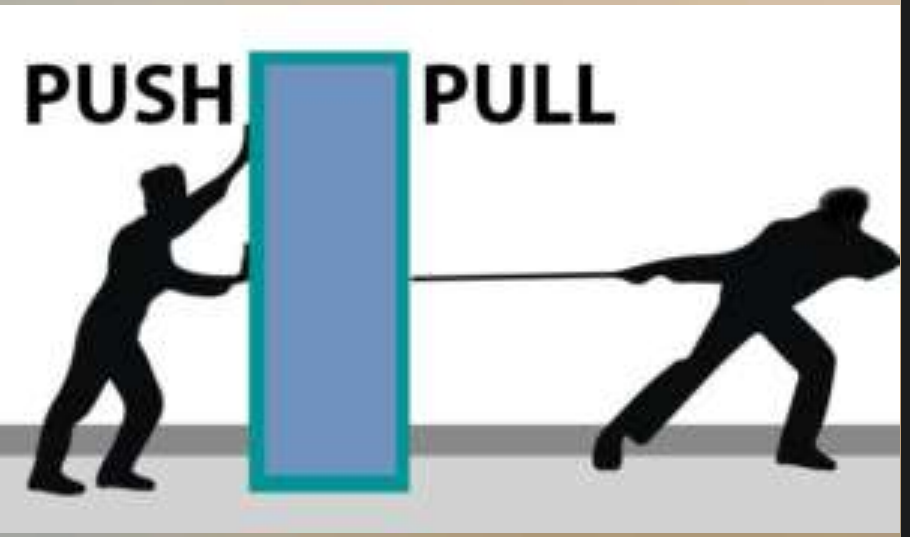


Introduction to Force

Force is a fundamental concept in physics. It is defined as an interaction that can cause a change in the motion of an object. Force can cause an object to **start moving, stop moving, or change direction**. It can also **deform an object**. Force is a vector quantity, meaning it has both **magnitude and direction**.

Ar. Sumeet Kumar
Lecturer (Architecture)
[GPW, Sirsa]
2024

Effects, Characteristics, and Representation of Force

Effects of Force

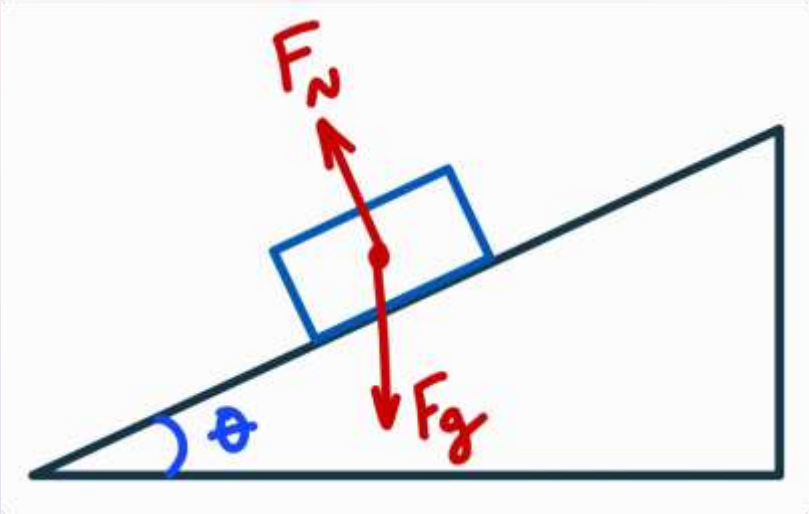
Force can change the motion of an object, causing it to accelerate, decelerate, or change direction. It can also deform an object, stretching or compressing it.

Characteristics of Force

Force is a vector quantity, meaning it has both magnitude (strength) and direction. It is measured in units of Newtons (N).

Representation of Force

Force is typically represented by an arrow, where the length of the arrow represents the magnitude of the force and the direction of the arrow represents the direction of the force.



Types of Forces and Force Systems

1 Contact Forces

Forces that occur when two objects are in direct contact, such as friction, normal force, and applied force.

