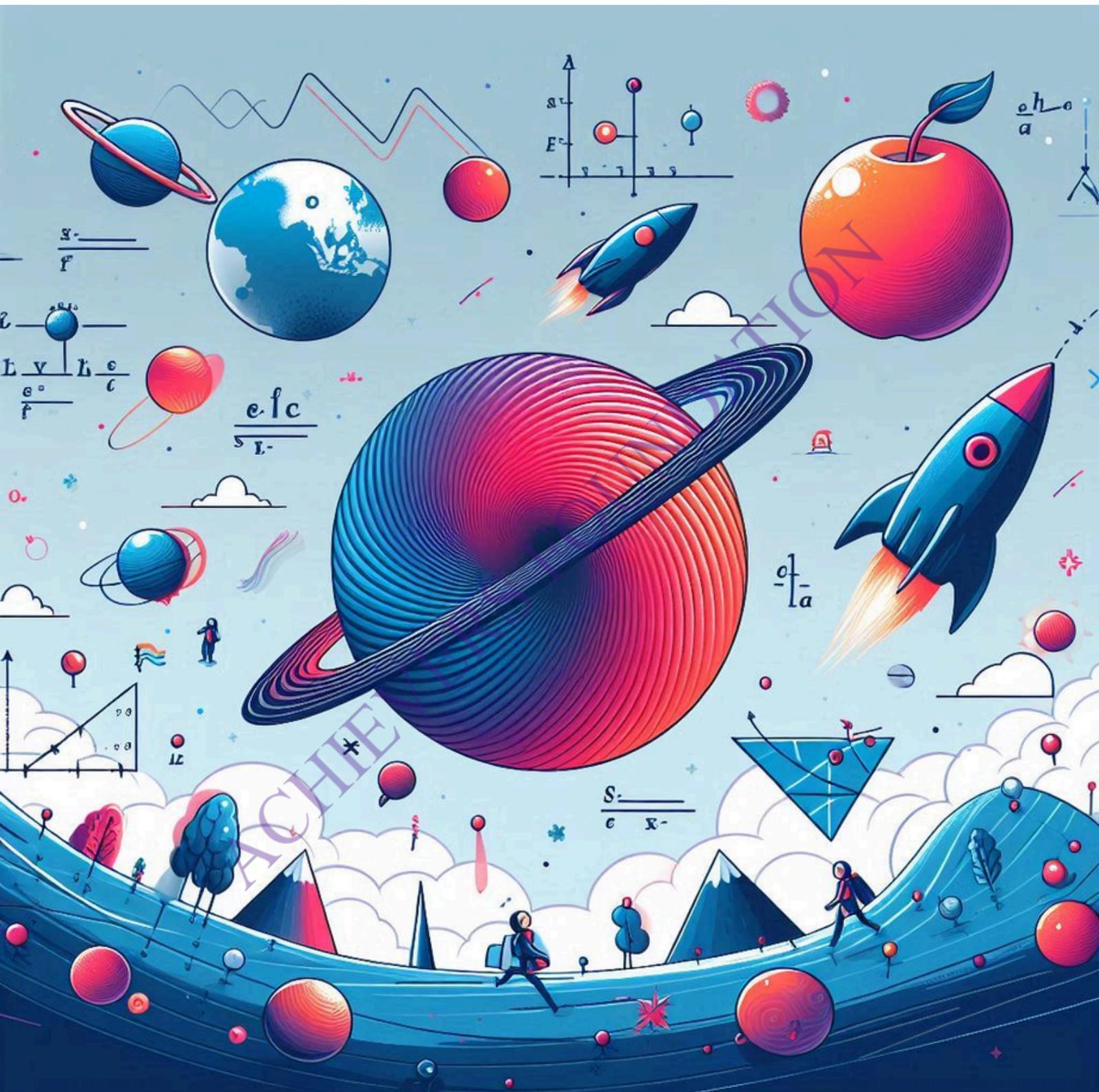


MOTION



Motion

We use general things around us that are moving. For example, we can observe air moving, clock hands ticking, and even the motion of Earth around the Sun, which causes day and night as well as seasons. To understand motion in detail, we first need to define what motion is.

Reference Point and Stationary Objects

To determine whether an object is in motion or at rest, we need to consider a reference point or a stationary object in the surroundings. A reference point is an object that does not change its position.

Example: If we consider a pole and a car, the pole remains stationary as it does not change its location, whereas the car can move. To determine whether the car is at rest or in motion, we compare its motion relative to the pole or another stationary object.

Rest and Motion

- **Rest:** When a body doesn't change its position relative to its surroundings or reference point, it is said to be at rest.
- **Motion:** When a body changes its position relative to its surroundings or reference point, it is in motion.

Characteristics of a Moving Object

When an object is in motion, it possesses the following characteristics:

1. It changes its position over time.
2. Its speed may vary depending on external factors.
3. It follows a particular path of motion (straight-line, circular, or random).
4. It has a velocity, which includes both speed and direction.

