Applied Mechanics

Chapter 3

Force Acting on Particle and Rigid Body

Lecture 3

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Learning Objectives:

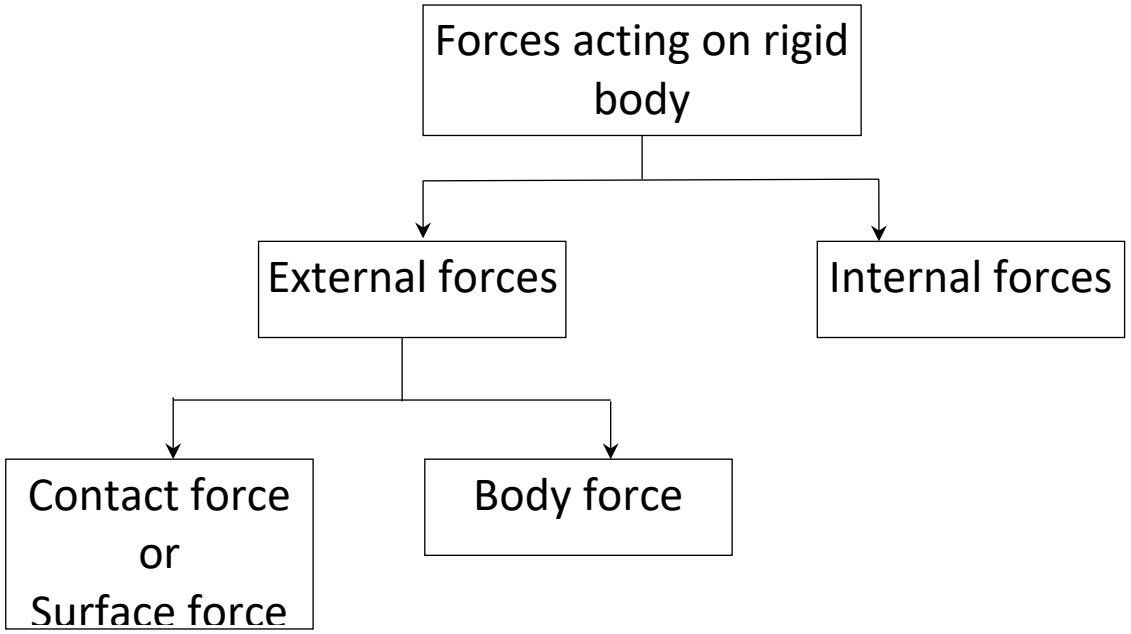
- to understand the concept of different types of forces.
- identify and differentiate between translational forces and rotational forces, and comprehend their application through relevant examples.
- to resolve forces into their components and compose forces to find resultant forces, utilizing relevant examples for practical understanding.
- to grasp the principle of transmissibility and its significance in mechanics, along with understanding equivalent forces and their applications through relevant examples.
- to analyze and solve problems related to forces acting on particles and rigid bodies.

3.Force Acting on Particle and Rigid Body

Force: It is a vector quantity and it is something which changes to tends to change the state of rest or of uniform motion of body in a straight line. It can accelerate or retards the motion.

Or in other words Forces are interactions that cause objects to accelerate, decelerate, or change direction. Rigid body are objects that don't deform under the application of forces.

Forces acting on rigid body



3.1 Different types of Forces:

Body force: Force exerted by one body on another body at a distance (e.g. gravitational force, magnetic force etc.) Or in other words a force which acts on each element of body

