Course Code: ESC106A
Course Title: Construction Materials and Engineering Mechanics

Lecture No. 12:

System of Forces

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Lecture Intended Learning Outcomes

At the end of this lecture, students will be able to:

- Define a force system
- Classify the force systems
- Apply theorem of moments to a non-concurrent force system
- Compare the analysis of concurrent and non concurrent force systems

Contents

- **Engineering Mechanics**

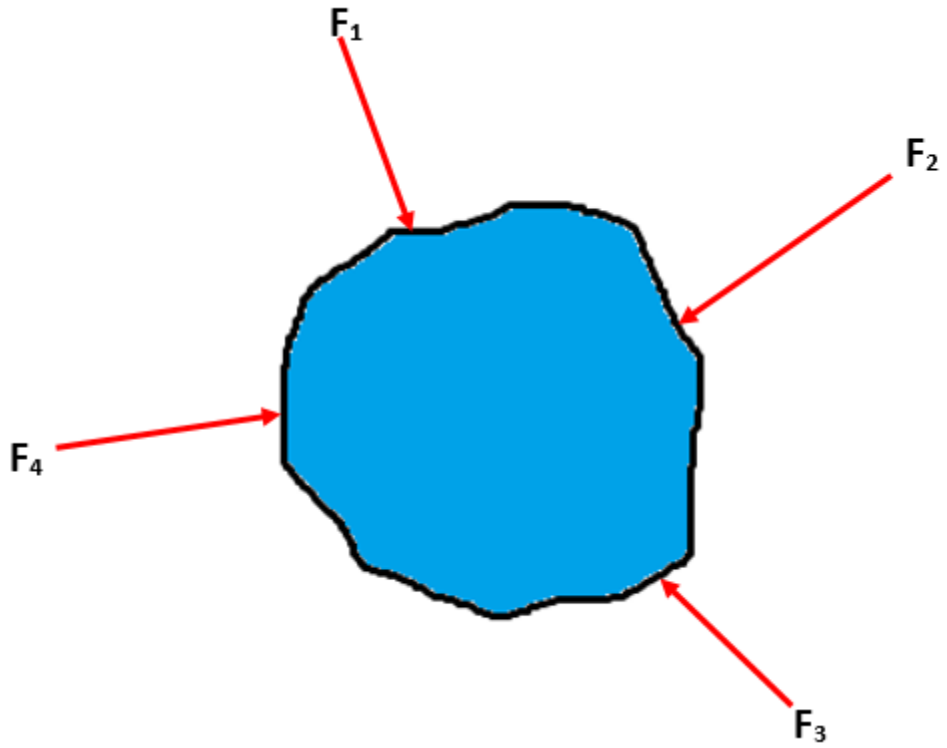
  Classification of force and force systems

