ENGINEERING MECHANICS

STATICS

Definition of Engineering Mechanics:

Definition: Engineering Mechanics is a branch of Physical Science which studies the action of forces up on different bodies and the resultant motion that those bodies experience.

Applications of Engineering Mechanics (Applied Mechanics)

It enables the study of natural phenomena of locomotion of animals, orbits of planets, blood circulation, and mountain formation. Other practical applications of Engineering Mechanics widely used in the sectors such as automobiles, shipbuilding, refineries, engines, air planes, computers, medical science and railways.

Applied Mechanics facilitates the better understanding of civil engineering, nuclear engineering, computer science engineering, chemical engineering, electrical engineering, aerospace engineering and material science engineering. Major application of Engineering Mechanics in forensic engineering helps in typical analysis of traffic accidents.

The following chart gives you the idea about different sub-branches of Engineering Mechanics:

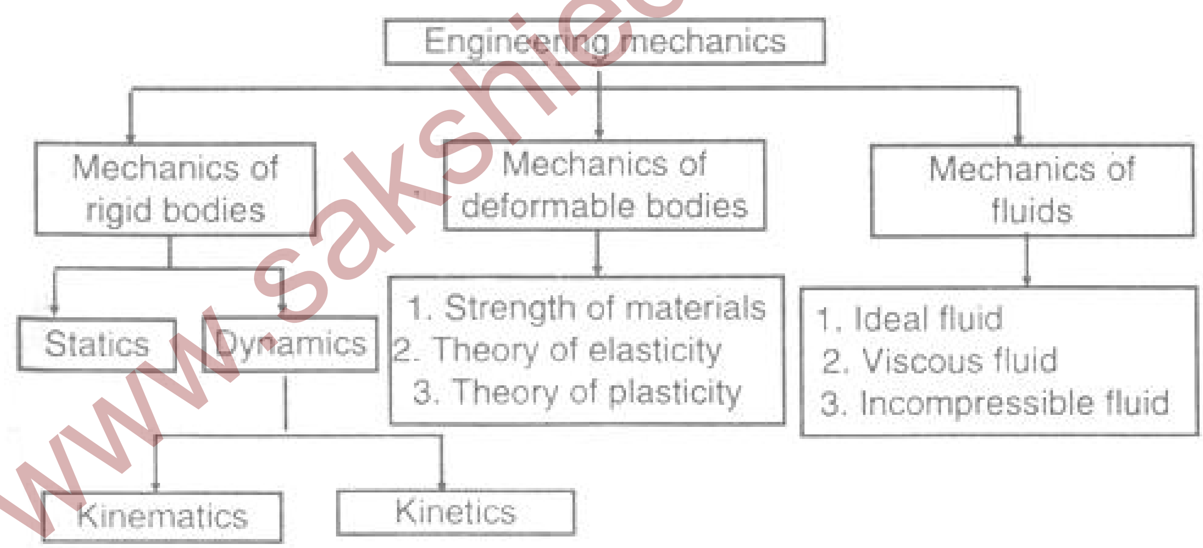


Figure 1: Outline of Engineering Mechanics

In this lesson, we shall focus on two topics viz. - Statics and Dynamics.

In Engineering Mechanics, all physical bodies (Mechanical Members) are considered as rigid bodies.

What is Rigid Body?

A Rigid Body can be defined as a definite amount of matter, the parts of which are fixed in position relative to other.

In short, when we apply load on a body, there wouldn't be any relative motion of the particles within the body.

But, in reality, the solid bodies are never rigid; they indeed deform under the pressure of the load.