2 Non-Contact Forces

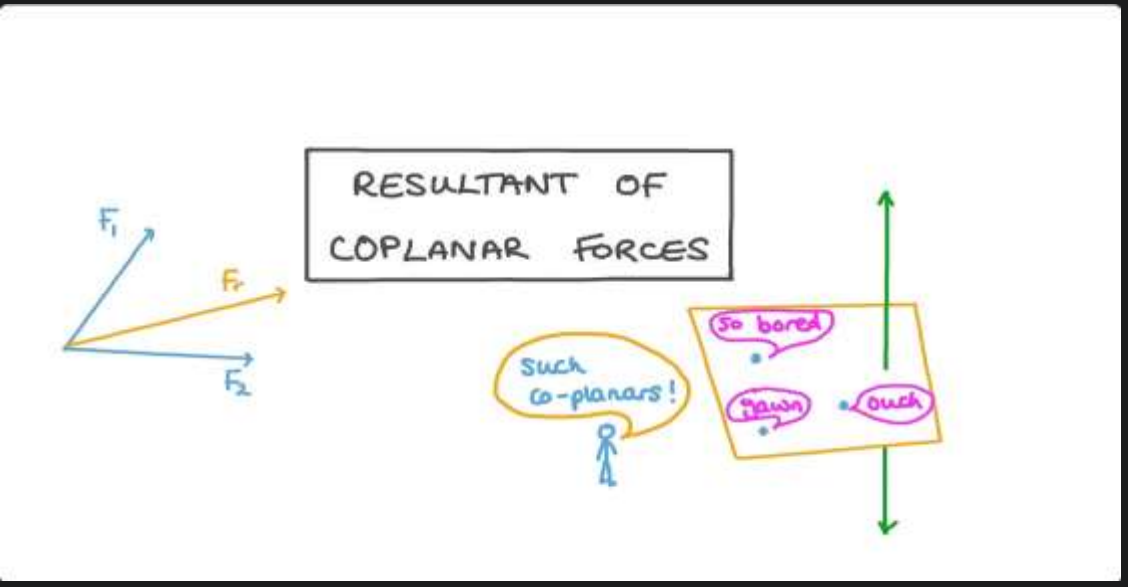
Forces that occur when two objects are not in direct contact, such as gravitational force, magnetic force, and electrostatic force.

3 Force Systems

A force system is a group of forces acting on an object. Forces can be classified based on their arrangement and interaction.

4 Equilibrium

When the net force on an object is zero, the object is in equilibrium and will remain at rest or move with constant velocity.