- **Analysis of Coplanar Concurrent and Non-Concurrent System of Forces**

  Resultant of Concurrent force systems by method of Resolution

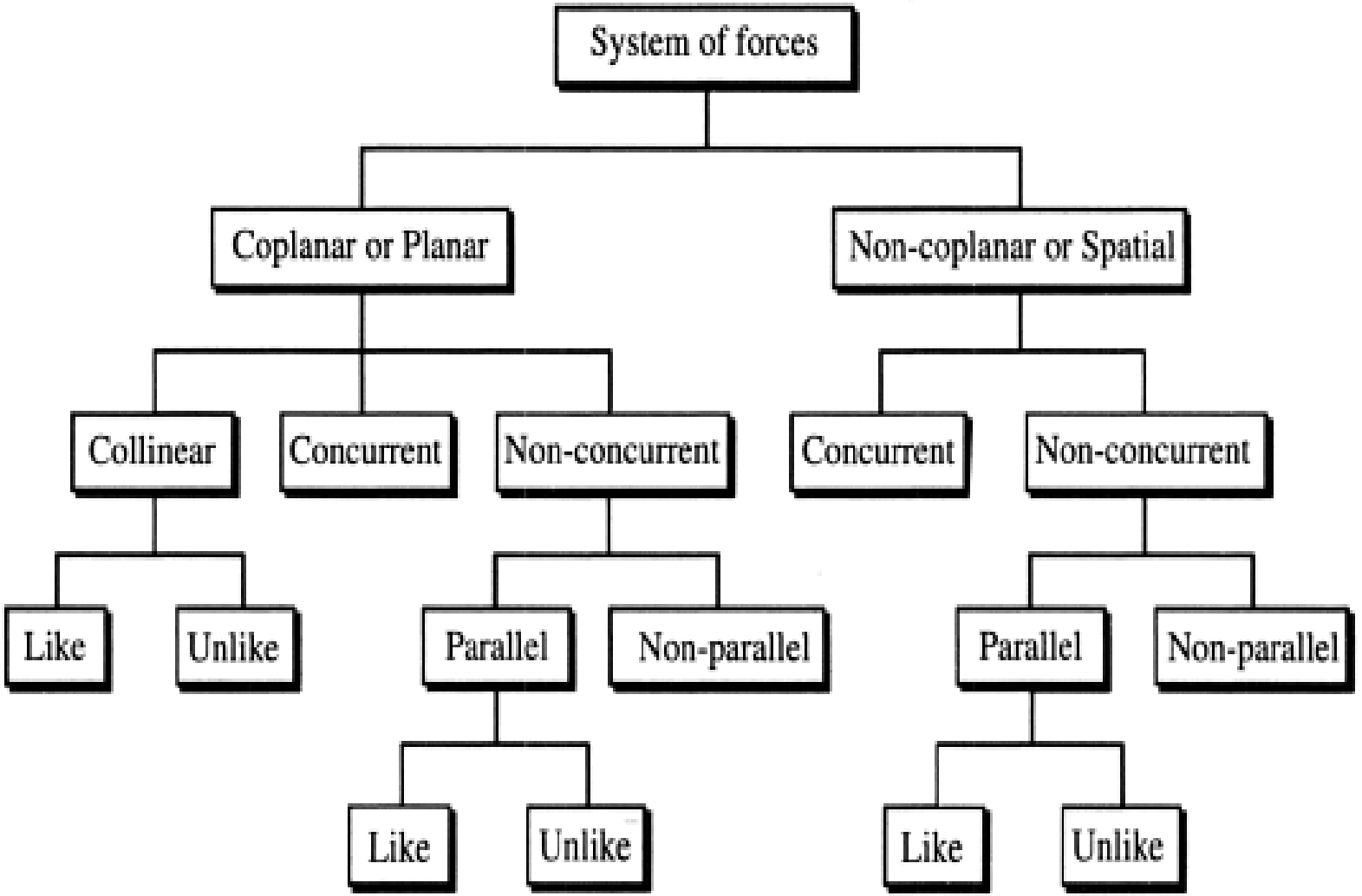
Force System

- A group or set of forces acting simultaneously on a body is called system of forces



A Force System

Forces System



Coplanar forces

- The forces acting on the same plane are called Coplanar force system

Non Coplanar forces

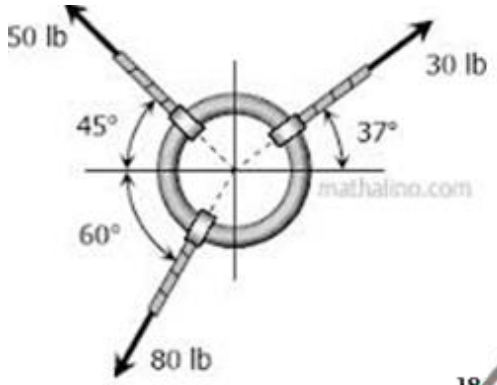
- The forces acting on different planes are called as Non Coplanar force system