Understanding motion is fundamental in physics, as it helps us analyze and describe how objects move in different scenarios.

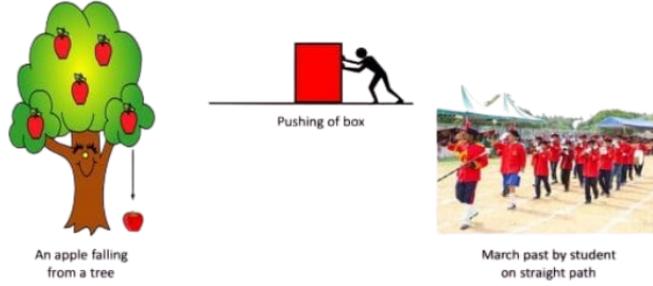
Types of Motion

Motion refers to the change in position of an object over time. Based on the nature of movement, motion can be classified into different types:

1. Linear Motion

- When an object moves in a straight line, it is called linear motion.
- Example: A car moving on a straight road.

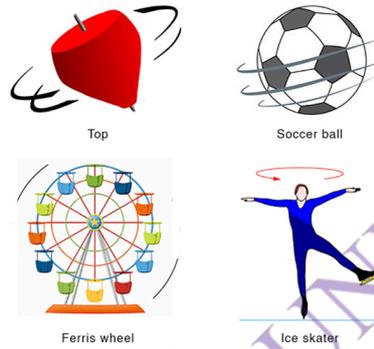
Examples of Rectilinear or Linear Motion



2. Rotational Motion

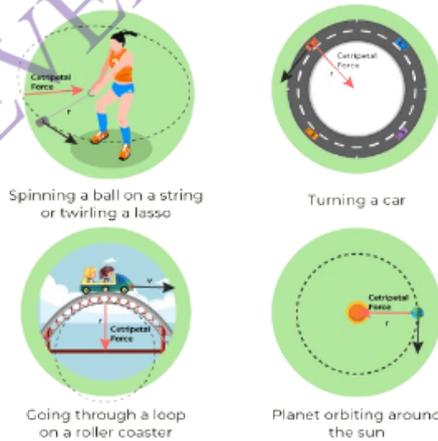
- When an object rotates around a fixed axis, it is said to be in rotational motion.
- Example: The Earth rotating on its axis, causing day and night.

Rotational Motion Examples



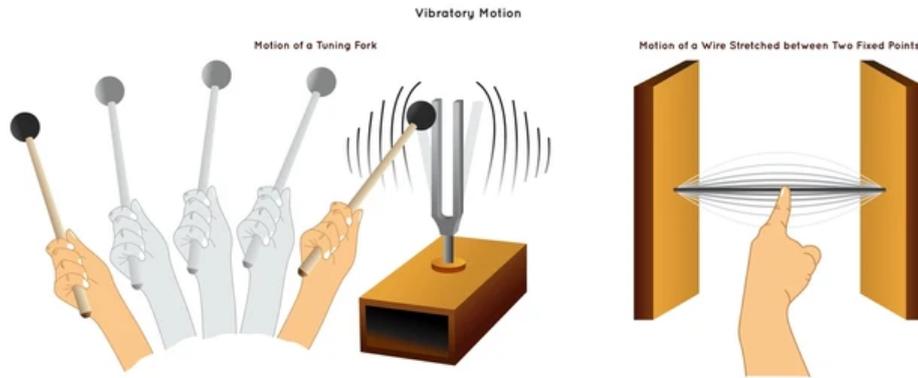
3. Circular Motion

- When an object moves along a curved or circular path, it is called circular motion.
- Example: A car moving around a roundabout.



4. Vibratory Motion

- When an object moves back and forth rapidly about a fixed position, it is called vibratory motion.
- Example: Guitar strings vibrating when plucked, producing sound.



This classification of motion helps in understanding different physical phenomena and their real-life applications.

Scalar and Vector Physical Quantities

Physical quantities are classified into scalar and vector quantities based on whether they require direction along with magnitude for their complete description.

1. Scalar Quantities

- Scalar quantities depend only on magnitude (value) and do not require direction.
- They are represented using symbols without arrows.
- Examples: Distance, speed, mass, temperature, time, energy.

✦ Example: If you travel 250 km from Chandigarh to Delhi, you only mention the distance traveled without specifying direction. This makes distance a scalar quantity.

2. Vector Quantities

- Vector quantities depend on both magnitude and direction.
- They are represented with an arrow (\rightarrow) over the symbol to indicate direction.
- Examples: Displacement, velocity, force, acceleration, momentum.

✦ Example: If you travel 25 km east, the direction is specified. This makes displacement a vector quantity.

