CGPA BOOSTER

Unit 1
Introduction to Mechanics

Study of behaviour

Background

Linear mathematical Relation

Assumption → Neglecting → Sol. is approximate

- The branch of physical science that deal with the state of rest or the state of motion of bodies is termed as **Mechanics.**
- The mechanics has grown into the analysis of complex structures like multi-storey buildings, aircrafts, space crafts and robotics under complex system of forces like dynamic forces, atmospheric forces and temperature forces.
- Archimedes (287–212 BC), Galileo (1564–1642), Sir Issac Newton (1642–1727) and Einstein (1878–1955) have contributed a lot to the development of mechanics. The mechanics developed by these researchers may be grouped as

Laws by Newton [Newtonian physics]

(i) Classical mechanics/Newtonian mechanics

Statics

(ii) Relativistic mechanics — [Relativity] →

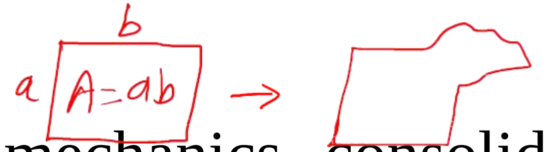
(iii) Quantum mechanics/Wave mechanics. — [Probalistic - microscopic]

Pressure = Force / Area

random motion of Particles

Background

Defined geometrical Shapes & Linear Relations



- Sir Issac Newton, the principal architect of mechanics, consolidated the philosophy and experimental findings developed around the state of rest and state of motion of the bodies and putforth them in the form of three laws of motion as well as the law of gravitation.
- Albert Einstein proved that Newtonian mechanics fails to explain the behaviour of high speed (speed of light) bodies. He putfourth the theory of **Relativistic mechanics.**
- Schrödinger (1887–1961) and Broglie (1892–1965) showed that Newtonian mechanics fails to explain the behaviour of particles when atomic distances are concerned. They putforth the theory of **Quantum mechanics.**

For all the problems between atomic distances to high speed distances there are various engineering problems for which Newtonian mechanics has stood the test of time and hence is the mechanics used by engineers.

In this Course we will deal with the application of Newtonian mechanics to solids

Basic Concepts

Law of Inertia?

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

- **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.

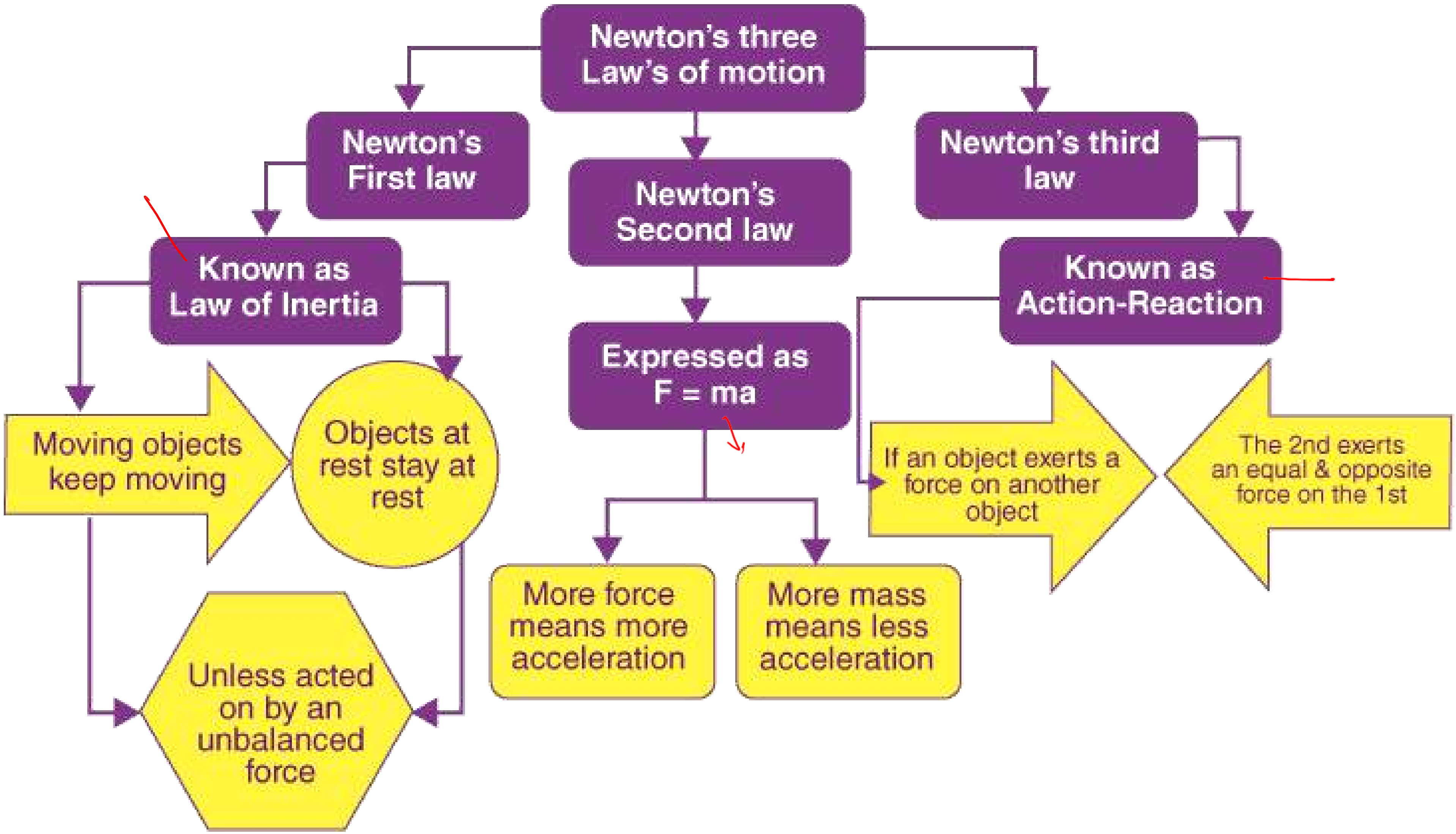
$m \times v$

in magnitud.

