Chapter 7: Motion — Detailed Premium Notes

1. Introduction to Motion

- Imagine sitting in a bus looking outside the window. Trees, poles, and shops seem to "move backward." But for someone standing on the roadside, you are the one in motion while the trees are at rest.

  👉 This shows that motion is always relative — it depends on who is observing.

- Motion means the change in position of an object with respect to a reference point, in a given time.
- If an object does not change its position with time, we say it is at rest.
- If the object changes its position continuously with time, it is said to be in motion.

🎯 Key Features of Motion

- Requires time (we see change only after some time passes).
- Requires a reference point (to compare movement).
- Can happen in different forms (straight, circular, oscillatory… but details come later).

🌟 Why is Motion Important?

- Motion is everywhere — from the tiny vibration of atoms to the vast movement of planets.
- Studying motion helps us:

- *Understand how vehicles move* 🚙
- *Predict paths of rockets* 🚀
- *Explain natural events like day and night* 🌞 🌛

In short:

Motion is the change of position of a body with time, relative to a chosen reference point.
It is one of the most basic concepts of physics, forming the foundation for understanding the physical world.

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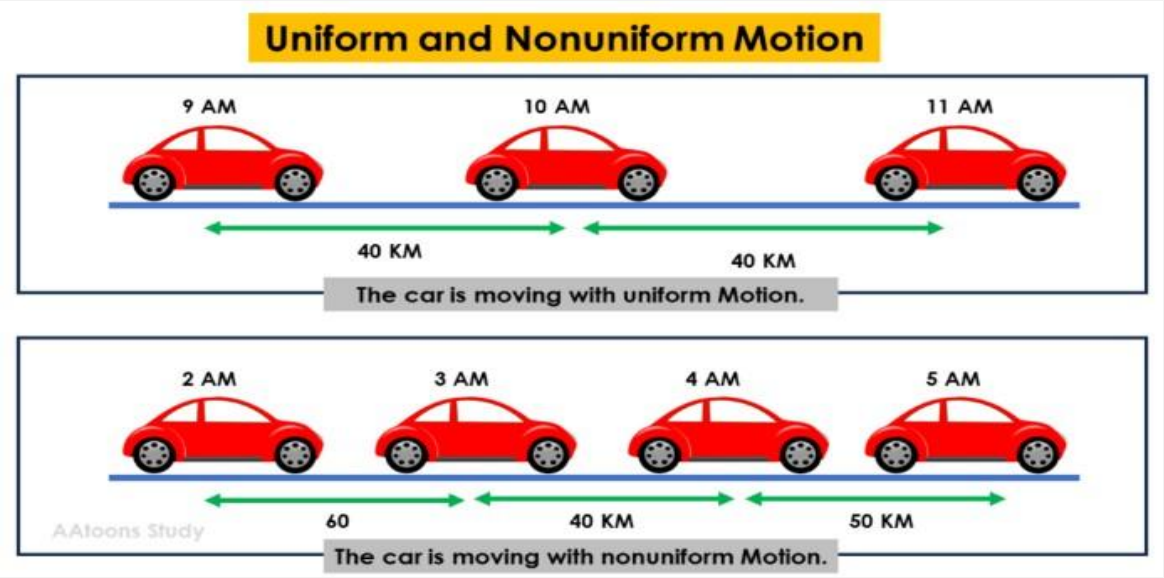
2. Types of Motion

Motion of objects can be divided based on how distance is covered with respect to time.



Uniform Motion:

- ***An object is said to have uniform motion if it covers equal distances in equal intervals of time, no matter how small those intervals are.***
- ***Speed remains constant throughout the motion.***

