

# **ATME College of Engineering**

**13<sup>th</sup> K M Stone, Bannur Road, Mysore – 570028**



**A T M E**  
**College of Engineering**

**DEPARTMENT OF CIVIL ENGINEERING**

**(ACADEMIC YEAR 2022-23)**

**ENGINEERING MECHANICS**

**SUB CODE: BCIVC203**

**SEMESTER: II**

### **Vision of the Institute**

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources

### **Mission of the Institute**

To keep pace with advancements in knowledge and make the students competitive and capable at the global level

To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torchbearers of tomorrow's society

To strive to attain ever-higher benchmarks of educational excellence

### **Vision of the Department**

To develop globally competent civil engineers who excel in academics, research and are ethically responsible for the development of the society.

### **Mission of the Department**

To provide quality education through faculty and state of the art infrastructure To identify current problems in the society pertaining to Civil Engineering disciplines and to address them effectively and efficiently

To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

### **PEO's**

Graduates who complete their UG course through our institution will be,

**PEO 1-** Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, or water resources engineering by using technical, communication and management skills.

**PEO 2-** Engaged in higher studies and research activities in various Civil Engineering fields and a life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities

**PEO 3-** Serve in a leadership position in any professional or community organization, or local/state engineering board

**PEO 4-** Registered as a professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

### **PROGRAM OUTCOMES**

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice. 44
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

#### **PSO's**

**PSO 1** – Provide necessary solutions to build infrastructure for all situations through competitive plans, maps and designs with the aid of a thorough Engineering Survey and Quantity Estimation.

**PSO 2** – Assess the impact of anthropogenic activities leading to environmental imbalance on land, in water & in air and provide necessary viable solutions revamping water resources and transportation for a sustainable development

# ENGINEERING MECHANICS

Subject Code	: BCIVC203	I.A. Marks	: 50
Hours/Week	: 4	Exam Hours	: 03
Total Hours	: 50	Exam Marks	: 50

## Module 1

**Resultant of coplanar force system:** Basic dimensions and units, Idealisations, Classification of force system, principle of transmissibility of a force, composition of forces, resolution of a force, Free body diagrams, moment, Principle of moments, couple, Resultant of coplanar concurrent force system, Resultant of coplanar non-concurrent force system, Numerical examples. **10 Hours**

## Module 2

**Equilibrium of coplanar force system:** Equilibrium of coplanar concurrent force system, Lami's theorem, Equilibrium of coplanar parallel force system, types of beams, types of loadings, types of supports, Equilibrium of coplanar non-concurrent force system, support reactions of statically determinate beams subjected to various types of loads, Numerical examples **10 Hours**

## Module 3

**Analysis of Trusses:** Introduction, Classification of trusses, analysis of plane perfect trusses by the method of joints and method of sections, Numerical examples.

**Friction:** Introduction, laws of Coulomb friction, equilibrium of blocks on horizontal plane, equilibrium of blocks on inclined plane, ladder friction, wedge friction Numerical examples.

**10 Hours**

## Module 4

**Centroid of Plane areas:** Introduction, Locating the centroid of rectangle, triangle, circle, semicircle, quadrant and sector of a circle using method of integration, centroid of composite areas and simple built up sections, Numerical examples.

**Moment of inertia of plane areas:** Introduction, Rectangular moment of inertia, polar moment of inertia, product of inertia, radius of gyration, parallel axes theorem, perpendicular axis theorem, moment of inertia of rectangular, triangular and circular areas from the method of integration, moment of inertia of composite areas and simple built up sections, Numerical examples. **10 Hours**

## Module 5

### **Kinematics:**

**Linear motion:** Introduction, Displacement, speed, velocity, acceleration, acceleration due to gravity, Numerical examples on linear motion Projectiles: Introduction, numerical examples on projectiles.

**Kinetics:** Introduction, D 'Alembert's principle of dynamic equilibrium and its application in-plane motion and connected bodies including pulleys, Numerical examples

**10 Hours**

### **List of Text Books**

1. Bansal R. K., Rakesh Ranjan Beohar and Ahmad Ali Khan, Basic Civil Engineering and Engineering Mechanics, 2015, Laxmi Publications.
2. Kolhapure B K, Elements of Civil Engineering and Engineering Mechanics, 2014, EBPB

### **List of Reference Books**

1. Beer F.P. and Johnston E. R., Mechanics for Engineers, Statics and Dynamics, 1987, McGraw Hill.
2. Irving H. Shames, Engineering Mechanics, 2019, Prentice-Hall.
3. Hibbler R. C., Engineering Mechanics: Principles of Statics and Dynamics, 2017, Pearson Press.
4. Timoshenko S, Young D. H., Rao J. V., Engineering Mechanics, 5th Edition, 2017, Pearson Press.
5. Bhavikatti S S, Engineering Mechanics, 2019, New Age International
6. Reddy Vijaykumar K and Suresh Kumar K, Engineering Mechanics, 2011, BS publication

### **Course Objectives**

1. To develop students' ability to analyze the problems involving forces, moments with their applications.
2. To analyse the member forces in trusses
3. To make students to learn the effect of friction on different planes
4. To develop the student's ability to find out the centre of gravity and moment of inertia and their applications.
5. To make the students learn about kinematics and kinetics and their applications

## **Course Outcomes**

1. Compute the resultant of a force system and resolution of a force
2. Comprehend the action for forces, moments, and other types of loads on rigid bodies and compute the reactive forces
3. Analyse the frictional resistance offered by different planes
4. Locate the centroid and compute the moment of inertia of sections
5. Analyze the bodies in motion

## MODULE 1

## Coplanar Concurrent &amp; Non-concurrent Force System

## 1.1 Introduction to Engineering Mechanics

## 1.1.1 Introduction

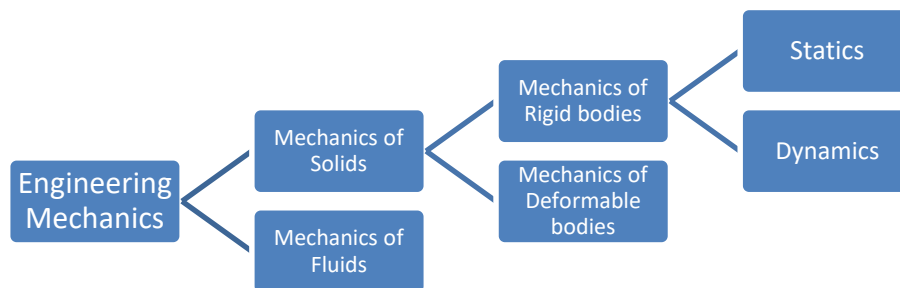
## Mechanics

It's a branch of science, which deals with the action of forces on bodies at rest or in motion.

## Engineering Mechanics

It is a branch of applied sciences that describes and predicts the state of rest or of uniform motion of **bodies** under the action of **forces**.

Engineering Mechanics deals with the application of principles of mechanics and different laws in a systematic manner.



- ❖ **Mechanics of Solids** is the branch of continuum mechanics that studies the behavior of **solid** materials, especially their motion and deformation under the action of forces, temperature changes, phase changes, and other external or internal agents.
- ❖ Mechanics of fluid or Fluid Mechanics is defined as the science which deals with the study of behaviour of fluids either at rest or in motion.
- ❖ Rigid body is an idealized solid whose size and shape are fixed and remains unaltered when forces are applied on it and study of those solids is called **Mechanics of Rigid body**.
- ❖ Any **body** that changes its shape and/or volume while being acted upon by any kind of external force is called Deformable body and study of those solids is called **Mechanics of Deformable body**.

- ❖ **Statics** is the branch of mechanics concerned with bodies at rest and forces in equilibrium.
- ❖ **Dynamics** is the branch of mechanics concerned with the motion of bodies under the action of forces.

### 1.1.2 Objectives

- To understand the basic concepts of Mechanics
- To understand the Principles of Mechanics
- To know the different types of force systems

### 1.1.3 Basic Concepts

**Matter:** Anything which has mass and requires space to occupy is called matter.

**Mass:** It is a measure of quality of matter contained by the body. **SI unit:** Kg.

**Volume:** It is a measure of space occupied by the body. Unit:  $m^3$

Note: Liter  $\rightarrow$  Unit of volume

1000 liters =  $1 m^3$

**State of rest and motion:** State of rest and state of motion are relative and depend on the frame of reference. A body is said to be in a state of rest w.r.t. a frame of reference if the position of the body w.r.t. that frame of reference is not changing with time. A body is said to be in a state of motion w.r.t. a frame of reference if the position of the body w.r.t. that frame of reference is changing with time.

**Scalar and Vector Quantities:** Quantities which require only magnitude to represent them are called scalar quantities.

Eg: Mass, Time interval.

Quantities which require both magnitude and direction to represent them are called Vector quantities.

Eg: Force, Velocity, etc.

**Displacement and distance travelled:** The total linear movement made by a body to change its position from one point to another is called distance travelled by the body. It is a scalar quantity.

Unit: Meter (m)

mm – Millimeter  $\rightarrow 10^{-3}m$

km – Kilo Meter  $\rightarrow 10^3m$



The total linear movement made by a body to change its position from one point to another moving along a particular direction is called displacement. Displacement is a vector quantity.

Unit: Meter (m).

**Speed and Velocity:** The distance travelled in a unit time is speed.

Unit: m/s or  $\text{ms}^{-1}$

The displacement in unit time is called velocity.

Unit:  $\text{m/s} \rightarrow \text{ms}^{-1}$

**Uniform motion and non-uniform motion:** If the velocity of the moving body remains constant then the motion is said to be uniform. If the velocity is changing with time, the motion is said to be non-uniform.

**Acceleration and retardation:** The time rate of change of velocity is called acceleration.

If the velocity is increasing with time then acceleration is positive. If the velocity is decreasing with time then acceleration is negative. Negative acceleration is called retardation or deceleration.

Unit:  $\text{m/s}^2 \rightarrow \text{ms}^{-2}$

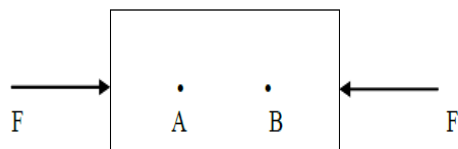
**Momentum:** It is the capacity of a moving body to impart motion to other bodies. Momentum of a moving body is given by the product of mass and velocity of the moving body.

$$\text{Momentum} = \text{Mass} \times \text{Velocity}, \quad \text{Unit: kg m/s or kg ms}^{-1}$$

**Particle:** A particle is a body of infinitely small volume and the entire mass of the body is assumed to be concentrated at a point.

**Rigid body:** It is one, which does not alter its shape, or size or the distance between any two points on the body does not change on the application of external forces.

**Deformable body:** It is one, which alters its shape, or size or the distance between any two points on the body changes on the application of external forces.



In the above example, the body considered is rigid as long as the distance between the points A and B remains the same before and after application of forces, or else it is considered as a deformable body.

**Rigid body:** The concept of rigid body is purely theoretical or imaginary. A rigid body is said to undergo, no deformation under the action of any external agency such as force and moments. In other words relative positions of the modules of a rigid body are fixed in space.