direction

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

Basic Concepts



Basic Terminologies in Mechanics [Language].

occupies space

- **Mass:** The quantity of the matter possessed by a body is called mass. Mass is a measure of the inertia of a body, which is its resistance to a change of a velocity. The mass of a body effects the gravitational attraction force between it and other bodies.

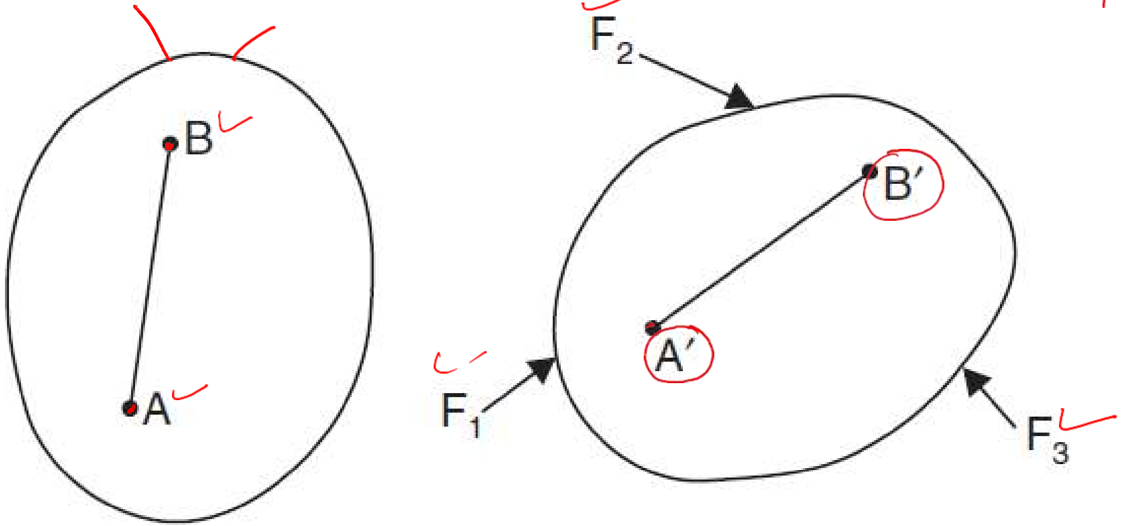
- **Time:** The time is the measure of succession of events. The successive event selected is the rotation of earth about its own axis and this is called a day. Time is not directly involved in the analysis of statics problems.

- **Space:** The geometric region in which study of body is involved is called space. A point in the space may be referred with respect to a predetermined point by a set of linear and angular measurements. The reference point is called the *origin* and the set of measurements as *coordinates*.

Basic Terminologies in Mechanics

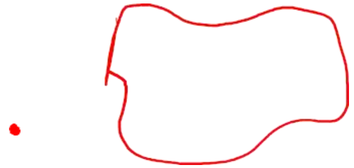
- **Length:** It is a concept to measure linear distances. m, mm, km -- -- -
- **Continuum:** The body is assumed to be a continuous distribution of matter. (Assumption).
- **Rigid Body:** A body is said to be rigid, if the relative positions of any two particles do not change under the action of the forces acting on it.

Deformation under the action of forces is not considered.



$$A'B' = AB$$

Basic Terminologies in Mechanics



- **Particle:** A particle may be defined as an object which has only mass and no size. Theoretically speaking, such a body cannot exist. However, in dealing with problems involving distances considerably larger compared to the size of the body, the body may be treated as a particle, without sacrificing accuracy.

  For example:

  — A bomber airplane is a particle for a gunner operating from the ground.