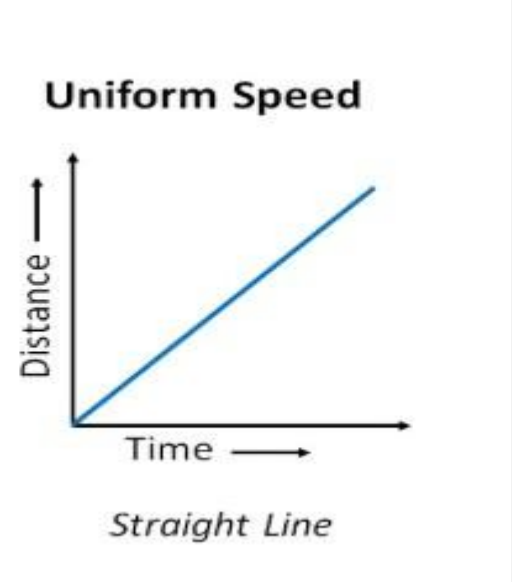
- ***Direction does not change (otherwise it would become circular motion).***
- ***The motion is predictable – we can easily calculate where the object will be after a given time.***

◇ *Examples:*

- ***A car moving steadily at 60 km/h on a straight, empty road.***
- ***Earth revolving around the Sun (almost uniform motion).***
- ***A ceiling fan's blade tips when rotating at constant speed.***

◇ *Graph Representation (Distance–Time Graph):*

- ***For uniform motion, the graph is a straight line sloping upwards.***
- ***This shows that distance increases equally with time.***



Non-Uniform Motion:

- ***An object is said to have non-uniform motion if it covers unequal distances in equal intervals of time.***
- ***The speed of the object keeps changing – sometimes increasing, sometimes decreasing.***
- ***The direction may also change (example: a car turning on a curved road).***
- ***The motion is not predictable by simple calculation.***

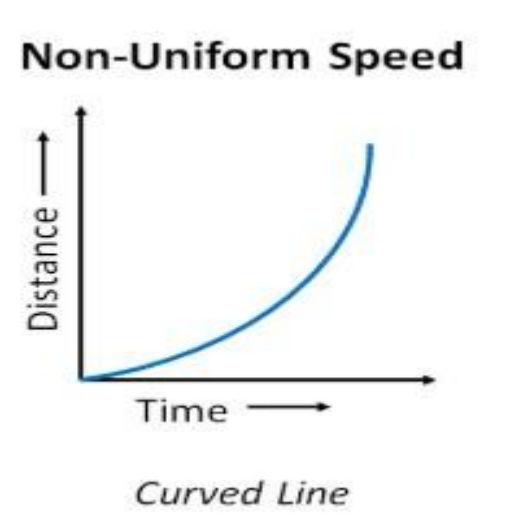
◇ *Examples:*

- ***A car moving in city traffic (stop–start motion).***
- ***A ball rolling down a slope (accelerated motion).***

- *A child on a swing (changes speed at different points).*

◇ *Graph Representation (Distance–Time Graph):*

- *For non-uniform motion, the graph is a curved line.*
- *The slope of the curve shows how speed is changing with time.*



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3. Distance and Displacement

Distance:

- *Distance is the total length of the actual path travelled by an object.*
- *It is a scalar quantity → depends only on magnitude, not direction.*
- *Distance is always positive and can never decrease with motion.*

◇ *Examples:*

- *If you walk 5 m east and then 5 m west, the distance travelled = 10 m.*
- *A bus following a curved road covers the whole curved length as distance.*

Displacement:

- *Displacement is the shortest straight-line distance between the initial and final position of an object.*
- *It is a vector quantity → depends on magnitude + direction.*
- *Displacement can be:*
  - *Positive (if final position is ahead of initial position),*

- *Zero (if you return to the same point),*
- *Negative (if final position is opposite to chosen direction).*

◇ ***Examples:***

- ***If you walk 5 m east and then 5 m west, the displacement = 0 (because you're back at the starting point).***
- ***A person moves 3 km north, then 4 km east → displacement = 5 km (shortest distance using Pythagoras).***

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4. Speed and Velocity

Speed:

- ***Speed is the distance travelled by an object per unit time.***
- ***It tells us how fast an object is moving, but it does not include direction.***
- ***Speed is a scalar quantity, which means it only has magnitude.***
- ***It is always positive and depends only on the total distance travelled.***

Formula:

Speed = Distance ÷ Time

Example:

If a car travels 120 km in 2 hours,

Speed = 120 ÷ 2 = 60 km/h

***Key point:** Speed tells us how fast something moves but not the direction in which it moves.*

Velocity:

- *Velocity is the displacement of an object per unit time.*
- *It tells us how fast and in which direction the object is moving.*
- *Velocity is a vector quantity, which means it has both magnitude and direction.*
- *Velocity can be positive, negative, or zero, depending on the direction of motion.*

Formula:

Velocity = Displacement ÷ Time

Example:

If a car moves 100 km towards the east in 2 hours, Velocity = 100 ÷ 2 = 50 km/h east
Key point: Velocity depends on displacement and direction, not just distance.