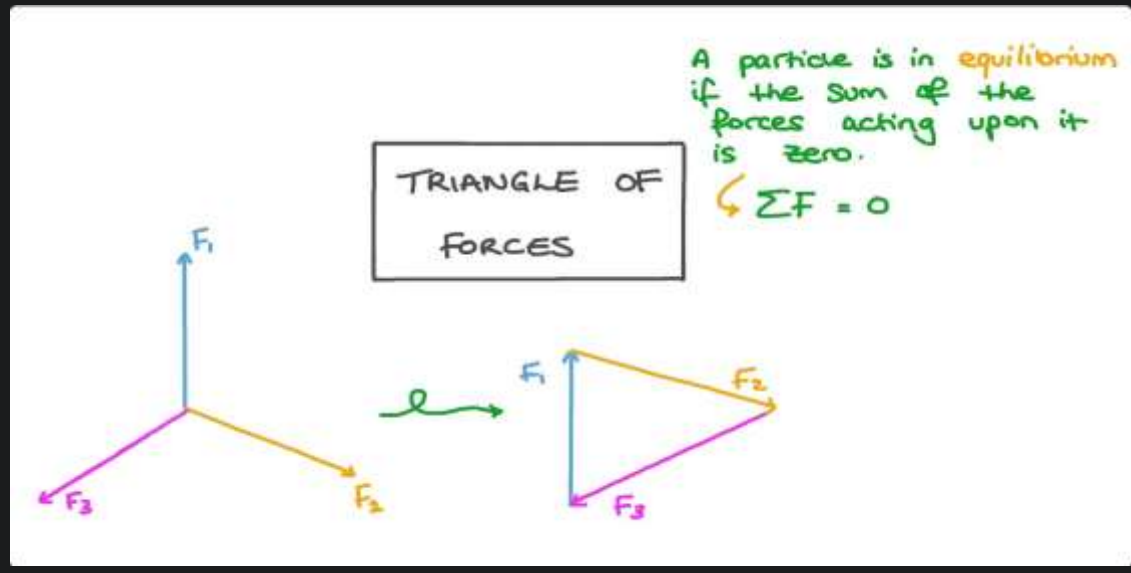


Coplanar Force Systems

A coplanar force system is a group of forces that act in the same plane. These forces can be either concurrent or non-concurrent. Concurrent forces act through a common point, while non-concurrent forces act through different points.

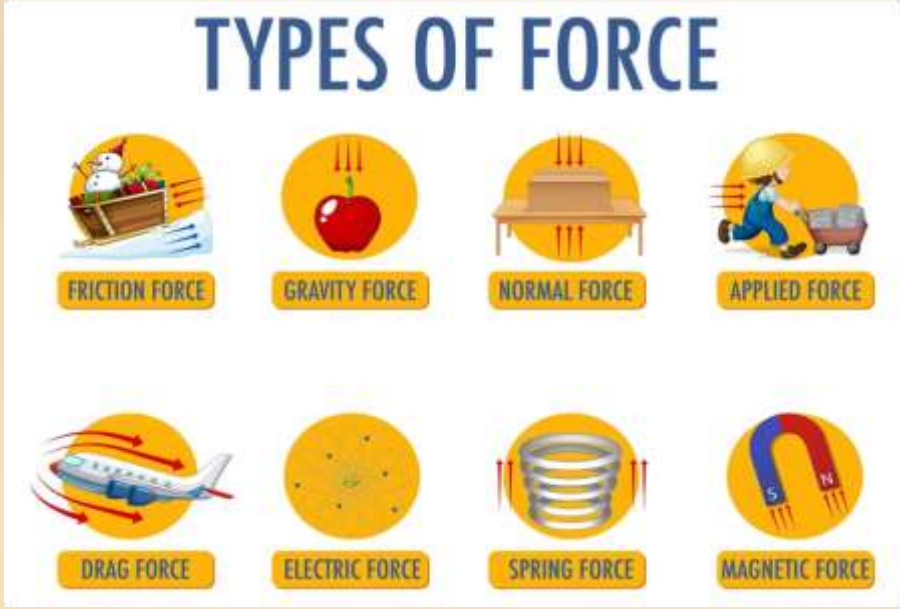
Non-Coplanar Force Systems

A non-coplanar force system is a group of forces that act in different planes. These forces are typically more complex to analyze and require advanced mathematical techniques. They are frequently seen in three-dimensional structures or objects.



Types of Coplanar Forces

Force Type	Definition	Example
Collinear Forces	Forces acting along the same line.	Two people pushing a box in the same direction.
Concurrent Forces	Forces acting through a common point.	Multiple ropes pulling on an object tied to a central point.
Parallel Forces	Forces acting along parallel lines.	The weight of a beam supported at both ends.
Non-Concurrent and Non-Parallel Forces	Forces that do not act through a common point and are not parallel.	Forces acting on a wrench to loosen a nut.



Resultant Force and Components of a Force

1

Resultant Force

The single force that produces the same effect as all the forces acting on an object. It is the vector sum of all the forces.