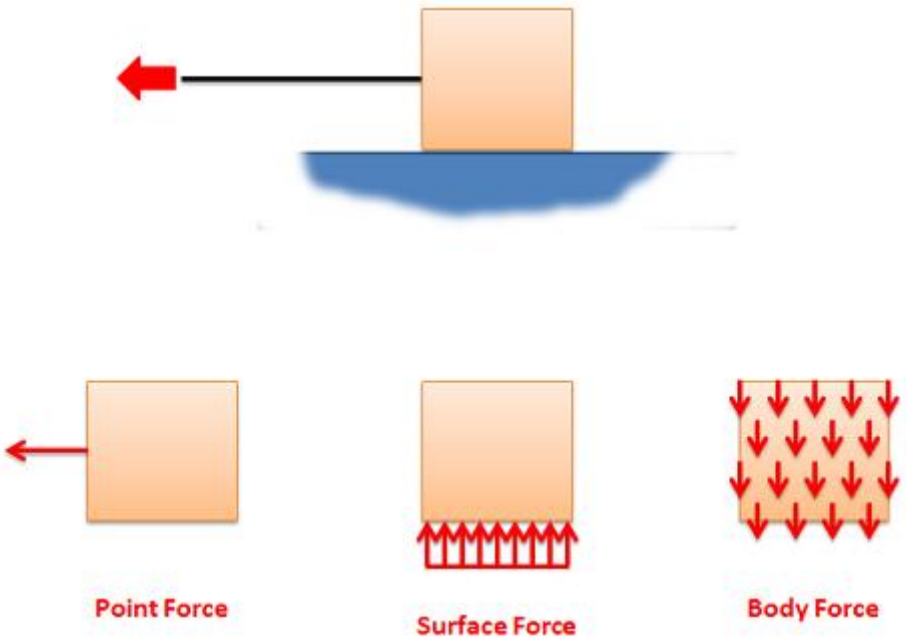
Surface traction: The tangential force which is produced due to the friction between two bodies without slipping called surface traction. 

Point load force: the force which acts on the single point or on the negligible area is termed as point forces.

Internal forces: Forces between the internal particles which holds the particles together forming rigid body.

External force: represents the action of one body to another and responsible for the change in external behavior of the body.

Contact force: It represents the forces exerted by one body on another body by contact.



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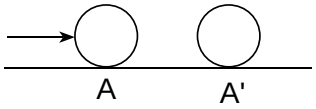
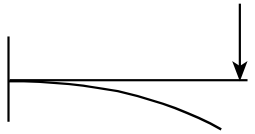
Translation force



The force which moves or tends to move a body from one place (point) to another place (point) is called translation force. It is acting along with the coordinate axis.

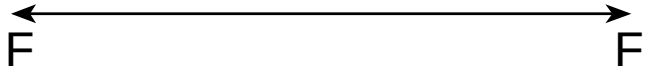
Rotational force: The force which tends to rotate the body about an axis is called rotational force. e.g. moment, turning of bolt etc.[2]



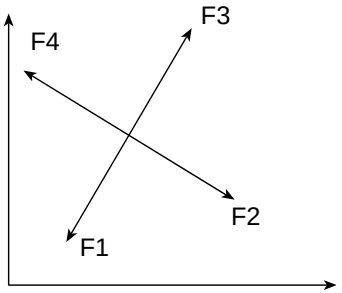
3.1.1 Force system

A force system is a collection of forces acting on a body in one or more planes.
According to the relative positions of the lines of action of the forces, the forces may be classified as follows:

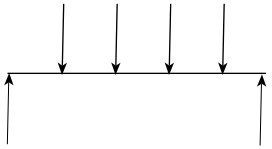
1. **Coplanar concurrent collinear force system**: Includes those forces whose vectors lie along the same straight line.



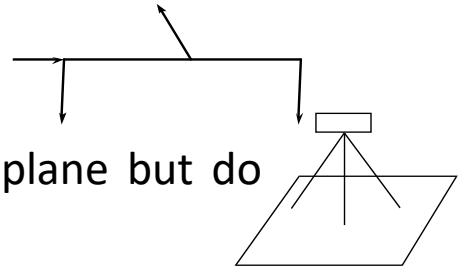
2. **Coplanar concurrent non-parallel force system:** Forces whose line of action passes through a common point are called concurrent forces. In this system lines of action of all the forces meet at a point but have different direction in the same plane.