Difference Between Speed and Velocity

- *Speed measures how fast an object moves, while velocity measures how fast and in which direction an object moves.*
- *Speed is scalar, velocity is vector.*
- *Speed is always positive, whereas velocity can be positive, negative, or zero.*
- *If a car goes 100 km and returns to its starting point, its speed = 100 km/h, but its velocity = 0, because the displacement is zero.*

Types of Speed and Velocity

- ***Uniform Speed/Velocity:** The object covers equal distances/displacements in equal intervals of time. Example: A car moving steadily at 60 km/h.*

- ***Non-Uniform Speed/Velocity:*** *The object covers unequal distances/displacements in equal intervals of time. Example: A car moving in city traffic.*
- ***Average Speed:*** *Total distance ÷ Total time.*
- ***Average Velocity:*** *Total displacement ÷ Total time.*

Summary

- *Speed = how fast an object moves (no direction).*
- *Velocity = how fast an object moves in a particular direction.*
- *Speed depends on distance, while velocity depends on displacement and direction.*

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5. Acceleration

Acceleration is the rate at which the velocity of an object changes with time. It tells us how fast an object is speeding up or slowing down. Acceleration is a vector quantity, which means it has both magnitude and direction.

The formula for acceleration is:

Acceleration (a) = (Final Velocity - Initial Velocity) ÷ Time a
= (v - u) / t
Where v is the final velocity, u is the initial velocity, and t is the time taken for the change.

Examples of acceleration:

- *A car increasing its speed from 0 to 60 km/h in 10 seconds.*
- *A ball rolling down a slope and picking up speed.*
- *A train slowing down as it approaches a station (negative acceleration).*

Types of acceleration:

- *Positive acceleration: Velocity increases with time. Example: a car moving faster on a straight road.*
- *Negative acceleration (deceleration/retardation): Velocity decreases with time. Example: a bicycle stopping at a red light.*
- *Zero acceleration: Velocity remains constant. Example: a car moving steadily at 60 km/h.*

Key points to remember:

- ***Acceleration depends on how much the velocity changes and how quickly it changes.***
- ***Faster the change in velocity, greater the acceleration.***
- ***The direction of acceleration is the same as the direction of change in velocity.***

Units of acceleration:

- ***In the SI system, it is measured in meters per second squared (m/s^2).***
- ***It can also be expressed in km/h^2 or cm/s^2 in different problems. In short, acceleration is how quickly an object changes its velocity. It can be positive, negative, or zero, and is calculated using the formula $a = (v - u) / t$.***

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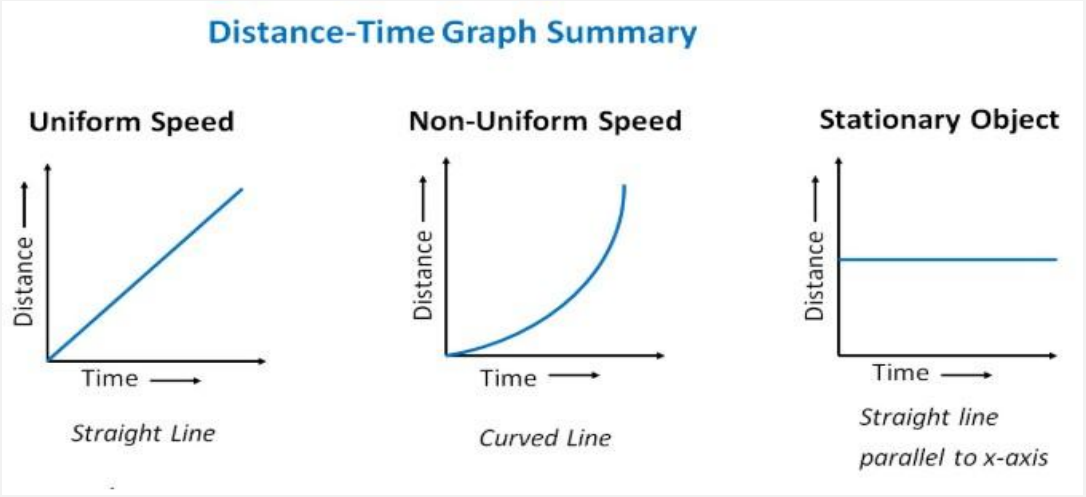
6. Graphical Representation of Motion