2

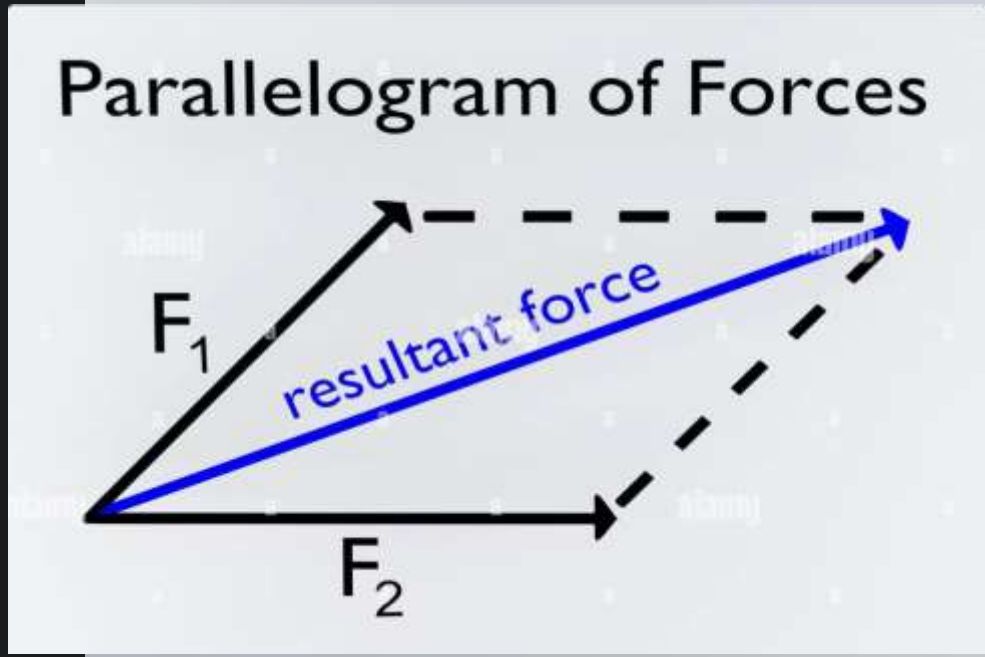
Components of a Force

Forces can be resolved into components that act perpendicular to each other. This simplifies analysis by considering forces along specific axes.

