Module 1 : Introduction to Engineering Mechanics

* **Introduction** : Mechanics is defined as that branch of Engineering which deals with the behaviour of bodies due to the action of forces.

Mechanics is divided into
1) Statics
2) Dynamics

Statics deals with the bodies under rest due to the action of forces.

Dynamics deals with the motion of bodies due to the action of forces.

Dynamics is divided into
i) Kinematics
ii) Kinetics

i) Kinematics is the study of motion of bodies without considering the cause of motion. Ex: Acceleration, Velocity etc.

ii) Kinetics is the study of motion of bodies by considering the forces which are responsible for motion.
Ex :- Gravity, friction, etc.

* **Basic Concepts of Idealization**

1) **Particle** : It is defined as an object which has only mass but no size.
Ex: A ship in mid-sea, An aeroplane in sky

2) **Continuum** : A continuous distribution of molecules in a body without intermolecular space is called as continuum.

3) **Rigid body** : It is defined as a body in which the relative positions of any two particles does not change under the action of forces.

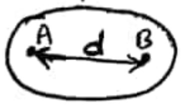


Fig.(1)

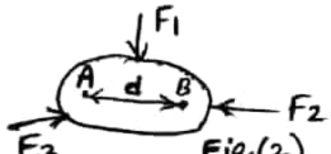


Fig.(2)

4) **Point force** : It is a force of body acting at a single (fixed) point is called point force.

Ex: The weight of man standing on the ladder.

5) **Deformable body** : It is a body which undergoes deformation when an external forces are applied on to it.

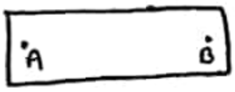


Fig.(1)

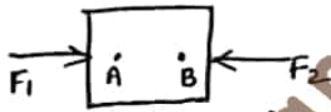


Fig.(2)

* Force, System of Force and its classification

Force : It is an external agency which changes or tends to change the state of rest or of uniform motion along a straight line.

System of Force (or) **Force System** : If two or more forces are acting on a body or a particle, then it is said to be a force system. (or) system of force.

Classification of System of Force

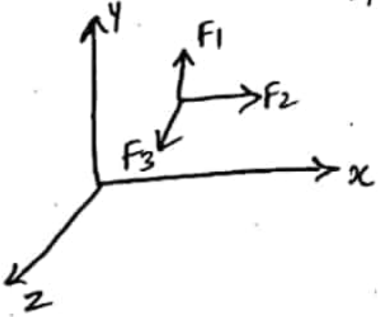
The system of force is classified into

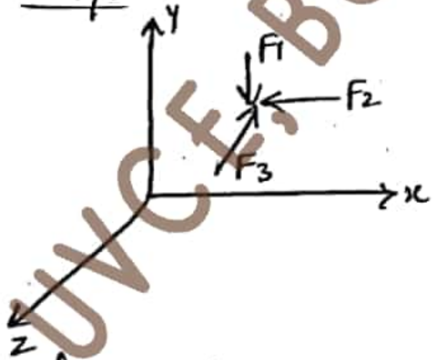
1) Coplanar Force System
2) Non Coplanar Force System
3) Collinear Force System

1) **Coplanar Force System** : If two or more forces are acting in a single plane, then it is said to be a Coplanar Force System

The types of Coplanar Force System are
i) Coplanar Concurrent Force System
ii) Coplanar Non-Concurrent Force System
iii) Coplanar parallel Force System

i) Coplanar Concurrent force system : If two or more forces are acting in a single plane and their lines of action pass through a single point is called Coplanar Concurrent force system.



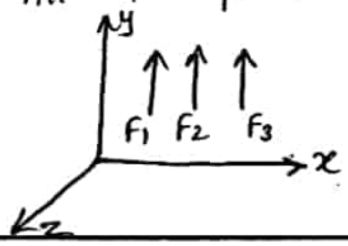


ii) Coplanar non-concurrent force system : If 2 or more forces are acting in a single plane and their lines of action doesnot meet pass through a single point. is called Coplanar non-Concurrent Force System.

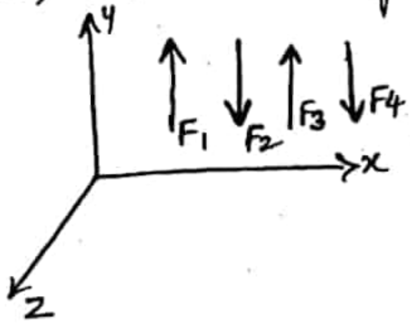
iii) Coplanar parallel force System : If 2 or more forces acting in a Single plane with their lines of action parallel to each other is called Coplanar parallel force System.

It is of two types:

a) Like parallel force system : All the forces act parallel to each other and are in the same direction.



b) Unlike parallel force system : The forces act parallel to each other, but some of the forces acting in opposite direction.

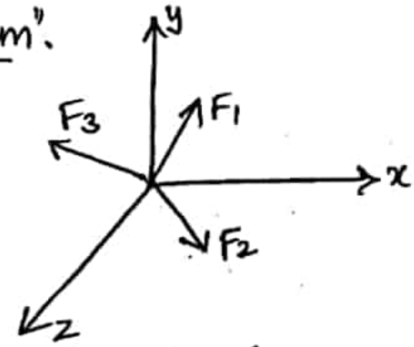


2) Non - Coplanar Force System : If two or more forces are acting in different planes, then it is said to be a Non - Coplanar Force System.

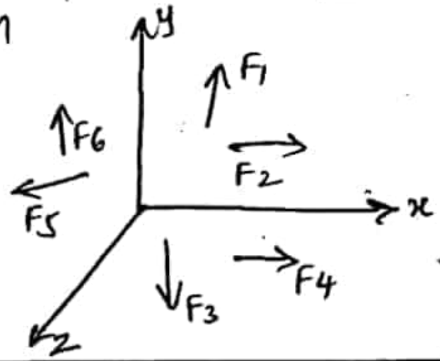
Types of Non- Coplanar force System are.

i) Non - Coplanar Concurrent force system
ii) Non - Coplanar non - Concurrent force system
iii) Non - Coplanar parallel force System

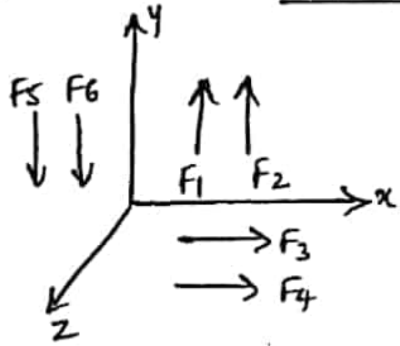
i) Non- Coplanar Concurrent force System : If two or more forces acting in different planes but pass through the same point, then it is said to be a "non- Coplanar Concurrent force System".



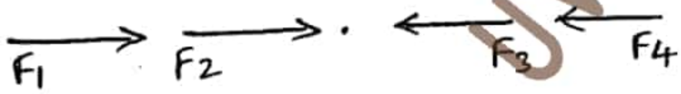
ii) Non - Coplanar non - Concurrent force system : If two or more forces acting in different planes but doesnot pass through the same point, is called Non Coplanar non- con -current force System



iii) <u>Non coplanar parallel force system</u>: If two or more forces are acting in different planes and are parallel to each other is called '<u>Non coplanar parallel force System</u>'.



3) <u>Collinear force System</u>: If the lines of action of two or more forces coincide with one another, is called '<u>Collinear force system</u>'.