Scalar vs Vector

SCALAR

A scalar quantity has magnitude only.



speed



mass



volume



time

VECTOR

A vector has both magnitude and direction.



velocity



weight

friction



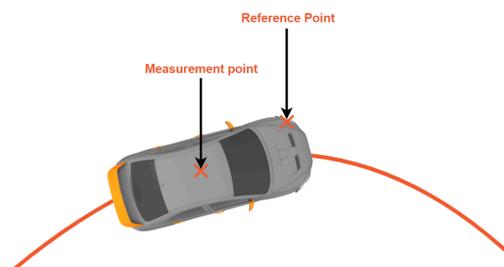
Reference Point and Reference Frame

1. Reference Point (Origin)

- To determine the position of an object, a reference point or origin is required.
- Motion is always relative; an object may appear moving to one observer and stationary to another.

✦ Example:

- A passenger inside a moving bus sees fellow passengers at rest.
- However, an observer outside the bus sees the passengers in motion.



2. Reference Frame

- A reference frame is a coordinate system used to describe the position and motion of an object.
- To ensure consistency in observations, all measurements should be made from the same reference frame.

Frame of Reference



Whether or not you are moving depends on **your** point-of-view.

From inside the box car, the woman in red is stationary (at rest).

From outside the box car, the woman in red is moving.

Types of Reference Frames

- **Inertial Frame:** A non-accelerating frame where Newton's laws of motion hold true.
- **Non-Inertial Frame:** A frame that accelerates, requiring additional fictitious forces for analysis.

Distance and Displacement

1. Distance

- Distance is the total path length covered by an object during its motion.
- It is a scalar quantity (depends only on magnitude, not direction).
- It is always positive and never decreases.
- The SI unit of distance is meter (m).

♦ Example:

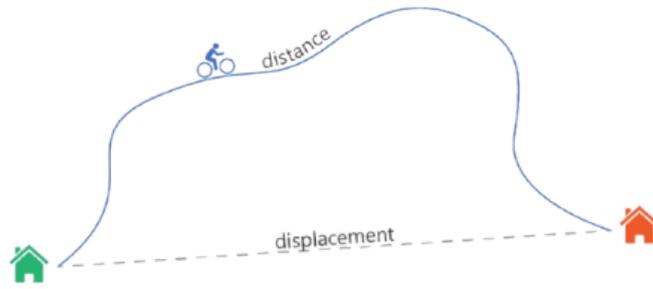
If a car moves 5 km east and then 3 km west, the total distance traveled is:
 $5 \text{ km} + 3 \text{ km} = 8 \text{ km}$

2. Displacement

- Displacement is the shortest straight-line distance from the initial position to the final position.
- It is a vector quantity (depends on both magnitude and direction).
- It can be positive, negative, or zero.
- The SI unit of displacement is meter (m).

♦ Example:

For the same car journey (5 km east, then 3 km west), the displacement is:
 $5 \text{ km} - 3 \text{ km} = 2 \text{ km east}$ (since displacement considers direction).



Distance vs Displacement

Differences Between Distance and Displacement

Feature	Distance	Displacement
Type	Scalar	Vector
Definition	Total path traveled	Shortest path from start to end
Value	Always positive	Can be positive, negative, or zero
Dependence on direction	No	Yes
Example	8 km (total)	2 km (east)

♦ Important Note:

- If an object returns to its starting point, its displacement is zero, but the distance is not zero.
- Distance is always greater than or equal to displacement (never less).

Time and Speed

1. Time

- Time is the period during which an event occurs.
- It is a scalar quantity (has magnitude but no direction).
- The SI unit of time is second (s).
- It is a fundamental physical quantity used in various measurements.

♦ Example:

The time taken for a car to travel from one city to another is measured in hours, minutes, or

seconds.

2. Speed

- Speed is the rate of change of distance.
- It tells how fast an object moves in a given time.
- It is a scalar quantity (depends only on magnitude, not direction).
- The SI unit of speed is meters per second (m/s).

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

✦ Example:

If a car travels 100 km in 2 hours, its speed is:

$$\text{Speed} = \frac{100 \text{ km}}{2 \text{ hours}} = 50 \text{ km/h}$$

3. Average Speed

- The total distance traveled divided by the total time taken.
- It gives the overall speed of an object during the entire journey.

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

✦ Example:

If a car covers 120 km in 3 hours, the average speed is:

$$\text{Average Speed} = \frac{120 \text{ km}}{3 \text{ hours}} = 40 \text{ km/h}$$

4. Key Points to Remember

- ✓ Speed is always positive (it cannot be negative).
- ✓ If an object does not move, its speed is zero.
- ✓ Time is independent of direction, making it a scalar quantity.
- ✓ Faster objects have higher speeds than slower objects.

	Case 1	Case 2
Distance	Same	Different
Time	Different	Same
Average Speed	$\frac{2ab}{(a+b)}$	$\frac{(x+y)}{2}$

Velocity

Velocity is the rate of change of displacement with respect to time. It is a vector quantity, meaning it has both magnitude and direction.

$$\text{Velocity (v)} = \frac{\text{Displacement}}{\text{Time}}$$

Displacement is the shortest distance between the initial and final positions. Time is the duration over which the displacement occurs.