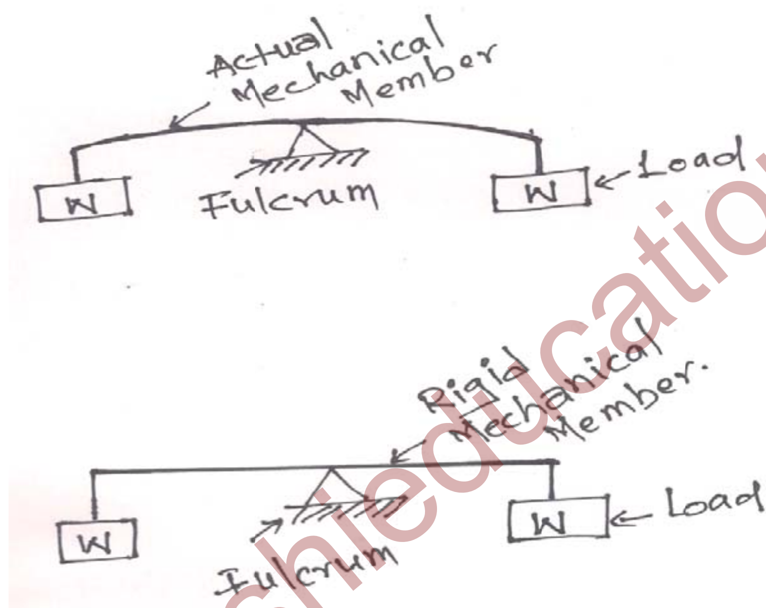


Figure 2: Schematic diagrams of Flexible and Rigid bodies for understanding

Best example for rigid bodies: While Internal Combustion Engine (IC Engine) is being designed; all the components would be assumed as Rigid Bodies (No deformation takes place).

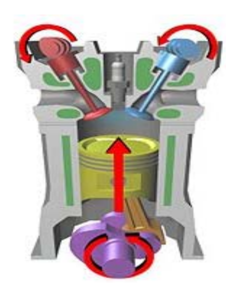


Figure 3: Solid Model of Internal combustion (IC) Engine as a rigid body

Flexible Rotor Blade (Aerofoil)

Best example for flexible body is Helicopter rotor blades.

Figure 4: IS-2 Helicopter with four rotor blades of Aerofoil shape

This rigid body Engineering Mechanics can be divided in to two branches as mentioned in the aforementioned tree. They are -

1. Statics
2. Dynamics

STATICS

Definition of Statics:

- It is a branch of Engineering Mechanics that concerned with the analysis of loads like force and torque (Moment) on physical bodies in static equilibrium.
- In short, it deals with the bodies having zero acceleration, that means the bodies are at rest or moving with constant velocity (i.e. total force in rest or zero with constant velocity.)
- In other words, sum of the forces must be zero.

$$\sum F=0$$

In Statics, we describe the motion of the bodies using Newton's second law of motion-

Force=Mass x Acceleration

$$F=M \times a \quad ; \qquad \sum F=0$$

Mass:

It is a property of a physical body which determines the bodies resistance to being accelerated by a force (Denoted by m, SI units are 'kg') .

What we are measuring by using simple balance is ***Mass*** .

Figure 5: Simple balance with standard weight and component to be measured

Principle of Transmissibility:

The Principle of Transmissibility of a force states that the external effect of the force on rigid body is same for all points of application along its line of action.

This also states that the conditions of equilibrium or conditions of motion of a rigid body will remain unchanged if force acting at a given point of the rigid body is replaced by a force of the same magnitude and same direction, but acting at a different point, provided that the two forces have the same line of action.

The below figure will gives the detailed representation of the principle of transmissibility.

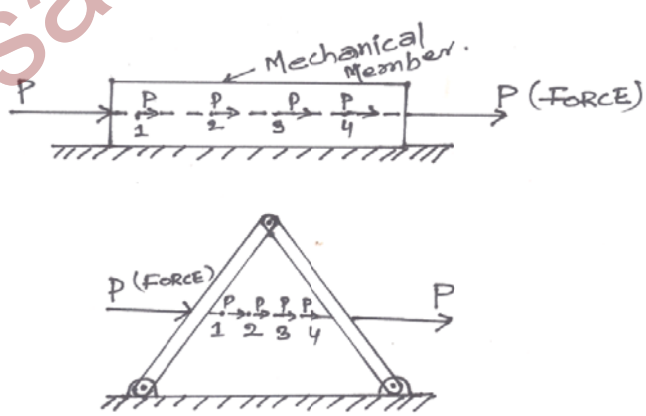


Figure 6: Representation of Principle of Transmissibility

In simple words, from above figure, if the force (P) acting on the body in a particular direction, the magnitude of that force is same along the length of the body and direction at point like 1,2,3,4 etc.

Let us see this image and try to understand the Principle of Transmissibility.

