WEEK 10

# Physics of Engineer

# Chapter 9: Mechanics of Particle and Rigid Body

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# Outline

- Introduction to Mechanics of Particles and Rigid Bodies
- Particles
- Kinematics of a Particle
- Equation of Motion
- Sample Application
- Rigid Bodies
- Force and Newton’s Laws
- Kinetics of Rigid Body
- Translational Motion of a Rigid Body

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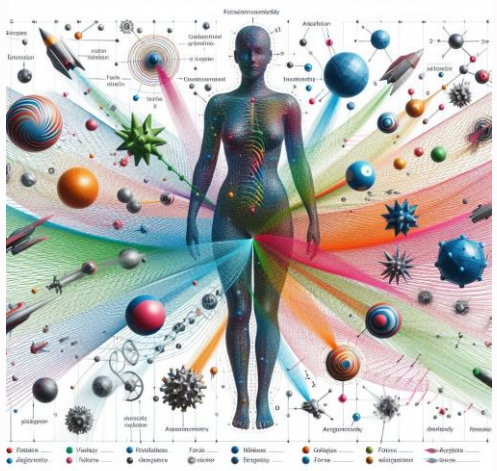
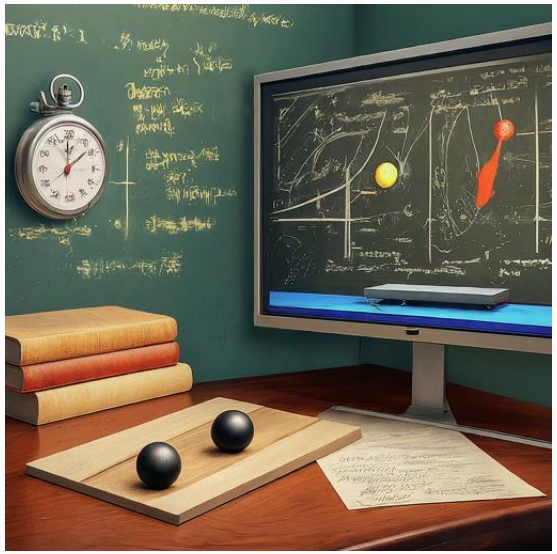
# Outline

- ❑ Rotational Motion of a Rigid Body
- ❑ Application of Rotational Motion
- ❑ Conclusion
- ❑ Exploring Resources and references