**Continuum:** The concept of continuum is purely theoretical or imaginary. Continuum is said to be made up of infinite number of molecules packed in such a way that, there is no gap between the molecules so that property functions remain same at all the points.

**Force:** According to Newton's I law, force is defined as an action or agent, which changes or tends to change the state of rest or of uniform motion of a body in a straight line.

**Units of force:** The gravitational (MKS) unit of force is the kilogram force and is denoted as kgf. The absolute (SI) unit of force is the Newton and is denoted as N.

**Note:**  $1 \text{ kgf} = g * \text{N}$  (But  $g = 9.81 \text{ m/s}^2$ ) Therefore  $1 \text{ kgf} = 9.81 \text{ N}$  or  $10 \text{ N}$ .

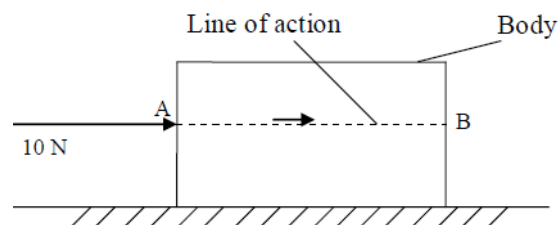
**Point force:** The concept of point force is purely theoretical or imaginary, here the force is assumed to be acting at a point or over infinity small area.

#### 1.1.4 Characteristics of a force

These are ones, which help in understanding a force completely, representing a force and also distinguishing one force from one another. A force is a vector quantity. It has four important characteristics, which can be listed as follows.

- 1) **Magnitude:** length of the vector
- 2) **Point of application:** It indicates the point on the body on which the force acts.
- 3) **Line of action:** The arrowhead placed on the line representing the direction represents it.
- 4) **Direction:** It is represented by a co-ordinate or cardinal system.

Ex.1: Consider a body being pushed by a force of 10 N as shown in figure below.



The characteristics of the force acting on the body are

- 1) Magnitude is 10 N.
- 2) Point of application is A.
- 3) Line of action is A to B or AB.

4) Direction is horizontally to right.

### **Idealization or assumptions in Mechanics:**

In applying the principles of mechanics to practical problems, a number of ideal conditions are assumed. They are as follows.

- 1) A body consists of continuous distribution of matter.
- 2) The body considered is perfectly rigid.
- 3) A particle has mass but not size.
- 4) A force acts through a very small point.

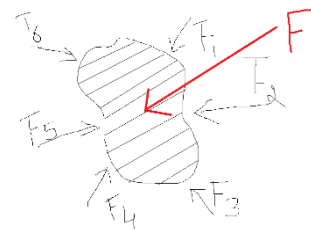
### **1.1.5 Types of forces**

1. **Gravitational Force:** Every object on the surface of the earth or near it, is attracted towards the center of the earth
2. **Reactive Force:** A force generated when an object applies a force on another object in contact with it
3. **Frictional Force:** The force of friction is the one which opposes the force causing movement of the body on the surface of the other
4. **Inertial Force:** Inertia force is present in every object which tends to resist any attempt to change its existing state of rest or motion by application of force from outside

### **1.1.6 Principles of Mechanics**

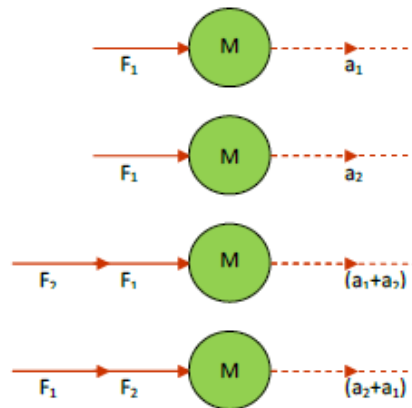
#### **Principle physical independence of forces:**

It states that if number of forces acting on the system, the effect produces by a single force is same as that of effect of force on the body taken individually.



#### **Principle of superposition of forces:**

If number of forces acting on the system, the net effect of forces is the algebraic sum of effect of individual forces



### Principle of transmissibility of forces:

The point of application of a force on a rigid body can be changed along the same line of action maintaining the same magnitude and direction without affecting the effect of the force on the body.



**Limitation of principle of transmissibility:** Principle of transmissibility can be used only for rigid bodies and cannot be used for deformable bodies.

### Assumptions made in Engineering Mechanics

- i) All bodies are rigid.
- ii) Particle concept can be used wherever applicable.
- iii) Principle of physical independence of forces is valid.
- iv) Principle of superposition of forces is valid.
- v) Principle of transmissibility of forces is valid.

### Newton's Laws of Motion

**Newton's I Law of Motion:** "Everybody continues to be in its state of rest or uniform motion unless compelled by an external agency".

**Newton's II Law of Motion:** "The rate of change of momentum is directly proportional to the magnitude of the force and it takes place in the direction of force".

#### Explanation:

Initial momentum =  $mu$

Final momentum =  $mv$

Change in momentum over a time interval 't' =  $mv - mu$

$$\text{Rate of change of momentum} = \frac{mv - mu}{t}$$

According to Newton's II law,

$$F \propto \frac{mv - mu}{t}$$

$$F \propto m \left( \frac{v - u}{t} \right)$$

$$F \propto ma$$

$$F = K ma$$

In SI, unit force is defined as that force which acts on a body of unit mass producing unit acceleration.

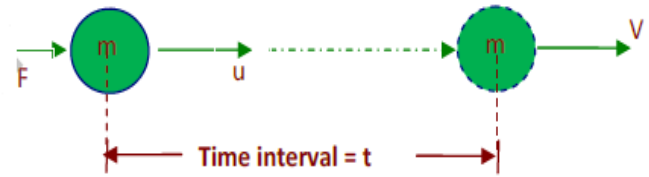
i.e.,  $F = 1$  when  $m = 1$  and  $a = 1$

then  $1 = k \cdot 1 \cdot 1$

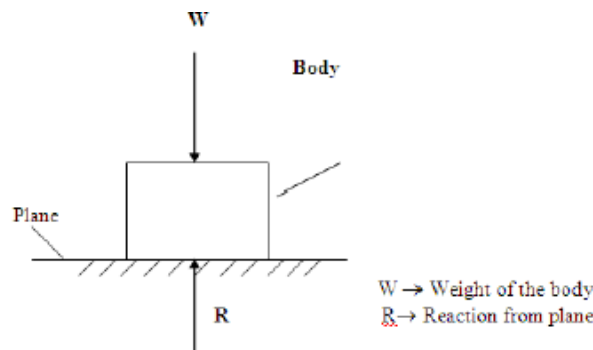
$$k = 1$$

$$F = ma$$

Unit of force: Newton (N) is the unit of force. One Newton is that force which acts on a body of mass 1 kg producing an acceleration of  $1 \text{ m/s}^2$ .



**Newton's III law:** It states, for every action there is an equal and opposite reaction. The significance of this law can be understood from the following figure. Consider a body weighing  $W$  resting on a plane. The body exerts a force  $W$  on the plane and in turn the plane exerts an equal and opposite reaction on the body.



### 1.1.7 Resolution of forces

The method to resolve or split a single force into two mutually perpendicular directions is called resolution of forces.

#### Principle of Resolution / Resolved parts

It states that, “the algebraic sum of the resolved part of a number of forces in a given direction is equal to resolved parts of their resultant in the same direction”.

A force  $F$  making an angle  $\theta$  wrt x-axis is shown in the figure below can be resolved into two mutually perpendicular components  $F_x$  and  $F_y$  acting along x and y axes respectively.



During resolution, first draw a horizontal line from tail of the given force  $F$  and then draw a vertical line from the end of horizontal line to meet the arrow of force  $F$ . then draw arrows on the horizontal and vertical lines in such a way that they meet the force arrow.

From triangle  $OAB$ ,

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

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

$$\tan\theta = \frac{F_y}{F_x} \quad \text{where } \theta \text{ is measured wrt Horizontal axis}$$

Therefore, the given force  $F$  can be resolved into two components  $F_x$  &  $F_y$  acting along  $X$  &  $Y$  axis.

The magnitude of the force  $F$  is given by

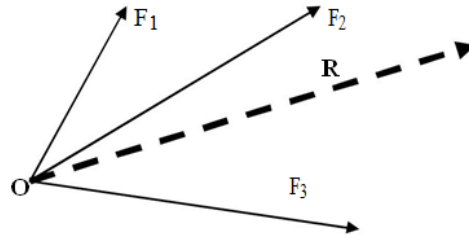
$$F = \sqrt{(F_x^2 + F_y^2)}$$

### Composition of Forces

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 individual force is called as composition of forces.

### Resultant Force:

Whenever a number of forces are acting on a body, it is possible to find a single force, which can produce the same effect as that produced by the given forces acting together. Such a single force is called as resultant force or resultant.



In the above figure R can be called as the resultant of the given forces  $F_1$ ,  $F_2$  and  $F_3$

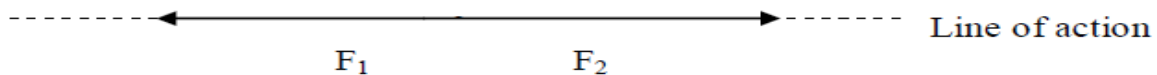
The process of determining the resultant force of a given force system is known as **Composition of forces**.

The resultant force of a given force system can be determined by **Graphical** and **Analytical** methods. In **analytical** methods two different principles namely: **Parallelogram law** of forces and **Method of Resolution** of forces are adopted.

### 1.1.8 Classification of force systems

Depending upon their relative positions, points of applications and lines of actions, the different force systems can be classified as follows.

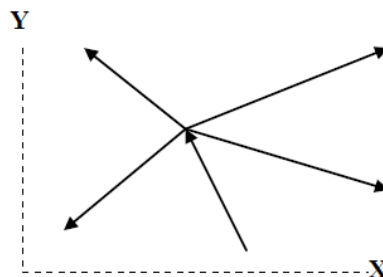
- 1) **Collinear forces:** It is a force system, in which all the forces have the same line of action.



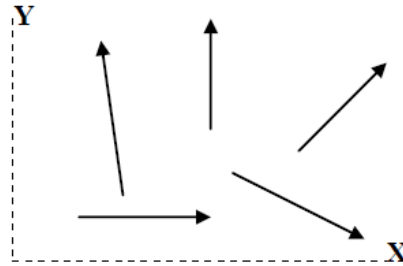
Ex.: Forces in a rope in a tug of war.

- 2) **Coplanar forces:** If the line of action of all forces are acting on the same line are referred as coplanar force system
- 3) **Non-coplanar force system:** If the line of action of forces are acting in different planes are referred as non-coplanar force system
- 4) **Coplanar Concurrent forces:** It is a force system, in which all the forces are lying in the same plane and lines of action meet a single point.

Ex.: The forces or loads and the support reactions in case of beams.

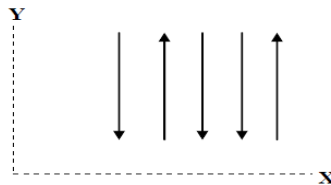


- 5) **Coplanar non-concurrent forces:** It is a force system, in which all the forces are lying in the same plane but lines of action do not meet a single point.