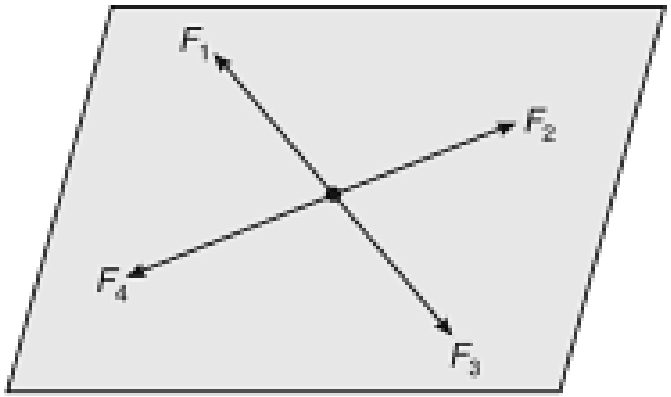
Types of Coplanar Forces
Collinear forces

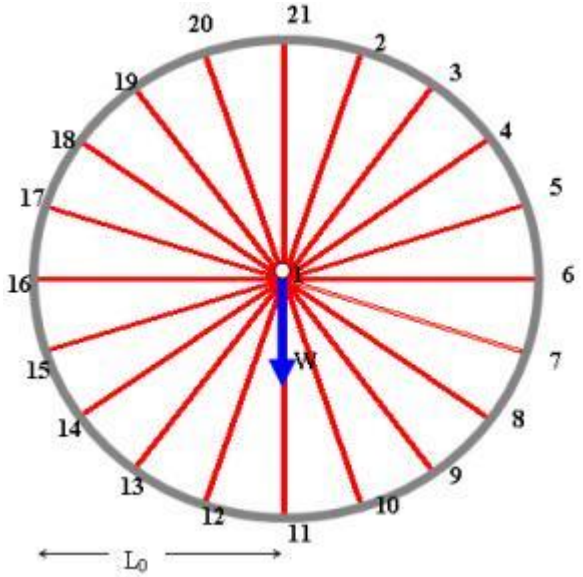
- **Collinear forces**: It is a force system, in which all the forces have the same line of action.
- **Ex**. Forces in a rope in a tug of war

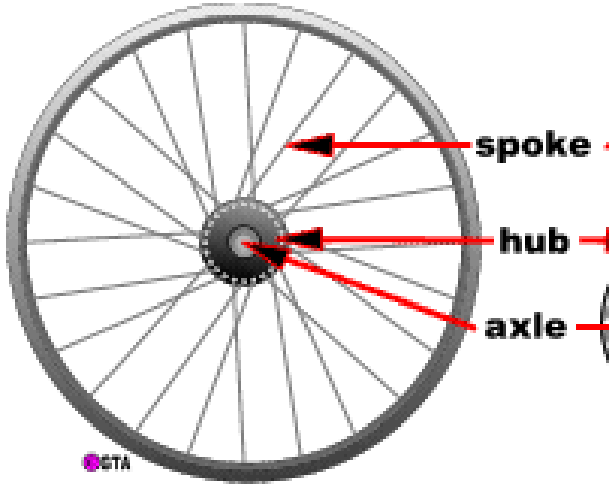
Coplanar Concurrent forces:

- Here all the forces lie in the same plane and lines of action meet at a single point.
- **Ex-** Forces acting in the spokes of a Bicycle





