m.

Numerical Question

Total distance = 100 + 40 = 140 m; total time = 20 + 10 = 30 s.

Average speed = 140 / 30 ≈ 4.67 m/s.

Displacement = 100 - 40 = 60 m north.

Average velocity = 60 / 30 = 2 m/s north.

Uniform Circular Motion

Definition and examples

Uniform circular motion occurs when an object moves along a circular path with constant speed. Examples include a child on a merry-go-round, a satellite orbiting Earth, or a car turning in a circular track.

Distance and displacement in circular motion

The distance travelled in one complete revolution is the circumference of the circle, $2\pi R$, where R is the radius. The displacement after one complete revolution is zero, as the object returns to its starting point.

Average speed and velocity

Average speed in one revolution is the circumference divided by the time period T: $v_{av} = 2\pi R / T$. Average velocity over one revolution is zero due to zero displacement.

Direction of velocity and acceleration

In uniform circular motion, the speed is constant but the direction of velocity changes continuously. The velocity vector is always tangent to the circle. The acceleration, called centripetal acceleration, points towards the center of the circle, causing the change in direction.

Real-world considerations

Uniform circular motion is an idealization. Real motions may involve varying speed or non-circular paths. Understanding uniform circular motion helps analyze planetary orbits, vehicle turns, and other circular motions.

Solved Examples

Example 1: A child on a merry-go-round of radius 2 m completes one revolution in 10 seconds. Find the average speed.

Solution: Circumference = $2\pi \times 2 = 4\pi$ m.

Average speed = $4\pi / 10 \approx 1.26$ m/s.

Example 2: A satellite moves in a circular orbit of radius 7000 km with a period of 90 minutes. Find its average speed.

Solution: Convert radius to meters: 7000 km = 7×10^6 m.

Period T = $90 \times 60 = 5400$ s.

Average speed = $2\pi \times 7 \times 10^6 / 5400 \approx 8140$ m/s.

Practice Set

Conceptual Questions

- Why is the acceleration in uniform circular motion directed towards the center?
- Explain why average velocity over one complete revolution is zero.

Application-based Question

- A car moves around a circular track of radius 50 m at a constant speed of 20 m/s. Calculate the time taken for one complete revolution.

Answer Key

Conceptual Questions

- Acceleration is towards the center because it changes the direction of velocity, keeping the object moving in a circle.
- Average velocity is zero because displacement after one revolution is zero.

Application-based Question

Time period T = circumference / speed = $2\pi \times 50 / 20 = 15.7$ s.

Quick Reference Table

Motion in a Straight Line

- Displacement (s): Net change in position, vector quantity, unit metre (m).
- Average speed: Total distance / time, scalar, unit m/s.
- Average velocity (v_{av}): Displacement / time, vector, unit m/s.
- Average acceleration (a): Change in velocity / time, vector, unit m/s^2.
- Kinematic equations (constant acceleration):
  - $v = u + at$
  - $s = ut + 1/2\ at^2$
  - $v^2 = u^2 + 2as$

Uniform Circular Motion

- Distance in one revolution = $2\pi R$.
- Average speed = $2\pi R / T$.
- Average velocity over one revolution = 0.
- Velocity direction: Tangent to circle.
- Acceleration direction: Towards center (centripetal acceleration).

Common Mistakes and Misconceptions

- Confusing distance travelled with displacement; displacement considers direction and can be zero even if distance is not.
- Assuming average speed and average velocity are always equal; they differ when direction changes.

- Believing acceleration only occurs when speed changes; acceleration also occurs when direction changes, as in circular motion.
- Misinterpreting position-time graphs as route maps; they show position changes over time, not the path taken.
- Using kinematic equations without ensuring acceleration is constant.

Glossary

- **Displacement:** Vector quantity representing change in position.
- **Average speed:** Total distance travelled divided by time.
- **Average velocity:** Displacement divided by time, vector quantity.
- **Acceleration:** Rate of change of velocity with time.
- **Uniform circular motion:** Motion in a circle at constant speed.
- **Centripetal acceleration:** Acceleration directed towards the center of circular path.
- **Kinematic equations:** Equations relating displacement, velocity, acceleration, and time for constant acceleration.

"