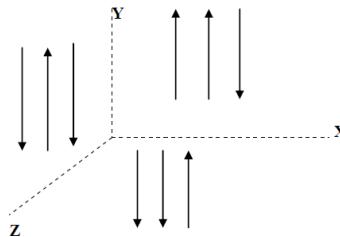
Ex.: Forces on a ladder and reactions from floor and wall, when a ladder rests on a floor and leans against a wall.

- 6) **Coplanar parallel forces:** It is a force system, in which all the forces are lying in the same plane and have parallel lines of action.



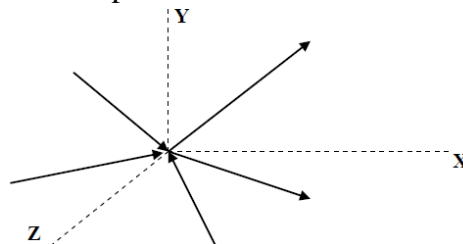
Ex.: The forces in the rope and pulley arrangement.

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



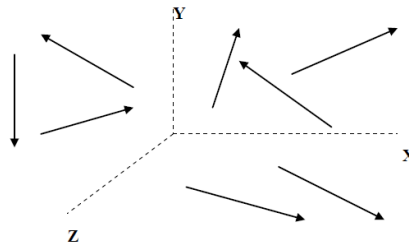
Ex: The forces acting and the reactions at the points of contact of bench with floor in a classroom.

- 8) **Non-coplanar concurrent forces:** It is a force system, in which all the forces are lying in the different planes and still have common point of action.



Ex.: The forces acting on a tripod when a camera is mounted on a tripod.

9) **Non- coplanar non-concurrent forces:** It is a force system, in which all the forces are lying in the different planes and also do not meet a single point.

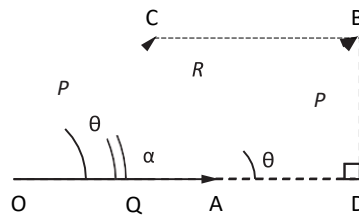


Ex.: Forces acting on a building frame.

### 1.1.9 Parallelogram of Forces

**Statement:** If two concurrent coplanar forces acting at a point be represented in magnitude and direction by the 2 sides of a parallelogram, then the diagonal of the parallelogram represents their resultant in magnitude and direction passing through the same point of intersection.

**Construction:**



**Proof:**

Let P & Q be the two forces acting at point O represented by the magnitude and direction by the two sides OC & OA respectively of the parallelogram OABC as shown in fig. Let  $\theta$  be the angle subtended between the forces P & Q and R makes an angle  $\alpha$  wrt horizontal.

Draw a perpendicular from point B to meet the line OA extended at point D.

Considering triangle ABD,

$$\cos\theta = \frac{\text{Adj}}{\text{Hyp}} = \frac{AD}{AB} = \frac{AD}{P} \quad \text{therefore } AD = P \cos\theta$$

$$\sin\theta = \frac{\text{Opp}}{\text{Hyp}} = \frac{BD}{AB} = \frac{BD}{P} \quad \text{therefore } BD = P \sin\theta$$

Considering triangle OBD

$$(OB)^2 = (OD)^2 + (BD)^2$$

$$(OB)^2 = (OA + AD)^2 + (BD)^2$$

$$(OB)^2 = (Q + P \cos\theta)^2 + (P \sin\theta)^2$$

$$(OB)^2 = Q^2 + P^2 \cos^2\theta + 2PQ \cos\theta + P^2 \sin^2\theta$$

$$(OB)^2 = Q^2 + P^2 (\cos^2\theta + \sin^2\theta) + 2PQ \cos\theta$$

$$(OB)^2 = P^2 + Q^2 + 2PQ \cos\theta$$

$$(OB) = R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta} \longrightarrow \text{Magnitude of the Resultant}$$

Direction of the resultant wrt horizontal

Considering the triangle OBD

$$\tan\alpha = \frac{\text{Opp}}{\text{Adj}} = \frac{BD}{OD} = \frac{BD}{OA+AD}$$

$$\tan\alpha = \frac{P \sin\theta}{Q+P\cos\theta}$$

$$\text{Therefore } \alpha = \tan^{-1} \frac{P \sin\theta}{Q+P\cos\theta}$$

$$\text{Case1: if } \theta = 0; R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta} \quad [\cos 0 = 1]$$

$$R = \sqrt{(P + Q)^2} = P + Q$$

$$\text{Case2: if } \theta = 90^\circ; R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta} \quad [\cos 90^\circ = 0]$$

$$R = \sqrt{P^2 + Q^2}$$

$$\text{Case3: if } \theta = 180^\circ; R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta} \quad [\cos 180 = -1]$$

$$R = \sqrt{(P - Q)^2} = P - Q$$

$$\text{Case4: if } P = Q; R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta}$$

$$R = \sqrt{P^2 + P^2 + 2P^2 \cos\theta}$$

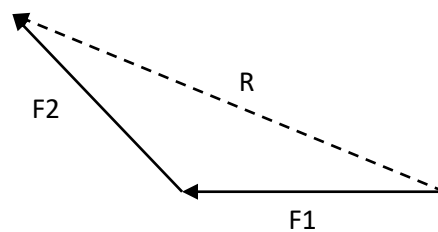
$$R = \sqrt{2P^2(1 + \cos\theta)}$$

$$R = \sqrt{2P^2 * 2\cos^2(\theta/2)}$$

$$R = 2P \cos(\theta/2)$$

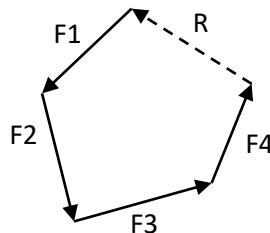
### 1.1.10 Triangular law of forces

It states that, if two forces acting simultaneously on a body are represented by magnitude & direction by the two sides of a triangle taken in order; their resultant is represented in magnitude and direction by the closing side of the triangle taken in the opposite direction.



**1.1.11 Polygon law of forces:**

It states that, if number of forces acting simultaneous on a body be represented in magnitude & direction by the sides of a polygon taken in order, the resultant is represented by both magnitude & direction by the closing side of the polygon in opposite direction.

**1.1.12 Resultant of Coplanar concurrent force system**

**Step1:** Resolve all the given forces horizontally & find out their algebraic sum ie  $\Sigma H$

**Step1:** Resolve all the given forces vertically & find out their algebraic sum ie  $\Sigma V$

**Step3:** The magnitude of the resultant can be determined by using the expression

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$$

**Step4:** Based on the sign convention of  $\Sigma H$  &  $\Sigma V$ . Resultant can be decided in which quadrant it acts

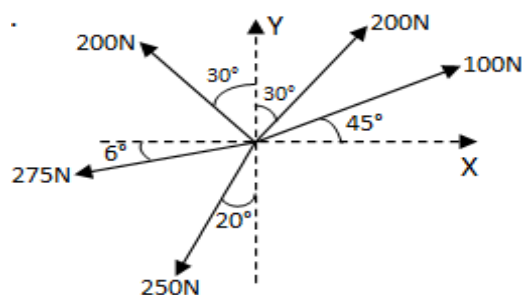
**Step5:** The direction of the resultant wrt horizontal can be determined by using the expression

$$\tan \alpha = \frac{\Sigma H}{\Sigma V}$$

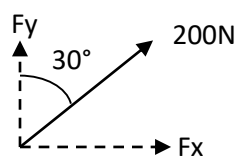
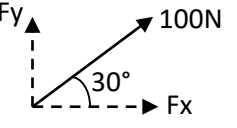
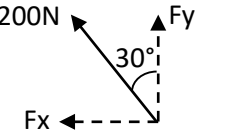
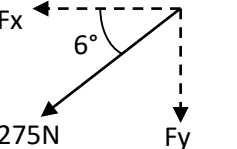
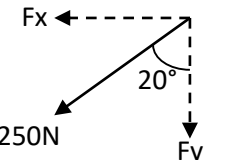
Note: Do not consider the sign convention while calculating the direction of resultant & only magnitude should be considered.

**Example 1:**

Five coplanar forces are acting at a point as shown in figure. Determine the resultant in terms of magnitude & direction.

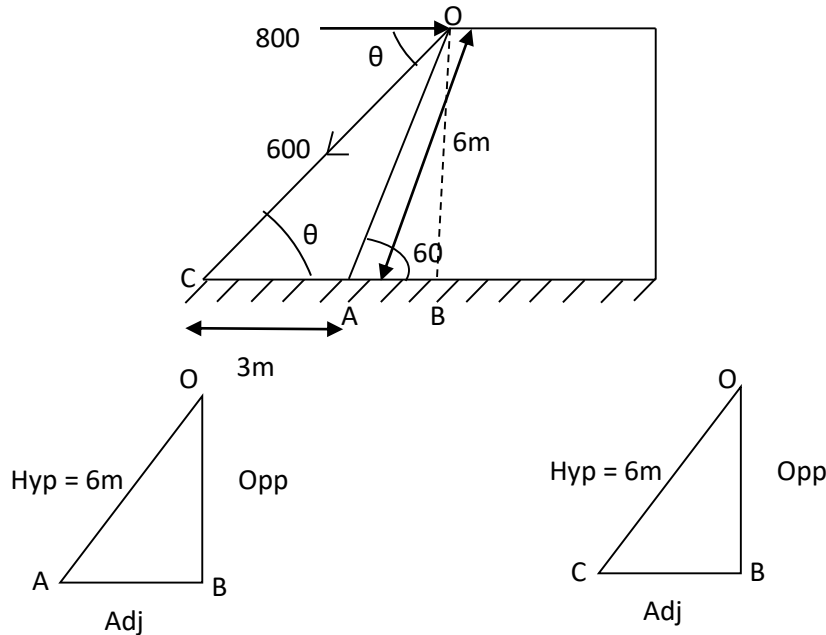


**Solution:**

<b>Force</b>	<b>Horizontal Component (Fx)</b>	<b>Vertical Component (Fy)</b>
	$= 200 \sin 30^\circ$	$= 200 \cos 30^\circ$
	$= 100 \cos 45^\circ$	$= 100 \sin 45^\circ$
	$= -200 \sin 30^\circ$	$= 200 \cos 30^\circ$
	$= -275 \sin 6^\circ$	$= -275 \cos 6^\circ$
	$= -250 \cos 20^\circ$	$= -250 \sin 20^\circ$
	<b><math>\Sigma F_x = -288.28\text{N}</math></b>	<b><math>\Sigma F_y = 153.45\text{N}</math></b>

$$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = \sqrt{(-288.28)^2 + (153.45)^2} = 326.57 \text{ N}$$

**Example 2:** Determine the resultant force acting on the structure at point O both in magnitude and direction.



Wkt,

$$\cos\theta = \frac{\text{Adj}}{\text{Hyp}}$$

$$\sin\theta = \frac{\text{Opp}}{\text{Hyp}}$$

$$\cos 60^\circ = \frac{\text{Adj}}{6}$$

$$\sin 60^\circ = \frac{\text{Opp}}{6}$$

$$\text{Adj} = \cos 60^\circ * 6 \quad \text{Opp} = \sin 60^\circ * 6$$

$$\text{Adj} = 3\text{m}$$

$$\text{Opp} = 5.196\text{m}$$

$$\tan\theta = \frac{5.196}{6}$$

$$\theta = \tan^{-1}\left(\frac{5.196}{6}\right) = 40.89^\circ$$

Wkt,

$$\cos\theta = \frac{\text{Adj}}{\text{Hyp}}$$

$$\sin\theta = \frac{\text{Opp}}{\text{Hyp}}$$

$$\cos 60^\circ = \frac{\text{Adj}}{6}$$

$$\sin 60^\circ = \frac{\text{Opp}}{6}$$

$$\text{Adj} = \cos 60^\circ * 6 \quad \text{Opp} = \sin 60^\circ * 6$$

$$\text{Adj} = 3\text{m}$$

$$\text{Opp} = 5.196\text{m}$$

Force	Horizontal Component (Fx)	Vertical Component (Fy)
	$= - 600 \cos 40.89^\circ$	$= - 600 \sin 40.89^\circ$
	$= 800$	-
	<b><math>\Sigma H = 346.41\text{N}</math></b>	<b><math>\Sigma V = - 392.76\text{N}</math></b>

$$R = \sqrt{\Sigma Fx^2 + \Sigma Fy^2} = \sqrt{(346.41)^2 + (-392.76)^2} = 523.69 \text{ N}$$

### 1.2.1 Moment of a Force

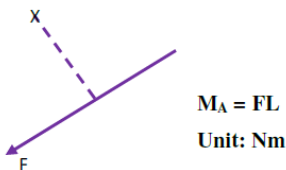
It is the capacity of a force to produce rotator motion. In other words moment of a force is its rotating capacity.