# Introduction to Mechanics of Particles and Rigid Bodies





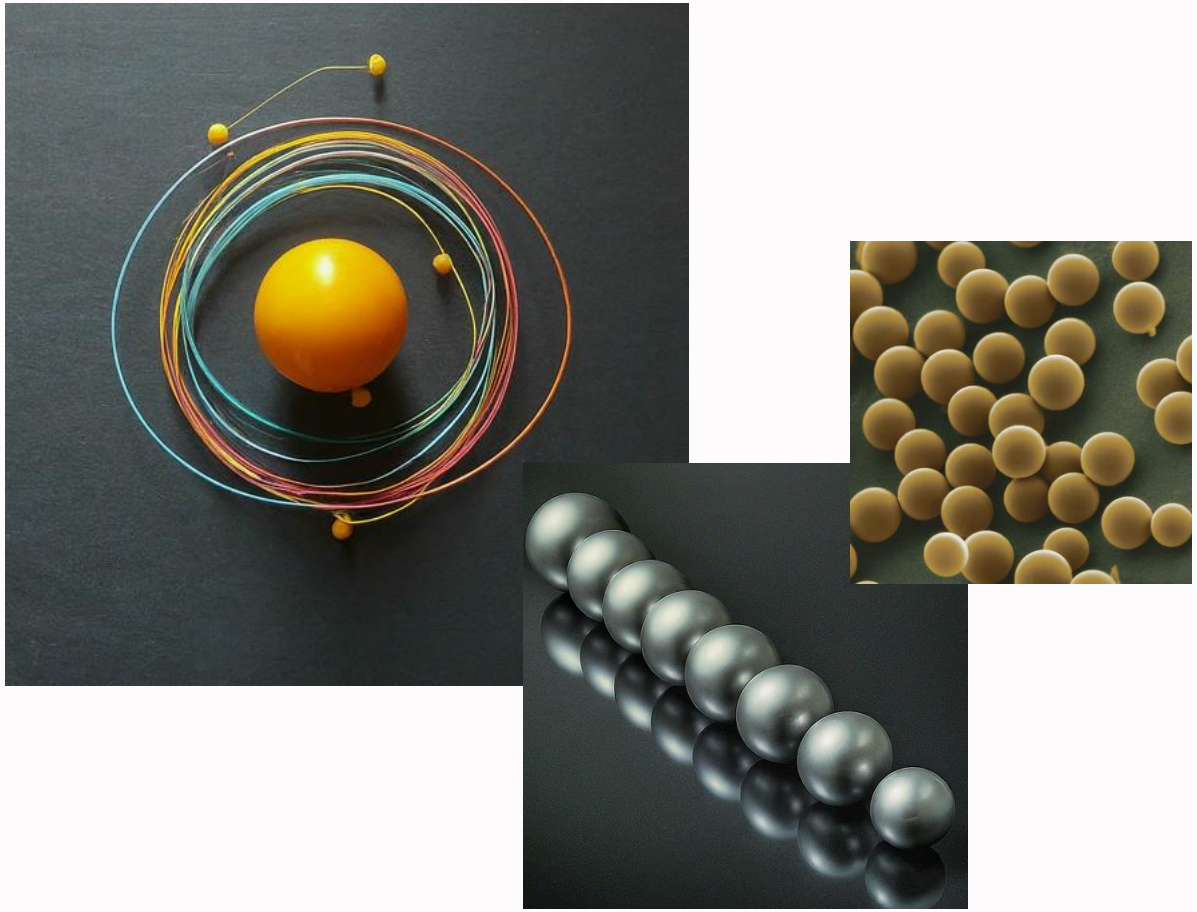
**What is Mechanics?**

- The study of motion and its causes.

**Sub-disciplines of Mechanics:**

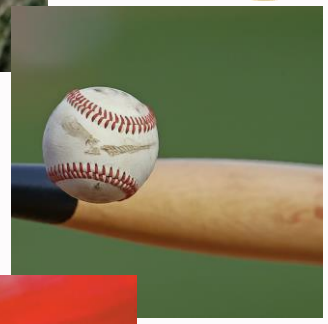
- Kinematics: Description of motion.
- Kinetics: Analysis of forces causing motion.

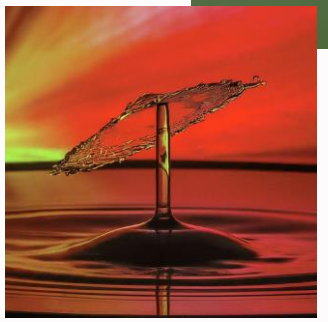
# Particles



- **Definition:** A point-like object with a mass but negligible size.
- **Parameters:**
  - Mass (m): Quantity of matter, measured in kilograms (kg).

# Kinematics of a Particle





- Description of motion of a particle.
- Parameters:
  - **Position vector (r):** Location of the particle relative to a reference point, denoted by an arrow (⟶). Measured in meters (m).
  - **Displacement (Δr):** Change in position vector over a time interval. $\Delta r = r_f - r_i$ (final position minus initial position).
  - **Velocity (v):** Rate of change of position vector. $v = \Delta r / \Delta t$ (displacement divided by time interval). Measured in meters per second (m/s).
  - **Acceleration (a):** Rate of change of velocity. $a = \Delta v / \Delta t$ (change in velocity divided by time interval). Measured in meters per second squared ($m/s^2$).

