Engineering Mechanics

For

ME / CE

By

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Syllabus for Engineering Mechanics

ME: Free-Body Diagrams and Equilibrium, Trusses and Frames, Virtual Work, Kinematics and Dynamics of Particles and of Rigid Bodies in Plane Motion, Impulse and Momentum (Linear and Angular) and Energy Formulations, Collisions

CE: System of Forces, Free-Body Diagrams, Equilibrium Equations, Internal Forces in Structures, Friction and its Applications, Kinematics of Point mass and Rigid Body, Centre of Mass, Euler's Equations of Motion, Impulse-Momentum, Energy Methods, Principles of Virtual Work.

Previous Year GATE Papers and Analysis

GATE Papers with answer key

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Subject wise Weightage Analysis

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Contents

"Try not to become a man of success, but rather try to become a man of value."

....Albert Einstein

CHAPTER 1

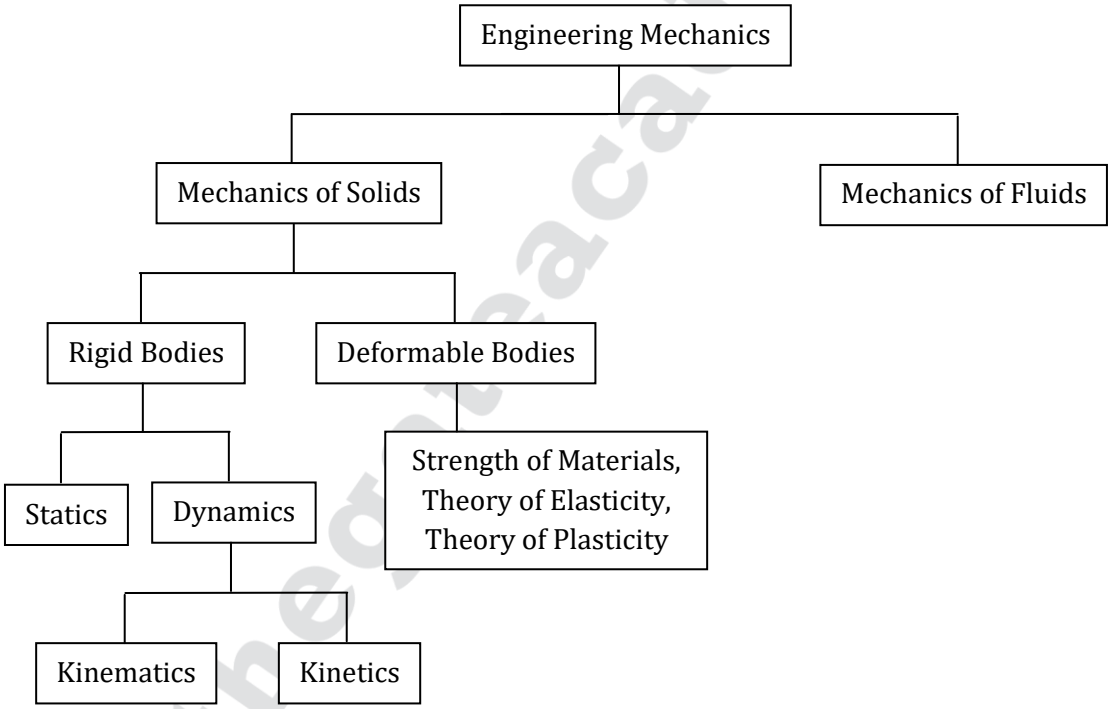
Introduction

Introduction

Mechanics is the science which deals with the action of forces on different types of bodies either in motion or at rest.

Engineering mechanics is the application of mechanics to solve problems involving common engineering elements.

Engineering Mechanics can be broadly classified as,



In this course material we will study about the mechanics of particles and rigid bodies.

- **Particle:** It is a portion of matter which is indefinitely small in size.
- **Rigid Body:** A rigid body may be defined as a body in which the relative positions of any two particles do not change under the action of forces. Statics deals primarily with the calculation of external forces which act on rigid body in equilibrium.