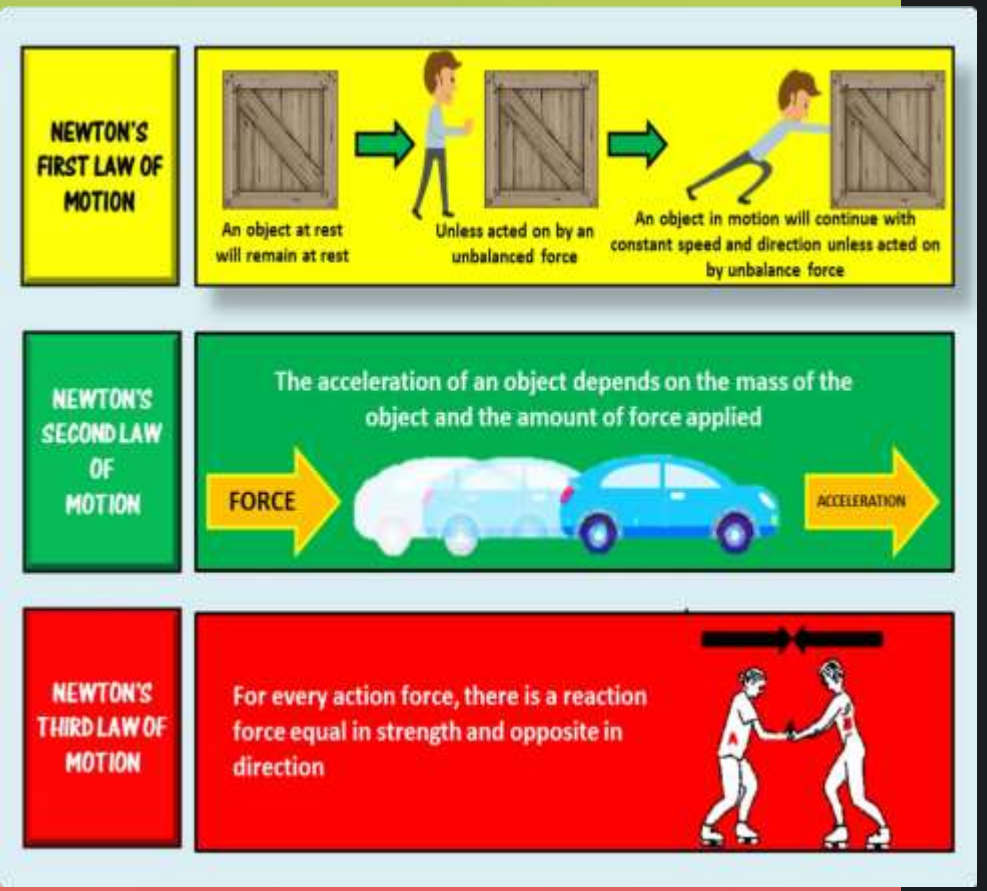
3

Force Resolution

The process of finding the components of a force is called force resolution. It is often used in solving problems involving inclined planes or objects with multiple forces acting on them.



Laws of Forces



Newton's First Law

An object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. This is represented by the equation F = ma.

Newton's Third Law

For every action, there is an equal and opposite reaction. When one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

Center of Gravity and Centroid: A Comprehensive Guide

The center of gravity and centroid are crucial concepts in engineering and physics, particularly when analyzing the stability and equilibrium of structures and objects.

Definition of Center of Gravity

The center of gravity (CG) is the point where the entire weight of an object can be considered to be concentrated. It's the average location of all the mass within an object.

Equilibrium

If an object is supported at its CG, it will be in perfect balance.

Stability

The location of the CG determines the stability of an object. A lower CG generally leads to greater stability.

Definition of Centroid

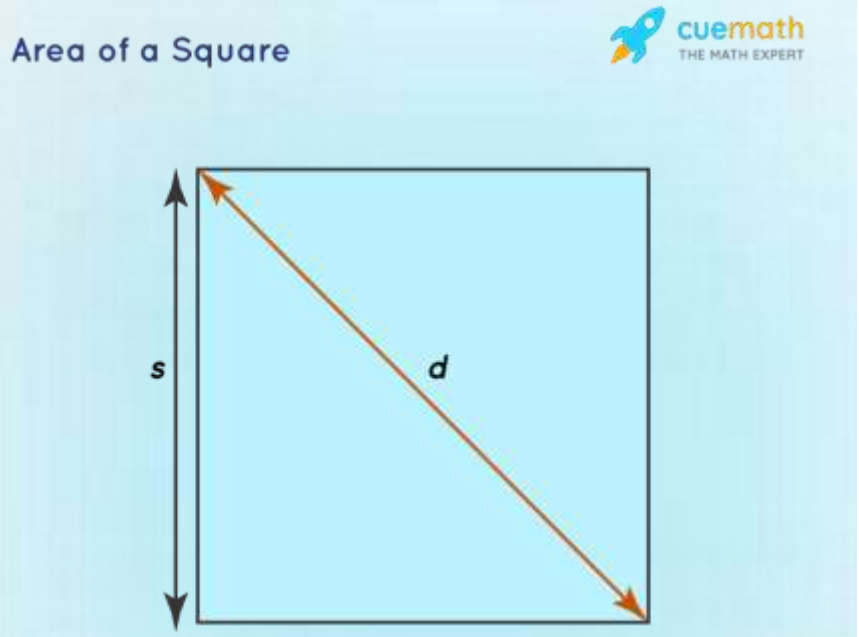
The centroid is the geometric center of a plane figure. It's the point where the figure would perfectly balance if it were cut out of a piece of cardboard.

Center of Gravity

In homogeneous objects, the centroid and the center of gravity coincide.

Non-Homogeneous Objects

For objects with varying density, the centroid and center of gravity may be different points.



Centroid by Method of Moments of Areas

The method of moments of areas is a technique to locate the centroid of a complex shape by dividing it into simpler geometric forms.

1 Sum of Areas

Divide the shape into smaller areas.

