Module 8: Kinematics and Motion (PHY 1100)

Introduction

Kinematics is the branch of physics that describes motion.

In kinematics, we focus on how objects move rather than why they move. The causes of motion (forces) are studied later in mechanics.

Kinematics describes motion using quantities such as:

- position
- distance
- displacement
- velocity
- acceleration
- time

Understanding these quantities allows us to analyze many types of motion, including moving vehicles, falling objects, and projectiles.

Distance and Displacement

Although the terms distance and displacement are sometimes used interchangeably in everyday language, they have different meanings in physics.

Distance

Distance is the total length of the path traveled.

Distance is always positive and does not depend on direction.

Displacement

Displacement describes the change in position from the starting point to the final point.

Displacement includes both magnitude and direction.

Example:

If a person walks 5 meters east and then 3 meters west:

Distance traveled = 8 meters
Displacement = 2 meters east

Velocity

Velocity describes how fast an object moves and the direction of motion.

The equation for average velocity is:

$v = d / t$

where

v = velocity
d = displacement
t = time

Example

A car travels 100 meters in 5 seconds.

Find the velocity.

$v = d / t$

$v = 100 / 5$

$v = 20$ m/s

The velocity of the car is 20 meters per second.

Acceleration

Acceleration describes how quickly velocity changes.

Acceleration occurs when an object:

- speeds up
- slows down
- changes direction

The equation for acceleration is:

$a = (v - v_o) / t$

where

a = acceleration
v = final velocity
v_o = initial velocity
t = time

Example

A car increases its velocity from 10 m/s to 20 m/s in 5 seconds.

Find the acceleration.

$a = (v - v_o) / t$

$a = (20 - 10) / 5$

$a = 10 / 5$

$a = 2$ m/s²

The acceleration is 2 meters per second squared.

Constant Acceleration Equations

When acceleration is constant, several equations describe the motion of an object.

These equations are called the kinematic equations.

Kinematic Equation 1

$v = v_o + at$

This equation relates velocity, acceleration, and time.

Kinematic Equation 2

$d = v_o t + \frac{1}{2}at^2$

This equation describes displacement when acceleration is constant.

Kinematic Equation 3

$v^2 = v_o^2 + 2ad$

This equation relates velocity, acceleration, and displacement.

Worked Example

A car starts from rest and accelerates at 3 m/s^2 for 4 seconds.

Find the final velocity.

Since the car starts from rest:

$v_o = 0$

Use equation:

$v = v_o + at$

$v = 0 + (3 \times 4)$

$v = 12$ m/s

Final velocity = 12 meters per second.

Example: Finding Distance

A car starts from rest and accelerates at 2 m/s^2 for 5 seconds.

Find the distance traveled.

Use equation:

$d = v_o t + \frac{1}{2}at^2$

Since the car starts from rest:

$v_o = 0$

Substitute values:

$d = ½ \times 2 \times 5^2$

$d = 1 \times 25$

$d = 25$ meters

Motion Graphs

Graphs are often used to represent motion.

Three common graphs include:

- position vs time
- velocity vs time
- acceleration vs time

Position vs Time Graph

A position vs time graph shows how an object's location changes with time.

The slope of this graph represents velocity.

Velocity vs Time Graph

A velocity vs time graph shows how velocity changes with time.

The slope of this graph represents acceleration.

Acceleration vs Time Graph

This graph shows how acceleration changes over time.

The area under a velocity-time graph represents displacement.

Example

If a car travels at a constant velocity, the velocity-time graph will be a horizontal line.

If the velocity increases steadily, the graph will be a straight line with positive slope.

Free Fall

Free fall occurs when an object moves under the influence of gravity alone.

Near Earth's surface, the acceleration due to gravity is approximately:

$g = 9.8\ m/s^2$

This means the velocity of a falling object increases by about 9.8 meters per second every second.

Example

An object falls for 3 seconds.

Find the final velocity.

$v = v_o + at$

$v = 0 + (9.8 \times 3)$

$v = 29.4$ m/s

Practice Problems

1. A car travels 150 meters in 10 seconds.
   Find its velocity.
2. A bicycle accelerates from 5 m/s to 15 m/s in 5 seconds.
   Find the acceleration.
3. An object accelerates at 2 m/s^2 for 6 seconds starting from rest.
   Find the final velocity.
4. A car accelerates at 3 m/s^2 for 4 seconds.
   Find the distance traveled.

Challenge Problems

1. A car starts from rest and accelerates at 4 m/s^2 for 6 seconds.
   Find the final velocity.
2. A ball falls freely for 4 seconds.
   Find the final velocity.
3. A car moving at 20 m/s accelerates at 2 m/s^2 for 5 seconds.
   Find the final velocity.