Average Velocity:

$$\text{Average Velocity} = \frac{\text{Initial Velocity (u)} + \text{Final Velocity (v)}}{2}$$

$$\text{Average Velocity} = \frac{u + v}{2}$$

Use this formula only when acceleration is uniform (constant).

Key Points:

- Velocity is different from speed. Speed only has magnitude (scalar), velocity has direction too.
- If an object returns to the starting point, its displacement = 0, so velocity = 0 even if speed isn't zero.
- Units of velocity: meters per second (m/s) in SI units.

Acceleration

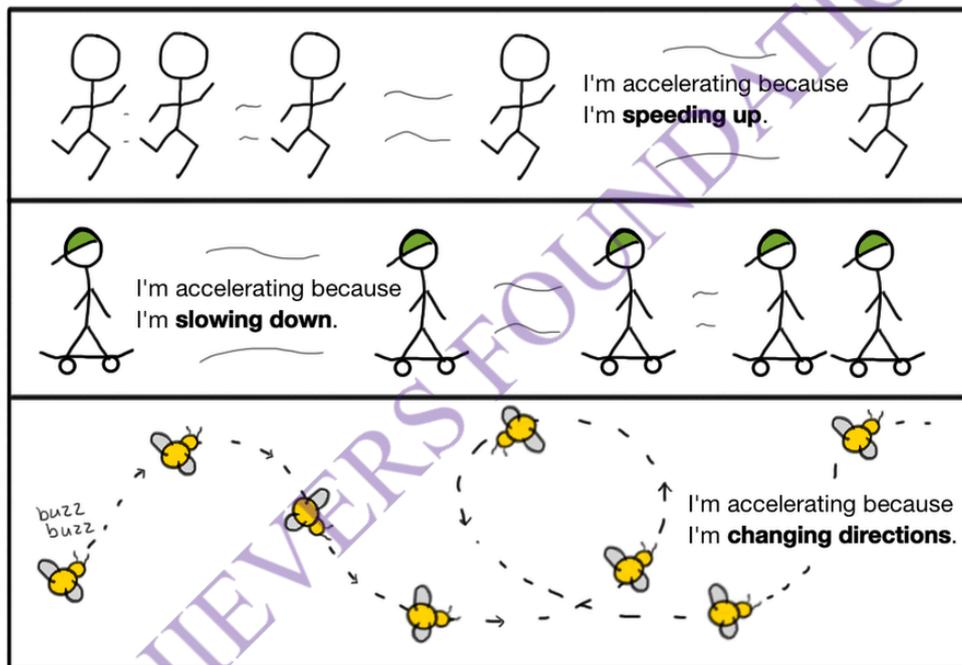
Acceleration is the rate of change of velocity with respect to time.
It tells us how quickly an object speeds up or slows down.

- It is a vector quantity (has magnitude and direction).
- It is denoted by the symbol “a”.

$$a = \frac{\text{Change in Velocity}}{\text{Time}} = \frac{v - u}{t}$$

Where:

- a = Acceleration
- v = Final velocity
- u = Initial velocity
- t = Time taken for the change



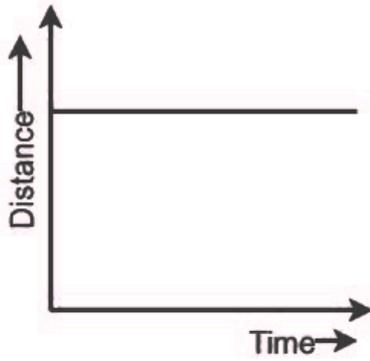
Graphical Representation

1. Distance-Time graph:

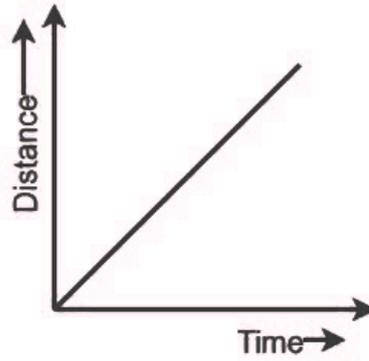
A Distance-Time Graph is a visual representation of how distance changes with time as an object moves. It helps us understand the motion of an object at a glance.

What It Shows:

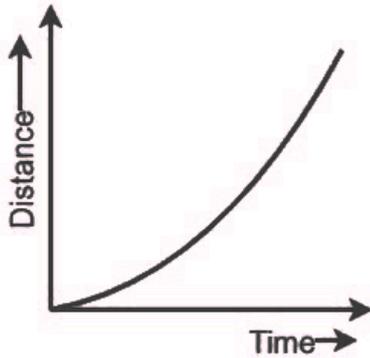
- The x-axis represents time.
- The y-axis represents distance.
- The slope of the graph gives the speed of the object.