Based on the direction of rotation produced moment of a force can be classified into

- Clockwise moment
- Anticlockwise moment / counter clockwise moment.

#### Calculation of Moment of a Force about a Point

Moment of a force about any point is given by the product of magnitude of force and perpendicular distance between the line of action of a force and the point about which moment is considered.



#### Sign Convention for Moment of a Force

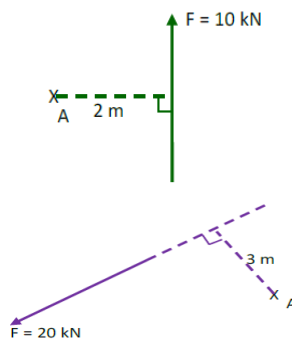
Clockwise moment positive and anticlockwise moment negative.

$$M_A = -10 \times 2$$

$$M_A = -20 \text{ kN m}$$

$$M_A = -20 \times 2$$

$$M_A = -40 \text{ kN m}$$

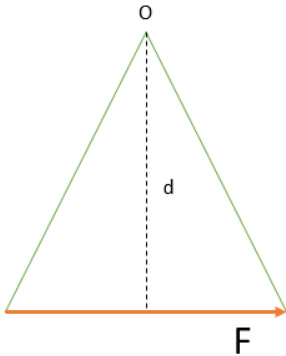


### 1.2.2 Couple

Couple consists of two equal, opposite and non-collinear forces.

#### Characteristics:

- As the two forces are equal in magnitude but opposite in direction, their resultant force is zero but a moment is associated with couple.
- A couple acting on a rigid body can produce only rotational motion. It cannot produce translational motion.
- Moment of couple is same about any point in the plane.
- The effect of a couple can be nullified only by another couple of equal magnitude but opposite sense of rotation.

**To Prove: Moment of force = 2 \* Area of Triangle**

$$\text{Moment} = \text{Force} * \text{Perpendicular Distance}$$

$$M = F * D$$

$$\text{Area of Triangle} = \frac{1}{2} * \text{base} * \text{Height}$$

$$= \frac{1}{2} * F * d$$

$$\text{Area of Triangle} = \frac{1}{2} * \text{base} * \text{Height}$$

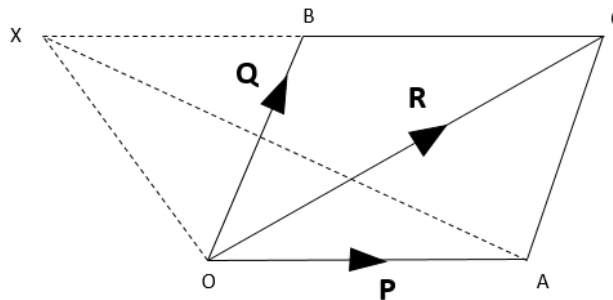
$$= \frac{1}{2} * M \text{ or}$$

$$2 * \text{Area of Triangle} = \text{Moment of force}$$

**1.2.3 Varignon's theorem of moments**

**Statement:** It states that the algebraic sum of moments due to all forces acting on an object about any point is equal to the moment of their resultant about the same point.

**Construction:**



**Proof:** Let  $P$  &  $Q$  be the coplanar forces acting along the sides  $OA$  &  $OB$  of the parallelogram  $OACB$ .  $R$  is the resultant of the two forces acting along the diagonal of the parallelogram.

Moment of a force  $P$  about  $X = 2 * \text{Area of Triangle OXA}$

Moment of a force  $Q$  about  $X = 2 * \text{Area of Triangle OXB}$

Moment of a force  $R$  about  $X = 2 * \text{Area of Triangle OXC}$

But triangle  $OXC = \text{triangle OXB} + \text{triangle OBC}$

By geometry, triangle  $OBC = \text{triangle OCA} = \text{triangle OXA}$  are similar

Therefore, Moment of a force  $R$  about  $X = 2 * (\text{Area of Triangle OXB} + \text{Area of Triangle OXA})$

Hence

Therefore, Moment of a force R about X = 2 \* (Area of Triangle OXB + Area of Triangle OXA)

Moment of a force R about X = Moment of a force Q about X + Moment of a force P about X

Therefore

**Moment of Resultant about a point = Algebraic sum of moment of all the forces about the same point**

### Procedure for problems on non-concurrent force system

1. Add all the Horizontal forces by considering the sign convention ie  $\sum F_x$
2. Add all the Vertical forces by considering the sign convention ie  $\sum F_y$
3. Determine the magnitude of Resultant

$$R = \sqrt{(\sum F_x)^2 + (\sum F_y)^2}$$

4. Direction of Resultant

$$\theta = \tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

5. For position of Resultant

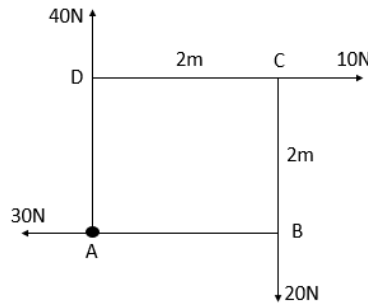
$$\text{Inclined Distance } d = \frac{\sum M}{R}$$

$$x - \text{intercept} = \left| \frac{\sum M}{\sum F_y} \right|$$

$$y - \text{intercept} = \left| \frac{\sum M}{\sum F_x} \right|$$

Four forces of magnitude 10N, 20N, 30N & 40N are simultaneously acting along the sides of a square of size 2mX2m as shown in fig. Determine the magnitude, direction & position of resultant force wrt point A

To find:  $R=?$ ,  $\Theta=?$ ,  $d=?$ ,  $x\text{-int}=?$  &  $y\text{-int}=?$



Step 1:  $\sum F_x = 10 - 30 = -20\text{N}$

Step 2:  $\sum F_y = 40 - 20 = 20\text{N}$

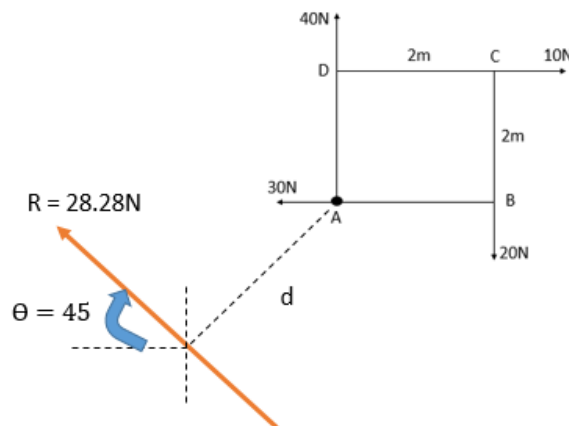
Step 3: Magnitude of resultant

$$R = \sqrt{(\sum F_x)^2 + (\sum F_y)^2} = \sqrt{(20)^2 + (20)^2} = 28.28\text{N}$$

Step 4: Direction of resultant

$$\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{20}{-20} = -1$$

Therefore,  $\theta = \tan^{-1}(1) = -45^\circ$  (Should be marked in clockwise direction)



Taking Moment of all the forces about point A

$$\sum M_A = (10 \times 2) + (20 \times 2) = 60\text{N-m}$$

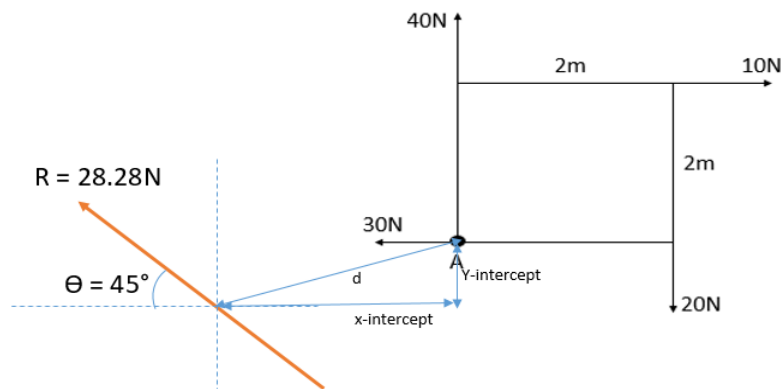
Assuming the position of resultant towards left of

$$\text{Point A } R \cdot d = \sum M_A$$

$$d = \frac{\sum M}{R} = \frac{60}{28.28} = 2.12\text{m}$$

$$x - \text{intercept} = \left| \frac{\sum M}{\sum F_y} \right| = \left| \frac{60}{20} \right| = 3\text{m}$$

$$y - \text{intercept} = \left| \frac{\sum M}{\sum F_x} \right| = \left| \frac{60}{-20} \right| = 3\text{m}$$



MODULE 2

**EQUILIBRIUM OF COPLANAR CONCURRENT & NON CON-  
CURRENT FORCE SYSTEM**

**Equilibrium**

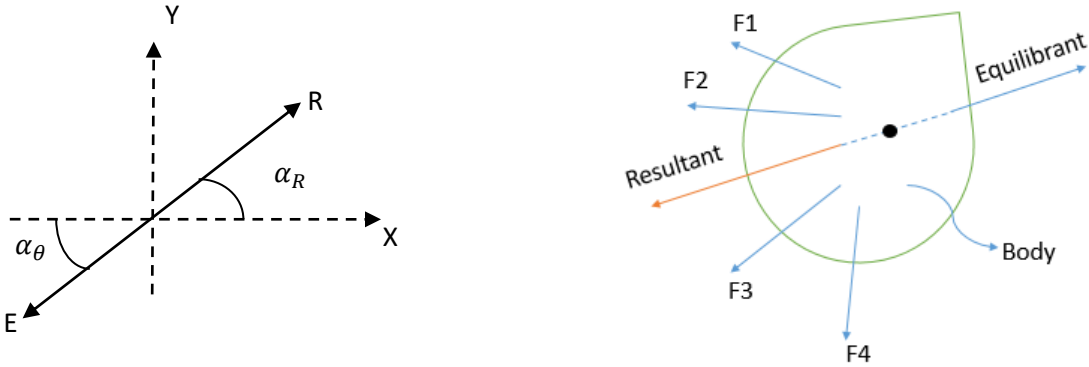
A stationary object remains at the state of rest under the action of external force, then the object is said to be in equilibrium

or

A system of forces acting on a body is said to be in equilibrium when the resultant of all the forces is zero and algebraic sum of all moments is equal to zero.