Graphical representation of motion is a way to show how an object moves using graphs. It helps us visualize motion and understand speed, velocity, and acceleration easily. The most common graphs are distance-time graphs and velocity-time graphs.

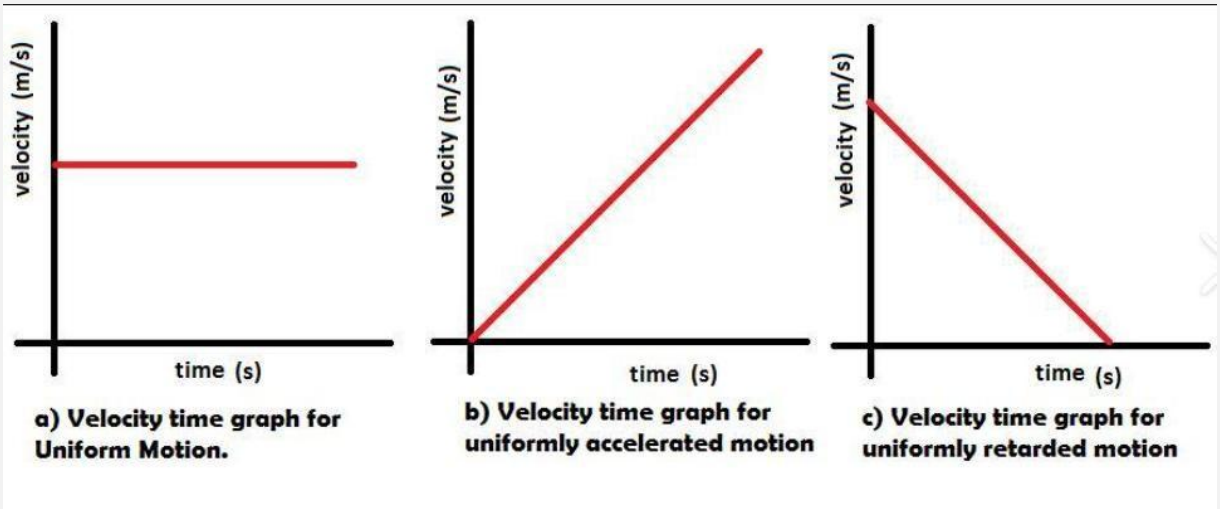
Distance-Time Graphs:

- ***A distance-time graph shows how the distance of an object changes with time.***
- ***The slope of the graph indicates the speed of the object.***
- ***If the graph is a straight line, the object is moving at uniform speed.***
- ***If the graph is curved, the object is moving at non-uniform speed (speed changes with time).***
- ***Horizontal lines indicate that the object is at rest.***



Velocity-Time Graphs:

- ***A velocity-time graph shows how the velocity of an object changes with time.***
- ***The slope of the velocity-time graph indicates acceleration.***
- ***A straight horizontal line means the object is moving with uniform velocity (zero acceleration).***
- ***A sloping line means the object is accelerating or decelerating.***
- ***The area under the graph represents the displacement of the object.***



Key Points:

- ***Distance-time graphs help us understand speed and motion.***
- ***Velocity-time graphs help us understand acceleration and displacement.***
- ***These graphs make motion easier to analyze and interpret. In short, graphical representation is a powerful tool to visualize motion, understand speed, velocity, and acceleration, and calculate important quantities like displacement from graphs.***

7. Equations of Motion (for Uniform Acceleration)

Equations of motion describe the relationship between distance, velocity, acceleration, and time when an object moves with uniform acceleration. These equations are useful to solve motion problems.