"I am a slow walker ... but I never walk backwards."
.....Abraham Lincoln

CHAPTER 2

Free Body Diagram and Equilibrium

Learning Objectives

After reading this chapter, you will know:

1. Equivalent Force System, Newton's Law of Motion
2. Equilibrium and Free Body Diagrams, Type of Equilibrium
3. Static Friction, Virtual Work, Trusses and Frames, Statics Related Problems

Introduction

Statics deals with system of forces that keeps a body in equilibrium. In other words the resultant of force systems on the body are zero.

Force

A force is completely defined only when the following three characters are specified.

- Magnitude
- Point of Application
- Line of action/Direction

Scalar and Vector

A quantity is said to be scalar if it is completely defined by its magnitude alone. e.g. length, energy, work etc. A quantity is said to be vector if it is completely defined only when its magnitude and direction is specified.

E.g.: Force, Acceleration.

Equivalent Force System

Coplanar Force System: If all the forces in the system lie in a single plane, it is called coplanar force system.

Concurrent Force System: If line of action of all the forces in a system passes through a single point it is called concurrent force system.

Collinear Force System: In a system, all the forces parallel to each other, if line of action of all forces lie along a single line then it is called a collinear force system.

Force System	Example
Coplanar like parallel force is straight	Weight of stationary train on rail off the track
Coplanar concurrent force	Forces on a rod resting against wall
Coplanar non- concurrent force	Forces on a ladder resting against a wall when a person stands on a rung which is not at its center of gravity
Non- coplanar parallel force	The weight of benches in class room
Non- coplanar concurrent force	A tripod carrying camera
Non- coplanar non-concurrent force	Forces acting on moving bus

Newton's Laws of Motion

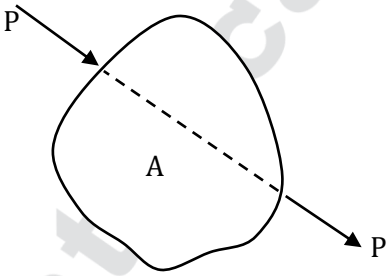
First Law: Everybody continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by force acting on it.

Second Law: The rate of change of momentum of a body is directly proportional to the applied force & it takes place in the direction in which the force acts.

$$F \propto \left(m\frac{dv}{dt}\right)$$

Third Law: For every action, there is an equal and opposite reaction.

Principle of Transmissibility of Forces: The state of rest or motion of rigid body is unaltered if a force action on a body is replaced by another force of the same magnitude and direction but acting anywhere on the body along the line of action of applied forces.



Parallelogram Law of Forces: If two forces acting simultaneously on a body at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram their resultant is represented in magnitude and direction by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces.

Equilibrium and Free Body Diagrams

Equilibrium: Any system of forces which keeps the body at rest is said to be equilibrium, or when the condition of the body is unaffected even though a number of forces acted upon it, is said to in equilibrium.

Laws of Equilibrium

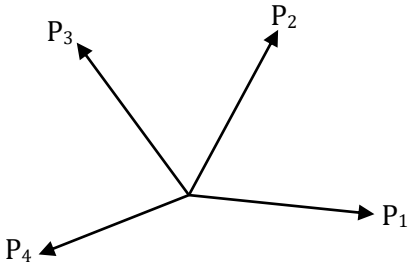
- **Force Law of Equilibrium:** For any system of forces keeping a body in equilibrium, the algebraic sum of forces, in any direction is zero, ie. $\Sigma F = 0$
- **Moment Law of Equilibrium**: For any system of forces keeping a body in equilibrium, the algebraic sum of the moments of all the forces about any point in their plane is zero.
  i.e., $\Sigma M = 0$
  $\Sigma F \times d = 0$
  This law is applicable only to coplanar, non-concurrent force systems.

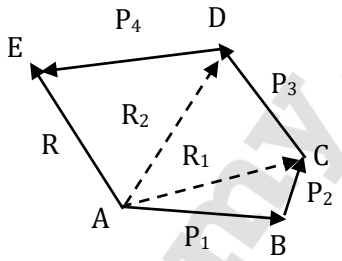
Coplanar Concurrent Forces

Triangle Law of Forces

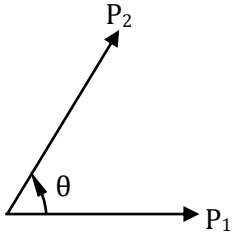
If two forces acting simultaneously on a body are represented by the sides of triangle taken in order, their resultant is represented by the closing side of the triangle taken in the opposite order.