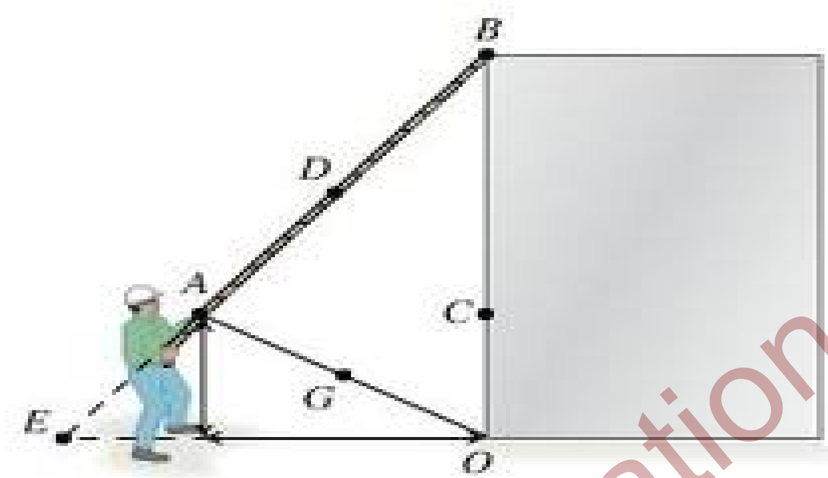


Figure 7: Schematic diagram for representing Principle of Transmissibility

From the above figure, Principle of Transmissibility is the force acting along the points E, A, D, B is same and similarly the resultant force acting along the points A, G, O is same weather it is pushing or pulling force.

Scalar and Vector Quantities:

Generally in Engineering Mechanics, there are three types of quantities to represent force and velocity.

1. Scalar Quantity --- Consists only Magnitude

2. Vector Quantity --- Consists both magnitude and direction

3. Tensor Quantity --- Consists magnitude but require two or more directional aspects to describe completely.

Representation of Vector:

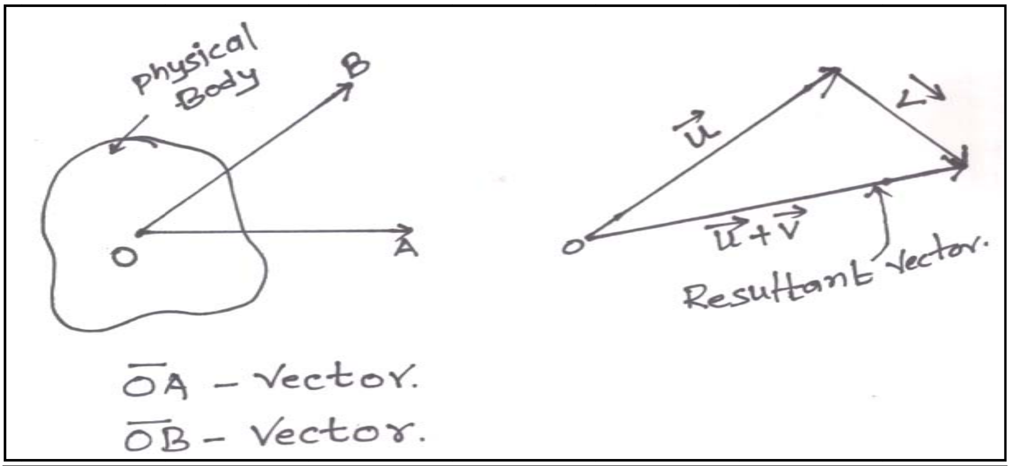


Figure 8: Representation of vector and vectors with triangle law

We can go through some of the *Scalar* and *Vector* Quantities in the following table -

Scalar Quantities	Vector Quantities
Length, Area, Volume	Displacement
Speed	Velocity
Mass	Acceleration
Density	Momentum
Pressure	Force
Temperature	Lift
Energy	Drag
Entropy	Thrust
Work, Power	Weight

***Free- body diagram* and its necessity in engineering mechanics**

- It is a sketch of the isolated body which show only the forces acting upon it by the removed elements is defined as a *free- body diagram.*
- Typically we will draw the free body diagram to show all forces on a body at rest.
- Free-body diagram help us to distinguish between action and reaction forces.