* <u>Characteristics of Force</u> (or) <u>Elements of a Force</u>

1) <u>Magnitude</u>: It is the intensity of force which is characterised by unit.

In fig.(1) Magnitude = 10N

In fig.(2) Magnitude = 20N

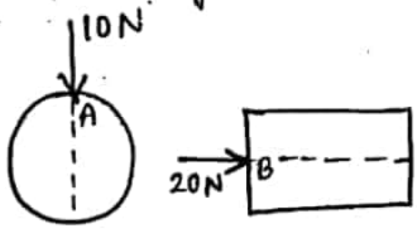


Fig.(1) Fig.(2)

2) <u>Point of application</u>: the location of tip of an arrow is called point of application.

In fig.(1) point of application is 'A'.

In fig (2) point of application is 'B'.

3) <u>Line of action</u>: A line drawn along a vector representing of a force is called 'Line of action'.

In fig.(1) Line of action is vertical & in fig(2) is horizontal.

4) <u>Direction</u>: It is the inclination of line of action of force with respect to fixed reference axis.

In fig(1) Direction is downward

In fig.(2) Direction is right side

* Basic principles of Engineering Mechanics

1) Principle of physical Independence of forces

It states that "the action of force on a body is not affected by the action of any other force on the body."

2) Principle of Superposition of Forces : It states that

"the net effect of a system of forces on a body is same as that of the combined effect of individ-ual forces on the body.

3) Principle of Transmissibility of Forces : It states that

"a force can be transmitted from one point to another point along the same line of action such that the effect produced by the force on a body remains unchanged or same.

Let us consider a rigid body subjected to a force 'F' at point 'A' as shown in fig. (1).

According to principle of transmissibility of force 'F' can be transmitted to a new point 'B' along the same line of action such that net effect remains unchanged.

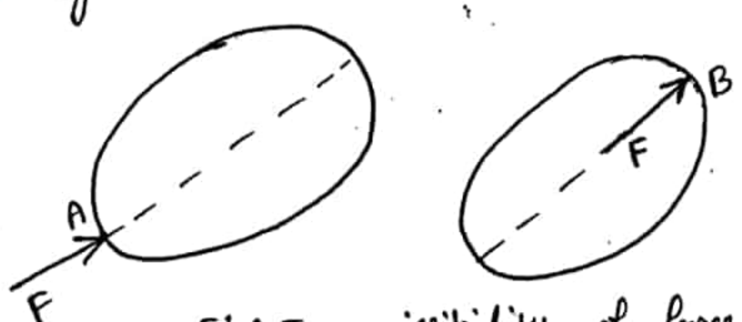


Fig: Transmissibility of force 'F' from point A to B

* Newton's Laws of Motion

i) **Newton's First Law**: It states that "every body continuous in its state of rest or of uniform motion in a straight line unless it is compelled by an external agency acting on it."

ii) **Newton's Second Law**: It states that "the rate of change of momentum of a body is directly proportional to the impressed force and it takes place in the direction of the force acting on it."

Force $\propto$ rate of change of momentum

But momentum = mass x velocity

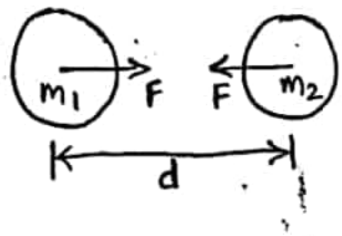
$\therefore$ Force $\propto$ mass x rate of change of velocity

$\therefore$ Force $\propto$ mass x acceleration

$$\boxed{F \propto m \times a}$$

iii) **Newton's Third Law**: It states that "for every action there is an equal and opposite reaction".

iv) **Newton's Gravitation Law** (or) **Newtons Law of Gravitation**
It states that "the force of attraction between any two bodies is directly proportional to their masses and inversely proportional to the square of the distance between them."



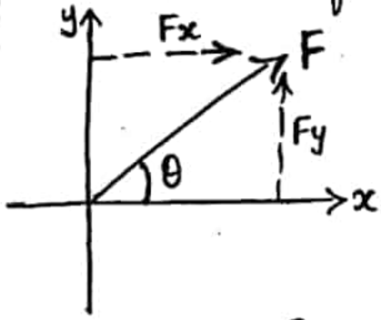
$$F \propto \frac{m_1 m_2}{d^2}$$

$$\boxed{F = G\frac{m_1 m_2}{d^2}}$$

Composition of Forces: It is the process of combining a number of forces into a single force (resultant) is called composition of forces.

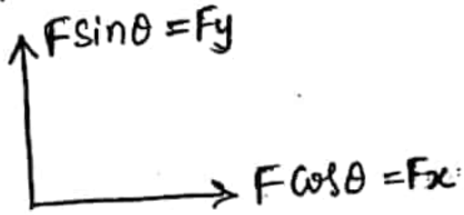
Resultant: It is the single force which will have the same effect as that of number of forces acting on a body.

* **Resolution of Force** : It is the process of splitting or resolving a single inclined force into two components which are perpendicular to each other is known as resolution of force.