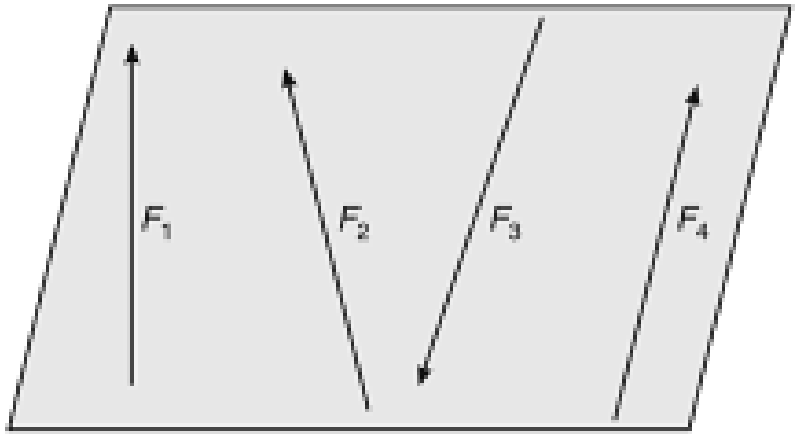


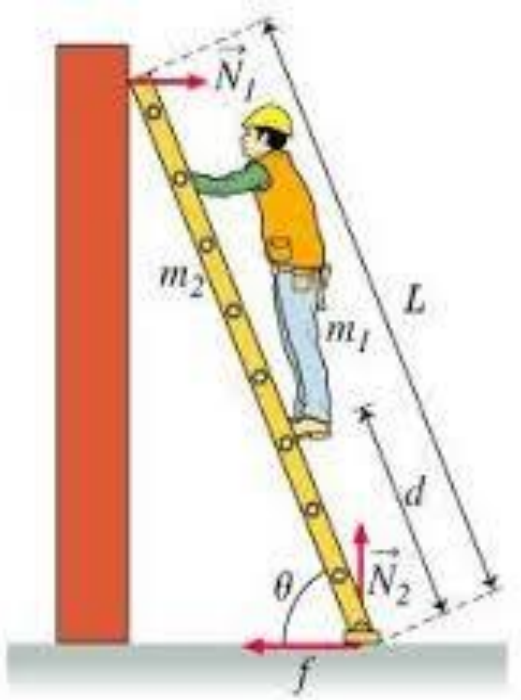


Coplanar Non-concurrent Forces

- It is a force system, in which all the forces are lying in the same plane but lines of action do not meet a single point.

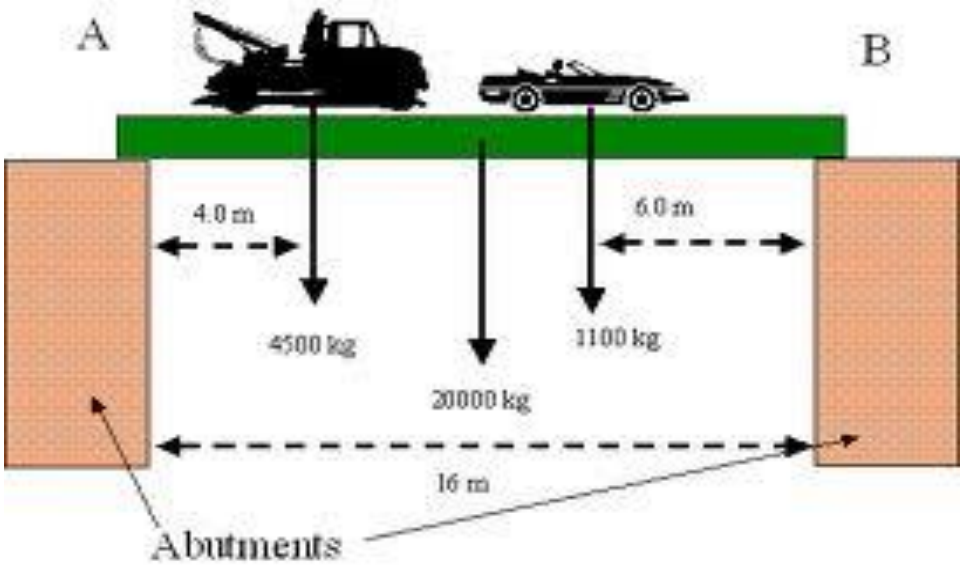
  Ex. Forces on a ladder and reactions from floor and wall, when a ladder rests on a floor and leans against a wall





Coplanar Parallel Forces:

- It is a force system, in which all the forces lie in the same plane and have parallel lines of action.
- Ex. The forces or loads and the support reactions in case of beams, self weights of persons sitting in a bench.