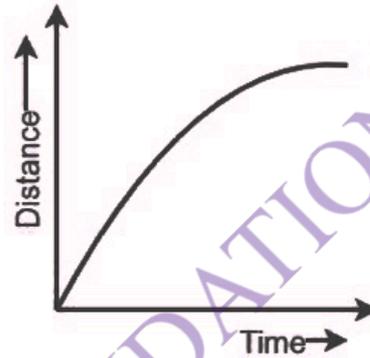
For Stationary body



(For uniform motion)



(For non-uniform motion when speed increases)



(For non-uniform motion when speed decreases)

Graph Shape	Description	Motion Type
◆ Straight line (upward slope)	Distance increases uniformly with time	Uniform motion
◆ Curved line	Distance increases non-uniformly with time	Accelerated motion
◆ Horizontal line	Distance remains constant over time	Object at rest

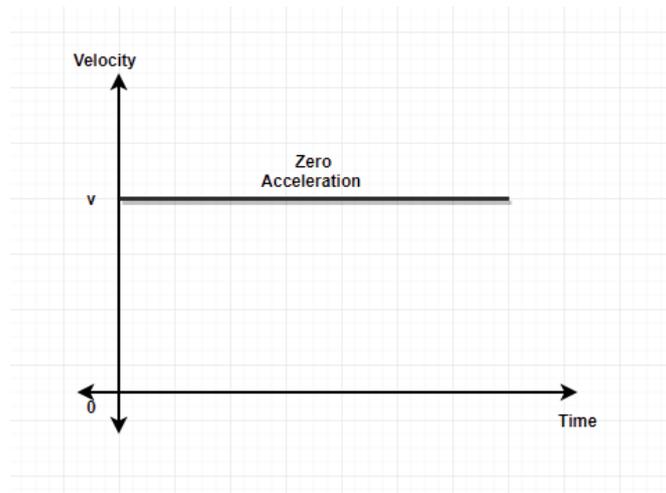
2.Velocity-Time Graph

A Velocity-Time Graph shows how an object's velocity changes over time. It is a valuable tool for analyzing acceleration, deceleration, and uniform motion.

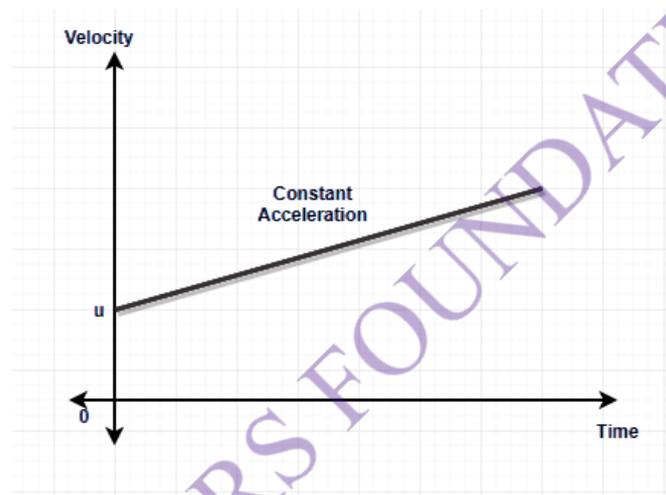
What It Shows:

- The x-axis represents time.
- The y-axis represents velocity.
- The slope of the graph gives the acceleration of the object.
- The area under the graph gives the displacement.

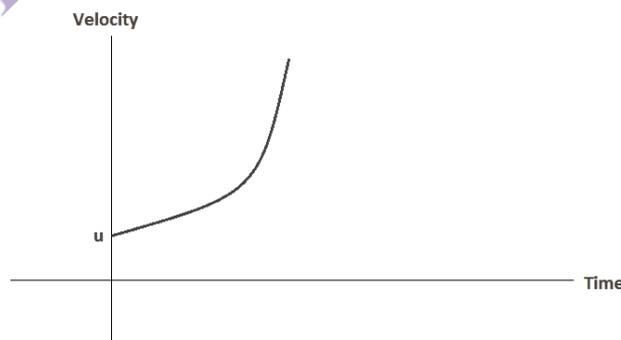
a. Velocity – time graphs with Constant Velocity (No Acceleration)



