MOTION IN A STRAIGHT LINE

What is Motion?

Motion is fundamental to physics.

Definition: An object is said to be in motion if it changes its position with respect to its surroundings over time.
Everything in the universe is in some form of motion, from subatomic particles to galaxies. Understanding motion helps us predict, analyze, and describe the world around us.

Rest and Motion: Are They Absolute?

Rest: An object is at rest if its position does not change with respect to its surroundings over time.
Relative Nature: Rest and motion are relative terms.
An object at rest for one observer might be in motion for another.

Example: A passenger inside a moving bus is at rest relative to other passengers in the bus,
but in motion relative to a person standing outside on the road.
This highlights the importance of choosing a "Frame of Reference."

Rectilinear Motion

Types of Motion:
Translational Motion: Motion along a straight or curved path (e.g., car on a road).
Rotational Motion: Motion about a fixed axis (e.g., spinning top).
Oscillatory/Vibratory Motion: To and fro motion about a mean position (e.g., pendulum).
Rectilinear Motion: A special case of translational motion where an object moves along a straight line. Also known as one-dimensional (1D) motion. Simplest type of motion to analyze.

Point Object & Frame of Reference

Point Object (Point Mass):
An object whose size is negligible compared to the distance it travels or the scale of motion being studied.
Simplifies analysis by ignoring rotation and deformation.
Example: A train moving from Delhi to Kolkata can be treated as a point object.
Frame of Reference:
A coordinate system and a clock used by an observer to specify the position of an object and measure time. •Essential for defining motion precisely.
Usually, a Cartesian coordinate system with three perpendicular axes (X, Y, Z) and an origin.

Describing Position

- To describe motion, we first need to define an object's position.
- Position: The location of an object in space at a given instant, relative to a chosen origin in the frame of reference.
- For Rectilinear Motion: Position can be described using a single coordinate (e.g., x-coordinate) along the straight line.

- Positive values usually denote one direction (e.g., right of origin).
- Negative values usually denote the opposite direction (e.g., left of origin).
- Origin (x=0) is the reference point.

Path Length (Distance)

- Definition: The total length of the actual path covered by an object during its motion, irrespective of the direction of motion.
- Nature: Scalar quantity (has magnitude only, no direction).
- Units: Measured in meters (m) in the SI system.
- Always Non-Negative: Path length can never be zero or negative for a moving object. It increases continuously with time.
- Example:If you walk 5 m east and then 3 m west, your total path length is 5m+3m=8m.

Displacement

- Definition: The change in position of an object. It is the shortest straight-line distance between the initial and final positions of the object, along with the direction.
- Nature: Vector quantity (has both magnitude and direction).
- Units: Measured in meters (m) in the SI system.
- Can be Zero, Positive, or Negative:
- Zero: If the object returns to its starting point.
- Positive/Negative: Depends on the chosen direction.
- Formula: $\Delta x = xf - xi$ (where xf is final position, xi is initial position).

Distance vs. Displacement: A Fundamental Comparison

Feature	Distance (Path Length)	Displacement
Definitiuon	Total path covered	Change in position (shortest path)
Nature	Scalar quantity	Vector quantity
Direction	No specific direction	Has specific direction
Value	Always non-negative	Can be positive, negative, or zero
Path Dep.	Depends on the actual path taken	Independent of the actual path, only initial and final points
Magnitude	≥Magnitude of Displacement	≤ Distance
Return to Start	Non-zero	Zero

Speed: How Quickly an Object Moves (Average Speed

- Definition: The rate at which an object covers distance.
- Nature: Scalar quantity.
- Units: Meters per second (m/s) in SI.
- Average Speed: Average Speed= Total Distance Covered /Total Time Taken
- Average Speed=$\Delta s/\Delta t$
- It gives a general idea of how fast an object moved over a period, but not at any specific instant.

Velocity: Speed with Direction (Average Velocity)

- The rate of change of an object's position with respect to time. It specifies both speed and direction.
- Nature: Vector quantity.
- Units: Meters per second (m/s) in SI.
- Average Velocity: Average Velocity=Total Displacement
- vavg= ΔtΔx= tf- tixf-xi •Can be positive, negative, or zero, depending on the displacement.

Instantaneous Speed and Instantaneous Velocity

- Instantaneous Speed: The speed of an object at a particular instant in time.
- It is the magnitude of the instantaneous velocity.
- Instantaneous Velocity: The velocity of an object at a specific moment in time.
- It is the limit of the average velocity as the time interval approaches zero.
- Mathematically: $v=\lim\Delta t\to 0\Delta t\Delta x= dtdx$ (the derivative of position with respect to time).
- Provides the exact speed and direction at a given point.