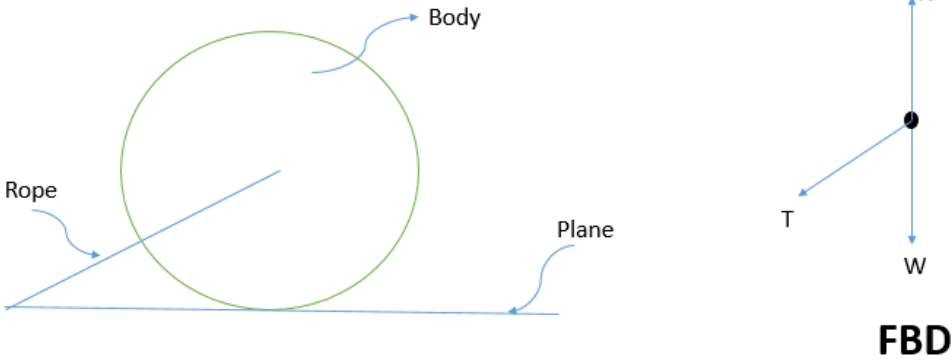
**Equilibrant**

It is a single force which equal, collinear and opposite to resultant force



**Free Body**

It is diagram which represents the line of action of forces on the body.



**Conditions of Equilibrium**

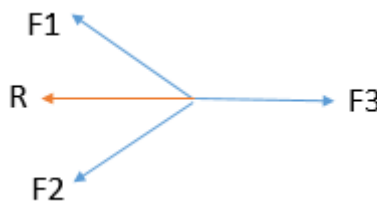
Co-planar Concurrent Force system	Co-planar Non-Concurrent Force system	Parallel Force system	Non-Coplanar Force System
$\sum F_x = 0$ $\sum F_y = 0$	$\sum F_x = 0$ $\sum F_y = 0$ $\sum M = 0$	$\sum F_x = 0$ $\sum M = 0$	$\sum F_x = 0$ $\sum F_y = 0$ $\sum F_z = 0$ $\sum M = 0$

**Principles of Equilibrium for Different Forces System**

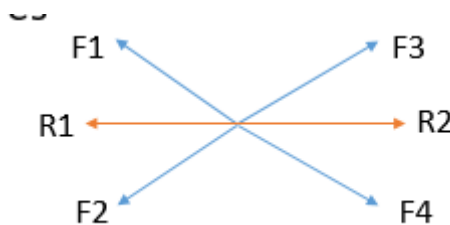
**Two Force System:** If a body is acted upon by two forces, then for body to be in equilibrium, two forces should have same magnitude, collinear and opposite direction.



**Three Force System:** If a body is acted upon by three forces, then for body to be in equilibrium, resultant of first two forces should have same magnitude, collinear and opposite to third force



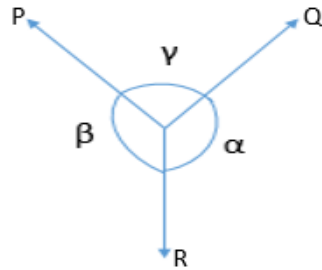
**Four Force System:** If a body is acted upon by four forces, then for body to be in equilibrium, resultant of first two forces should have same magnitude, collinear and opposite with the resultant of other two forces



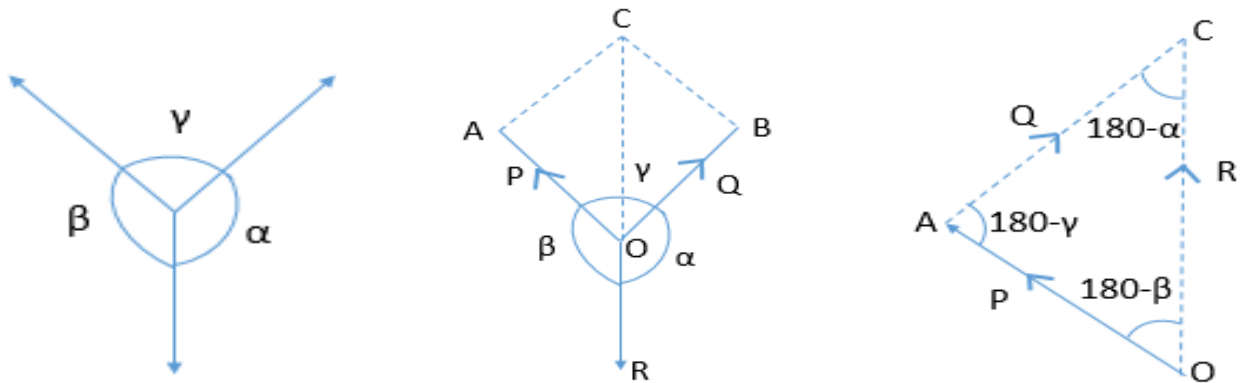
**Lami's theorem**

**Statement:** If number of coplanar forces acting on a body said to be in equilibrium, then the magnitude of each force is directly proportional to the sine of the angle between other two forces

To Prove:  $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$



**Construction:**



**Proof:**

From triangle OAC,

$$\angle AOC = 180 - \beta$$

$$\angle BOC = \angle ACO = 180 - \alpha$$

$$\angle CAO = 180 - (\angle ACO + \angle AOC)$$

$$\angle CAO = 180 - (180 - \alpha + 180 - \beta) = \alpha + \beta - 180 \text{ ----- (1)}$$

$$\alpha + \beta + \gamma = 360^\circ$$

Subtracting  $180^\circ$  on both the sides

$$\alpha + \beta + \gamma - 180^\circ = 360^\circ - 180^\circ$$

From (1)  $\alpha + \beta - 180 = \text{CAO}$

$$\text{CAO} = 180^\circ - \gamma$$

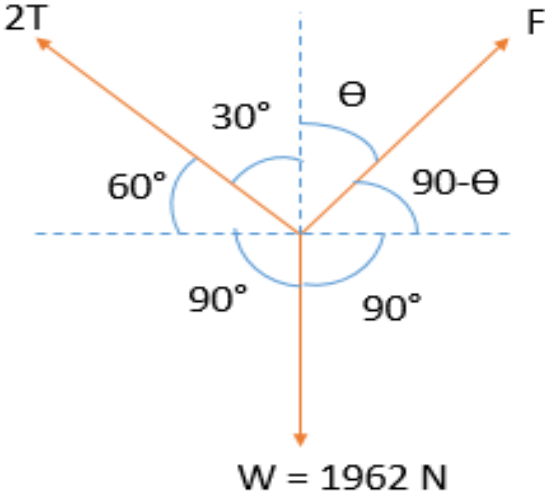
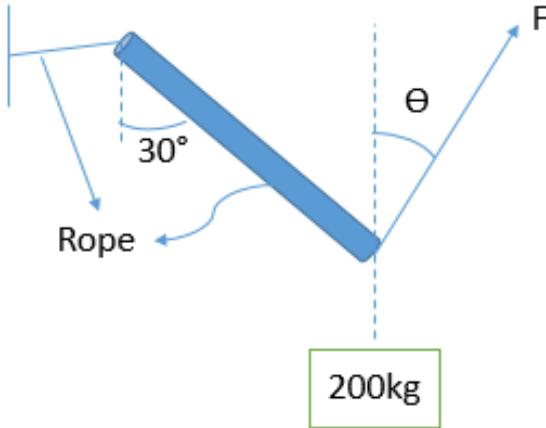
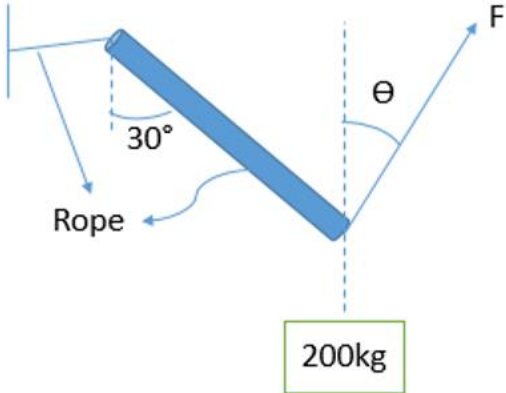
As per the definition  $\frac{P}{\sin(\text{ACO})} = \frac{Q}{\sin(\text{AOC})} = \frac{R}{\sin(\text{CAO})}$

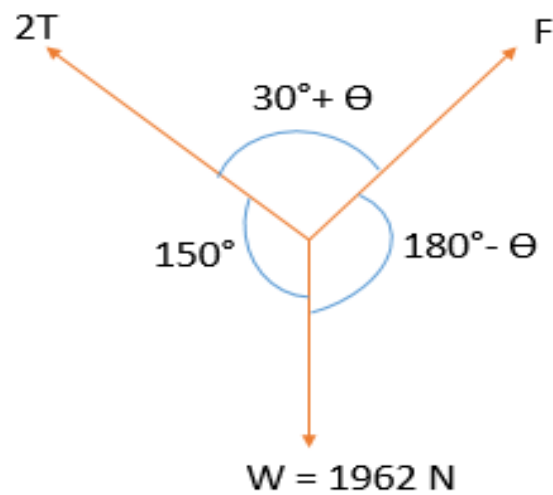
$$\frac{P}{\sin(180^\circ - \alpha)} = \frac{Q}{\sin(180^\circ - \beta)} = \frac{R}{\sin(180^\circ - \gamma)}$$

$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$$

A Crate of mass 200kg is to be supported by a rope and pulley arrangement as shown in fig. Determine the magnitude of force F and also find its direction.

Given: Mass W = 200kg = 200\*9.81 = 1962N





**Applying Lami's theorem**

$$\frac{2T}{\sin(180^\circ - \theta)} = \frac{F}{\sin(150^\circ)} = \frac{1962}{\sin(30^\circ + \theta)} \quad \sin\theta \text{ will be max when } \theta = 90^\circ$$

**Therefore,  $\theta = 60^\circ$**

**Now Equating**

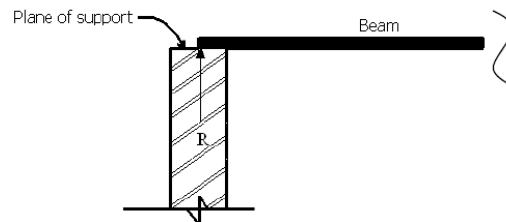
$$\frac{F}{\sin(150^\circ)} = \frac{1962}{\sin(90^\circ)} \quad \longrightarrow \quad F = 981 \text{ N}$$

## SUPPORT REACTIONS

### Introduction

### Support

Supports are structures which prevent the beam or the body from moving and help to maintain equilibrium.