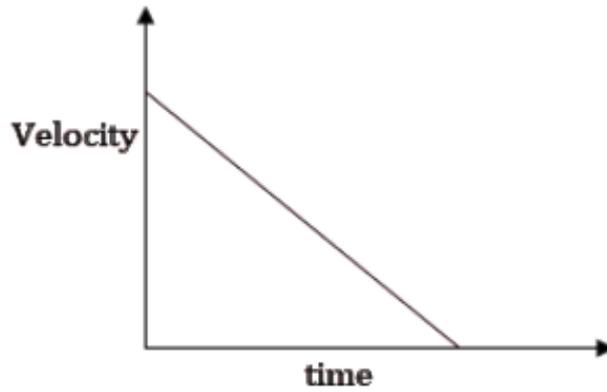
b. Velocity -time graphs with Increasing Velocity (Constant Acceleration)



c. Velocity -Time Graph with increasing Acceleration

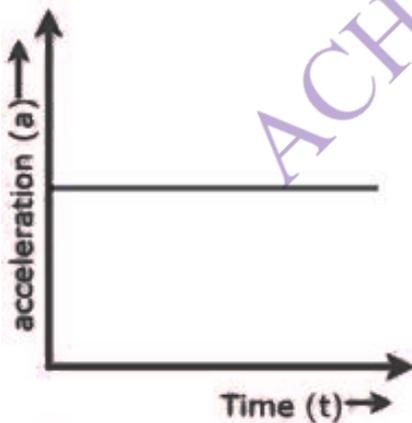


d. Velocity -Time Graph with Decreasing Acceleration

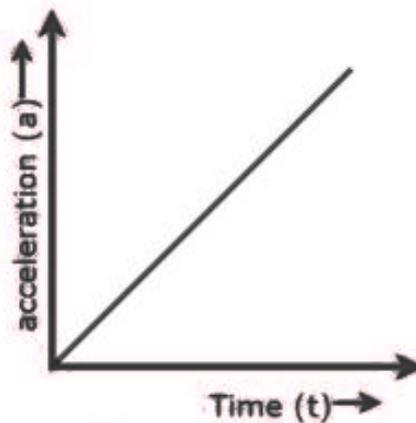


Graph Shape	Description	Motion Type
▲ Straight line (upward slope)	Constant acceleration	Uniform acceleration
▼ Straight line (downward slope)	Constant deceleration (retardation)	Uniform negative acceleration
Horizontal line	Constant velocity	Zero acceleration
Curved line	Acceleration is changing	Non-uniform acceleration

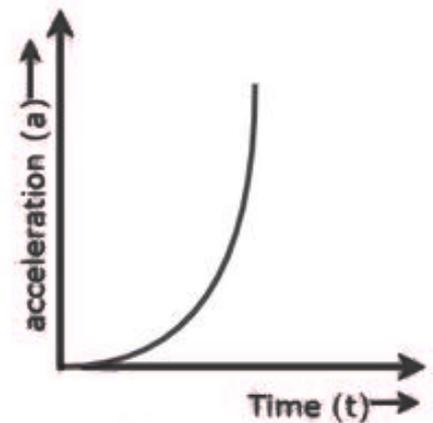
3. Acceleration Time Graph



Constant acceleration



For uniformly increasing acceleration



For non-uniformly accelerated body

Equations of motion

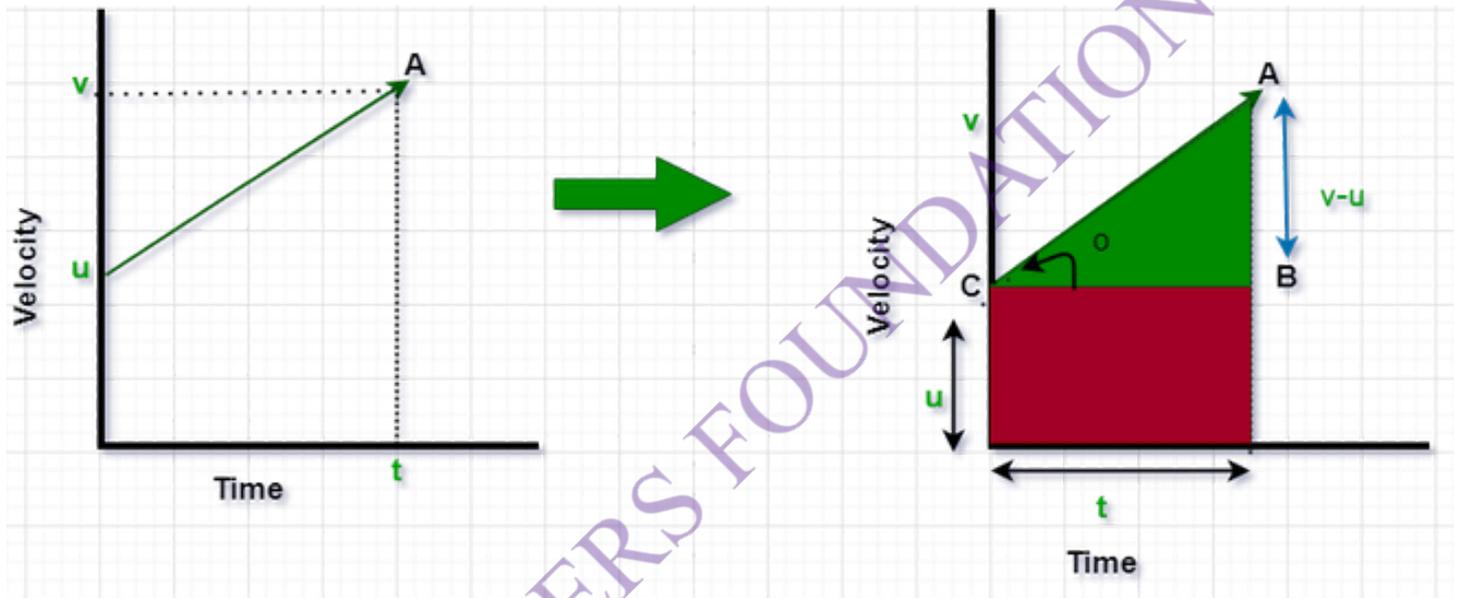
The equations of motion describe the relationship between the key quantities of a moving object—such as displacement, velocity, acceleration, and time—under uniform acceleration.