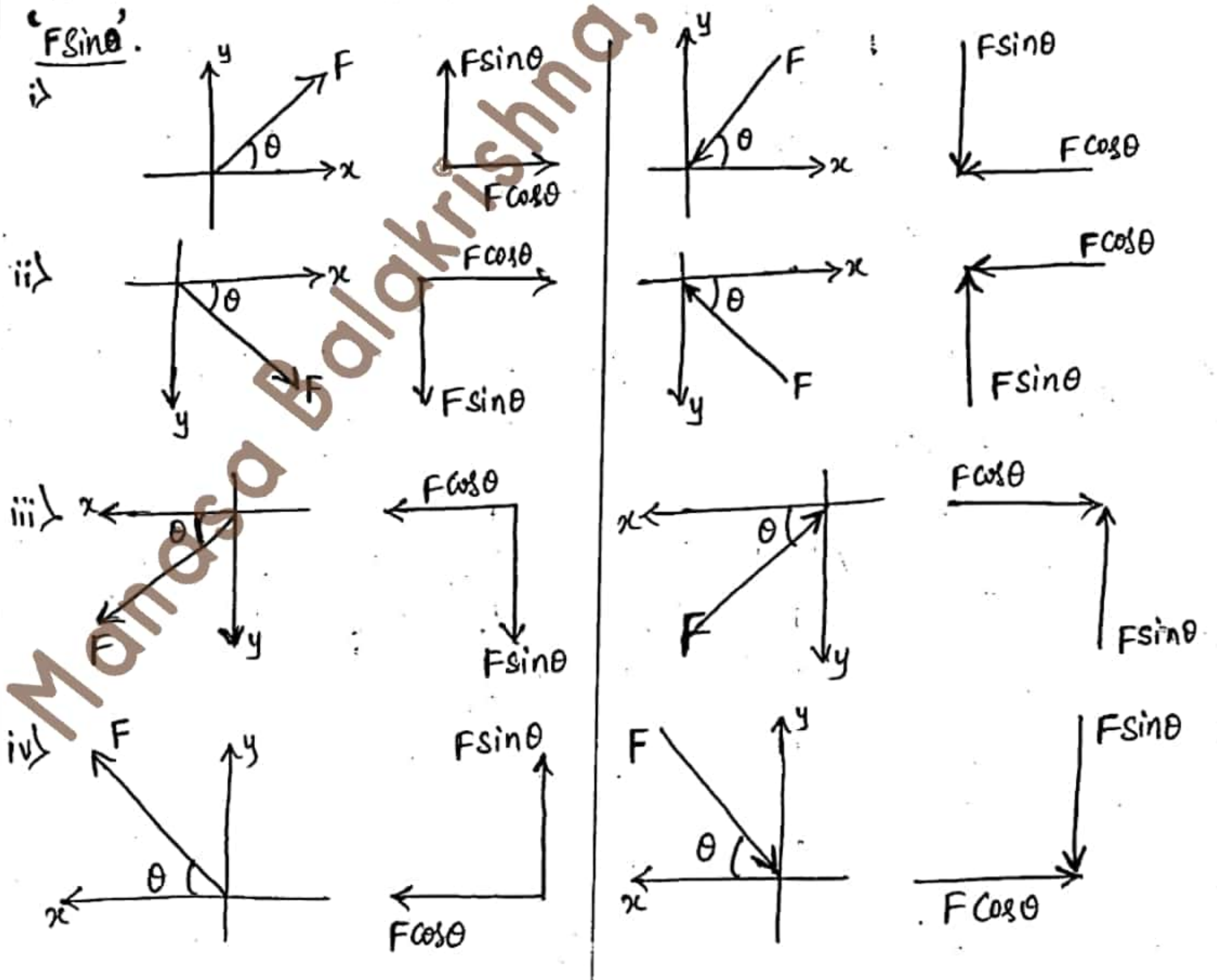


$$\sin\theta = \frac{F_y}{F} \quad \therefore \quad F_y = F\sin\theta$$

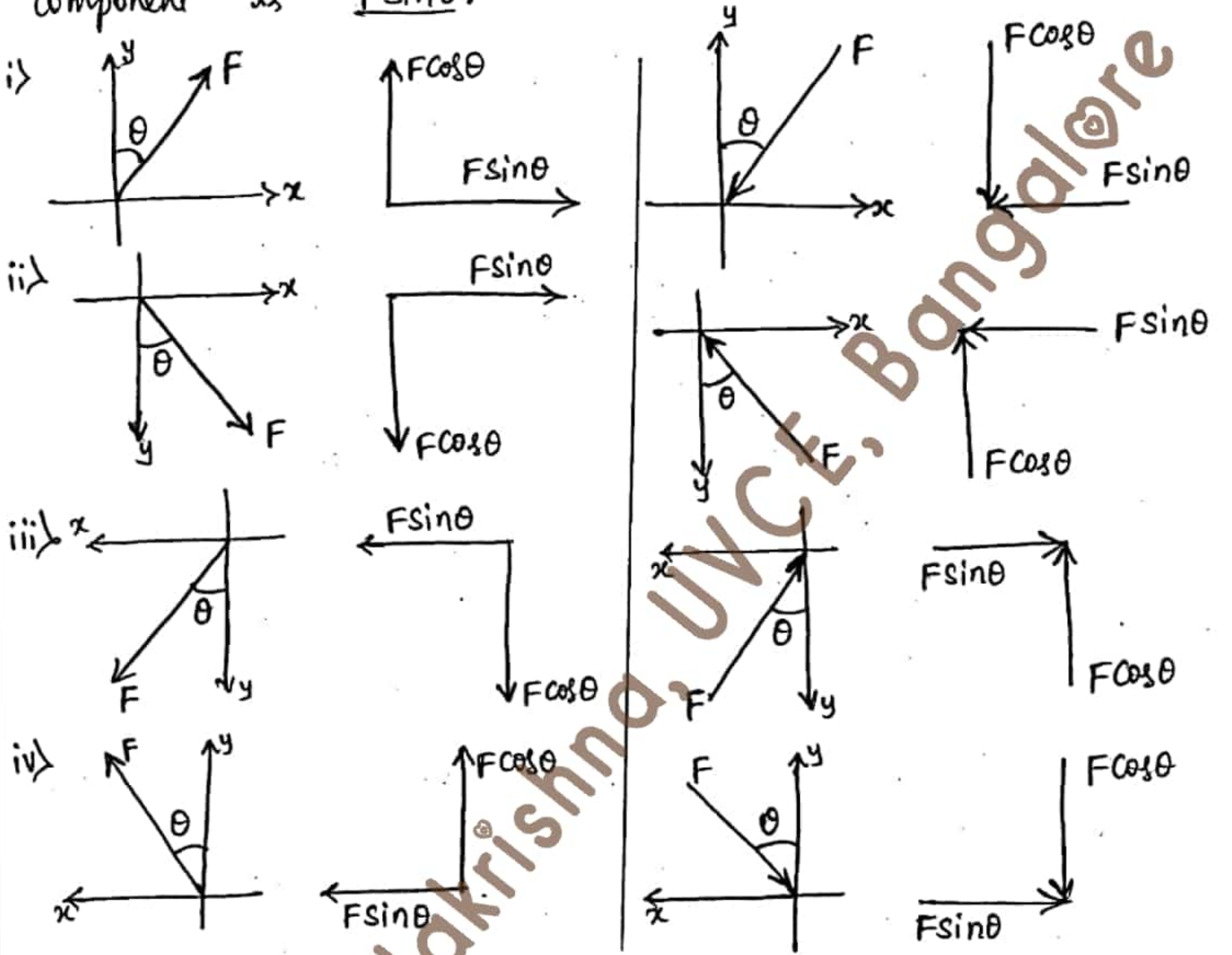
$$\cos\theta = \frac{F_x}{F} \quad \therefore \quad F_x = F\cos\theta$$



Case 1: If the inclination of force w. r. to x-axis, then horizontal component is 'Fcosθ' & vertical component is 'Fsinθ'.



Case 2: If the inclination of force is w.r. to y-axis then vertical component is 'F cosθ' and horizontal component is 'F sinθ'.



Law of Parallelogram of Forces

Statement: If two forces are acting simultaneously on a body and away from the body, with the two adjacent sides of the parallelogram representing both magnitude and direction then the magnitude and direction of the resultant can be represented by the diagonal of the parallelogram starting from the common point of the two forces.

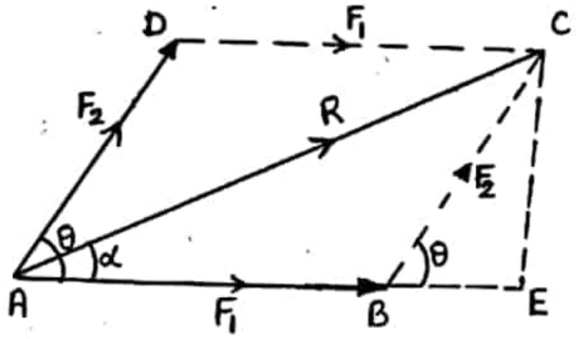


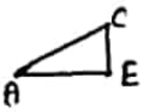
Fig. Parallelogram Law of forces

Proof: Let F_1 & F_2 be the two forces represented by sides AB & AD of the parallelogram, the resultant is represented by AC as shown in figure.