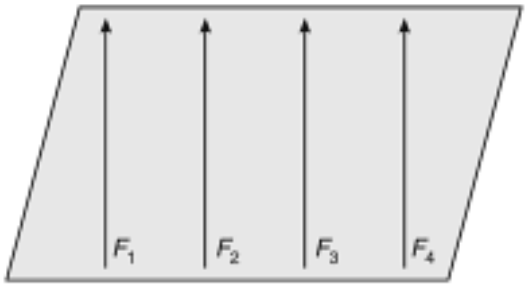


Coplanar Parallel Forces

They are of two types,

- Like parallel forces
- Unlike parallel forces

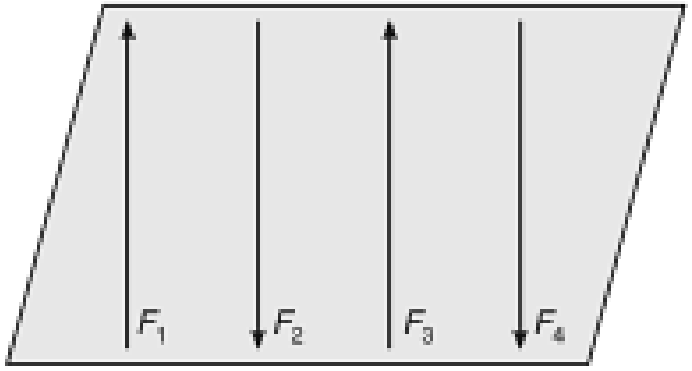
In like parallel force system all the forces act parallel to one another and are in the same direction.