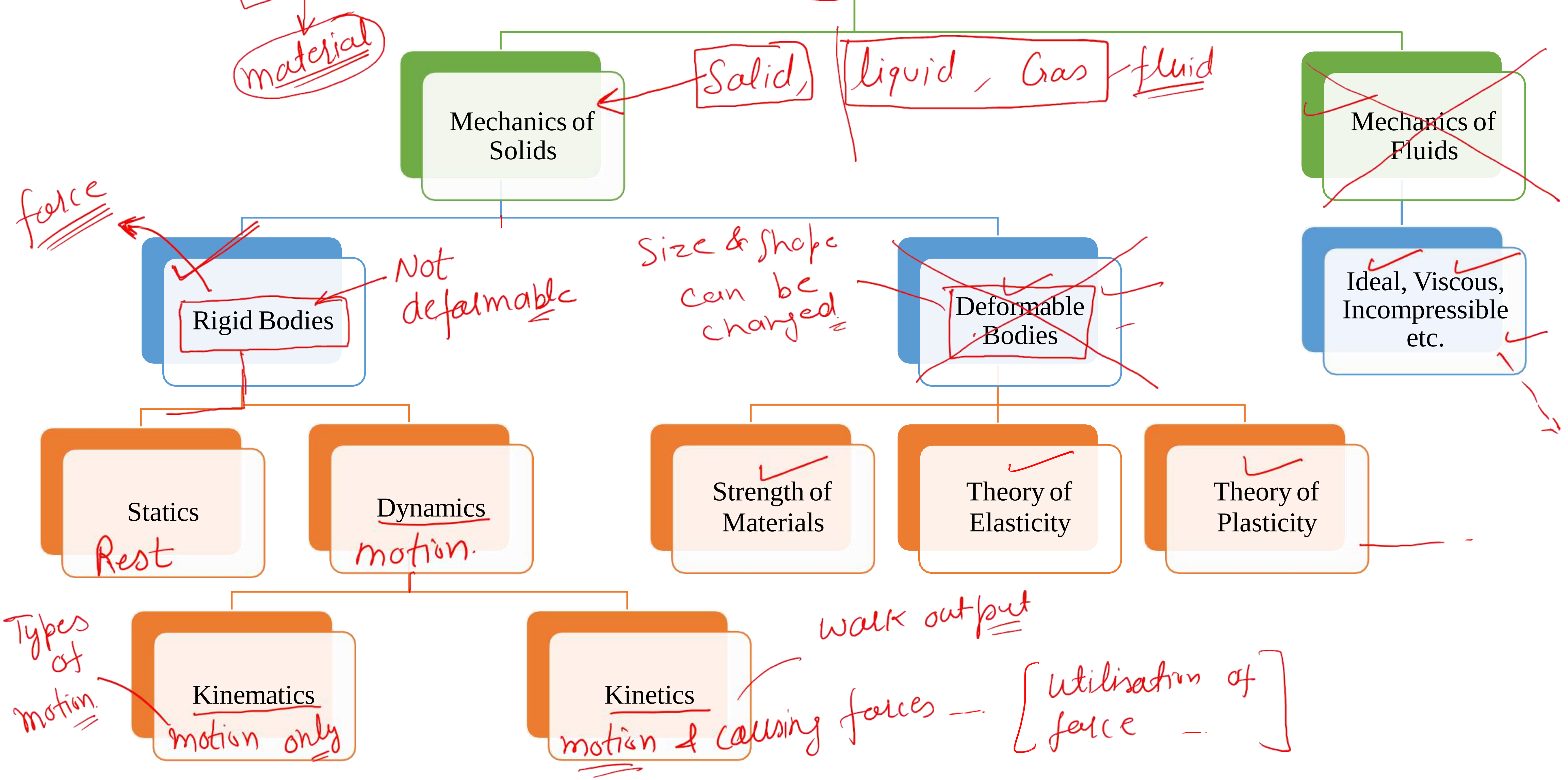
  — A ship in mid sea is a particle in the study of its relative motion from a control tower.

  — In the study of movement of the earth in celestial sphere, earth is treated as a particle.