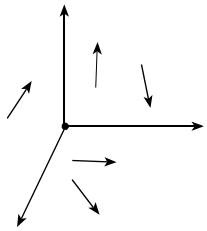
3. **Coplanar non concurrent parallel force system:** Line of action of all forces are in same plane and parallel.



4. **Coplanar non-concurrent non-parallel force system:** Line of action of all forces in same plane but not passes through a common point and not parallel.



5. **Non- coplanar concurrent force-system:** force is not in same plane but do passes through a common point.
6. **Non-coplanar non-concurrent force system:**
   Line of action of all forces does not lie in same plane and do not through a common point.[1]



3.2 Resolution and composition of forces

3.2.1 Resolution

A single, force can be replaced by two forces acting in the directions which will produce the same effects as the given force. Thus, breaking up of a force into two parts is called the resolution of force.

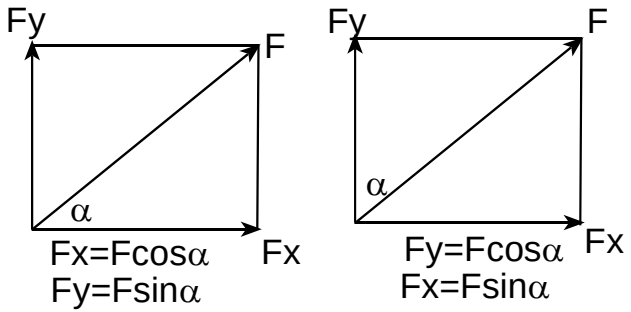
Force is resolved in two ways

1.Mutually perpendicular components

2.Non-perpendicular components.

1. Mutually perpendicular components: (rectangular components of forces)

(Note: *Cos component is the force component with this makes an angle)*

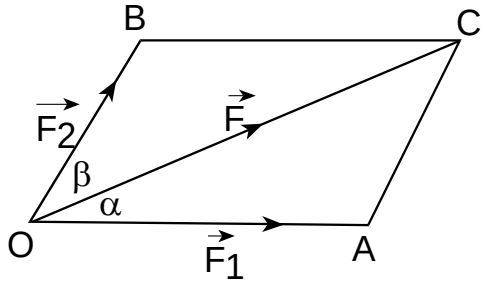


2. Non-perpendicular components:

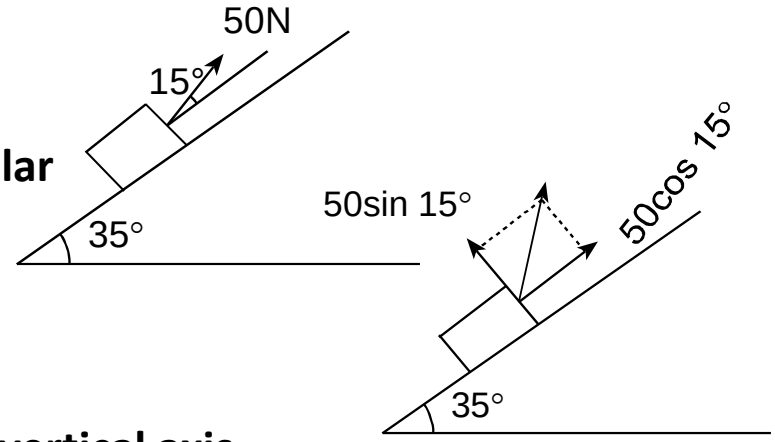
$$\frac{OA}{\sin\beta} = \frac{AC}{\sin\alpha} = \frac{OC}{\sin\,[180 - (\alpha + \beta)}$$

$$\left[\frac{F_1}{\sin\beta} = \frac{F}{\sin\,(\alpha + \beta)} = \frac{F_2}{\sin\alpha}\right]$$

[From this, finding the components F_1 and F_2]



Q. Find the components of force of magnitude 50 N acting on a block as shown in figure. (i)Along lines parallel and perpendicular to the inclined plane and (ii) along the horizontal and vertical axes.