Like Parallel Force system

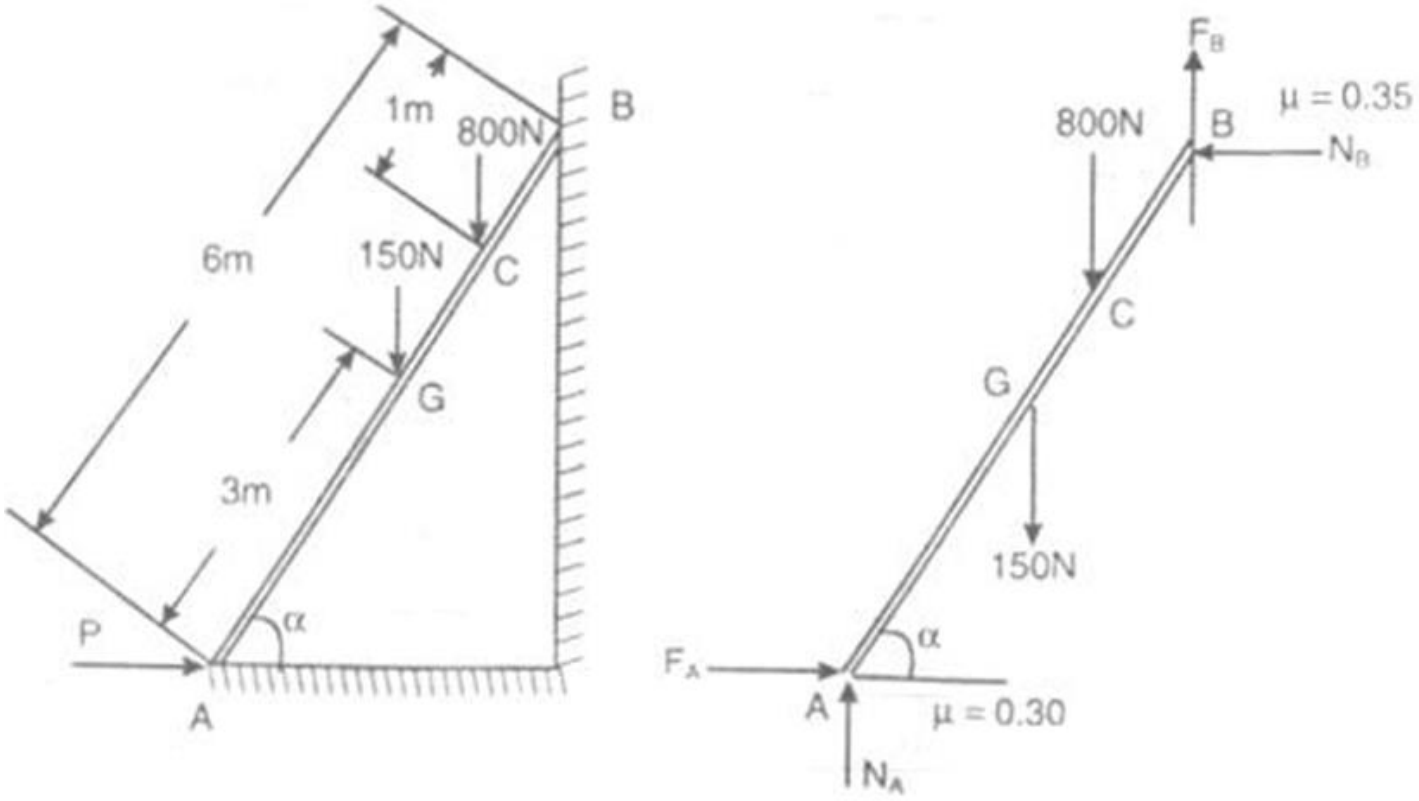
Coplanar Parallel Forces

In unlike parallel force system forces act parallel to one another but some of the forces have their line of action in opposite direction.



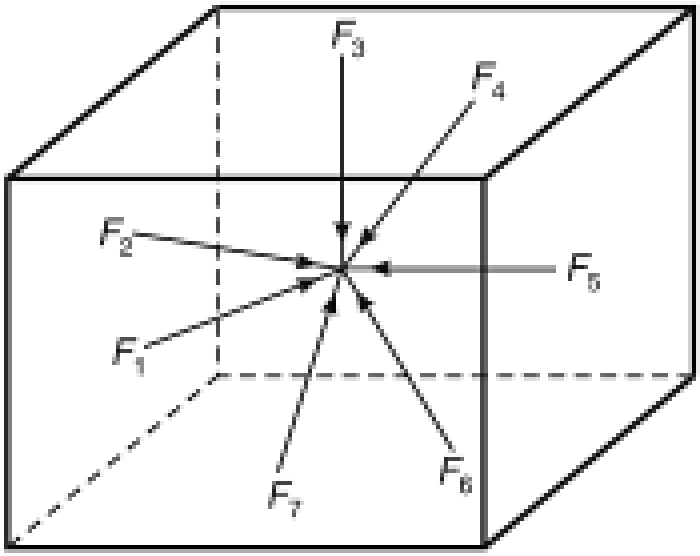
Unlike Parallel Force system

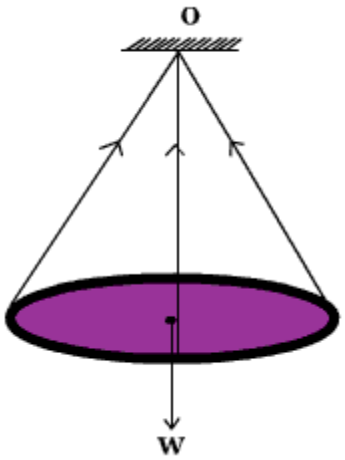
Coplanar Parallel Forces



Non- Coplanar Concurrent Forces:

- It is a force system, in which all the forces lie in the different planes and still have a common point of concurrency.