Solution → Devices → material

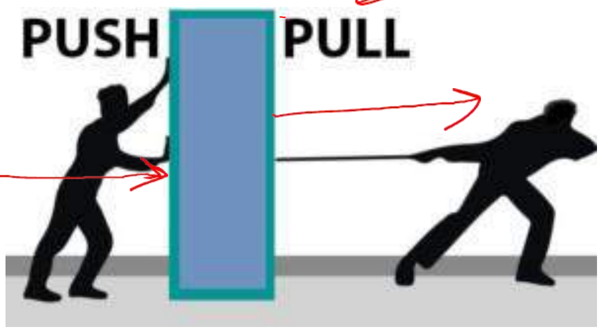
Engineering Mechanics

Behaviour



Laws of Force

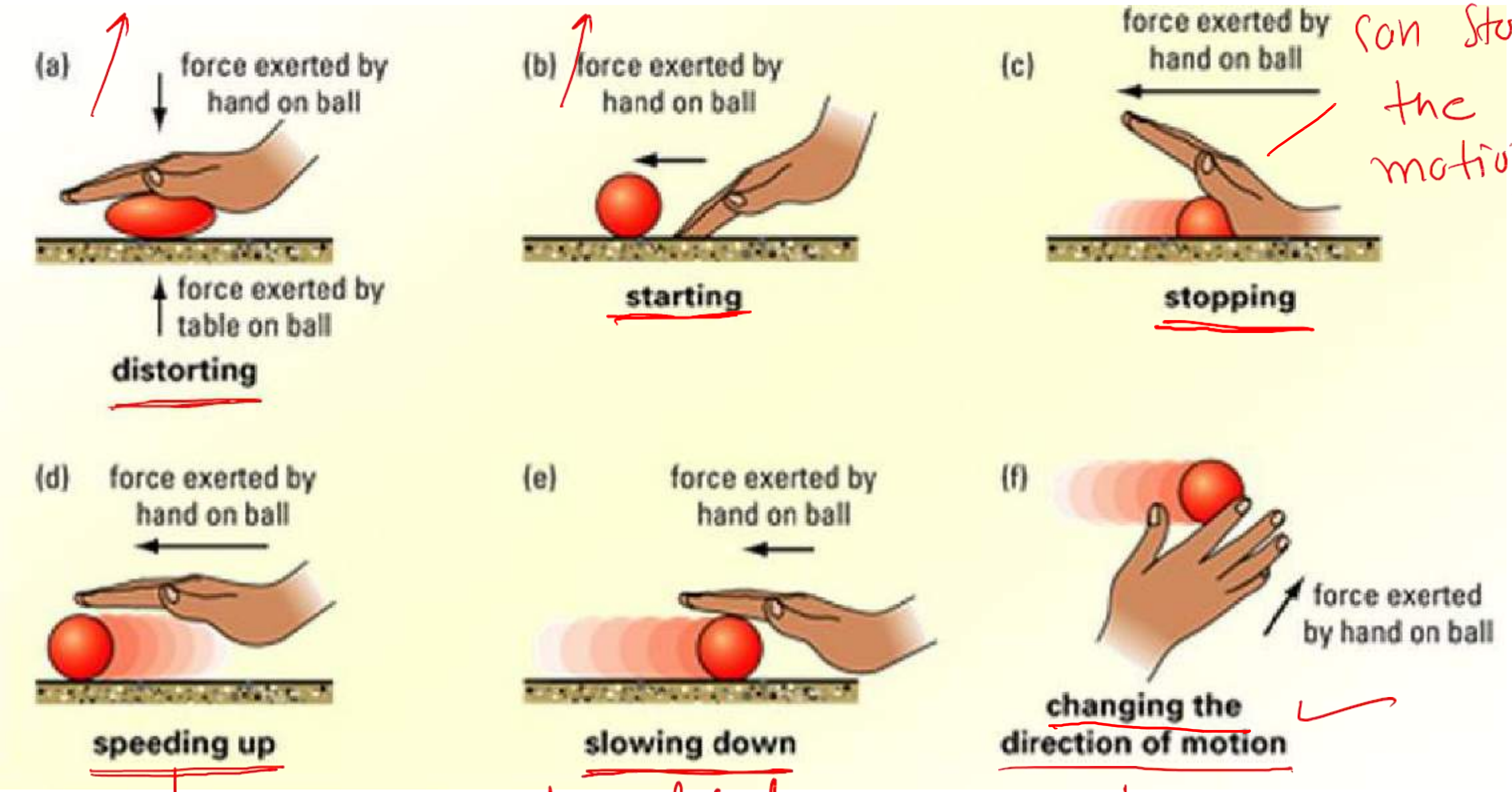
- Force:



Change the shape of object

can start the motion

can stop the motion



Accelerate the moving body

deaccelerate or retard the moving body

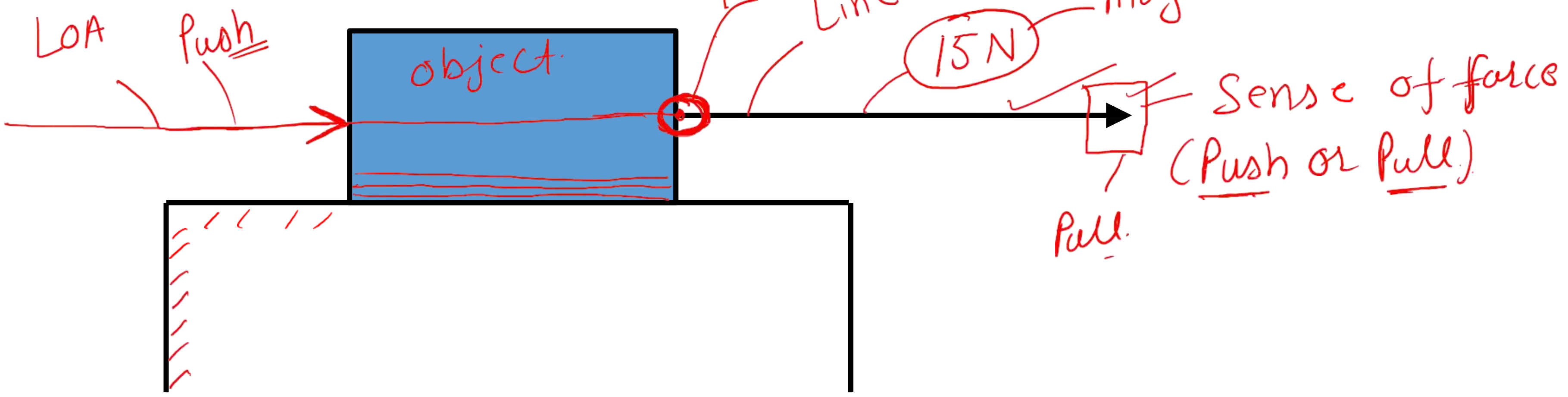
divert

Laws of Force

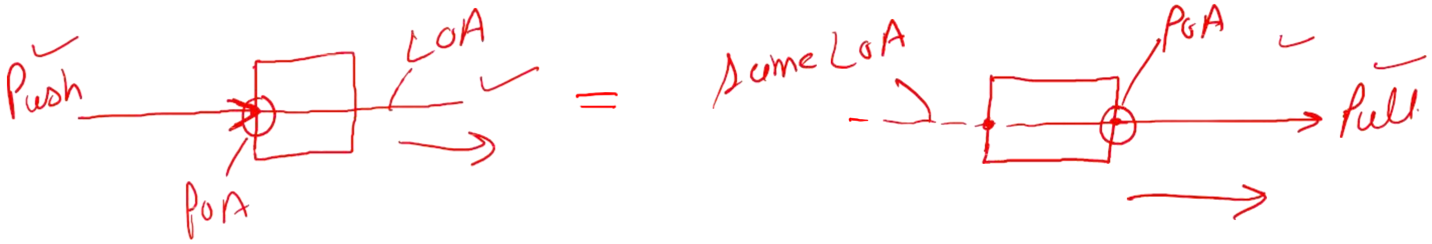
- Characteristics of a Force / Representation of force

