

Branches of physics

Kinematics and Dynamics



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**Types of Kinematics and Dynamics**

**Introduction**

Kinematics and dynamics are foundational topics in classical mechanics, each focusing on different aspects of motion. Kinematics describes the motion of objects without considering the forces that cause the motion, while dynamics examines the forces and torques that affect that motion. Understanding these concepts is crucial in fields ranging from engineering and robotics to sports science and biomechanics.

(Resnick, 1968)

# Bibliography

Resnick, H. a. (1968). *Fundamentals of physics.* New York: Wiley.

# 1. Kinematics

## 1.1 Overview of Kinematics

Kinematics involves analyzing motion in terms of displacement, velocity, and acceleration. It focuses on how objects move rather than why they move. The primary objective is to describe motion through mathematical equations and graphical representations.

* **Displacement**: The vector quantity that defines the change in position of an object.
* **Velocity**: The rate of change of displacement, often described as average or instantaneous velocity.
* **Acceleration**: The rate of change of velocity, which can be constant or variable.

## 1.2 Types of Motion

### 1.2.1 Linear Motion

Linear motion occurs when an object moves along a straight line. The equations of motion for constant acceleration are given by:

1. v=u + a\*t
2. s=u\*t + 1/2\*at2
3. v2= u2 + 2as

Where:

* u = initial velocity
* v = final velocity
* a = acceleration
* s = displacement
* t = time

Figure shows the velocity time Graph as a straight line.

**Example**: A car accelerates from rest (u = 0) at 2 m/s² for 5 seconds. The final velocity can be calculated as follows:

v=0 + (2 m/s2) \* (5 s)

**1.2.2 Rotational Motion**

Rotational motion involves objects rotating around an axis. Important concepts include:

* **Angular Displacement**: The angle through which an object rotates.
* **Angular Velocity**: The rate of change of angular displacement.
* **Angular Acceleration**: The rate of change of angular velocity. Example of Rotational motion

The equations of motion for rotational systems are analogous to linear motion:

|  |  |
| --- | --- |
| Formula of types of Rotational motion | |
| Angular Displacement | ω=αt + ωꝊ |
| Angular Velocity | θ=ωot+1/2\*αt2 |
| Angular Acceleration | ω2=ω02+2αθ |

Where:

* ω = final angular velocity
* α = angular acceleration
* θ = angular displacement
* ω0= initial angular velocity

**Example**: A wheel spins from rest with an angular acceleration of 3 rad/s² for 4 seconds. The final angular velocity is:

ω=0+(3 rad/s2) \*(4 s) =12 rad/s

### 1.2.3 Projectile Motion:

Projectile motion describes the motion of objects that are thrown or projected into the air, subject only to the acceleration of gravity. Key features include:

* **Horizontal Motion**: Uniform motion since no horizontal forces act on the projectile.
* **Vertical Motion**: Accelerated motion due to gravity (approximately 9.81 m/s.

**Equations**:

* Horizontal distance: x=v0xt
* Vertical distance: y=v0yt−1/2\*gt2

**Example**: A ball is thrown with an initial velocity of 20 m/s at a 45-degree angle. The horizontal and vertical components can be calculated using trigonometric functions.

## 1.3 Relative Motion

Relative motion involves analyzing the motion of an object in relation to a particular frame of reference. For example, a train moving at 60 km/h relative to the ground and a passenger walking at 5 km/h in the opposite direction would have a relative velocity of:

V​ = 60km/h−5km/h=55km/h

Understanding relative motion is crucial in navigation and tracking moving objects.

## 1.4 Applications of Kinematics

Kinematics is widely applied in various fields:

* **Engineering**: Designing mechanisms and analyzing motion in machines.
* **Sports**: Enhancing athletic performance by analyzing movements.
* **Robotics**: Programming robotic arms and understanding motion trajectories.

# 2. Dynamics

## 2.1 Overview of Dynamics

Dynamics focuses on the forces and torques that influence motion. It connects the concepts of kinematics with the forces that cause changes in motion, governed primarily by Newton's laws.

## 2.2 Newton's Laws of Motion

### 2.2.1 First Law (Inertia):

An object at rest will remain at rest, and an object in motion will continue in motion at a constant velocity unless acted upon by a net external force. This law explains the concept of inertia, where mass is a measure of an object's resistance to changes in motion.

**Example**: A hockey puck sliding on ice will eventually come to a stop due to friction, demonstrating that an external force is required to change its state of motion.

### 2.2.2 Second Law (F=ma):

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. This can be expressed as:

F=ma

Where:

* F = net force
* m = mass
* a = acceleration

**Example**: If a 10 kg object experiences a net force of 20 N, its acceleration can be calculated as follows:

a=F/m=20 N/10 kg=2 m/s2

### 2.2.3 Third Law (Action-Reaction):

For every action, there is an equal and opposite reaction. This principle explains interactions between two bodies.

**Example**: When a person jumps off a small boat, the boat moves backward due to the action of the person pushing against it.

## 2.3 Types of Forces

### 2.3.1 Gravitational Force

Gravitational force is the attractive force between two masses, calculated using Newton's law of universal gravitation:

F=G\*m1m2/r2

Where:

* G = gravitational constant
* m1, m2 = masses
* r = distance between the centers of the masses

This force plays a crucial role in the motion of celestial bodies and everyday objects on Earth.

### 2.3.2 Frictional Force

Friction opposes the relative motion of two surfaces in contact. It can be classified into two types:

* **Static Friction**: The force that prevents motion until a certain threshold is overcome.
* **Kinetic Friction**: The force acting on moving objects.

The magnitude of friction is often calculated as:

Ff=μ\*N

Where:

* μ = coefficient of friction
* N = normal force

### 2.3.3 Tension and Normal Forces

* **Tension** is the force transmitted through a string or rope when it is pulled tight.
* **Normal Force** is the perpendicular force exerted by a surface on an object resting on it.

These forces are essential in analyzing systems in equilibrium and those involving pulleys.

## 2.4 Work, Energy, and Power

* **Work (W)** is defined as the product of force and displacement in the direction of the force:

W=F ⋅ d ⋅ cos(θ)

Where θ is the angle between the force and displacement vector.

* **Energy** is the capacity to do work, existing in various forms such as kinetic energy (KE) and potential energy (PE):

KE=1/2mv2 , PE=m\*g\*h

* **Power (P)** is the rate of doing work, calculated as:

P=W/t

Where t is the time taken to do the work.

# 3. Advanced Topics in Kinematics and Dynamics

## 3.1 Kinematic Equations for Non-Uniform Motion

In scenarios where acceleration is not constant, kinematic equations become more complex. Graphical methods, such as displacement-time and velocity-time graphs, are often employed to analyze motion in these cases.

## 3.2 Dynamics of Rigid Bodies

Rigid body dynamics involves the study of solid objects that do not deform under stress. It includes translational and rotational motion analysis, where both linear and angular momentum must be considered.

## 3.3 Oscillatory Motion

Oscillatory motion, such as that of a pendulum or spring, is characterized by periodic movement. Simple harmonic motion (SHM) is a specific type of oscillation defined by the restoring force being directly proportional to displacement.

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