Solution:

i) Components of force parallel and perpendicular to the inclined plane

F parallel = 50 cos15° = 48.3 N

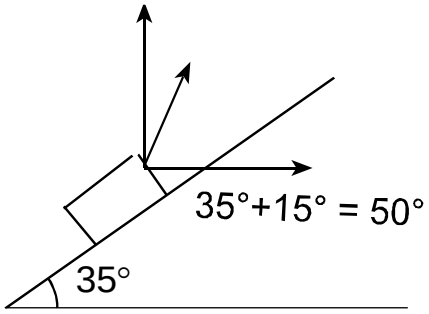
F perpendicular = 50 sin 15° = 12.94 N

ii) Components of the force along horizontal and vertical axis

The inclination of the force w.r.t horizontal axis is 50°. Hence its components along horizontal and vertical axes are

Fx = 50 cos50° = 32.14 N

Fy = 50 sin 50° = 38.3 N



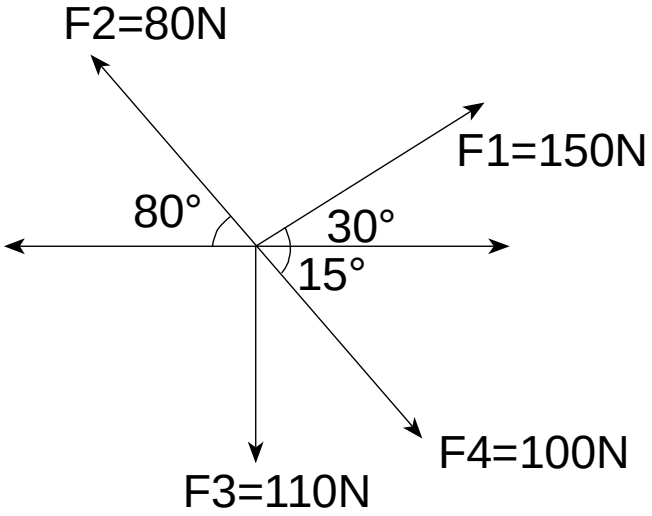
3.2.2 Composition of Forces

The process of finding the resultant force of a number of given forces is called composition of forces.

Or in other words It is the process of combining a number of forces into a single force such that the net effect produced by the single force is equal to the algebraic sum of the effects produced by the individual forces. The single force in this case is called the resultant force which produces the same effect on the body as that produced by the individual forces acting together.[4]

Example

Q. Forces act on a system. Determine the resultant of the forces in this system.



$\overset{+}{\rightarrow}$

$\Sigma F_x = 150 \cos 30° - 80\cos 80° + 100 \cos 15° = 212.60N$

$(+\uparrow)\ \Sigma Fy = 150 \sin 30° + 80 \sin 80° - 110 - 100 \sin 15° = 17.9N$

$R = \sqrt{\Sigma fx^2 + \Sigma fy^2}$

$= \sqrt{212.60^2 + 17.9^2}$

$= 213.35\ N$

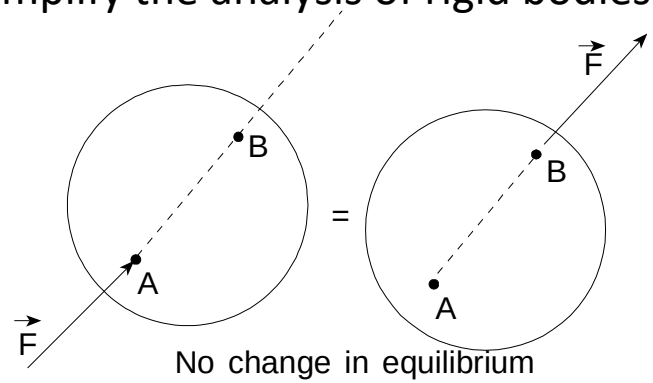
$\theta = \tan^{-1}\frac{17.9}{212.60} = 4.81°$

θ = angle made by resultant with horizontal.