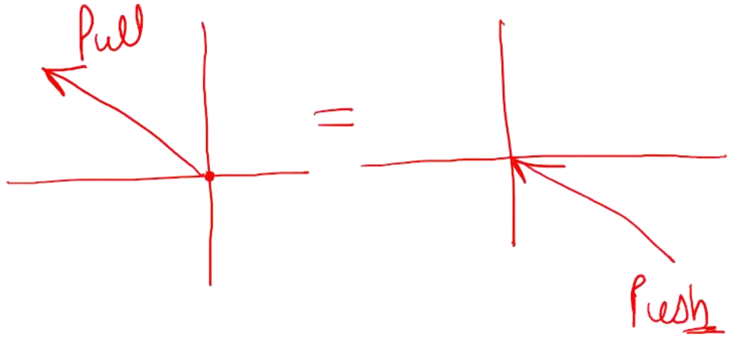
① PoA ② LOA

③ Sense ④ Magnitude



Principle of transmissibility :→ A given force can be represented at any other POA at same LoA without changing its final effect.



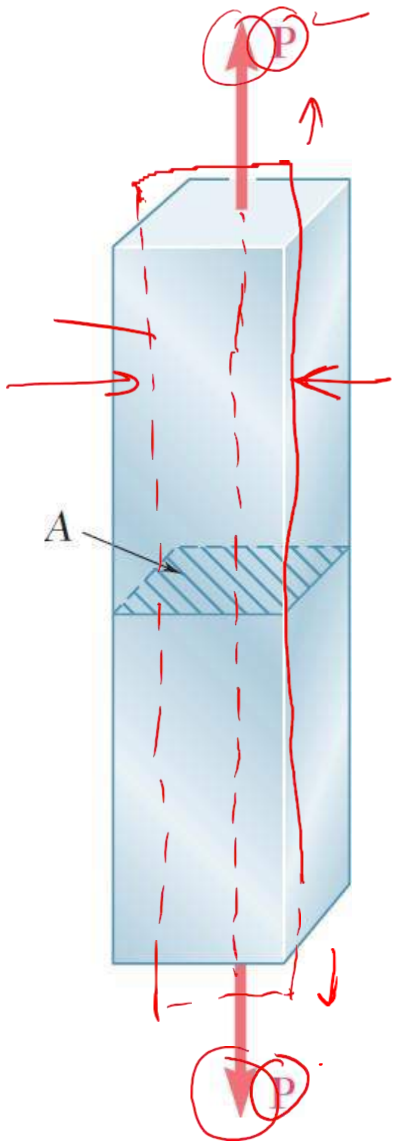


Types of Forces

- Tensile Force: Two forces, equal in magnitude, opposite in direction. acting on same LOA and pointing outwards the object.

  effect :→ → to increase the dimention in longitudinal direction

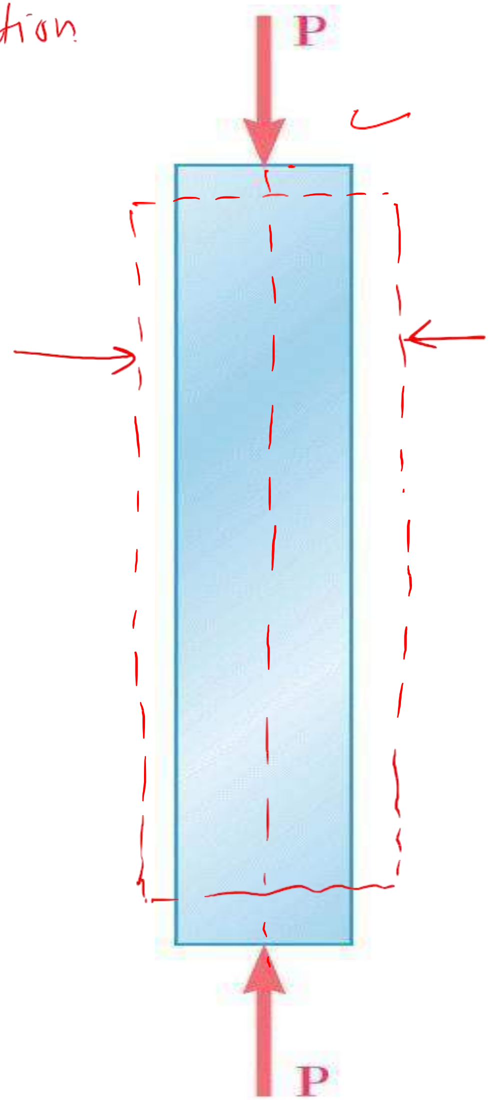
  → to decrease the dimension in lateral direction.