### Support Reaction

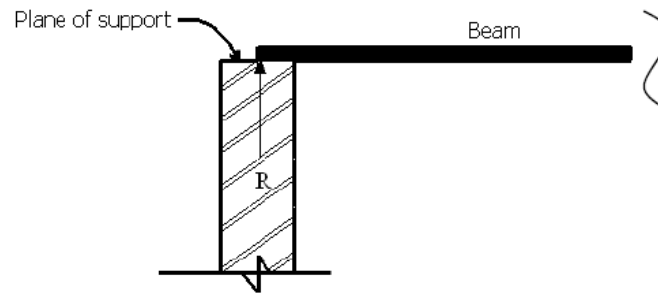
The reactions exerted by support to the beam are called as support reactions



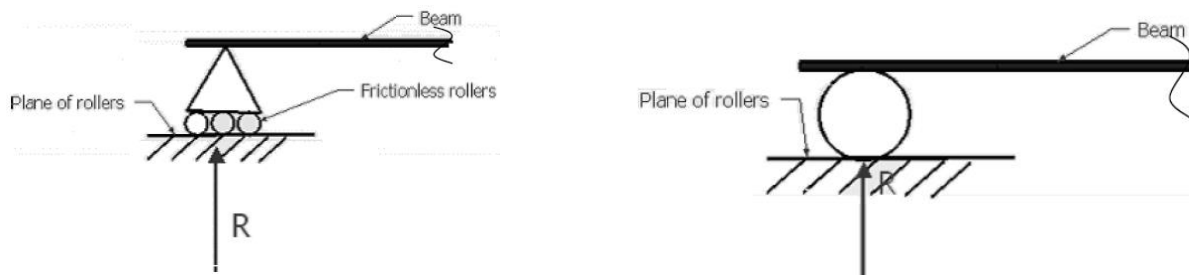
### Types of Supports for beams

Supports are structures which prevent the beam or the body from moving and help to maintain equilibrium. A beam can have different types of supports as follows. The support reactions developed at each support are represented as follows.

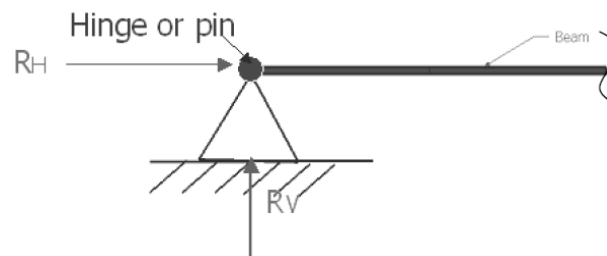
- 1) **Simple support:** This is a support where a beam rests freely on a support. The beam is free to move only horizontally and also can rotate about the support. In such a support one reaction, which is perpendicular to the plane of support, is developed.



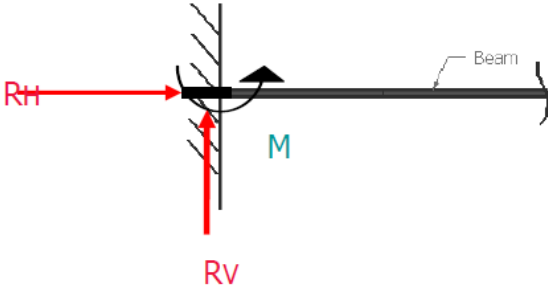
**Roller support:** This is a support in which a beam rests on rollers, which are frictionless. At such a support, the beam is free to move horizontally and as well rotate about the support. Here one reaction which is perpendicular to the plane of rollers is developed.



**Hinged Support:** A Hinged beam support can resist both vertical and horizontal forces but not a moment. They will allow the structural member to rotate, but not to translate in any direction. The representation of a hinged support includes both horizontal and vertical forces. Hinged supported beam also called pinned supported beam.



2) **Fixed support:** This is a support which prevents the beam from moving in any direction and also prevents rotation of the beam. In such a support a horizontal reaction, vertical reaction and a Fixed End Moment are developed to keep the beam in equilibrium.

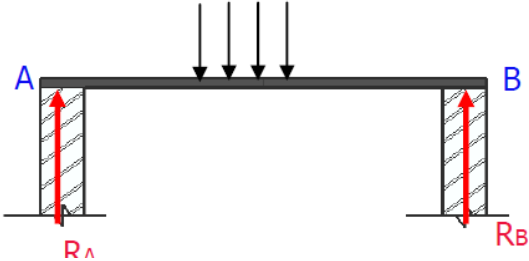


**Types of beams**

Depending upon the supports over which a beam can rest (at its two ends), beams can be classified as follows.

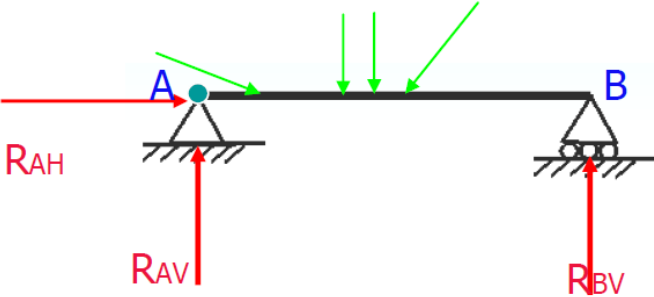
**1. Simply supported beam**

A beam is said to be simply supported when both ends of the beam rest on simple supports. Such a beam can carry or resist vertical loads only.



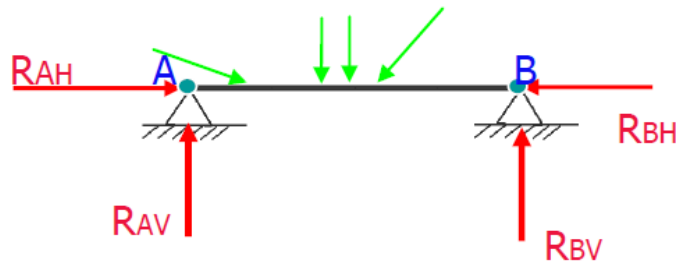
**2. Beam with one end hinged & other on rollers**

It is a beam where one end of the beam is hinged to a support and the other end rests on a roller support. Such a beam can carry any type of loads.



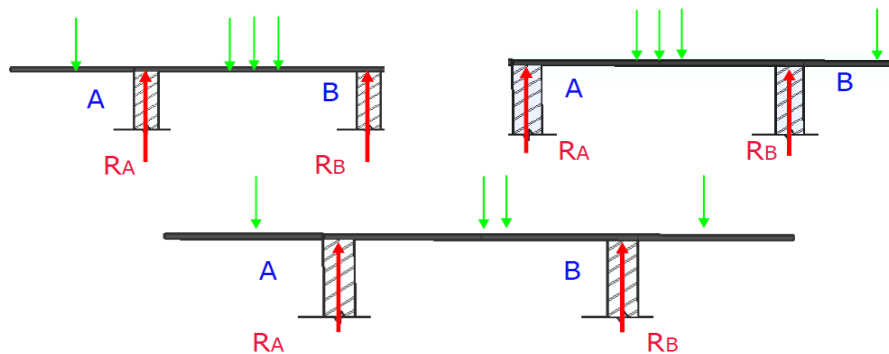
### 3. Hinged Beam

It is a beam which is hinged to supports at both ends. Such a beam can carry loads in any direction.



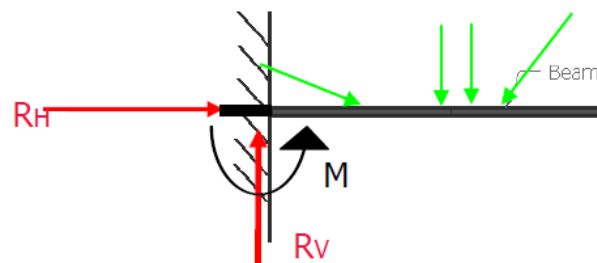
### 4. Over hanging beam

It is a beam which projects beyond the supports. A beam can have over hanging portions on one side or on both sides.



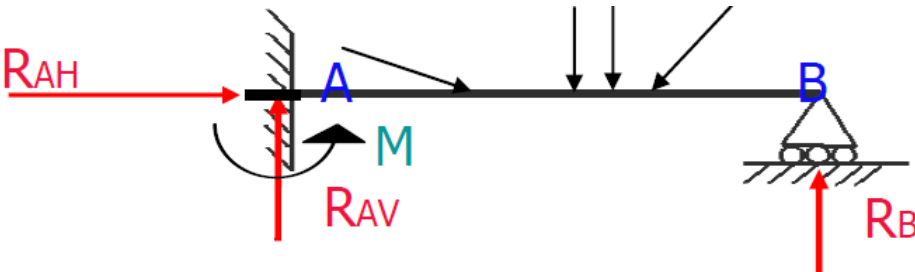
### 5. Cantilever Beams:

It is a beam, with one end fixed and other end free. Such a beam can carry loads in any directions.



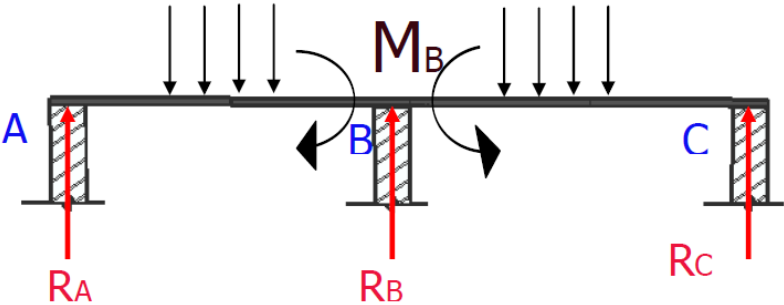
6. Propped cantilever:

It is a beam which has a fixed support at one end and a simple support at the other end.



7. Continuous beam:

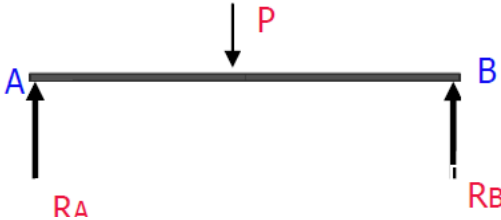
It is a beam which rests over a series of supports at more than two points.



Types of loads:

The various types of loads that can act over a beam can e listed as follows.