$AB = DC = F_1$

$AD = BC = F_2$

Consider Δ^{le} ACE

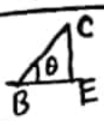


$AC^2 = AE^2 + CE^2$

$R^2 = (AB + BE)^2 + CE^2$

$$\boxed{R^2 = (F_1 + BE)^2 + CE^2} \longrightarrow (1)$$

Consider Δ^{le} BCE



$\sin\theta = \frac{CE}{BC} = \frac{CE}{F_2}$ $\qquad$ $\cos\theta = \frac{BE}{BC} = \frac{BE}{F_2}$

$\therefore \boxed{CE = F_2\sin\theta}$ $\qquad$ $\boxed{BE = F_2\cos\theta}$

From eqn (1)

$R^2 = (F_1 + F_2\cos\theta)^2 + (F_2\sin\theta)^2$

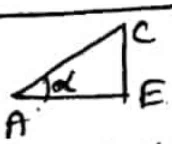
$R^2 = F_1^2 + F_2^2\cos^2\theta + 2F_1F_2\cos\theta + F_2^2\sin^2\theta$

$R^2 = F_1^2 + F_2^2(\cos^2\theta + \sin^2\theta) + 2F_1F_2\cos\theta$

$R^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$

$$\therefore \boxed{R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}}$$

Consider Δ^{le} ACE

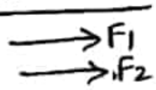


$\tan\alpha = \frac{CE}{AE} = \frac{CE}{AB + BE} = \frac{F_2\sin\theta}{F_1 + F_2\cos\theta}$

$$\therefore \boxed{\alpha = \tan^{-1}\left[\frac{F_2\sin\theta}{F_1 + F_2\cos\theta}\right]}$$

Special Cases:

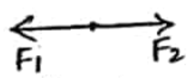
Case 1



$\theta = 0^\circ$ $\qquad$ $\cos\theta = 1$, $\sin\theta = 0$

$\therefore \boxed{R = F_1 + F_2, \ \alpha = 0^\circ}$

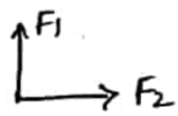
Case 2



$\theta = 180^\circ$ $\qquad$ $\cos\theta = -1$, $\sin\theta = 0$

$\boxed{R = \sqrt{(F_1 \pm F_2)^2}, \ \alpha = 0^\circ \text{ or } 180^\circ}$

Case 3



$\theta = 90^\circ$, $\cos\theta = 0$, $\sin\theta = 1$

$\therefore \boxed{R = \sqrt{F_1^2 + F_2^2}, \ \alpha = \tan^{-1}\left(\frac{F_2}{F_1}\right)}$

* Resultant of Coplanar Concurrent Force System

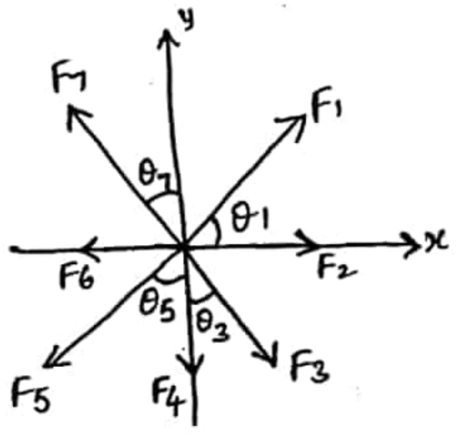
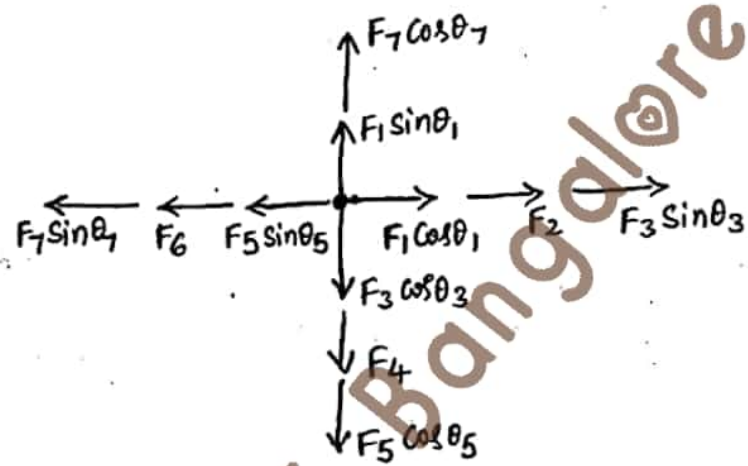


Fig.(1)



Steps:

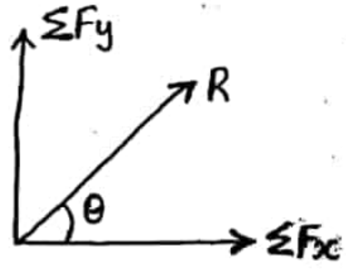
1) Select the coordinate axes.
2) Resolve the inclined forces along x & y direction.
3) Calculate the algebraic sum of all the forces acting in the x-direction (ΣF_x) and also in y-direction (ΣF_y)

$$\Sigma F_x \text{ (or) } \Sigma H = F_1 \cos\theta_1 + F_2 + F_3 \sin\theta_3 - F_5 \sin\theta_5 - F_6 - F_7 \sin\theta_7$$

$$\Sigma F_y \text{ (or) } \Sigma V = F_1 \sin\theta_1 + F_7 \cos\theta_7 - F_3 \cos\theta_3 - F_4 - F_5 \cos\theta_5$$

4) Determine the magnitude of the resultant (R) using the formula $\boxed{R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}}$ (or) $R = \sqrt{\Sigma H^2 + \Sigma V^2}$

5) Determine the direction of the resultant using the formula $\boxed{\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right)}$



* Sign Convention

↑ +ve

↓ −ve

→ +ve

← +ve

* **Polygonal Law of Forces**: If a number of forces acting on a particle can be represented in both magnitude and direction by the sides of the polygon taken in order, then the resultant can be represented in magnitude and direction by the closing side of the polygon taken in the opposite order.

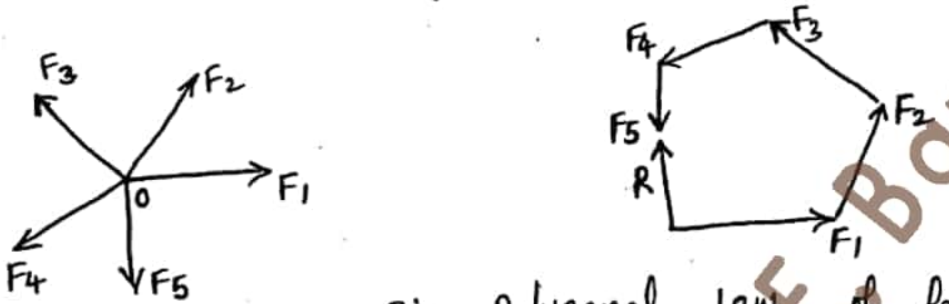
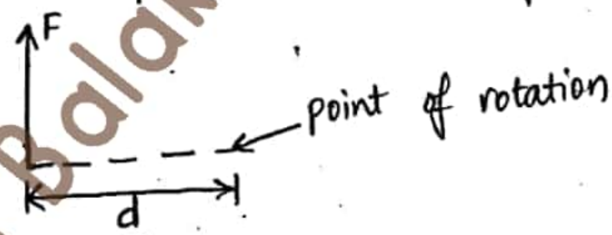


Fig. Polygonal Law of forces

* **Moment of Force**: The turning effect or rotational effect produced by a force on a body is called 'Moment of Force'.