• Compressive Force: Two forces, equal in magnitude, opposite in direction acting on same LoA and pointing towards the object.

effect :→ → to decrease the dimension in longitudinal direction

→ to increase the dim. in lateral direction

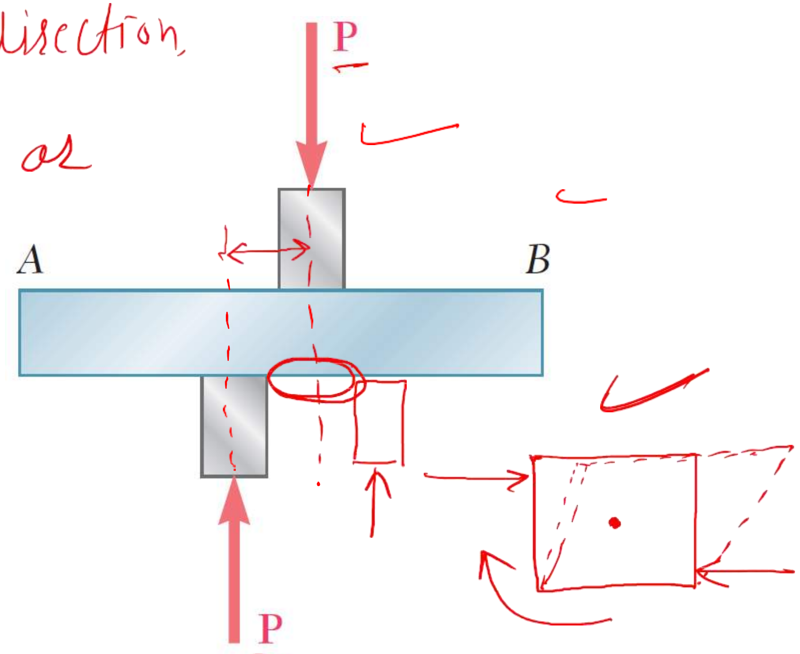


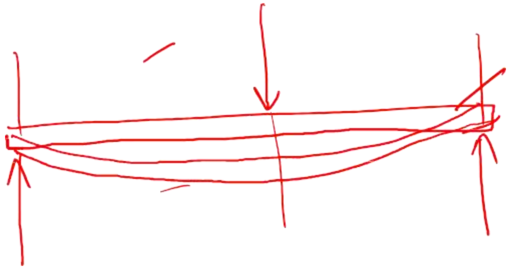
- Shear Force: Two forces, equal in magnitude, opposite in direction, acting at different and parallel LoA but may be towards or outwards the object.

effect:-> Shearing, cutting, Punching, Bending.

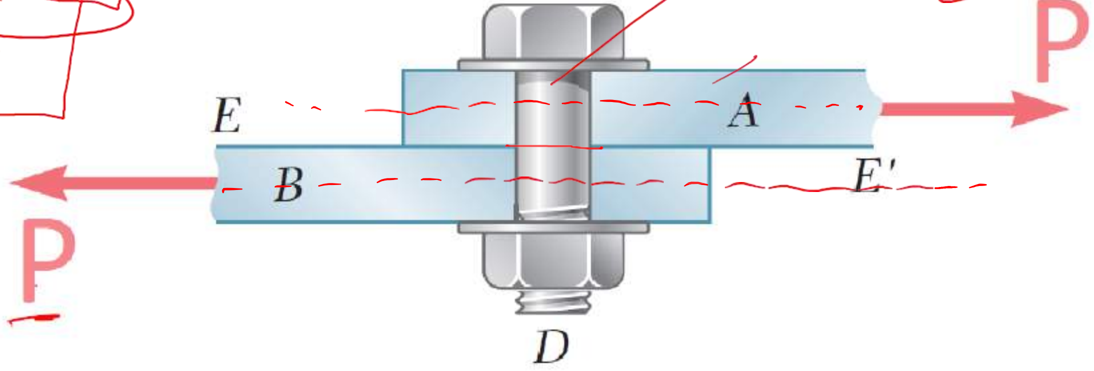
Tearing,

Rotation* (force should act as couple)