- **First Equation of Motion:** $v = u + at$
- **Second Equation of Motion:** $s = ut + \frac{1}{2}at^2$
- **Third Equation of Motion:** $v^2 = u^2 + 2as$

where, v and u are the initial and the final velocities, a is the acceleration, t is the time taken and s is the displacement of an object.

Derivation of Equation of motion graphically

1. First equation



The plot shows that the object has a variable velocity that is increasing from u to v as the slope is positive velocity is increasing in a positive direction.

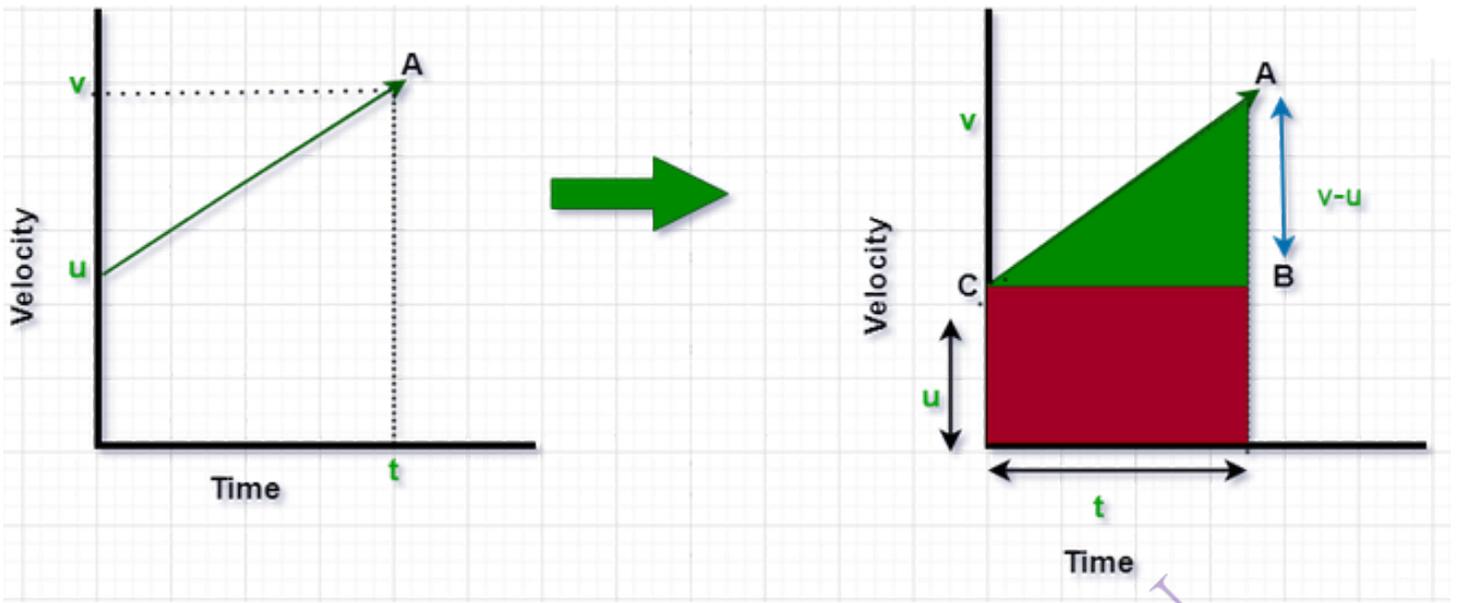
Now we will calculate the acceleration using this motion graph. Acceleration is the tangent of the angle in $v-t$ graph.

$$\text{Acceleration (a)} = \tan(\theta) = \frac{\text{Change in Velocity}}{\text{Time}} = \frac{v - u}{t}$$

$$a = \frac{v - u}{t} \Rightarrow v = u + at$$

This leads us to the First Equation of Motion, derived using geometry and graph.