The magnitude of the moment is given by the product of the magnitude of the force and the perpendicular distance between the line of action of the force and the point or axis of rotation.



Types of Moments

1) **Clockwise moment**: If the tendency of a force is to rotate the body in the clockwise direction then it is said to be clockwise moment and is taken as positive (+ve).

2) **Anticlockwise moment**: If the tendency of a force is to rotate the body in the anticlockwise direction then it is said to be Anticlockwise moment and is taken as negative (−ve).

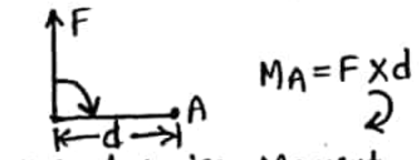


Fig: Clockwise Moment

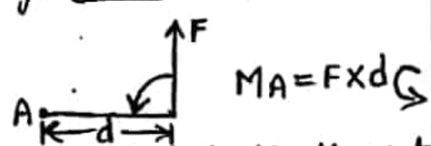
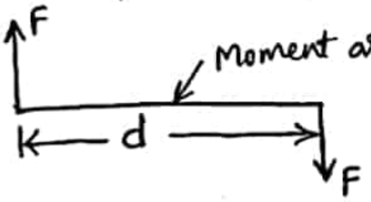


Fig: Anticlockwise Moment

*** Couple :** Two equal, opposite and parallel forces separ-ated by a definite distance to form a couple.



d = Moment arm (or) $\perp^{ler}$ distance b/w two forces

characteristics (or) properties of Couple

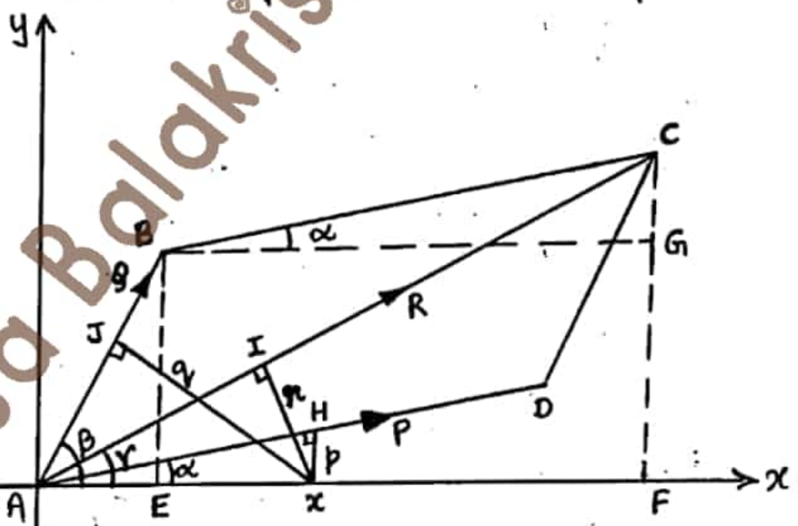
1) Couple consists of two equal, opposite and parallel forces
2) The magnitude of moment of couple is equal to the product of magnitude of one of the force and moment arm.
3) Resultant of the couple forces is zero.
4) Moment of couple about any point is remains constant and equals to $F \times d$.

*** Varignon's theorem**

Statement: The algebraic sum of moments of a coplanar forces about any point is equal to the moment of their resultant force about same point.

Moment of R = Moment of P + Moment of Q

Proof:



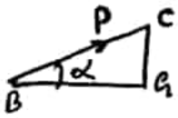
Consider two forces P & Q and its Resultant R as shown in figure obtained by the parallelogram law.

Let α, β and γ are the angles between x-axis and the forces P, Q and R respectively.

Let p, q and r are the moment arms of P, Q and R forces respectively from the moment arm centre of x.

Draw BE and CF perpendicular to x-axis and BG parallel to x-axis.

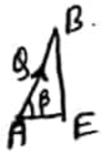
Consider the Δ^{le} BCG



$$\sin\alpha = \frac{CG}{BC} = \frac{CG}{P}$$

$$\therefore \boxed{CG = P\sin\alpha}$$

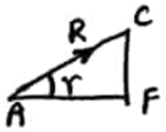
Consider Δ^{le} ABE



$$\sin\beta = \frac{BE}{AB} = \frac{BE}{Q}$$

$$\therefore \boxed{BE = Q\sin\beta}$$

Consider Δ^{le} ACF



$$\sin\gamma = \frac{CF}{AC} = \frac{CF}{R}$$

$$\therefore \boxed{CF = R\sin\gamma}$$

We know that

$$CF = CG + GF$$

$$CF = CG + BE$$

$GF = BE$

$$R\sin\gamma = P\sin\alpha + Q\sin\beta$$

Multiply 'Ax' on both sides

$$Ax \cdot R\sin\gamma = Ax\cdot P\sin\alpha + Ax \cdot Q\sin\beta$$

$$\boxed{R\cdot Ax\sin\gamma = P\cdot Ax\sin\alpha + Q\cdot Ax\sin\beta} \longrightarrow (1)$$

Consider Δ^{le} AxH

$$\sin\alpha = \frac{Hx}{Ax} = \frac{p}{Ax}$$

$$\therefore \underline{p = Ax\sin\alpha}$$

Consider Δ^{le} AxI

$$\sin\gamma = \frac{Ix}{Ax} = \frac{r}{Ax}$$

$$\underline{r = Ax\sin\gamma}$$

Consider Δ^{le} AxJ

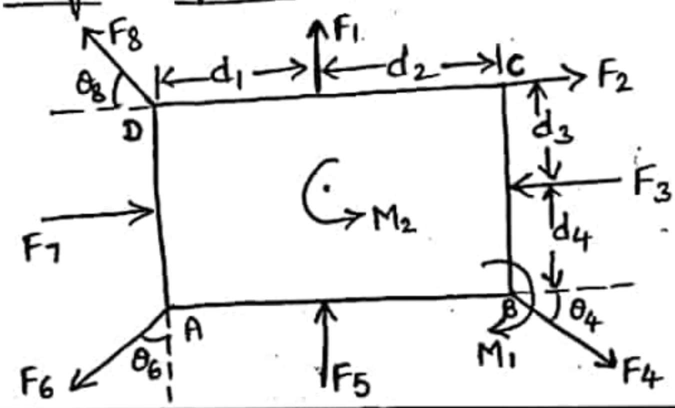
$$\sin\beta = \frac{Jx}{Ax} = \frac{q}{Ax}$$