# Equations of Motion

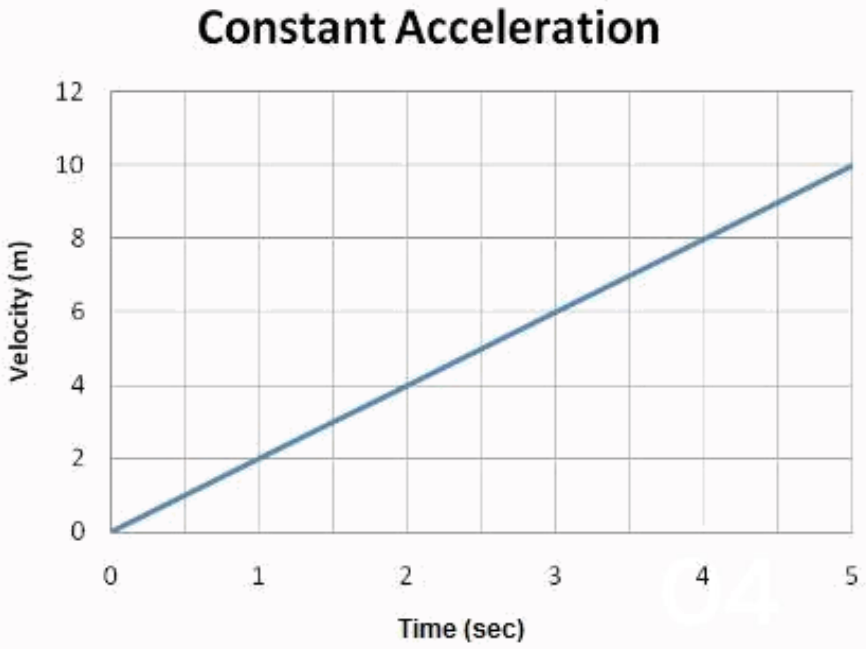
- Relate the kinematic parameters of a particle.
- 1D Motion with constant acceleration:

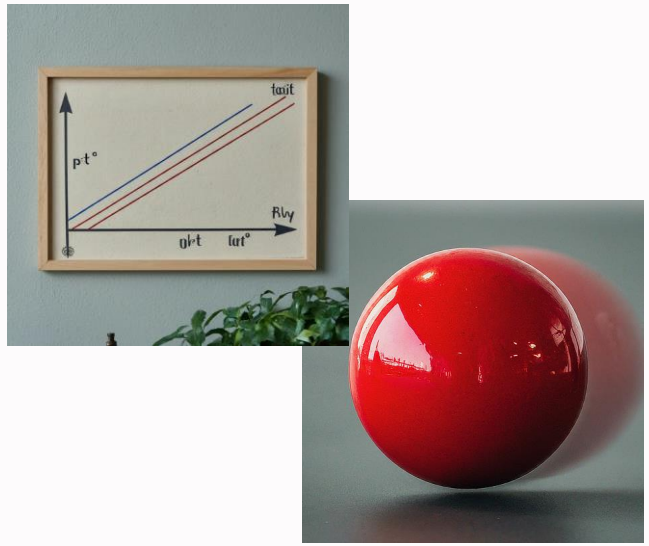
$$v = u + at$$

(final velocity = initial velocity + acceleration × time)