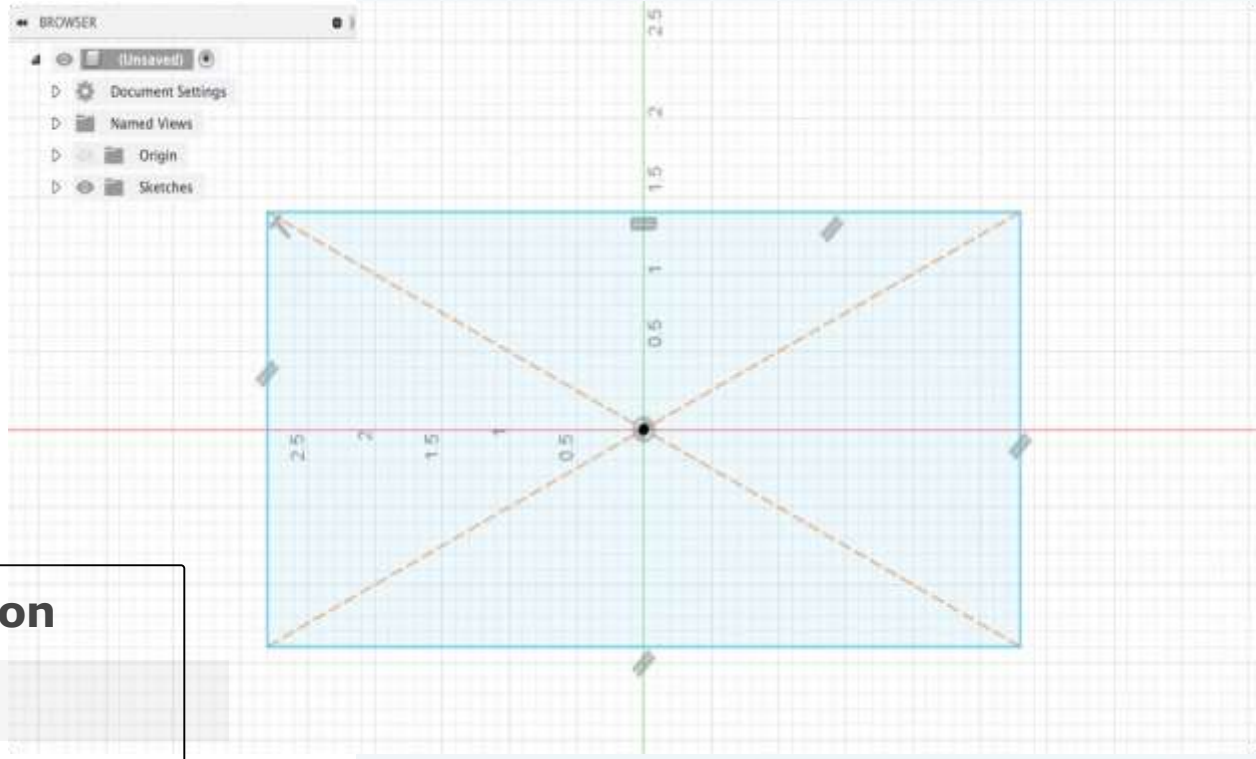
2 Moments

Calculate the moment of each area about a reference axis.

3 Centroid

The centroid is found by dividing the total moment by the total area.

Centroid of Square and Rectangular Cross-Section



For a square or rectangle, the centroid is located at the intersection of the diagonals. This point is exactly in the middle of the shape.

Shape	Centroid Location
Square	$x = a/2, y = b/2$
Rectangle	$x = a/2, y = b/2$

Centroid of Triangular Cross-Section

The centroid of a triangle is located at a point that is one-third of the distance from each vertex to the midpoint of the opposite side.

1

Midpoint

Find the midpoint of any side of the triangle.