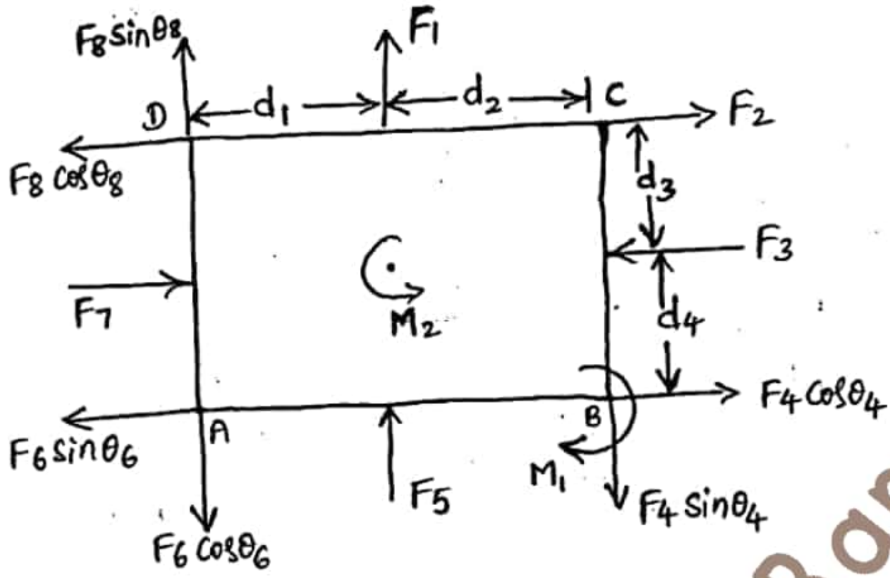
$$\underline{q = Ax\sin\beta}$$

From eq^n (1)

$$\boxed{R\cdot r = P\cdot p + Q\cdot q}$$

* Resultant of Coplanar Non-Concurrent Force System



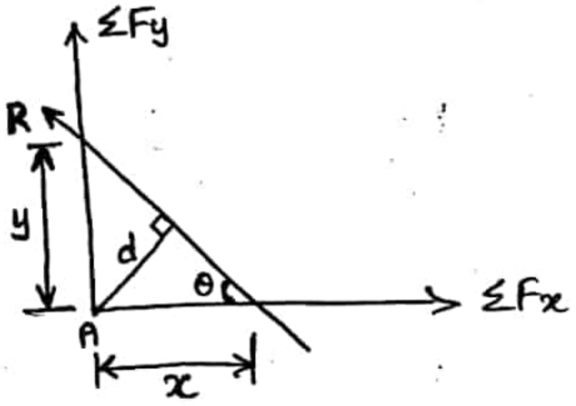


Steps:

1. Select the coordinate axis
2. Resolve the inclined forces along x and y axis
3. Calculate the algebraic sum of component forces along x & y direction

ie;
$$\Sigma F_x = F_2 - F_3 + F_4\cos\theta_4 - F_6\sin\theta_6 + F_7 - F_8\cos\theta_8$$
$$\Sigma F_y = F_1 - F_4\sin\theta_4 + F_5 - F_6\cos\theta_6 + F_8\sin\theta_8$$

4. Calculate the magnitude of resultant using $R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$
5. Calculate the direction of resultant by using.
$$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right)$$
6. Calculate the algebraic sum of moments of component forces about any reference point
$$\Sigma M_A = -(F_1 \times d_1) + F_2 \times (d_3+d_4) - (F_3 \times d_4) + F_4\sin\theta_4 \times (d_1+d_2)$$
$$-(F_5 \times d_1) + (F_7 \times d_4) - F_8\cos\theta_8 (d_3+d_4) + M_1 - M_2$$
7. Calculate the $\perp^{ler}$ distance of the action of resultant from reference point. $d = \left|\frac{\Sigma M_A}{R}\right|$
8. Calculate x-intercept and y-intercept using
$$x\text{-intercept} = \left|\frac{\Sigma M_A}{\Sigma F_y}\right|$$
$$y\text{-intercept} = \left|\frac{\Sigma M_A}{\Sigma F_x}\right|$$



Note:

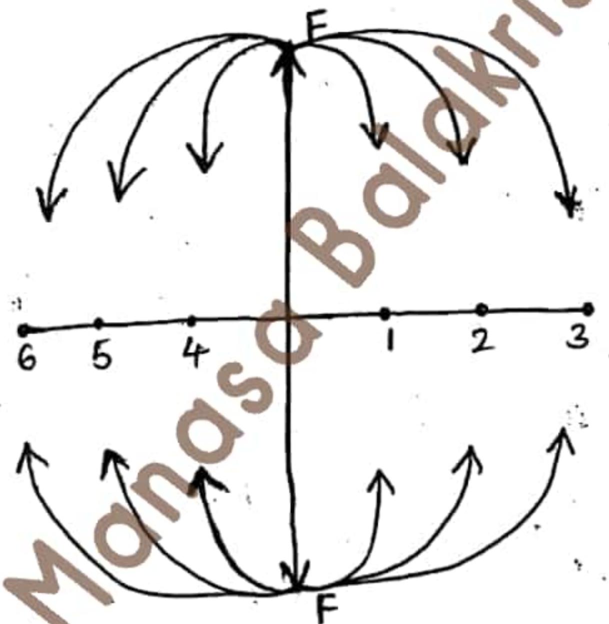
i) Do not consider the effect of moment in ΣF_x & ΣF_y.

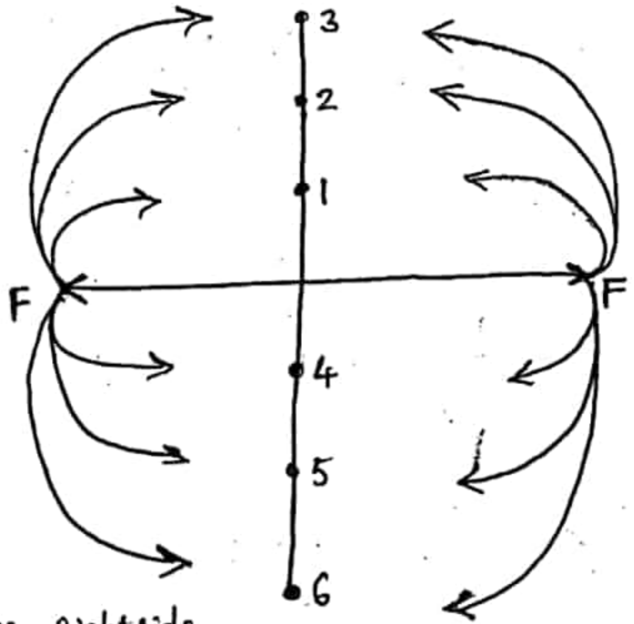
ii) If moments are given in a problem, use +ve sign for a clockwise moment and -ve sign for anti-clockwise moment.

Sign Convention for Moment

i) Clockwise Moment ↻ +ve

ii) Anticlockwise Moment ↺ -ve





Force upward direction
- points Rightside ↻
- points Leftside ↺

Force Downward direction
- points Rightside ↺
- Points Leftside ↻

Force Rightside
- points upwards ↺
- points downwards ↻

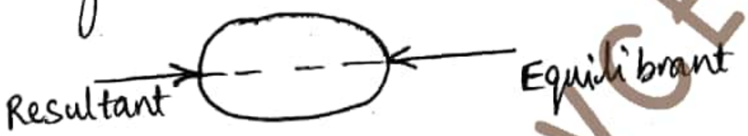
Force Leftside
- points upwards ↻
- points downwards ↺

Module-2 Equilibrium of Forces

* **Equilibrium**: A body is said to be in the state of equilibrium if it is at rest under the action of forces.

* **Equilibrant**: It is a single force which keeps the system or body in equilibrium is called equilibrant.

Equilibrant having magnitude equal to resultant but acting in opposite direction.