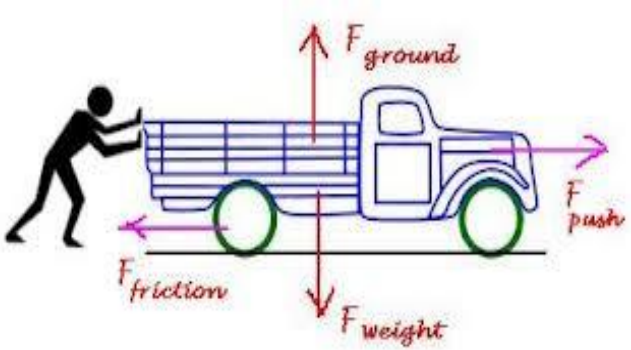


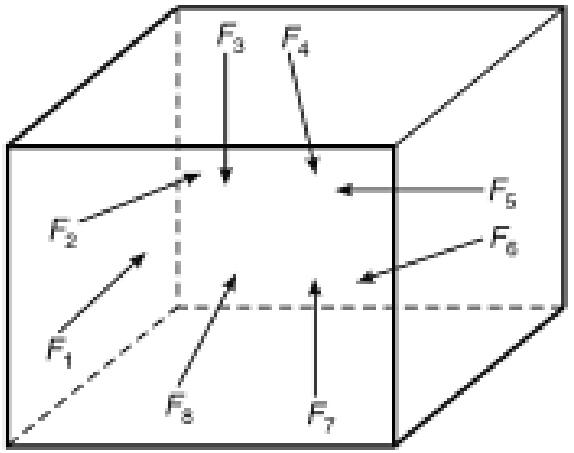


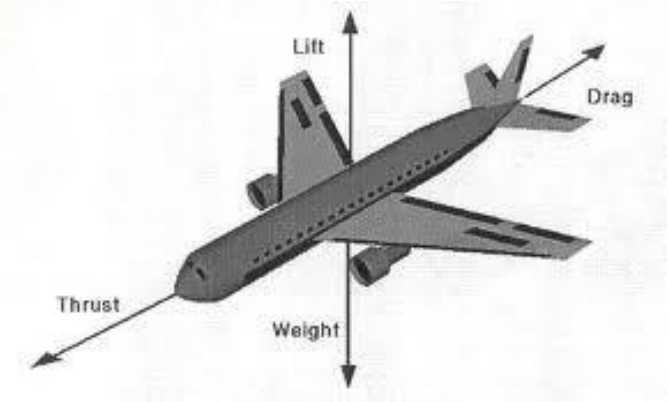
Non- Coplanar Concurrent Force system

Non- Coplanar Non-concurrent Forces:

- It is a force system, in which all the forces lie in different planes and also do not meet a single point.
- Ex. Forces acting on a moving bus, submarine under water, aeroplane flying in the sky, building frame.



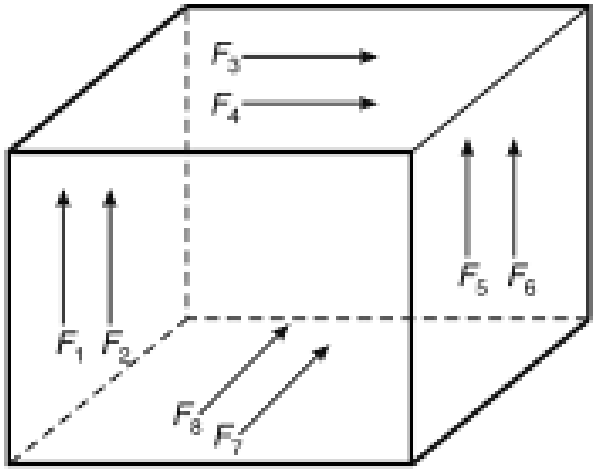




Non- Coplanar Non-concurrent Force system

Non- Coplanar Parallel Forces:

- It is a force system, in which all the forces are lying in different planes and still have parallel lines of action.