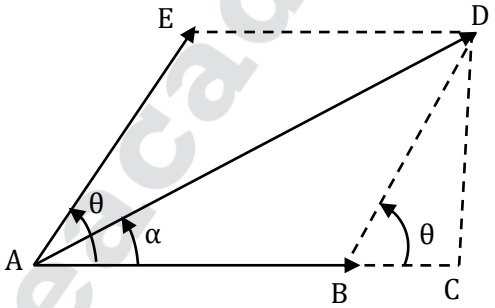
Polygon Law of Forces





If a number of forces acting at a point be represented in magnitude and direction by the sides of a polygon in order, then the resultant of all these forces may be represented in magnitude and direction by the closing side of the polygon taken in opposite order.





Resultant, $(R) = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta}$

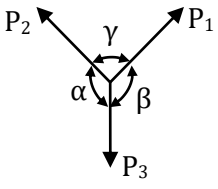
$\tan\alpha = \left(\frac{P_2\sin\theta}{P_1+P_2\cos\theta}\right)$

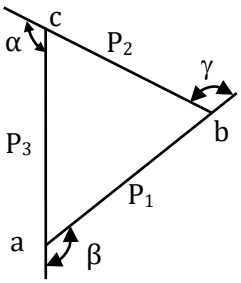
Where,

θ = Angle between two forces, α = Inclination of resultant with force P_1

When forces acting on a body are collinear, their resultant is equal to the algebraic sum of the forces.

Lami's Theorem: (Only three coplanar concurrent forces) If a body is in equilibrium under the action of three forces, then each force is proportional to the sine of the angle between the other two forces.

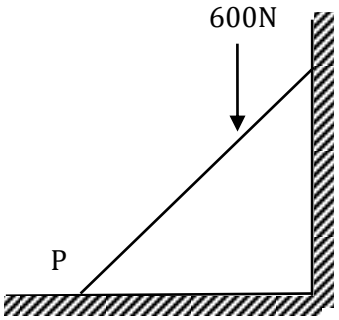


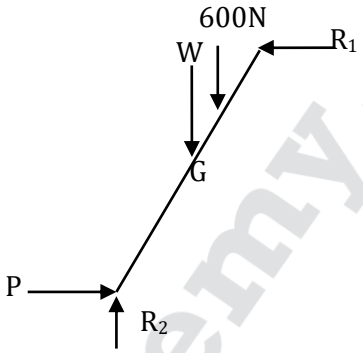


$$\frac{P_1}{\sin\alpha} = \frac{P_2}{\sin\beta} = \frac{P_3}{\sin\gamma}$$

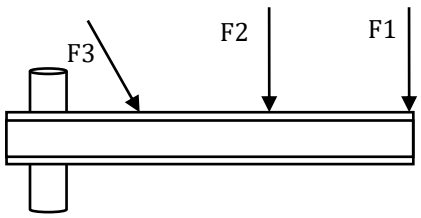
Free Body Diagram: A free body diagram is a pictorial representation used to analyze the forces acting on a free body. Once we decide which body or combination of bodies to analyze, we then treat this body or combination as a single body isolated from all our surrounding bodies.
A free body diagram shows all contact and non-contact forces acting on the bodies.