The following table will give the conversion of actual diagram in to the *free- body diagram* -

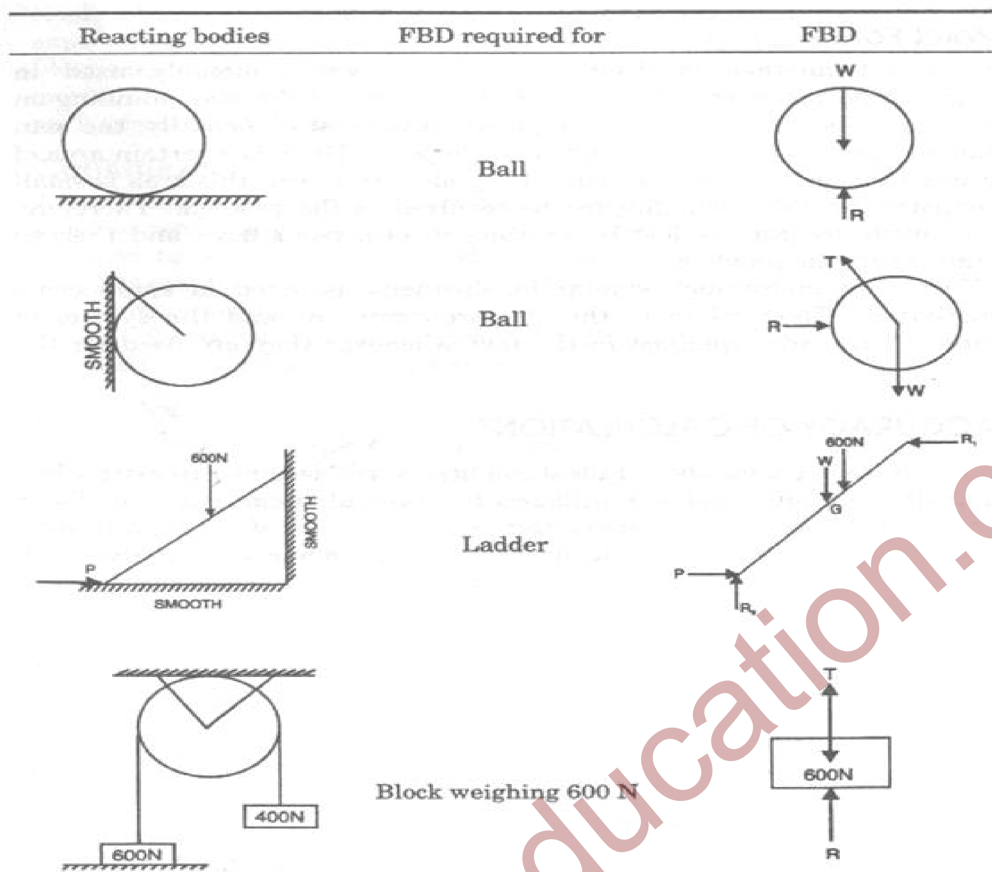


Figure 9: Actual system diagram with reaction bodies and free body diagrams

Detailed explanation of conversion into actual diagram to free body diagram

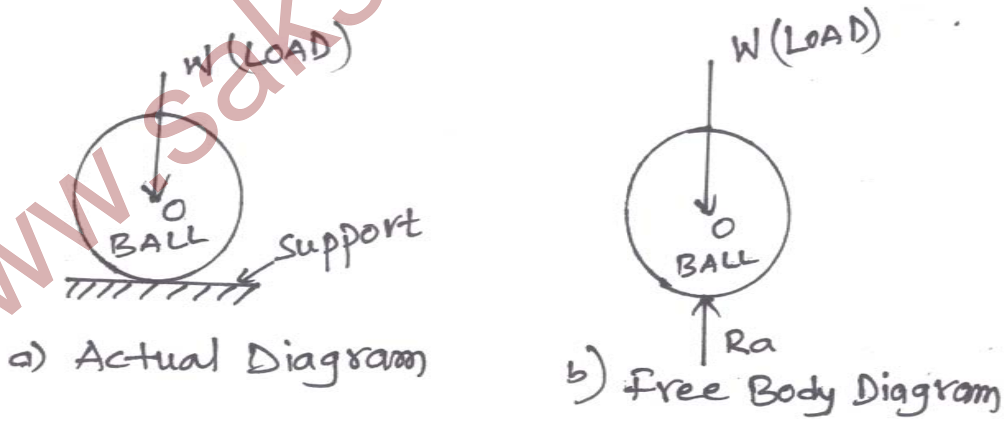


Figure 10: Ball with horizontal support and free body diagram

The support for the ball will be replaced with the reaction force R_a .