2

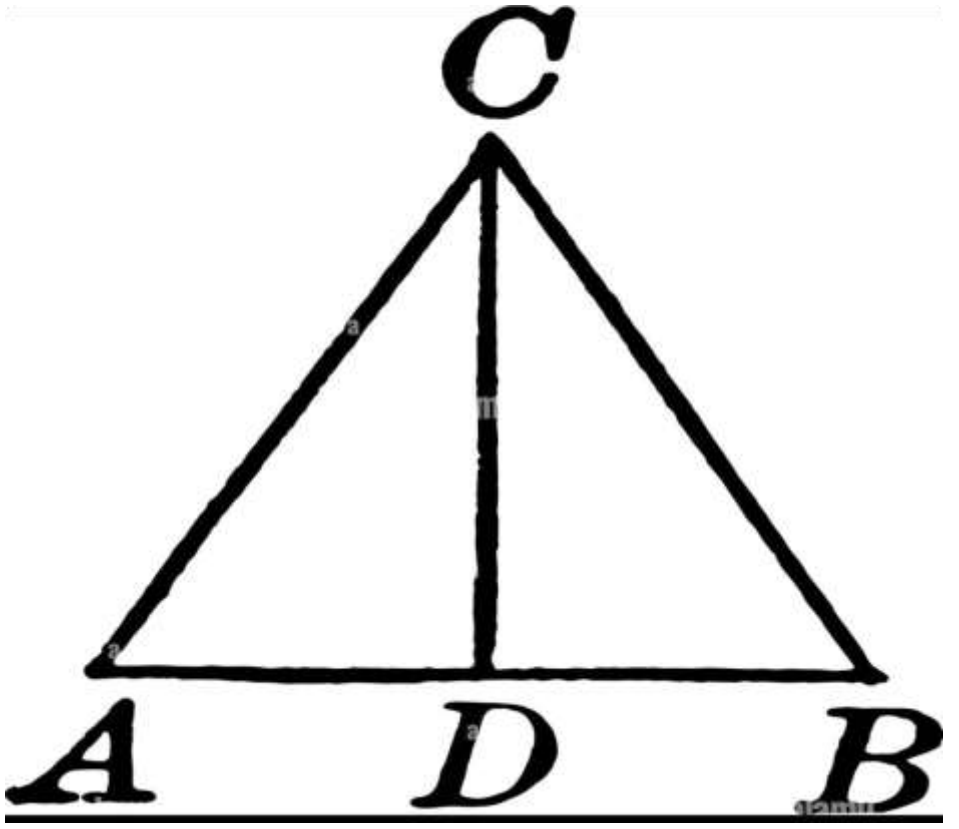
Connect

Draw a line from the vertex opposite that side to the midpoint.

3

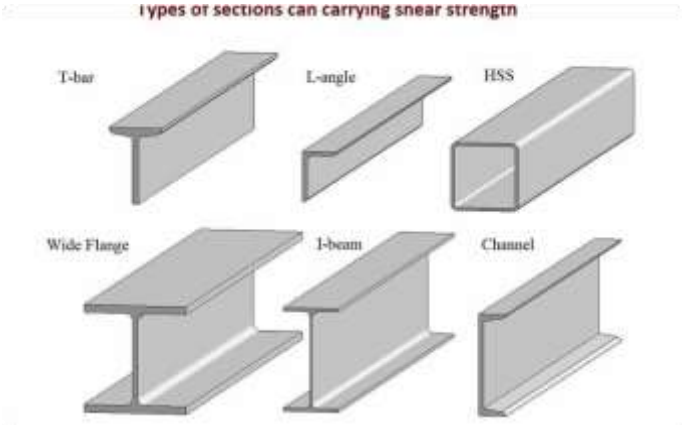
Centroid

The centroid is located one-third of the way along this line from the midpoint.



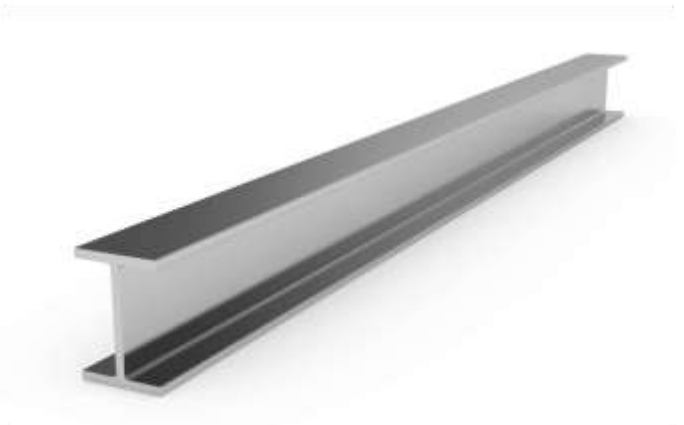
Centroid of L-Shaped, T-Shaped and I-Shaped Cross-Section

To find the centroid of complex shapes like L, T, and I shapes, break them down into simpler shapes (rectangles and triangles), then apply the method of moments.