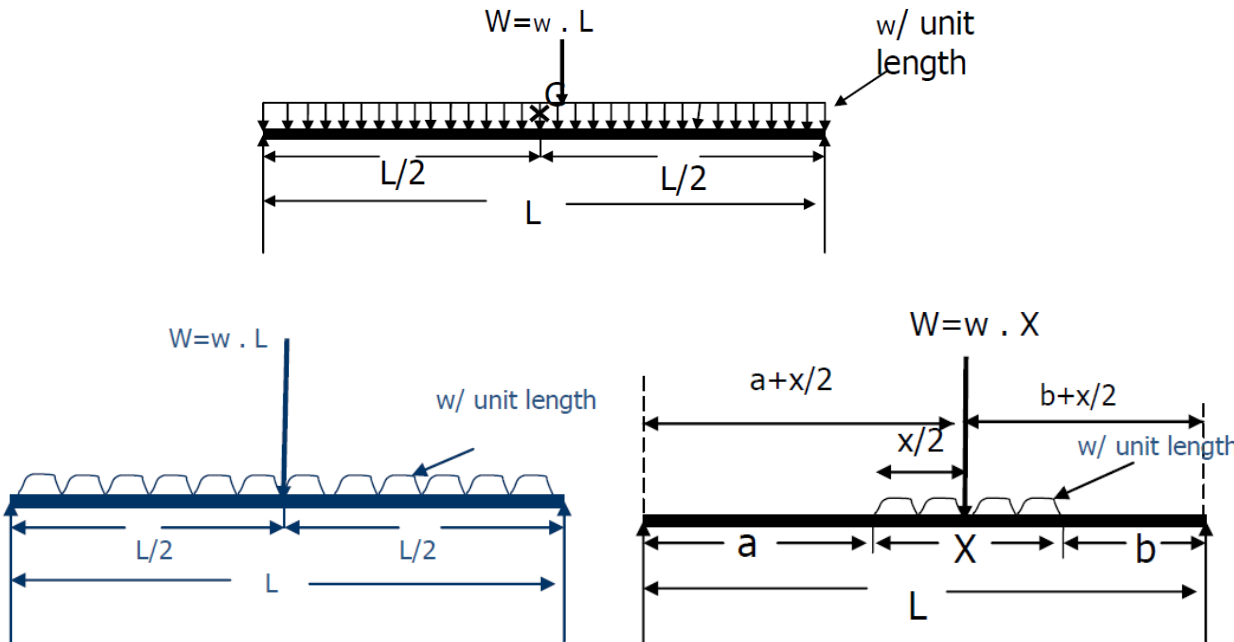
- 1. **Point load or concentrated load:** If a load acts over a very small length of the beam, it is assumed to act at the midpoint of the loaded length and such a loading is termed as Point load or Concentrated load.



- 2. **Uniformly distributed load (UDL):** If a beam is loaded in such a manner that each unit length of the beam carries the same intensity of loading, then such a loading is called UDL. A UDL cannot be considered in the same manner for applying conditions of equilibrium on

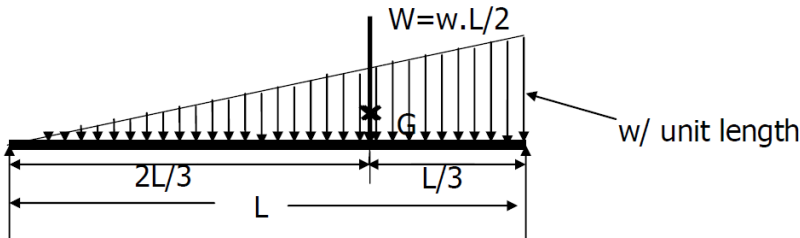
the beam. The UDL should be replaced by an equivalent point load or total load acting through the mid-point of the loaded length.

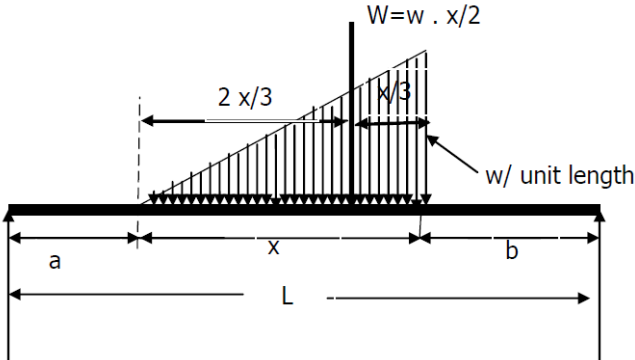
The magnitude of the point load or total load is equal to the product of the intensity of loading and the loaded length (distance).



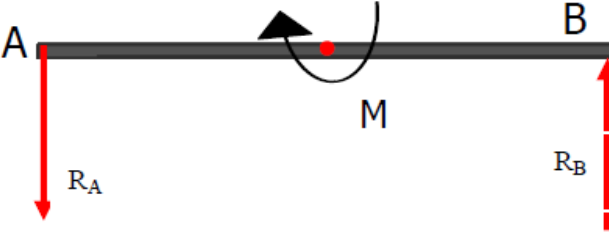
**3. Uniformly varying load (UVL):** If a beam is loaded in such a manner, that the intensity of loading varies linearly or uniformly over each unit distance of the beam, then such a load is termed as UVL.

In applying conditions of equilibrium, a given UVL should be replaced by an equivalent point load or total load acting through the centroid of the loading diagram (right angle triangle). The magnitude of the equivalent point load or total load is equal to the area of the loading diagram.

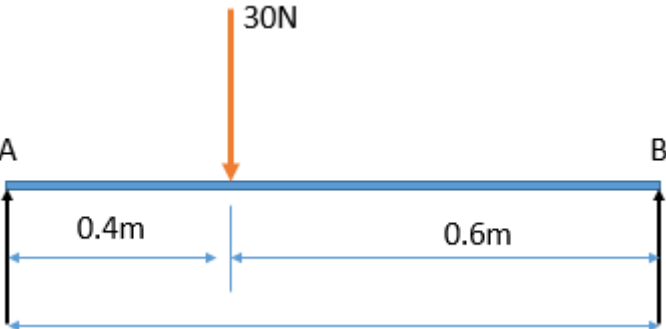


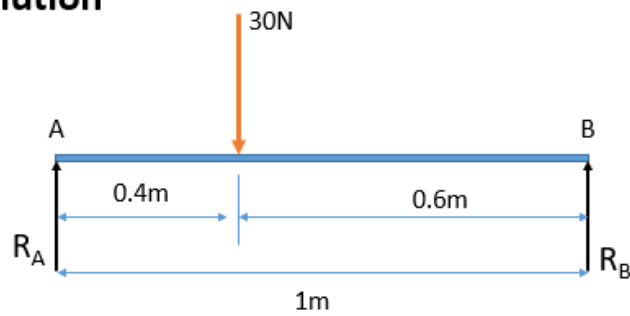


4. **External moment:** A beam can also be subjected to external moments at certain points as shown in figure. These moments should be considered while calculating the algebraic sum of moments of forces about a point on the beam



Determine the support reaction for a simply supported beam as shown in fig



**Solution**

We have three conditions of equilibriums

$$\sum F_x = 0$$

$$\sum F_y = 0$$

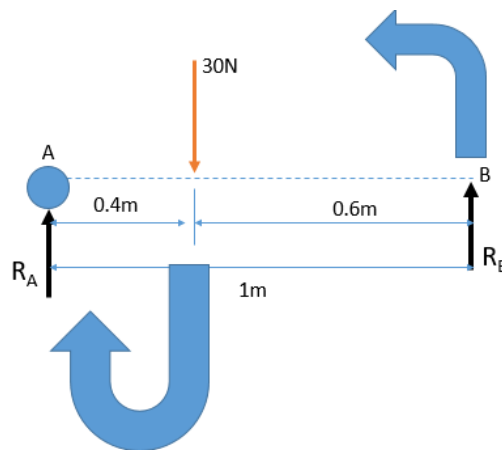
$$\sum M = 0$$

$$\sum F_y = 0$$

$$R_A + R_B - 30 = 0$$

$$R_A + R_B = 30$$

Taking Moment of about A



$$\sum M_A = 0 \quad (R_A * 0) + (30 * 0.4) - (R_B * 1) = 0$$

$$R_B = 12\text{N}$$

*wkt*

$$R_A + R_B = 30$$

$$R_A + 12 = 30$$

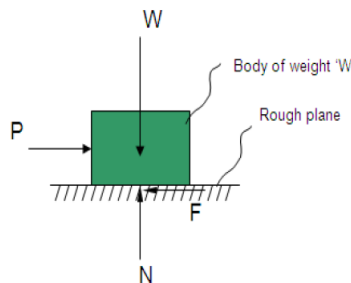
$$R_A = 30 - 12 = 18\text{N}$$

## Module – 3

### Friction

#### Introduction

Whenever a body moves or tends to move over another surface or body, a force which opposes the motion of the body is developed tangentially at the surface of contact; such an opposing force developed is called friction or frictional resistance. The frictional resistance is developed due to the interlocking of the surface irregularities at the contact surface b/w two bodies. Consider a body weighing  $W$  resting on a rough plane & subjected to a force 'P' to displace the body.



Where  $P$  = Applied force  $N$  = Normal reaction from rough surface  $F$  = Frictional resistance  $W$  = Weight of the body.

The body can start moving or slide over the plane if the force 'P' overcomes the frictional 'F'.

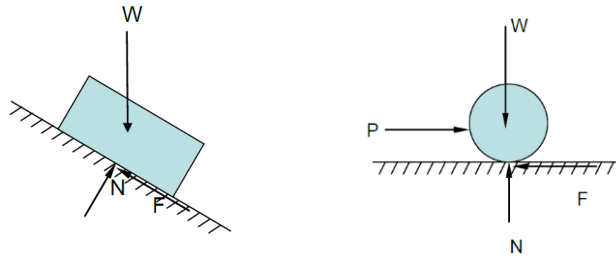
#### Limiting Friction

The resisting frictional force which opposes the sliding of one over the other has a limiting value and if the applied force is greater than the limiting value of force, it begins to move. The limiting value of force is called as limiting friction at the stage where body will be in equilibrium.

#### Types of Friction

- The friction experienced by a body when it is at rest or in equilibrium is known as static friction. It can range between a zero to limiting friction value.
- The friction experienced by a body when it is moving is called dynamic friction.
- The dynamic friction experienced by a body as it slides over a plane as it is shown in figure is called sliding friction.

- The dynamic friction experienced by a body as it rolls over surface as shown in figure is called rolling friction.



### Co-efficient of Friction

It is the ratio of limiting friction force  $F$  to the normal reaction  $N$  b/w two surfaces

It is defined by the relationship 
$$\mu = \frac{F}{N}$$

Where  $\mu$  – Represents co-efficient of friction  $F$  – Represents frictional resistance  $N$  – Represents normal reaction.