* **Equations of Equilibrium**

1) Coplanar Concurrent Force system

$\Sigma F_x = 0$ $\quad \rightarrow = \leftarrow$

$\Sigma F_y = 0$ $\quad \uparrow = \downarrow$

2) Coplanar non-concurrent Force system

$\Sigma F_x = 0$ $\quad \rightarrow = \leftarrow$

$\Sigma F_y = 0$ $\quad \uparrow = \downarrow$

$\Sigma M = 0$ $\quad \circlearrowright = \circlearrowleft$

3) Parallel Force system

$\Sigma F = 0$, $\Sigma M = 0$

4) Non coplanar Force system

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma F_z = 0$

$\Sigma M = 0$

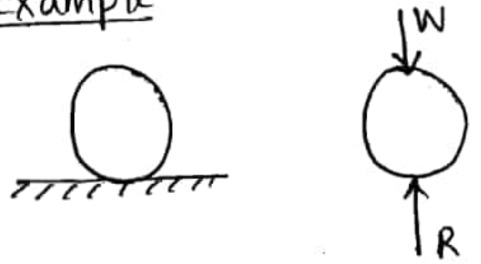
* **Free Body Diagram (FBD)**: It is a simple line diagram of body or a group of bodies completely isolated from surroundings

ie, i) Self weight → 'W' always acting vertically downwards

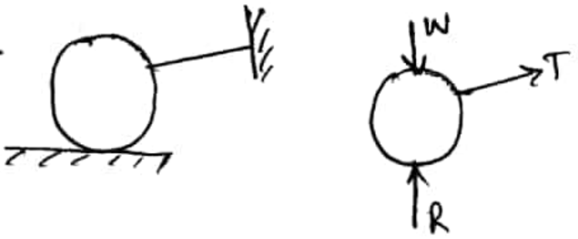
ii) Normal reaction → 'R' acting perpendicular to plane

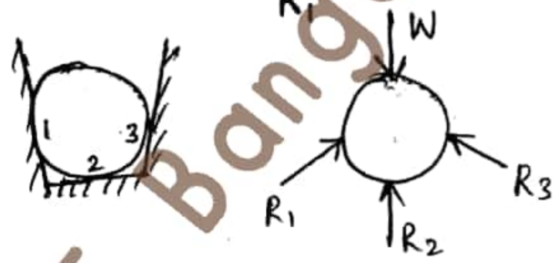
iii) Forces acting on the body
iv) Geometry of the body.

Example

1)


2)


3)


4)


* Lami's Theorem

<u>Statement</u>: If the body is in equilibrium condition under the action of only three concurrent forces, then the magnitude of each force is directly proportional to the sine of the angle between the other two forces.

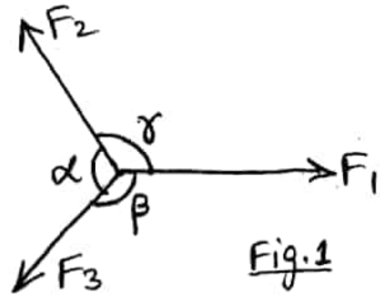


Fig.1

<u>Proof</u>: Consider a body subjected to three concurrent forces F_1, F_2 & F_3 as shown in fig. 1.

The body is in equilibrium condition even after the application of these 3 forces

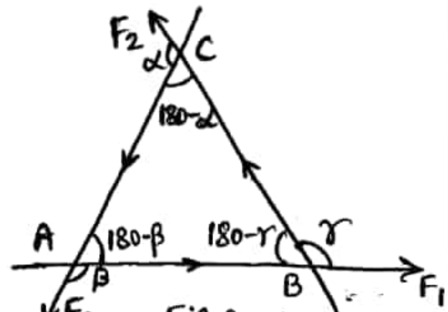


Fig.2

Draw F_1, F_2 & F_3 in magnitude and direction which closes resulting in a triangle ABC as shown in fig.2

Consider Δ^{le} ABC

Apply sine rule

$$\frac{AB}{\sin(180-\alpha)} = \frac{BC}{\sin(180-\beta)} = \frac{CA}{\sin(180-\gamma)}$$

$$\frac{F_1}{\sin(180-\alpha)} = \frac{F_2}{\sin(180-\beta)} = \frac{F_3}{\sin(180-\gamma)}$$

$$\boxed{\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}}$$

<u>Limitations / significance</u>

i) It is applicable only when the body is in equilibrium
ii) It is applicable only when three con-current forces are acting on a body.
iii) The forces acting on a body should be convergent or divergent.

SUPPORT REACTIONS

Beam: Beam is a horizontal structural member used to carry vertical load, shear load and sometime horizontal load.

Types of Beams

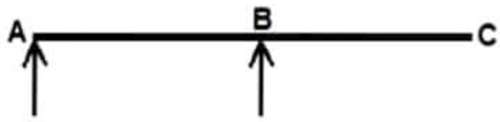
1. Simply Supported Beam
2. Cantilever Beam
3. Fixed Beam
4. Overhanging Beam
5. Continuous Beam

1. **Simply Supported Beam:** It is a beam which consists of simple supports at both the ends.
2. **Cantilever Beam:** It is a beam which consists of fixed support at one end and other end is free.
3. **Fixed Beam:** It is a beam which consists of fixed supports at both ends.
4. **Overhanging Beam**: It is a beam which is freely supported at two points and having one or both ends extending beyond the supports.
5. **Continuous Beam:** It is a beam which consists of three or more than three supports.

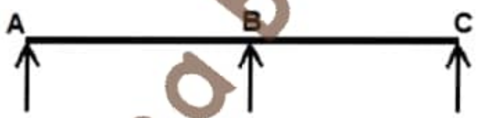
1. Simply Supported Beam

2. Cantilever Beam

3. Fixed Beam



4. Overhanging Beam



5. Continuous Beam

Statically Determinate Beams and Statically Indeterminate Beams

1. Statically Determinate Beams

a. The beams can be analysed by using equations of equilibrium ($\Sigma V=0$, $\Sigma H=0$ & $\Sigma M=0$) is called statically determinate beams.

b. The total number of unknowns in the beam are less than or equal to 3.
Example: Simply Supported beam, Cantilever beam

2. **Statically Indeterminate Beams**
   a. The beams cannot be analysed by using equations of equilibrium is called statically indeterminate beams.
   b. The total number of unknowns in the beam is more than 3.
   Example: Fixed beam, Continuous beam

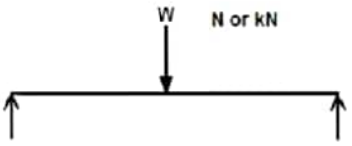
Types of Loads

1. Point or Concentrated Load
2. Uniformly Distributed Load (UDL)
3. Uniformly Varying Load (UVL)

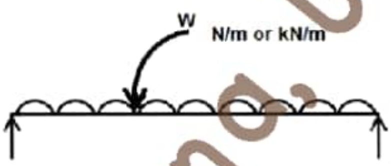
1. **Point or Concentrated Load:** The load is concentrated at a point on a beam is known as *Point load*. It is represented in N or kN.

2. **Uniformly Distributed Load (UDL):** The load which is uniformly distributed along the entire length of the beam is known as *Uniformly Distributed Load*. It is represented in N/m or kN/m.

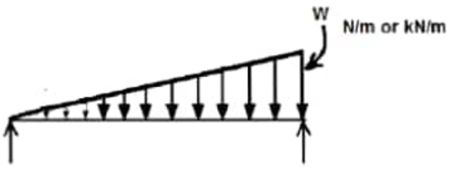
3. **Uniformly Varying Load (UVL):** The load which is uniformly varies along the entire length of the beam is known as *Uniformly Varying Load*. It is represented in N/m or kN/m.