L-Shape

Divide the L-shape into two rectangles.



T-Shape

Divide the T-shape into a rectangle and a triangle.

I-Shape

Divide the I-shape into three rectangles.

Moments of Inertia

The moment of inertia measures an object's resistance to rotational motion about a specific axis. It's a crucial factor in structural analysis and design.

1

First Moment

The product of an area and its distance from the axis.

2

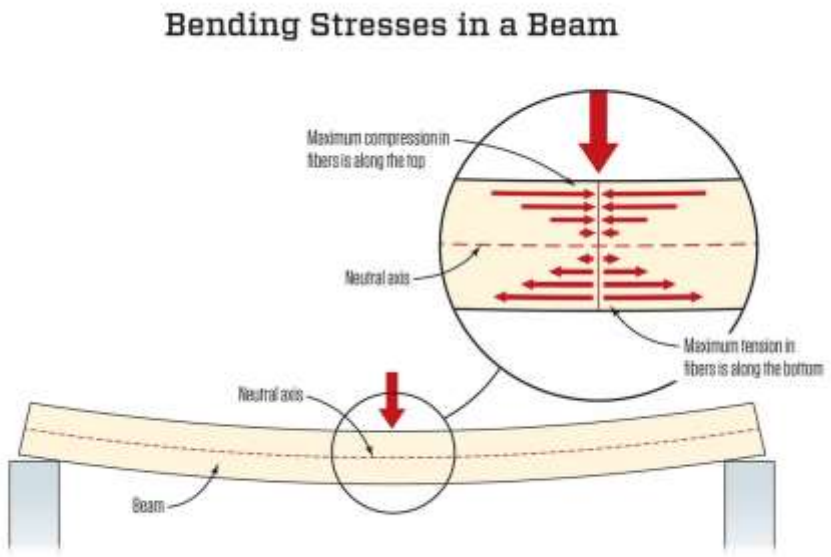
Second Moment

The product of the square of an area's distance from the axis and the area itself.

3

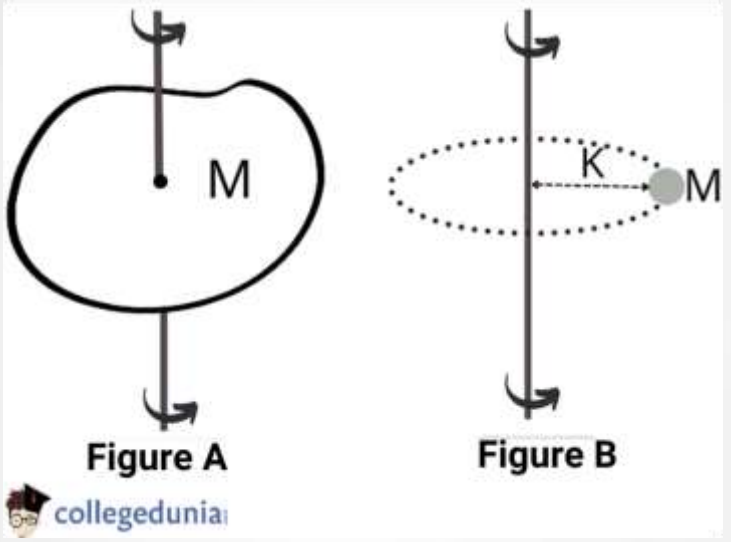
Summation

Summing the second moments of all individual areas.



Radius of Gyration

The radius of gyration is the distance from the axis of rotation where the entire mass of an object can be assumed to be concentrated.



Moment of Inertia

The radius of gyration is related to the moment of inertia.

Distance

It represents an equivalent distance from the axis.

Concentration

It describes the distribution of mass around the axis.