3.3 Principle of Transmissibility and Equivalent Forces

3.3.1 Principle of Transmissibility

It states that the conditions of equilibrium or of motion of a rigid body remains unchanged if a force acting at a given point of the rigid body is replaced by a force of the same magnitude and direction, but acting at a different point, provided that the two forces have the same line of action. Any force that has the same magnitude and direction, and which has a point of application somewhere along the same line of action will cause the same acceleration and will result in the same moment. Therefore, the points of application of forces may be moved along the line of action to simplify the analysis of rigid bodies.[3]

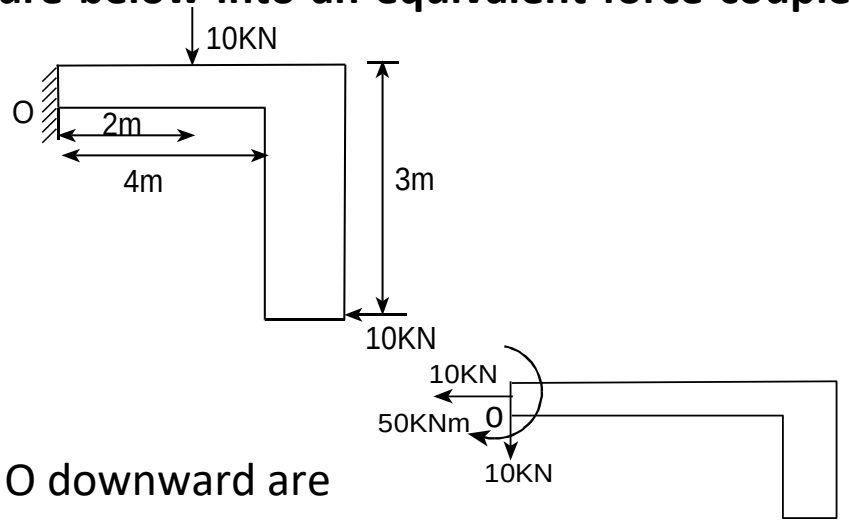


3.3.2 Equivalent Forces:

The concept of equivalent force is used in mechanics to simplify the analysis of complex systems by replacing a system of forces with a single force that has the same effect on an object as the original system of forces. This concept is based on the principle of equilibrium, which states that if an object is in a state of equilibrium (i.e., it is not accelerating), then the vector sum of all the forces acting on the object must be zero.

Imagine you have several different forces pushing or pulling on an object from different directions. When you combine all of these forces together, you can find one single force that has the same overall effect as all of the original forces combined. This single force is called the resultant force. It's like finding the "total" force that's equivalent to having all the individual forces acting at once. So, instead of dealing with multiple forces, you simplify things by treating them as one.

Q. Resolve the force system as shown in the figure below into an equivalent force couple system about 0.



Solution:

Note: Equivalent force couple system means shifts the force and moment at point where the questions ask for equivalent system.

10 KN force at O leftward and 10 KN force at O downward are shift as it is and take moment about point O for equivalent couple.

$M_o = 10 \times 2 + 10 \times 3$

$= 20 + 30 = 50$ KNM (+ve clockwise) This moment is applied at point O for equivalent couple and equivalent system at point O as shown in figure.

References

[1] Kumar, D. (2019). *Engineering Mechanics.* New delhi: S.K Kataria and Sons.

[2] Neupane, P. a. (2024). *A Text book of Engineering Mechanics.* Bhotahity Kathmandu: Heritage Publisher and Distributors PVT .LTD.

[3] Mechanics Map - Principle of Transmissibility (psu.edu)

[4] M.N. SHESHA PRAKASH, G. B. (August, 2014). *Elements Of Civil Engineering And Engineering Mechanics.* Rimjhim House, 111, Patparganj, Delhi: PHI Learning Private Limited.

Thank You!!!