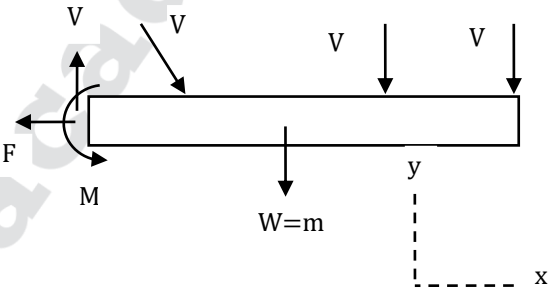
Sample Free Body Diagrams



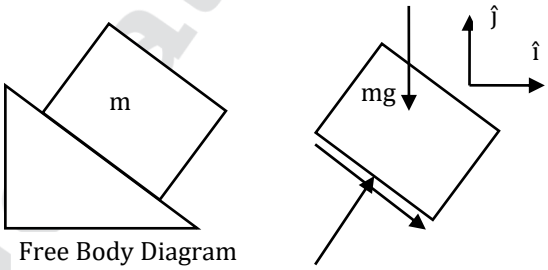


A Ladder Resting on Smooth Wall





A Cantilever Beam



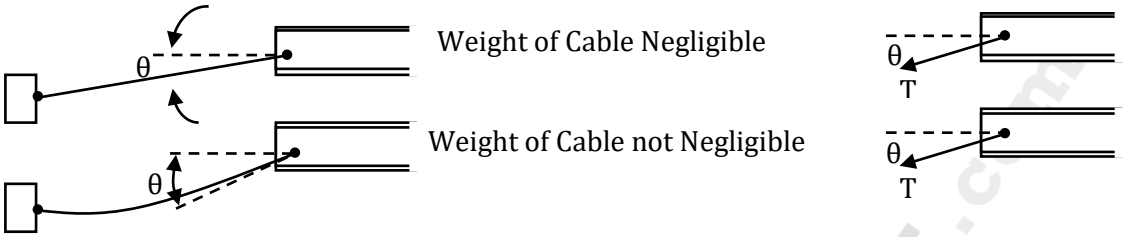
A Block on a Ramp

In a free body diagram all the contacts/supports are replaced by reaction forces which will exert on the structure. A mechanical system comprises of different types of contacts/supports.

Types of Contacts/Supports

Following types of mechanical contacts can be found in various structures,

- **Flexible Cable, Belt, Chain or Rope**



Force exerted by the cable is always a tension away from the body in the direction of the cables.

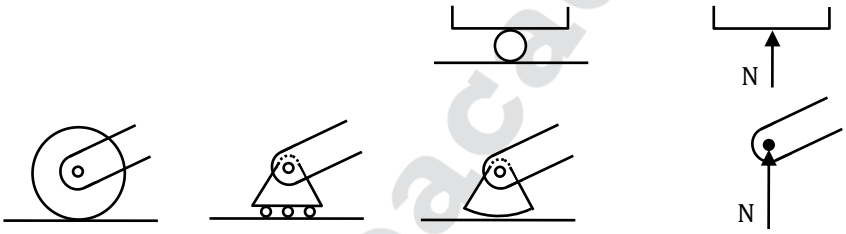
- **Smooth Surfaces**

Contact force is compressive and is normal to the surfaces.

- **Rough Surfaces**

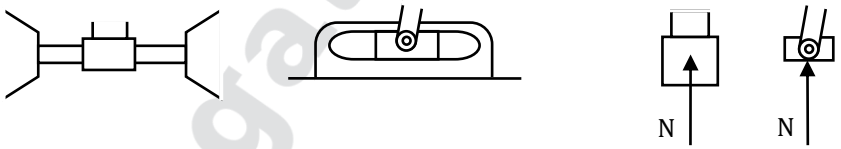
Rough surfaces are capable of supporting a tangential component F (frictional force as well as a normal component N of the resultant R.

- **Roller Support**



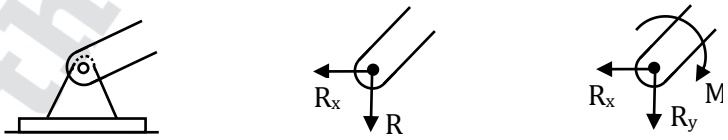
Roller, rocker or ball support transmits a compressive force normal to supporting surface.

- **Freely Sliding Guide**



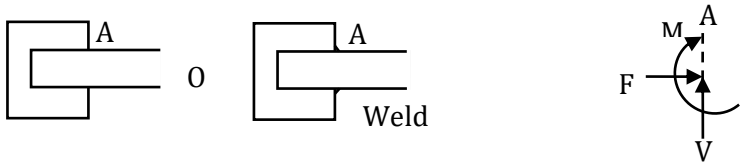
Collar or slider support force normal to guide only. There is no tangential force as surfaces are considered to be smooth.

- **Pin Connection**



A freely hinged pin supports a force in any direction in the plane normal to the axis; usually shown as two components R_x and R_y. A pin not free to turn also supports a couple M.

- **Built in or Fixed End**



A built-in or fixed end supports an axial force F, a transverse force V, and a bending moment M.