Speed vs. Velocity: The Direction Matters

Feature	Speed	Velocity
Definitiuon	Rate of covering distance	Rate of change of position
Nature	Scalar quantity	Vector quantity
Direction	No specific direction	Has specific direction
Value	Always non-negative (instantaneous speed)	Can be positive, negative, or zero
Magnitude	Can be equal to or greater than magnitude of velocity	Can be equal to or less than speed (magnitude)
Change	Changes with change in magnitude	Changes with change in magnitude OR direction OR both

Acceleration: The Rate of Change of Velocity

- The rate at which the velocity of an object changes over time.
- Nature: Vector quantity.
- Units: Meters per second squared (m/s2) in SI.
- An object accelerates if its speed changes, or its direction changes, or both.
- Formula (General): $a=\Delta t\Delta v=tf-tivf-vi$

Average, Instantaneous, and Types of Acceleration

Average Acceleration:

- aavg= ChangeinVelocity/ TimeTaken =tf-tivf-vi
- Instantaneous Acceleration:
- The acceleration of an object at a specific instant in time.
- a=limΔt→0ΔtΔv=dtdv (the derivative of velocity with respect to time).
- Types of Acceleration in 1D:
- Positive Acceleration: Velocity increases in the positive direction.
- Negative Acceleration (Deceleration/Retardation): Velocity decreases in the positive direction, or increases in the negative direction.
- Zero Acceleration: Velocity is constant (uniform velocity).

Graphical Representation of Motion: Why Use Graphs?

- Graphs provide a visual and intuitive way to understand the relationship between different physical quantities in motion.
- They help in quickly identifying patterns, trends, and specific values.
- Commonly used graphs:
- Position-Time (x-t) graphs
- Velocity-Time (v-t) graphs
- Acceleration-Time (a-t) graphs (less common for basic 1D motion)

Position-Time (x-t) Graphs: Object at Rest

- Shows how an object's position changes with time.
- Graph for Object at Rest:
- A horizontal straight line parallel to the time axis.
- Explanation: The position (x-coordinate) remains constant as time progresses.
- Slope of an x-t graph represents velocity. For an object at rest, the slope is zero, hence velocity is zero.

x-t Graphs: Uniform Velocity Motion

- Uniform Velocity:

An object moves with uniform velocity if it covers equal displacements in equal intervals of time.

- Graph for Uniform Positive Velocity:

A straight line inclined upwards (positive slope).
Explanation: Position increases linearly with time.

- Graph for Uniform Negative Velocity:

A straight line inclined downwards (negative slope).
Explanation: Position decreases linearly with time.

- The slope of the x-t graph is constant and non-zero.

x-t Graphs: Non-Uniform Velocity and Deriving Velocity

- Non-Uniform Velocity: Velocity changes over time.
- Graph for Non-Uniform Velocity:
- A curved line.

Explanation: The rate of change of position is not constant.

- Deriving Velocity from x-t Graph:

The slope of the x-t graph gives the velocity.

- For a straight line (uniform velocity), slope = $\Delta x./\Delta t$
- For a curved line (non-uniform velocity), the instantaneous velocity at any point is given by the slope of the tangent to the curve at that point.

Velocity-Time (v-t) Graphs: Uniform Velocity

- Purpose: Shows how an object's velocity changes with time.
- Graph for Uniform Velocity (Constant Velocity):
- A horizontal straight line parallel to the time axis.
- Explanation: Velocity remains constant as time progresses.
- This implies zero acceleration.

v-t Graphs: Uniform Acceleration and Deriving Acceleration

- Uniform Acceleration:

An object moves with uniform acceleration if its velocity changes by equal amounts in equal intervals of time.

- Graph for Uniform Positive Acceleration:

A straight line inclined upwards (positive slope).
Explanation: Velocity increases linearly with time.

- Graph for Uniform Negative Acceleration:

A straight line inclined downwards (negative slope).
Explanation: Velocity decreases linearly with time.

- Deriving Acceleration from v-t Graph:
- The slope of the v-t graph gives the acceleration.
- Slope = ΔtΔv.

v-t Graphs: Non-Uniform Acceleration

- Non-Uniform Acceleration: Acceleration changes over time.
- Graph for Non-Uniform Acceleration:
- A curved line.
- Explanation: The rate of change of velocity is not constant.
- In such cases, the instantaneous acceleration at any point is given by the slope of the tangent to the curve at that point.

v-t Graphs: Finding Displacement from Area Under Curve

- Deriving Displacement from v-t Graph:
- The area under the velocity-time (v-t) graph gives the displacement of the object. For uniform velocity (rectangle), Area = velocity × time. For uniform acceleration (trapezoid/triangle),
- Area = 21(sum of parallel sides)×height or other geometric formulas.
- Area above the time axis represents positive displacement, and area below represents negative displacement.

Thank you

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