Dynamics

Summary of Key Terms

Inertia

The tendency of an object to resist any change in its motion. An object with greater mass has greater inertia (it is "harder to start or stop").

- In **Naval Architecture**, the *moment of inertia* (units: m^4) is a measure of resistance to bending (related to stiffness/deflection of beams and hull girders).
- In **angular motion and physics**, the *moment of inertia* (units: $\text{kg} \cdot \text{m}^2$) is a measure of resistance to angular acceleration (rotational inertia).

Linear Momentum (p)

Momentum is the "quantity of motion" an object has. It is calculated as:

$$p = mv$$

where

- p = linear momentum ($\text{kg} \cdot \text{m/s}$)
- m = mass (kg)
- v = velocity (m/s)

Momentum is a **vector quantity** (it has both magnitude and direction).

Newton's Laws of Motion

First Law (Law of Inertia)

An object will stay at rest or keep moving in a straight line at constant speed unless an unbalanced (net) external force acts on it.

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.

$$F_{\text{net}} = ma \quad \text{or} \quad a = \frac{F_{\text{net}}}{m}$$

Third Law (Action-Reaction)

Whenever two objects interact, they exert equal and opposite forces on each other.
"For every action force, there is an equal and opposite reaction force."

Conservation of Linear Momentum

If no external forces act on a system (or if the external forces cancel out), the total momentum of the system stays constant.

In collisions or explosions:

Total momentum before = Total momentum after

Example: When two objects collide and stick together or bounce apart, the momentum lost by one is exactly gained by the other, so the total remains the same.

Angular Momentum

The rotational equivalent of linear momentum. It describes how much "rotational motion" a spinning or orbiting object has.

Angular momentum depends on mass, speed, and distance from the axis of rotation.

Radius of Gyration (k)

A geometric property of a rigid body that indicates how the mass is distributed relative to a specified axis of rotation. It is defined such that:

$$I = mk^2$$

where

- I = moment of inertia ($\text{kg} \cdot \text{m}^2$)
- m = total mass (kg)
- k = radius of gyration (m)

Practical Examples for Radius of Gyration

- **Smaller** $k \rightarrow$ mass is concentrated closer to the axis $\rightarrow$ **lower** rotational inertia
  $\rightarrow$ easier/faster to speed up or slow down rotation
  (e.g., engine crankshafts, turbine rotors).
- **Larger** $k \rightarrow$ mass is distributed farther from the axis $\rightarrow$ **higher** rotational inertia
  $\rightarrow$ better for storing rotational energy
  (e.g., flywheels; a hollow cylinder has a larger k than a solid cylinder of the same mass and outer radius).