The first equation of motion is:

$v = u + a \times t$

where v is the final velocity, u is the initial velocity, a is the acceleration, and t is the time.

This equation shows how the velocity of an object changes with time under uniform acceleration.

The second equation of motion is: $s = u \times t + 1/2 \times a \times t^2$ *where s is the distance travelled, u is the initial velocity, a is the acceleration, and t is the time.*

This equation gives the distance covered by an object in a given time when acceleration is uniform.

The third equation of motion is:

$v^2 = u^2 + 2 \times a \times s$ *where v is the final velocity, u is the initial velocity, a is the acceleration, and s is the distance travelled.*

This equation relates velocity and distance without involving time.

Key points to remember:

- *These equations are valid only for uniform acceleration.*
- *They help calculate unknown quantities like distance, velocity, time, or acceleration if the other values are given.*
- *Using these equations, we can describe motion mathematically in a simple way.*

In short, the three equations of motion for uniform acceleration are:

$v = u + a \times t$ $s = u \times t + 1/2 \times a \times t^2$ $v^2 = u^2 + 2 \times a \times s$

They provide a complete description of motion when acceleration is constant.

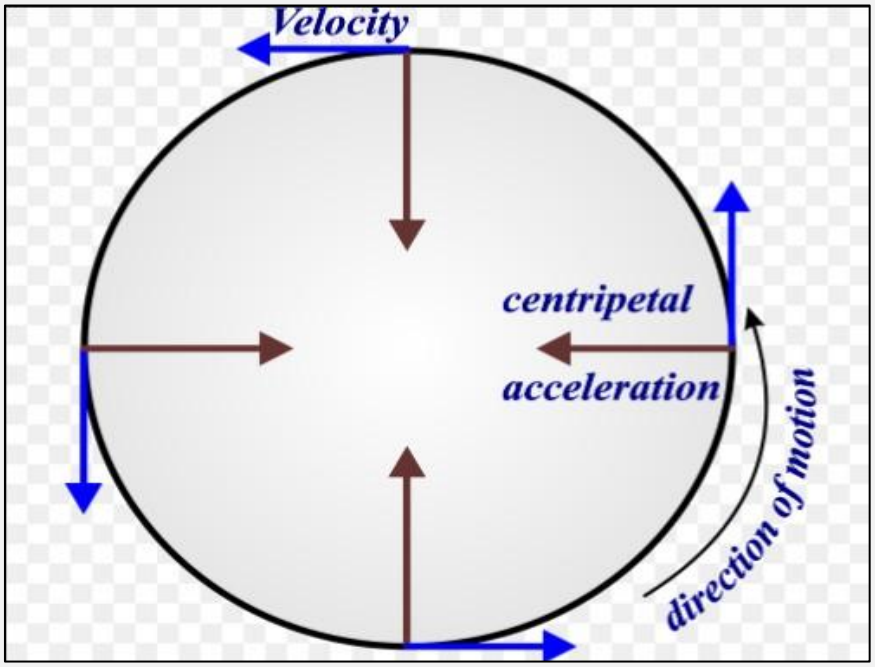
8. Uniform Circular Motion

Uniform circular motion is the motion of an object along a circular path with constant speed. Even though the speed remains the same, the direction of motion keeps changing continuously, so the velocity is constantly changing.
Since velocity is changing, the object is considered to be accelerating even if its speed is constant. This acceleration is called centripetal acceleration and it is always directed towards the center of the circular path.

Key points of uniform circular motion:

- ***The object moves along a circular path with constant speed.***
- ***The direction of velocity changes continuously.***
- ***There is always a centripetal force acting towards the center of the circle, which keeps the object moving in the circular path.***
- ***Examples include a car moving around a circular track, a satellite orbiting the Earth, or a stone tied to a string and whirled in a circle.***

In short, uniform circular motion is motion along a circle at constant speed, with velocity constantly changing due to continuous change in direction, and the object experiences centripetal acceleration toward the center.



9. Important Points

- ***Motion is relative; depends on observer's reference point.***
- ***Uniform motion means no change in velocity.***
- ***Acceleration involves change in velocity (magnitude or direction).***
- ***In real life, most motions are non-uniform.***
- ***SI unit of speed and velocity is meter per second (m/s).***