Non- Coplanar Parallel Force system

System of Forces

Force System	*Characteristic*	*Examples*
Collinear forces	Line of action of all the forces act along the same line.	Forces on a rope in a tug of war
Coplanar parallel forces	All forces are parallel to each other and lie in a single plane.	System of forces acting on a beam subjected to vertical loads (including reactions)
Coplanar like parallel forces	All forces are parallel to each other, lie in a single plane and are acting in the same direction.	Weight of a stationary train on a rail when the track is straight
Coplanar concurrent forces	Line of action of all forces pass through a single point and forces lie in the same plane.	Forces on a rod resting against a wall

System of Forces

Force System	*Characteristic*	*Examples*
Coplanar non-concurrent forces	All forces do not meet at a point, but lie in a single plane.	Forces on a ladder resting against a wall when a person stands on a rung which is not at its centre of gravity
Non-coplanar parallel forces	All the forces are parallel to each other, but not in the same plane.	The weight of benches in a class room
Non-coplanar concurrent forces	All forces do not lie in the same plane, but their lines of action pass through a single point.	A tripod carrying a camera
Non-coplanar non-concurrent forces	All forces do not lie in the same plane and their lines of action do not pass through a single point.	Forces acting on a moving bus

Resultant of Concurrent Force system (more than 2 forces)

Procedure

- Resolve all the forces along the X and Y axes.
- Calculate the algebraic sum of all the forces acting along the x-direction **(ie. ΣF_x)** and also along the y- direction **(ie. ΣF_y)**
- Determine the direction of the resultant using the formula ,

$$R=\sqrt{(\Sigma Fx)2 +(\Sigma Fy)2}$$

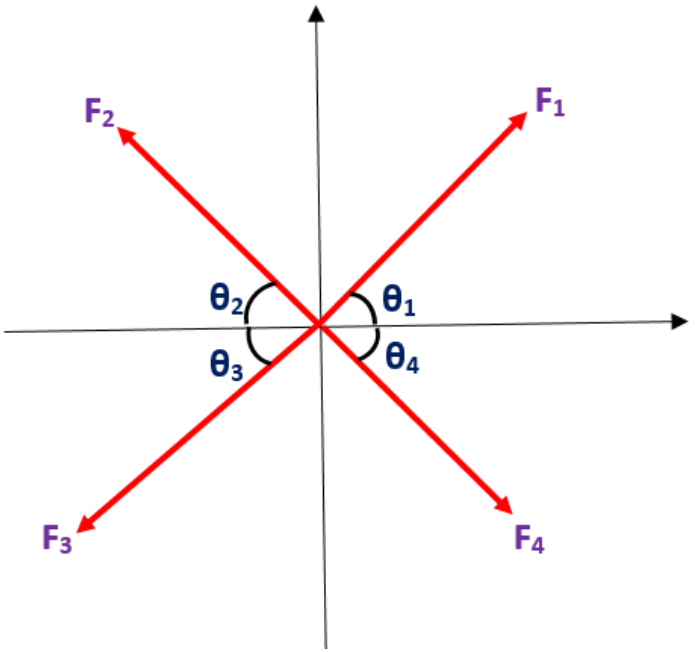
- Determine the direction of the resultant using the formula,

$$\alpha = \tan^{-1}(\Sigma F_y / \Sigma F_x)$$

Position of the Resultant

Resultant may lie in any four Quadrants depending upon

1) $\sum F_x$ (+ve) and $\sum F_y$ (+ve) 1st Quadrant
2) $\sum F_x$ (-ve) and $\sum F_y$ (+ve) 2nd Quadrant
3) $\sum F_x$ (-ve) and $\sum F_y$ (-ve) 3rd Quadrant
4) $\sum F_x$ (+ve) and $\sum F_y$ (-ve) 4th Quadrant



Note:

- If resultant is horizontal then $\sum F_x = R$ and $\sum F_y = 0$
- If resultant is vertical then $\sum F_y = R$ and $\sum F_x = 0$
- If resultant is zero then $\sum F_y = 0$ and $\sum F_x = 0$

Summary

- A group or set of forces acting simultaneously on a body is called system of forces
- Forces acting on the same plane are called coplanar force system whereas forces acting on the different plane are as called non coplanar force system
- Planar forces are further classified into collinear, coplanar concurrent and coplanar non concurrent forces whereas spatial forces are classified into spatial concurrent and spatial non concurrent forces
- A force system, in which all the forces have the same line of action are known as collinear forces