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

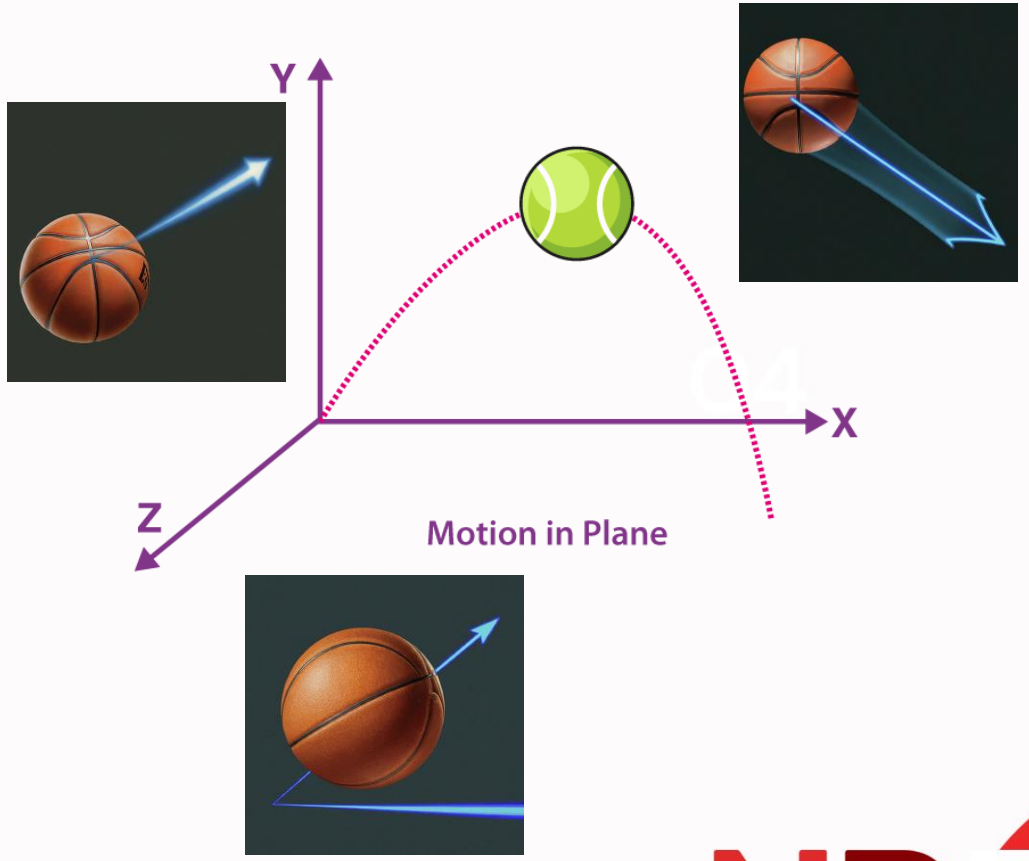
(displacement = initial velocity × time + ½ × acceleration × time²)