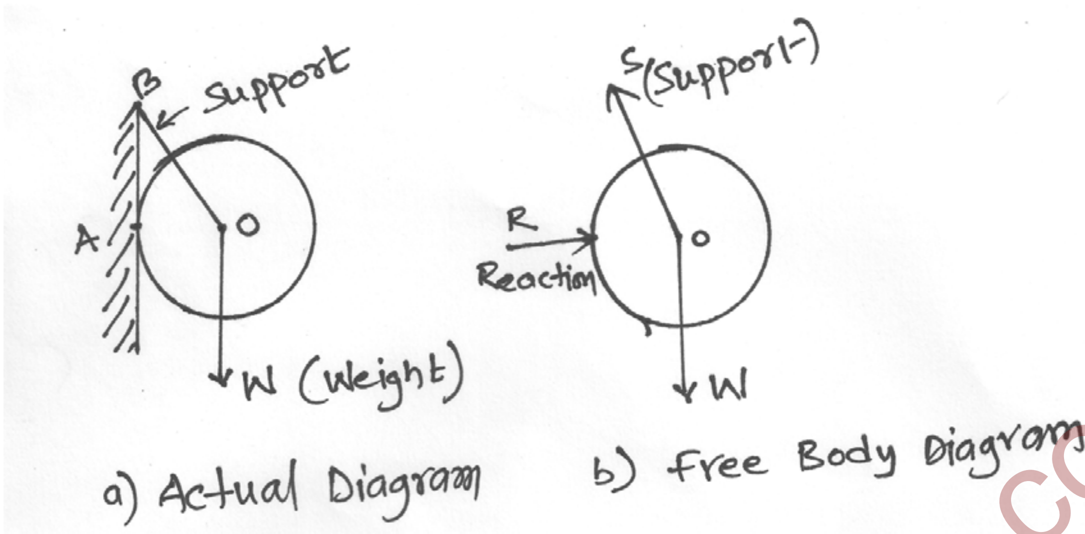


Figure11: Ball with Vertical support and free body diagram

In above figure 5 (b) & 6 (b) are completely isolated from support and in which all forces acting on it are shown in vector is called *free- body diagram*

Equilibrium Law

Two forces can be equilibrium only if they are equal in magnitude, opposite in direction and collinear in action.

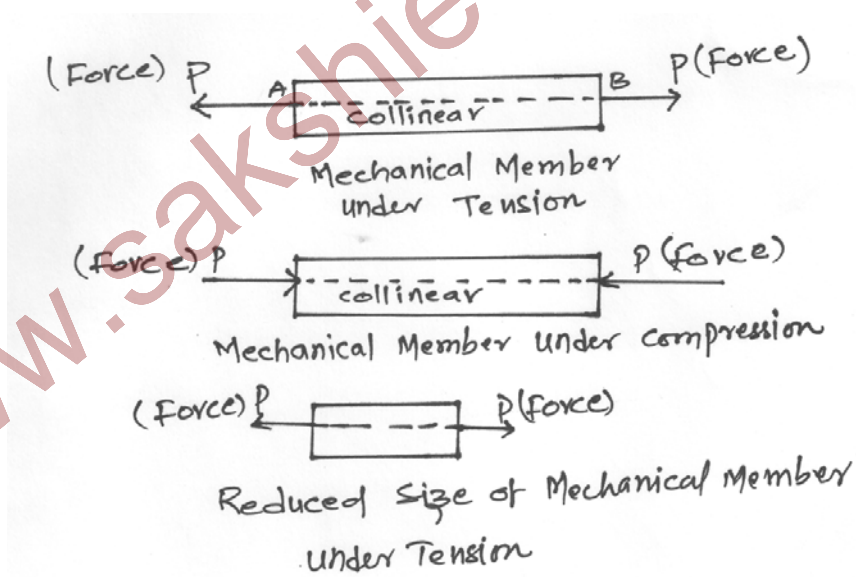


Figure 12: Mechanical members under Equilibrium law of forces

Parallelogram Law:

If two forces, represented by vector OA and OB acting under an angle of α are applied to body at point 'O', their action is equivalent to the action of one force represented by the vector OC -

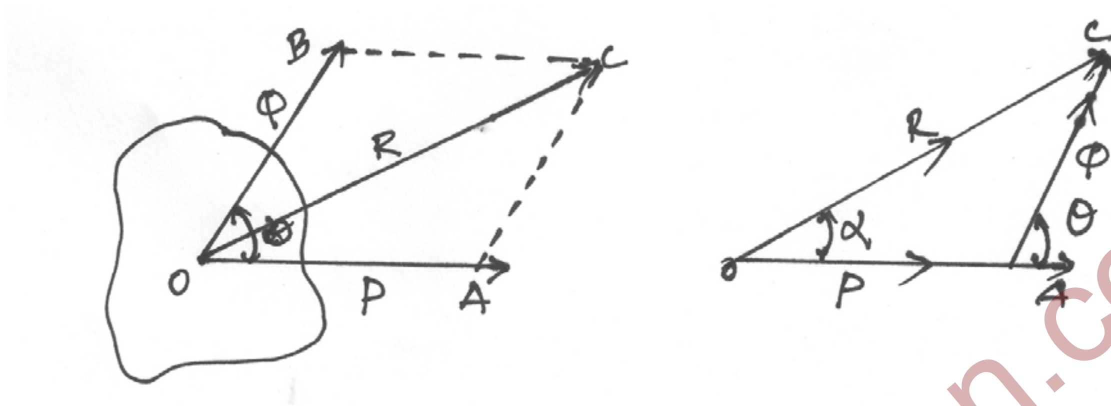


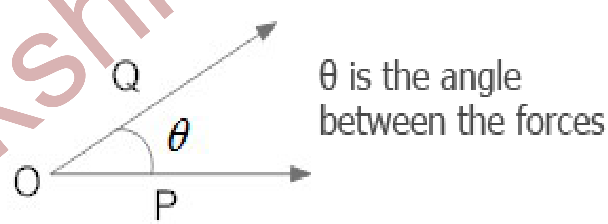
Figure 13: Parallelogram law of forces

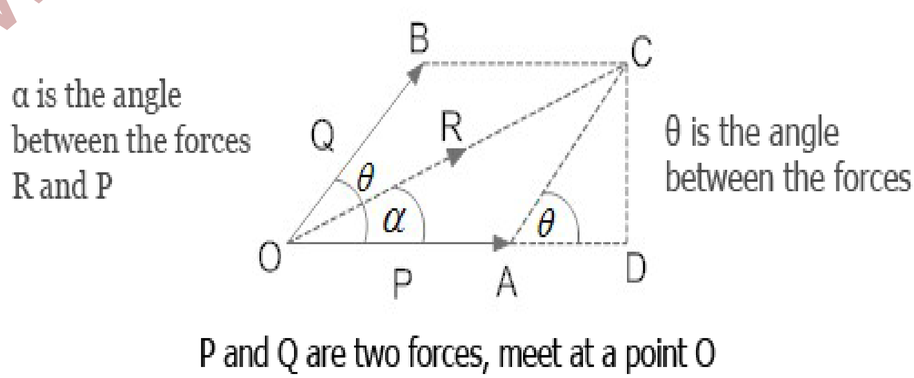
From above figure the vector OC is called Resultant of two vectors OA & OB.

The vectors OA & OB called components of OC.

- Derivation to calculate the resultant force OC(R):

Let us take OA=P & OB=Q





Now $\angle CAD = \alpha$ :: because $OB // CA$ and OA is common base.