Shearing

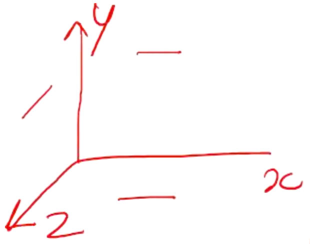


System of Forces

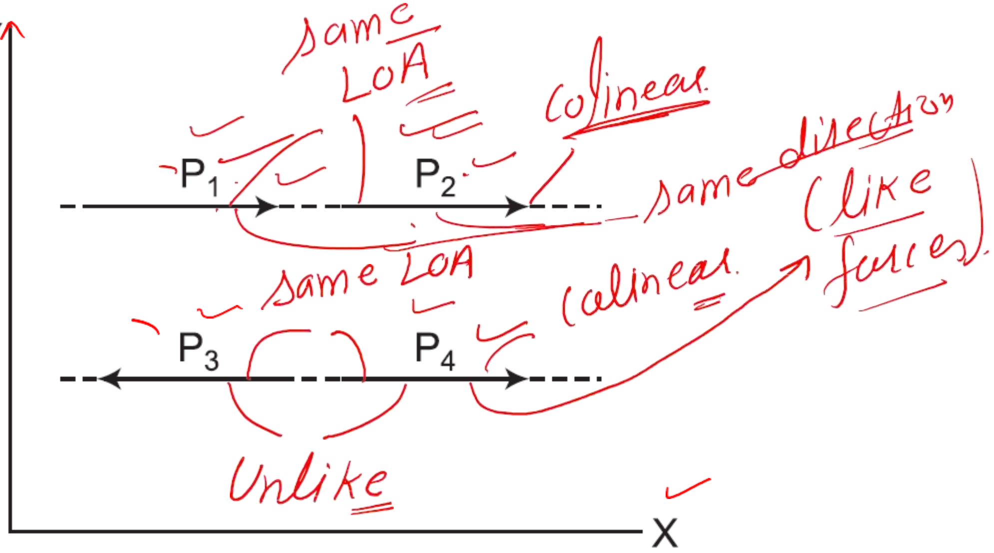
the way in which the forces are acting

- Coplaner
  Single Same Plane.
  2D
  - Colinear
  - Concurrent
  - Parallel
    - Like
    - Unlike
  - non con-current forces
- Non-coplanar
  forces act in different Planes
  3-D
  - Concurrent
  - Parallel
  - Non-con-current-non-parallel

System of Forces (Coplanar) → Same Plane.

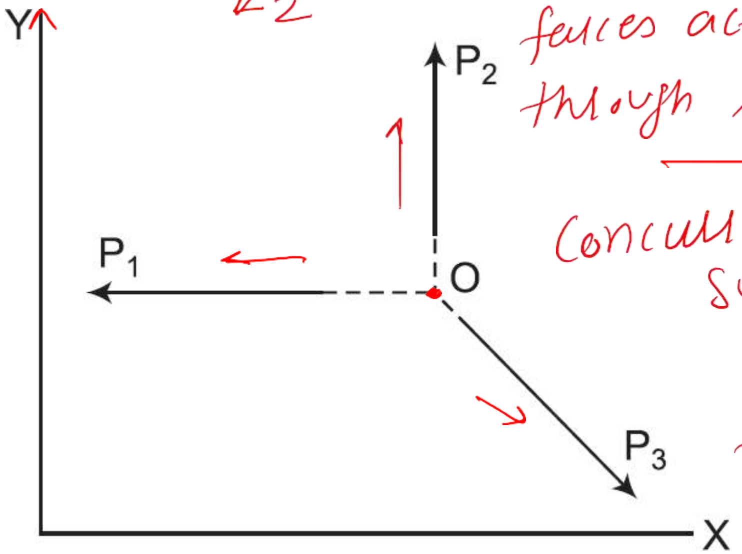


Colinear system of forces

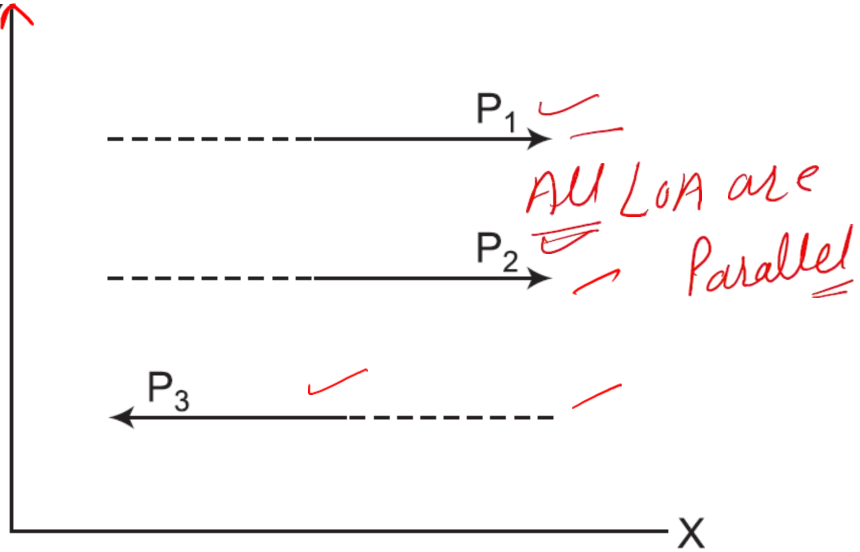


forces acting on/through same POA

Concurrent system of forces.