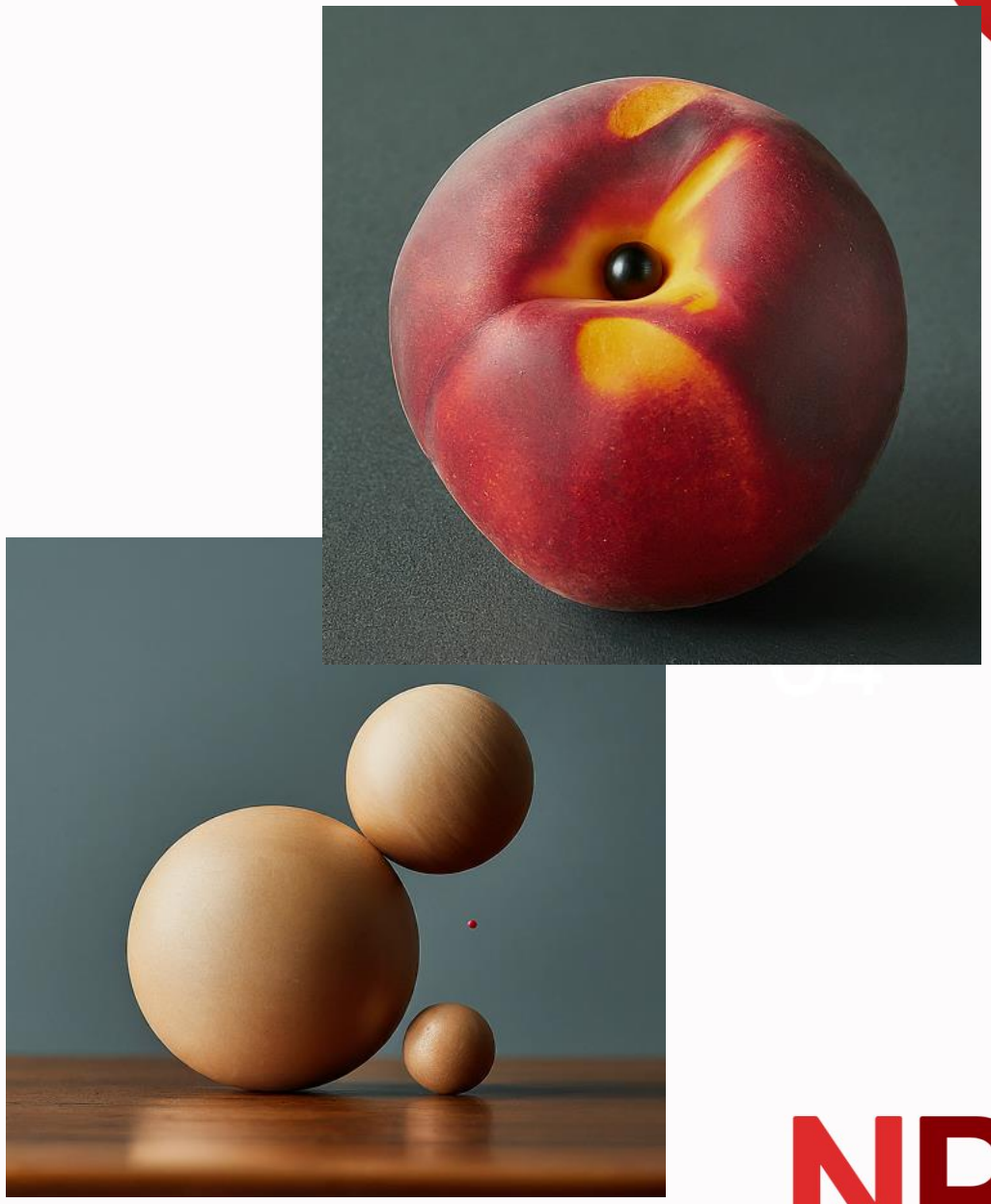
# Sample Application: Projectile Motion

- A thrown object neglecting air resistance.
- Motion is a combination of horizontal and vertical components.
- Horizontal motion: Constant velocity (no horizontal force).
- Vertical motion: Constant acceleration due to gravity ($g \approx 9.8\ m/s^2$).



# Rigid Bodies

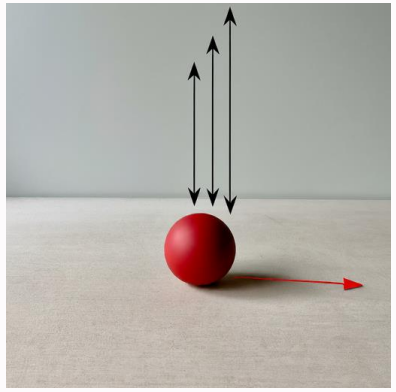
- **Definition:** An object with a fixed, non-deformable shape and a distribution of mass.
- **Parameters:**
  - Mass (m): Total mass of the rigid body (same as for a particle).
  - Center of Mass (COM): The point where the entire mass of the body can be considered concentrated. Denoted by CM.



# Forces and Newton's Laws

- **Force:** An interaction that can cause an object to change its state of motion (measured in Newtons, N).
- **Newton's Laws of Motion:**
  - First Law (Law of Inertia): An object at rest stays at rest and an object in motion stays in motion with constant velocity unless acted upon by a net force.
  - Second Law (Law of Acceleration): The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass ($a = F_{net} / m$).