In ΔACD :: $\cos\alpha = AD/AC \Rightarrow AD = AC\cos\alpha$

:: But $AC = Q$; *i.e.*, $AD = Q\cos\alpha$ ...(*i*)

And $\sin a = CD/AC \Rightarrow CD = AC\sin\alpha$

$\Rightarrow CD = Q\sin\alpha$ ...(*ii*)

Now in $\Delta OCD \Rightarrow OC^2 = OD^2 + CD^2$

$$\Rightarrow R^2 = (OA + AD)^2 + CD^2$$

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

$$\Rightarrow = P^2 + Q^2\cos^2\alpha + 2PQ\cos\alpha + Q^2\sin\alpha$$

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

Triangle Law:

If two forces are represented by their force vectors placed tip-to tail, their resultant is the vector direction from tail of the first vector to that tip of the second vector-

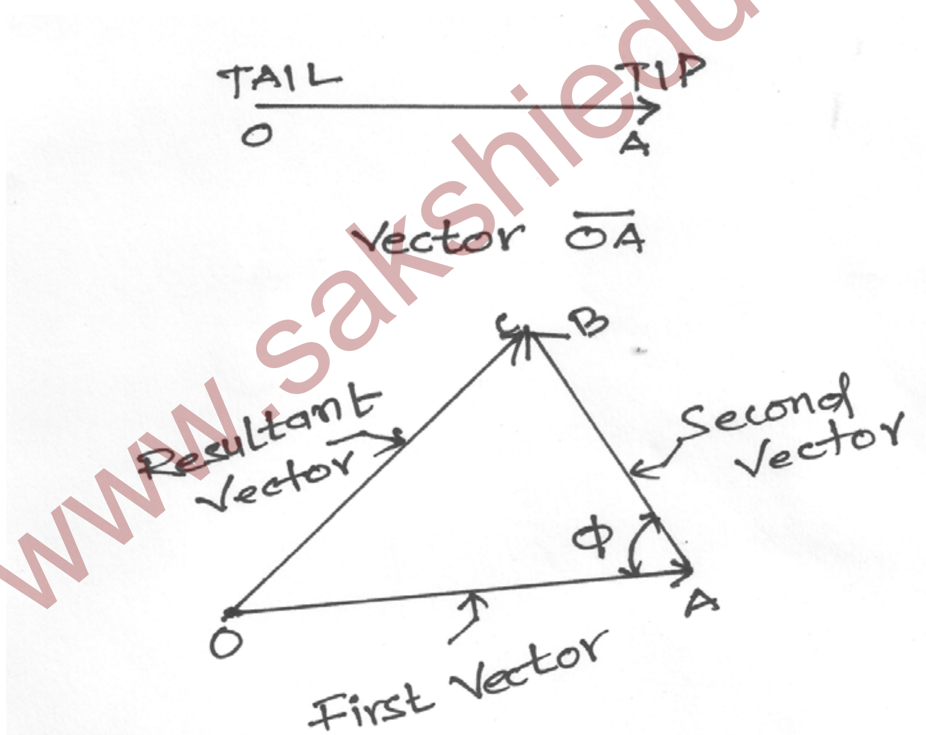


Figure 14: Triangle Law of Forces

If the α=0 or Ø=180 is called collinear forces, in this case sum of the two vectors OA and OB gives the resultant vector.

R=OA+OB

Force System:

Generally the forces acting on any object will be divided two forces they are-

1. Co-planer

2. Non Co-planer

These forces can be further divided as follows in the below chart:

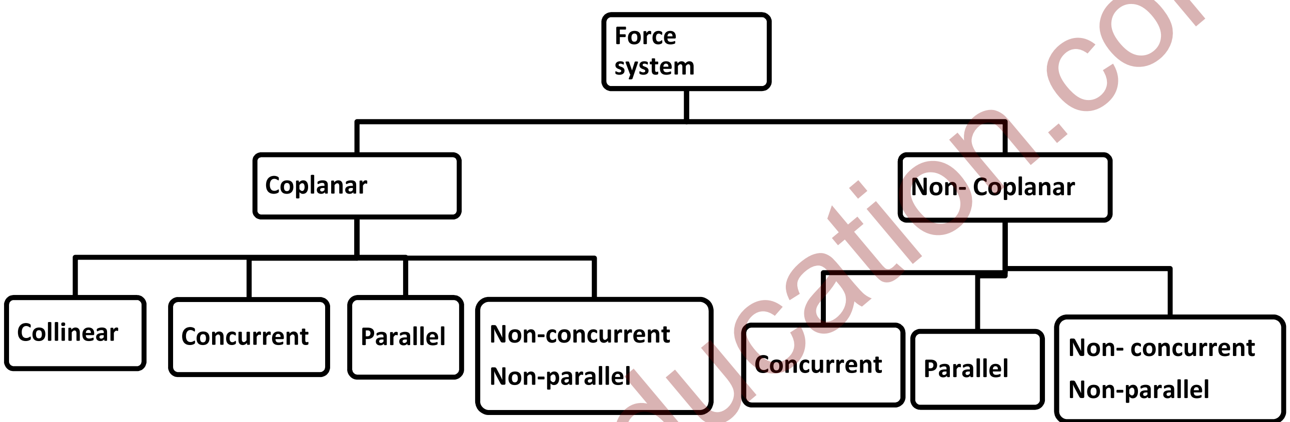


Figure 15: Tree for system of forces on any object

Concurrent Forces in a Plane:

A concurrent force system contains force, whose lines of action meet at some one point; force may be tensile (Pulling) or compressive (Pushing)

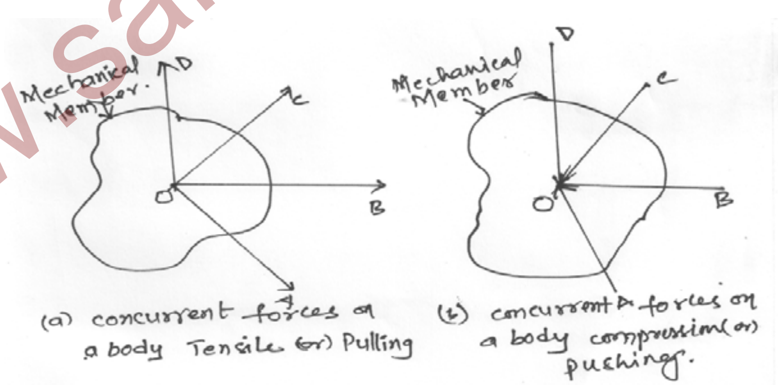


Figure 16: Concurrent forces in a plane

In the coplanar concurrent force system all the forces acts in only any one plane.

To determine the resultant of three or more concurrent forces that are not collinear requires determining the sum of three or more vectors

- We can go through the below example to better understand the concurrent forces in a plane.

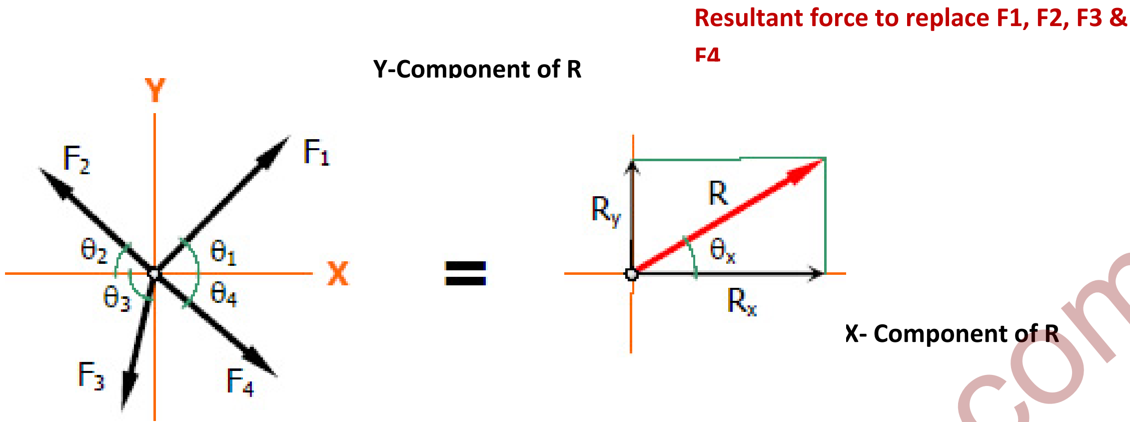


Figure 17: Replacing the concurrent forces with equivalent resultant force

- The forces F1, F2, F3, F4 Concurrent forces acting with the angles of θ1, θ2, θ3, θ4 respectively.
- all above forces can be replaced with the resultants force R with an angle of θx with x-axis
- where R_x and R_y are the X and Y components of Resultant force vector R

- R. SUDHAKAR

Scientist, DRDO.