Note:  $\mu = 0$  for smooth surfaces

### Laws of Friction

#### Static Laws of Friction

- The frictional force always acts in the direction opposite to that in which the body tends to move.
- The magnitude of limiting friction bears a constant ratio to the normal reaction b/w two contact surfaces

$$\frac{F}{N} = \text{constant}$$

- The force of friction is independent of the area of contact b/w two surfaces
- The force of friction depends upon the roughness of surface in contact

**Dynamic Laws of Friction**

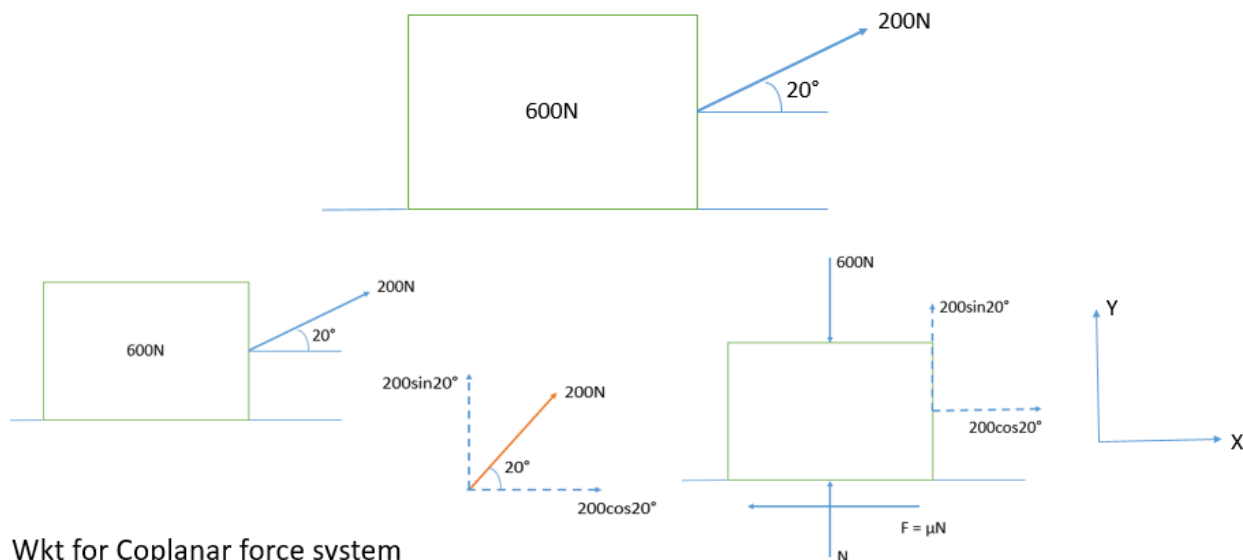
- The frictional force always acts in the direction opposite to that in which the body tends to move.
- The magnitude of kinetic friction bears a constant ratio to the normal reaction b/w two contact surfaces but this ratio is slightly less than in case of limiting friction

$$\frac{F}{N} = \text{constant}$$

- The force of friction remains constant for moderate speeds but decreases slightly with increasing speed

A block shown in fig is just moved by a force of 200N. The weight of the block is 600N. Determine the coefficient of static friction b/w the block & floor

To find:  $\mu = ?$



Wkt for Coplanar force system

Conditions of equilibrium is  $\sum F_X = 0$  &  $\sum F_Y = 0$

$$\sum F_X = 0$$

$$200\cos 20^\circ - F = 0$$

$$200\cos 20^\circ - \mu N = 0$$

$$\mu N = 187.93\text{N}$$

$$\sum F_Y = 0$$

$$200\sin 20^\circ - 600 + N = 0$$

$$N = 531.59\text{N}$$

$$\mu N = 187.93$$

$$\mu = \frac{187.93}{531.59} = 0.35$$

## Truss

### Introduction

A truss or pin jointed frame is made up of several straight members connected by smooth pins at their ends called joints.

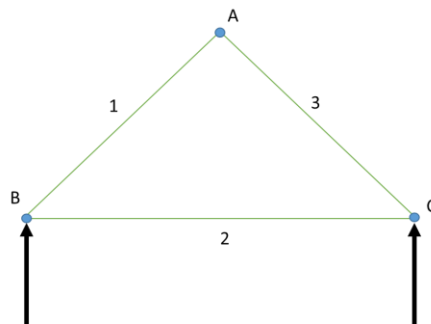
The primary function of truss is to support the loads at the joints and transmit these loads to the supports through axial members

### Types of Truss

- Perfect frame
- Imperfect frame

### Perfect Frame

Perfect frame is made up of number of members just sufficient to keep it in equilibrium



$$m = (n * j) - r$$

Where m = no of members

n = 2 (for 2D-dimension frame)

n = 3 (for 3D- dimension frame)

j = no of joints

r = 3 (no of available conditions

of equilibrium ie.  $\sum F_x = 0$ ,

$\sum F_y = 0$  &  $\sum M = 0$ )

$$m = 3, n = 2, j = 3 \text{ \& } r = 3$$

$$\text{Therefore } 3 = (2 * 3) - 3$$

$$3 = 3 \text{ therefore a perfect frame}$$

### Imperfect Frame

The frame which does not satisfies the  $m = nj-r$  is called an imperfect frame or in other words, a frame in which number of members are more or less than  $nj-r$

$$m \neq (n * j) - r$$

The imperfect frame are further classified

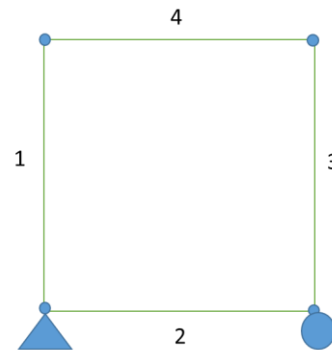
into two types

- Deficient frame  $m < nj-r$
- Redundant frame  $m > nj-r$

$$m = 4, n = 2, j = 4 \text{ \& } r = 3$$

$$\text{Therefore } 4 = (2 * 4) - 3$$

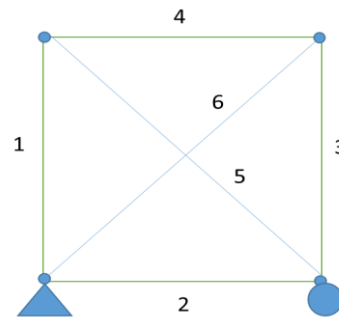
$$4 < 5 \text{ therefore a Deficient frame}$$



$$m = 6, n = 2, j = 4 \text{ \& } r = 3$$

$$\text{Therefore } 6 = (2 * 4) - 3$$

$6 > 5$  therefore a Redundant frame



### Assumptions made in pin jointed truss

- The frame is perfect one
- All the members are pin jointed
- The frame is loaded at joint only
- The self-weight of the member is negligible
- The cross-sectional area of the member is uniform

### Analysis of truss

#### Method of Analysis of Truss

- Method of joints
- Method of section

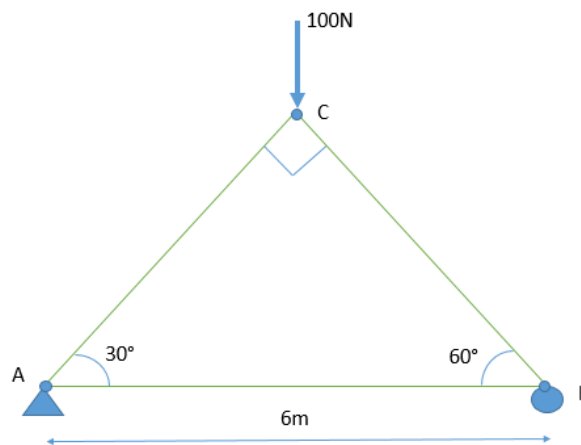
#### Method of Joints

- Finding out the nature of force in the member
- Every joint is considered separately as a free body in equilibrium
- The joint is selected in such a way that, **not more than two unknown forces occurs at any joint**
- Each of the joint will constitute a coplanar concurrent force system in equilibrium
- The unknown forces in the member are then determined by applying the conditions of equilibrium ie  $\sum F_x = 0$  &  $\sum F_y = 0$

**Method of Sections**

- Imaginary section is drawn through the members for which forces to be determined
- **Section should be drawn in such a way that it should not cut more than 3 members in which max of 2 should be unknown**
- Any one part of truss, on any one side of the section is treated as free body diagram
- By using the condition of equilibrium  $\sum M = 0$ , unknown forces can be determined

**Find out the forces in the member AB, BC & AC of the truss shown in fig**



**Solution**

From the triangle ABC,

$$\cos 30^\circ = \frac{AC}{AB} = \frac{AC}{6} \quad AC = 6 * \cos 30^\circ = 5.2\text{m}$$

From triangle ACD,

$$\cos 30^\circ = \frac{AD}{AC} = \frac{AD}{5.2} \quad AD = 5.2 * \cos 30^\circ = 4.5\text{m}$$

$$\sum F_x = 0, R_{AH} = 0$$

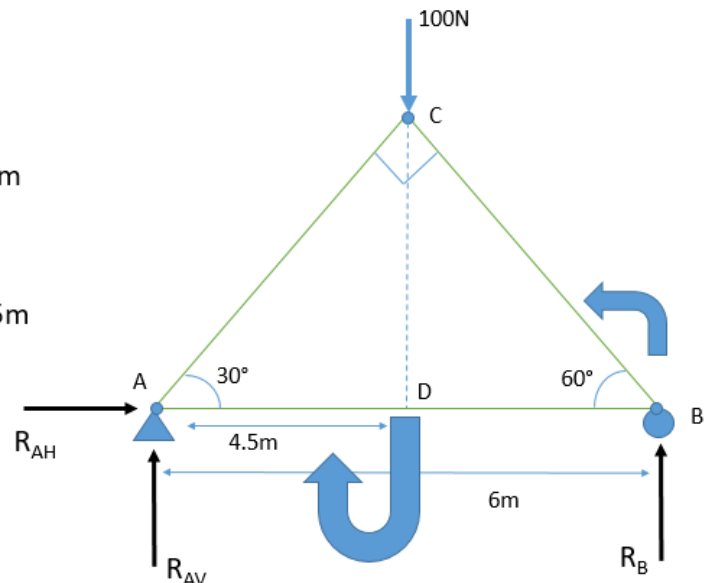
$$\sum F_y = 0, R_{AV} + R_B - 100 = 0$$

$$R_{AV} + R_B = 100$$

*Taking moment of forces about A*

$$\sum M_A = 0, (R_{AH} * 0) + (R_{AV} * 0) + (100 * 4.5) - (R_B * 6) = 0$$

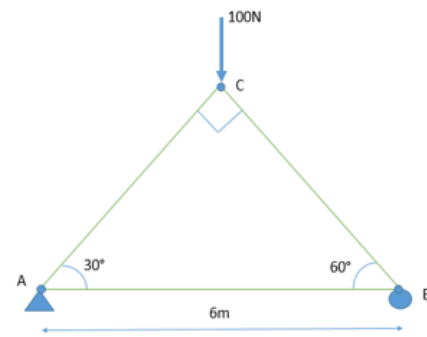
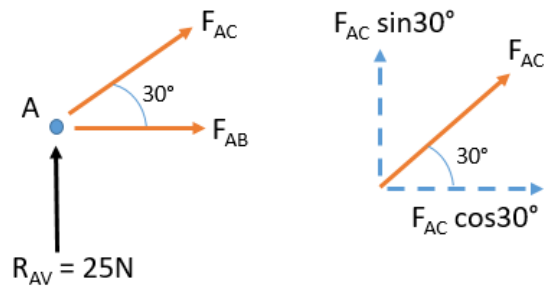
$$R_B = 75\text{N}$$



Wkt  $R_{AV} + R_B = 100$

$$R_{AV} + 75 = 100 \quad R_{AV} = 25\text{N}$$

Consider Joint A



$$\sum F_y = 0, 25 + F_{AC} \sin 30^\circ = 0$$

$$F_{AC} = -50\text{N (C)}$$

$$\sum F_x = 0, F_{AB} + F_{AC} \cos 30^\circ = 0$$

$$F_{AB} + (-50 * \cos 30^\circ) = 0$$

$$F_{AB} = 43.24\text{N (T)}$$