2. Second equation



Displacement = Area under v-t Graph

The Displacement of the object (S) = Area of triangle + Area of rectangle

OR

Displacement s is the area of the trapezium

Area of trapezium = $\frac{1}{2} \times (\text{sum of parallel sides}) \times \text{height}$

$$s = \frac{1}{2} \times (u + v) \times t$$

Now, use the first equation of motion:

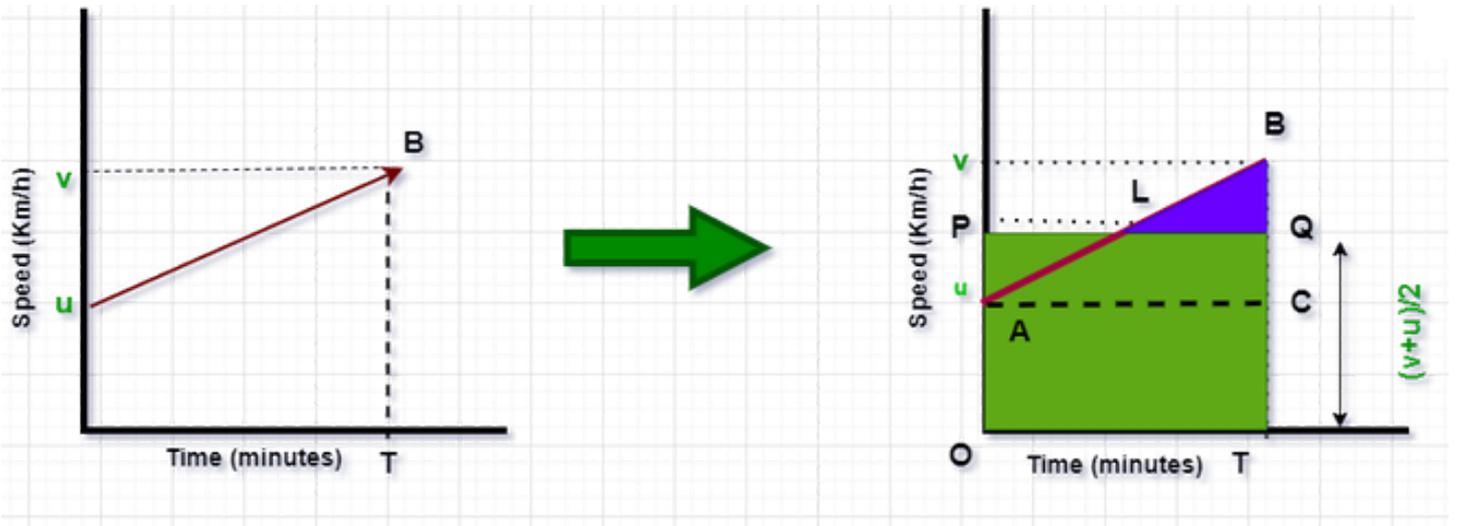
$$v = u + at$$

Substitute this into the equation:

$$s = \frac{1}{2} \times (u + u + at) \times t = \frac{1}{2} \times (2u + at) \times t$$

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

3. Third equation



Circular Motion

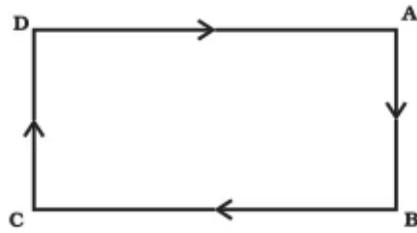
The motion of a particle along a circular path is called circular motion. The particle moves around a fixed center at a certain radius.

Uniform Circular Motion (UCM):

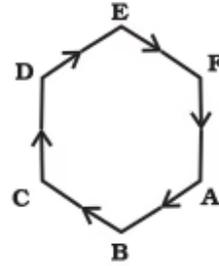
If a body moves along the circumference of a circle and covers equal distances in equal intervals of time, its motion is called uniform circular motion.

Feature	Description
Speed	Remains constant
Velocity	Changes continuously because direction keeps changing
Acceleration	Present and always directed toward the center (called centripetal acceleration)
Path	Circular

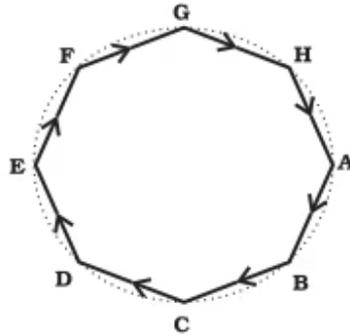
UCM is an example of accelerated motion even though speed is constant.



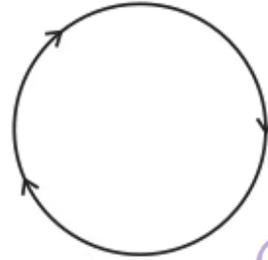
(a) Rectangular track



(b) Hexagonal track



(c) Octagonal shaped track



(d) A circular track

Examples of Uniform Circular Motion

(i) Motion of moon around the earth.

(ii) Motion of a satellite around its planet.

(iii) Motion of earth around the sun.

(iv) An athlete running on a circular track with constant speed.

(v) Motion of tips of the second hand, minute hand and hour hand of a wrist watch.

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