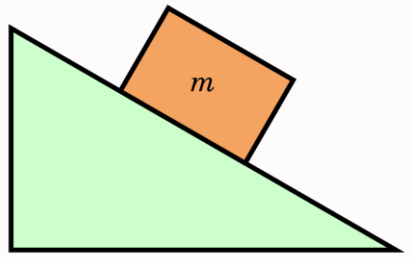




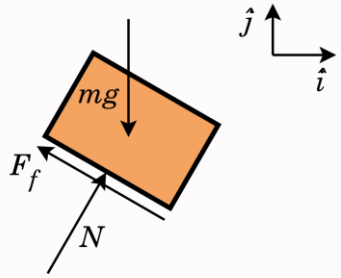
# Newton's Laws (Continued)

- **Third Law (Law of Action-Reaction):** For every action, there is an equal and opposite reaction force.
- **Free Body Diagram (FBD):**
  - A diagram showing all forces acting on a body.

A block on a ramp

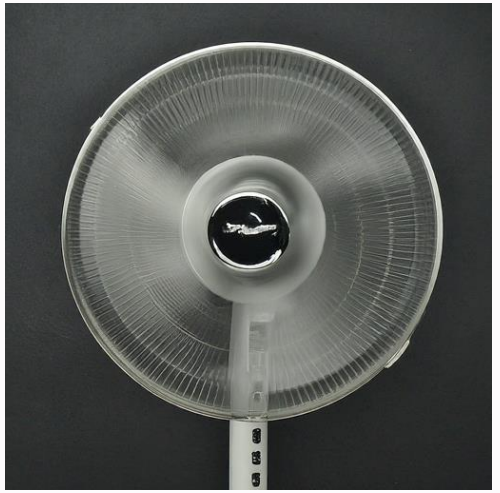



Free body diagram of just the block

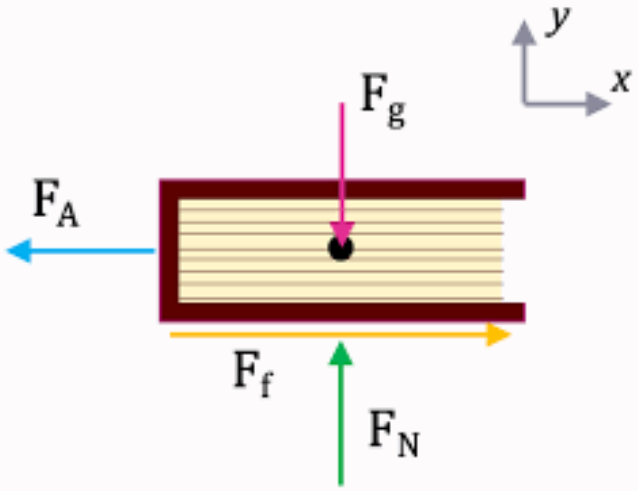


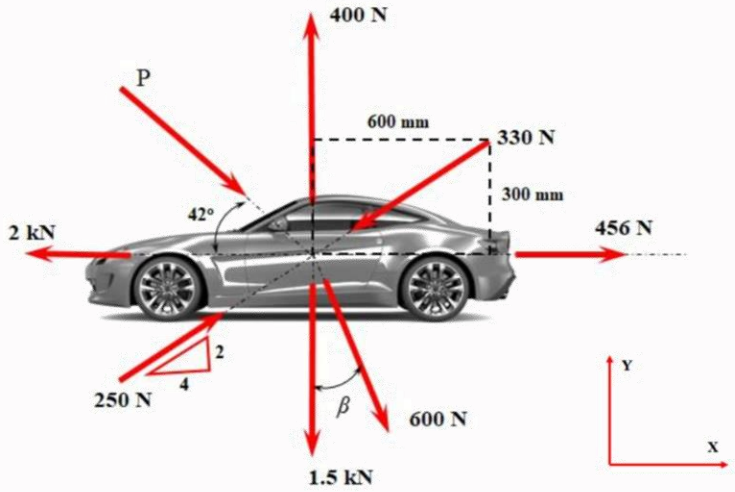
# Kinetics of a Rigid Body

- Rigid body motion can be described by the motion of its center of mass (COM).
- Two types of motion for a rigid body:
  - Translation: Movement of the COM without any rotation.
  - Rotation: Movement about a fixed axis or point.