1. Point Load



2. Uniformly Distributed Load



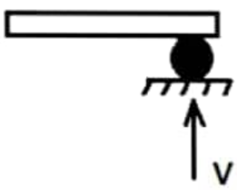
3. Uniformly Varying Load

Types of Supports

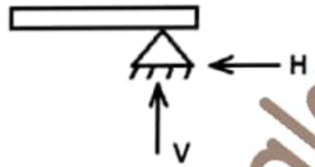
1. Simple Support
2. Roller Support
3. Hinged or Pinned Support
4. Fixed Support

1. **Simple Support:** It is a support in which the beam rests freely on a support. The beam is free to move only horizontally and also can rotate about the support. In this support one reaction which is perpendicular to the plane of support is developed.

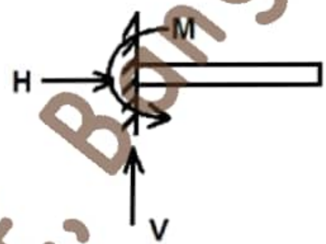
2. **Roller Support:** It is a support in which the beam rests on rollers. In this support the beam is free to move horizontally and as well rotate about the support. In roller support one reaction which is perpendicular to the plane of rollers is developed.



3. **Hinged or Pinned Support:** It is a support which can resist both vertical and horizontal forces but they cannot resist moment. In this support a horizontal and vertical reaction is developed.



4. **Fixed Support:** It is a support which prevents the beam from moving in any direction and also prevents rotation of the beam. In fixed support a horizontal, vertical reaction and fixed end moment are developed to keep the beam in equilibrium.



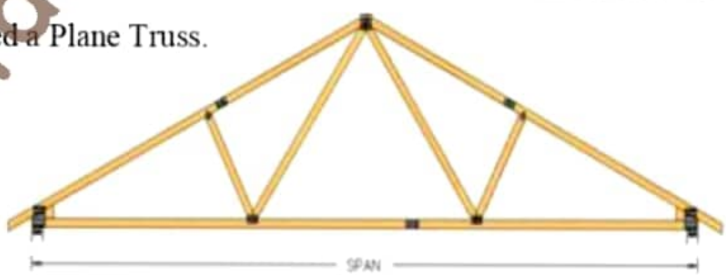
S.no	Types of Support	Representation by	Reaction Force	No. of Unknowns
1.	Simple Support		Vertical	01 (V)
2.	Roller Support		Vertical	01 (V)
3.	Hinged Support or Pinned Support		Horizontal and vertical	02 (V & H)
4.	Fixed Support		Horizontal, vertical and moments	03 (V, H & M)

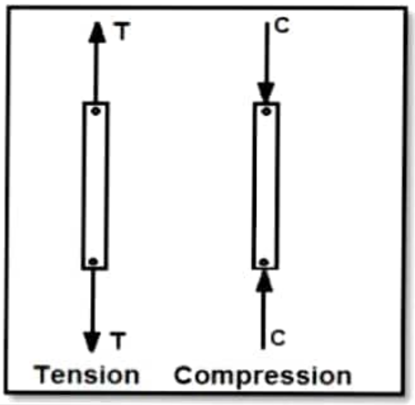
ANALYSIS OF SIMPLE TRUSSES

Truss: It is a framework composed of members joined at their ends to form a rigid structure is called Truss or Simple Truss.

Joints are modelled by smooth pin connections. Members are either under tension or compression. Joints are usually formed by bolting or welding.

Plane Truss: If the members of truss lie in a single plane is called a Plane Truss.





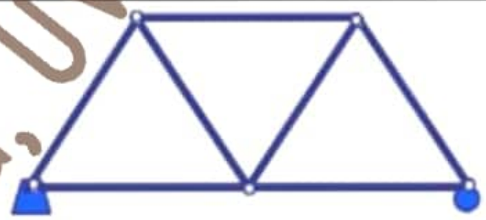
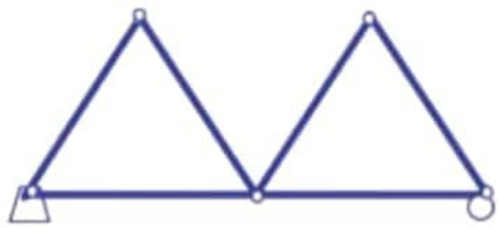
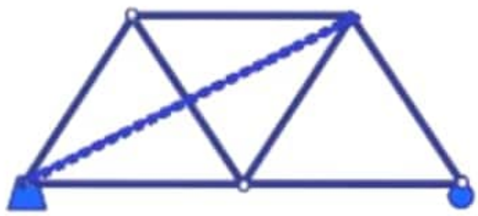
Types of Trusses

1. Rigid truss or Perfect truss
2. Non rigid truss or Deficient truss
3. Over rigid truss or Redundant truss

1. **Rigid truss or Perfect truss:** It is a truss in which the number of members are sufficient to resist the external loads.
   The relationship between the number of members and joints is given by $m = 2j-3$

2. **Non rigid truss or Deficient truss:** It is a truss in which the number of members are less than that required for a perfect truss.
   The relationship between the number of members and joints is given by $m < 2j-3$

3. **Over rigid truss or Redundant truss:** It is a truss in which the number of members are more than that required for a perfect truss.
   The relationship between the number of members and joints is given by $m > 2j-3$

Rigid Truss $m = 7$ (members) $j = 5$ (connection joints) $m = 2j-3$ $7 = 2x5 - 3$ $7 = 7$	
Non Rigid Truss $m = 6$ and $j = 5$ $m < 2j-3$ $6 < (2 \times 5) - 3$ $6 < 7$	
Over Rigid Truss $m = 8$ and $j = 5$ $m > 2j-3$ $8 > (2 \times 5) - 3$ $8 > 7$	

Assumptions made in the Analysis of Trusses

1. The members of trusses are straight.
2. The cross section of members is uniform.
3. Forces are acting only at joints.
4. All members are pin jointed members.
5. All members are rigid.
6. All members of trusses are two force members subjected to either equal and opposite tension and compression.

Analysis of Statically Determinate Trusses

Plane trusses can be analysed by

1. Method of Joints
2. Method of Sections

1. Method of Joints

Steps involved in the method of joints are,

- Calculate the support reactions by using equations of equilibrium ($\Sigma V=0$, $\Sigma H=0$ & $\Sigma M=0$).
- Consider any joint with minimum number of unknowns (Max. of 2).
- Initially assume that all the members are under tension (arrow head away from the joint is positive).
- Apply the conditions of equilibrium ($\Sigma V=0$ & $\Sigma H=0$) and determine the forces in the members.
- If the force value is positive then assumption is right, if it is negative then assumption is wrong and it indicates that particular member is under compression, so that reverse the direction of force while considering it in the next joint.
- Same procedure has to be followed for other joints to determine the internal forces in the remaining members of a truss.
- Note down the results in a tabular format.

Member	Force	Nature of Force

2. Method of Sections

In this method a section line has to be passed through the members in which the internal forces need to be calculated. This method is suitable when it is necessary to find the forces induced in a few or selected members of a truss.

Some of the points to be remembered in using the method of section are as follows,

- The section line should be complete.
- The section line should pass through the members, but not through the joints.
- The section line can pass through maximum of three members because only three conditions of equilibrium area available.
- The section line can pass through the four members in a situation where members are meeting at a common point.
- The moment equation of equilibrium can be applied about a point may be beyond the portion under consideration.
- Consider either left portion or right portion whichever is easy for the analysis, as both portions are under equilibrium