# Translational Motion of a Rigid Body





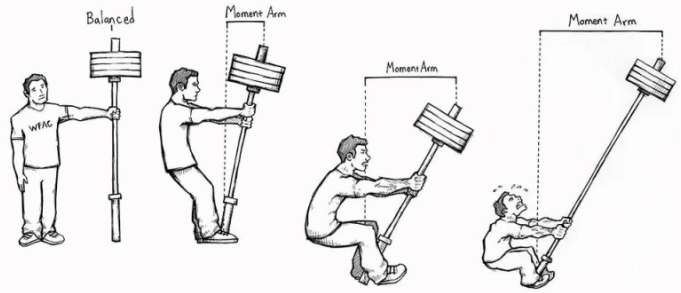

- Analyzed using the same concepts as for a particle (Newton's Laws, FBDs).
- COM acts as a point-like mass for translational motion.

# Rotational Motion of a Rigid Body

- **Torque (τ):** Rotational equivalent of force.

$$\tau = r \times F$$

(torque = moment arm × force), where r is the distance from the axis of rotation to the line of action of the force.



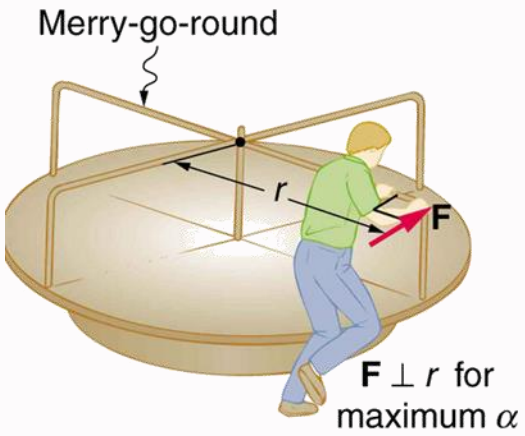

- **Angular momentum (L):** Measure of an object's rotational inertia.

$$L = I\omega$$

(angular momentum = moment of inertia × angular velocity), where I is the moment of inertia and **ω** is the angular velocity.

- **Moment of inertia (I):** Distribution of mass within a rigid body that resists changes in its rotational state.

# Applications of Rotational Motion




- Everyday examples of rotational motion and torque (e.g., opening a door, Ferris wheel).
- Problem-solving using torque and angular momentum.

# Conclusion

**Content:**

Summarize the main concepts covered in the presentation:

- Kinematics of particles (motion description)
- Kinetics of particles and rigid bodies (forces and motion)
- Applications of mechanics in various scenarios (equilibrium, friction, work & energy, conservation laws)

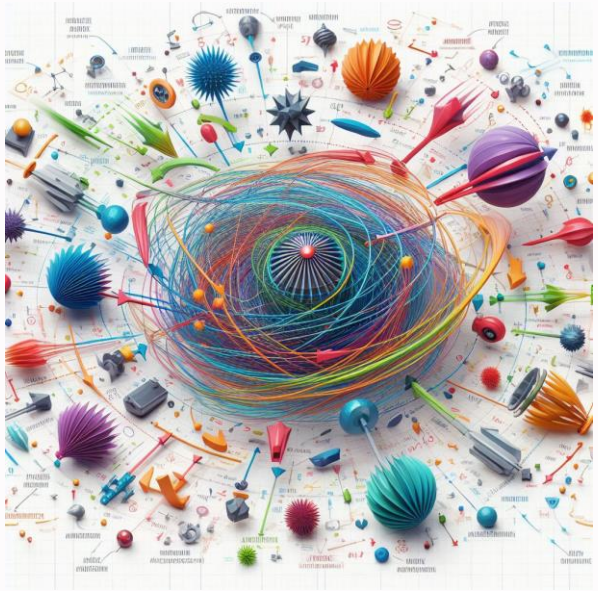
Importance of understanding mechanics:

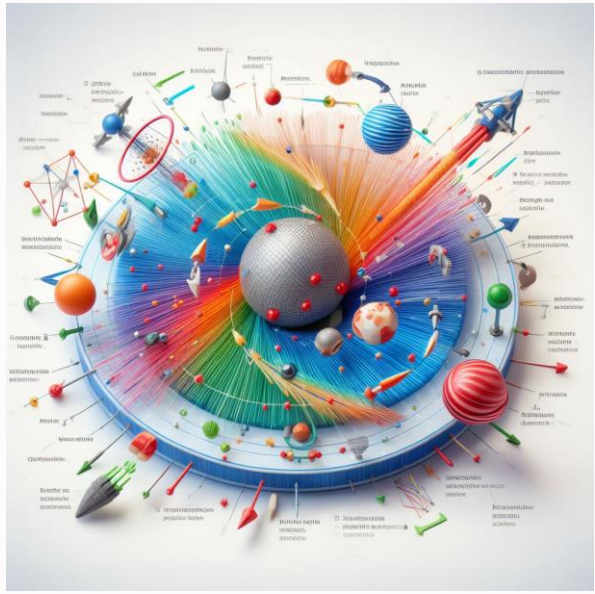
- Foundational concept in physics
- Explains motion of objects in our world
- Applicable in various engineering and technological fields

# Conclusion

**Concluding Statement:**

- Mechanics provides a powerful framework for analyzing motion and its causes. By understanding these principles, you can gain a deeper appreciation for the physical world around you.





# Exploring Resources and References

**Textbooks:**

**Introductory Level:**

- Mechanics by Randall D. Knight (Pearson) ([Link to bookstore or publisher website]) - This widely used textbook provides a clear and concise introduction to mechanics, covering both particles and rigid bodies.
- An Introduction to Mechanics by Daniel Kleppner and Robert Kolenkow (Dover Publications) ([Link to bookstore or publisher website]) - A classic text offering a thorough and rigorous approach to mechanics, suitable for students seeking a deeper understanding.

**Intermediate Level:**

- Classical Mechanics by Herbert Goldstein, Charles P. Poole, and John L. Safko (Pearson) ([Link to bookstore or publisher website]) - A comprehensive and advanced text, covering classical mechanics concepts in detail. (Consider recommending this for students interested in a deeper dive after mastering the basics.)
- Analytical Mechanics by Louis N. Hand and Janet D. Finch (Cambridge University Press) ([Link to bookstore or publisher website]) - Another advanced text with a strong focus on the mathematical analysis of mechanics. (Similar to the previous one, this might be suitable for highly motivated students.)

# Exploring Resources and References

**Exploring Online Resources:**

- Websites: Include links to reputable websites: (e.g., Khan Academy: https://www.khanacademy.org/science/physics, MIT OpenCourseware: https://ocw.mit.edu/)
- Simulations: Suggest interactive simulations related to mechanics concepts. (e.g., PhET Interactive Simulations: https://phet.colorado.edu/en/simulations/browse)

**Reference:**


- Tipler, P. A., & Mosca, G. (2003). Physics for Scientists and Engineers: Mechanics, Oscillations and Waves, Thermodynamics (Vol. 1). W. H. Freeman.
- Khan Academy. (n.d.). Mechanics. Retrieved from https://www.khanacademy.org/science/physics

WEEK 10

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