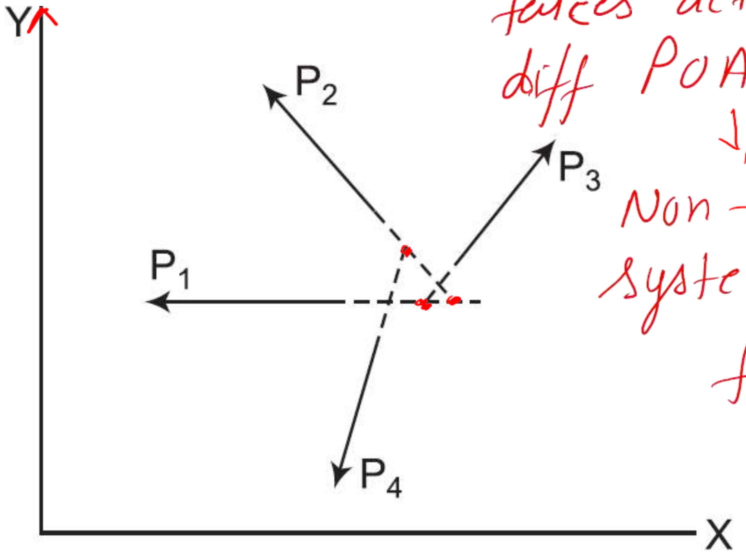


Parallel system of forces



forces acting on diff POA

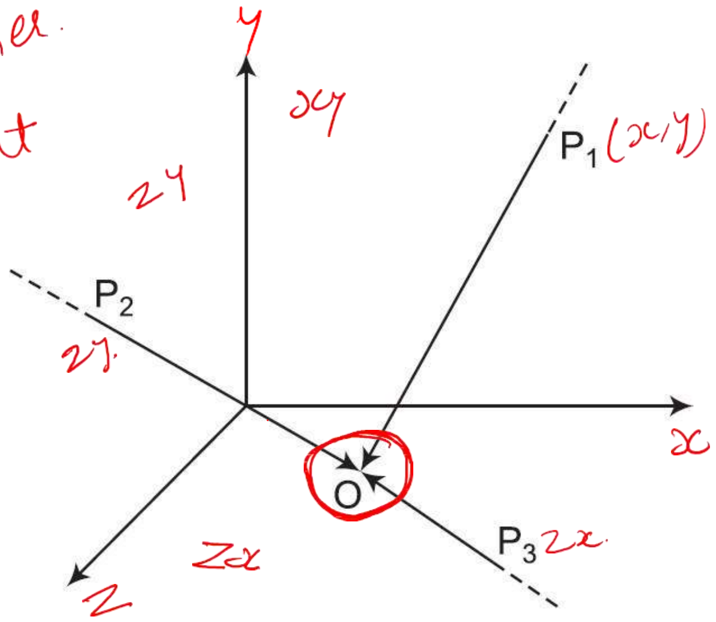
Non-concurrent system of forces

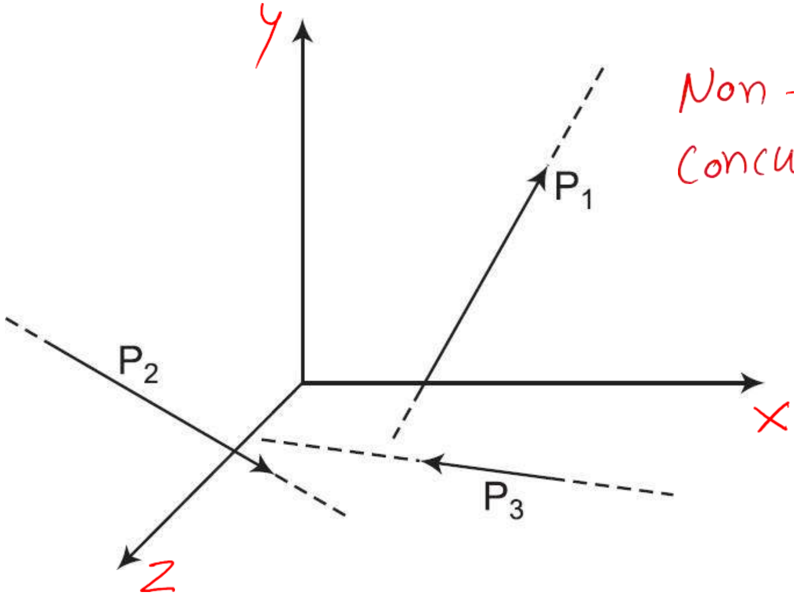


System of Forces (Non-Coplaner)

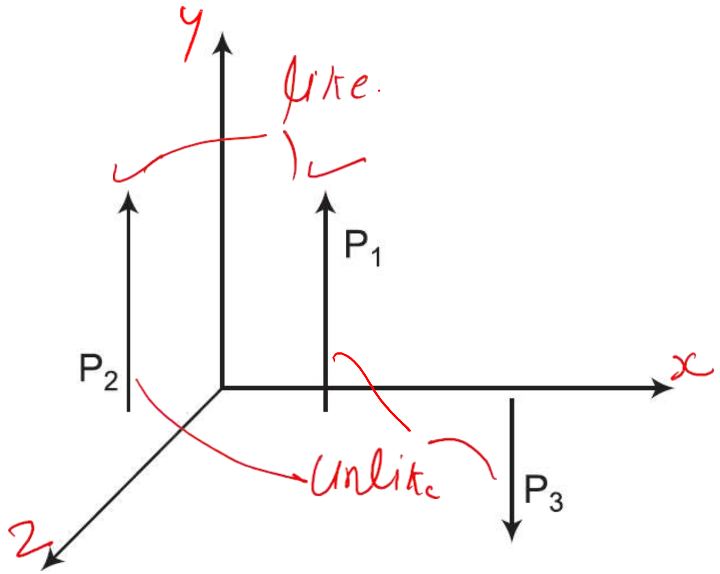
forces acting in diff Planes.

No-coplaner concurrent system of force.



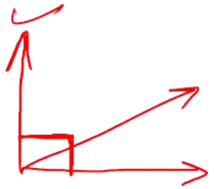


Non-concurrent.



Parallel

Resolution of a Force

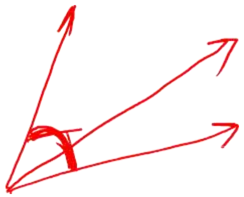


- Resolution is the process of splitting up the given force into components, without changing its effect on the body.

- There are mainly two methods of resolving a force.

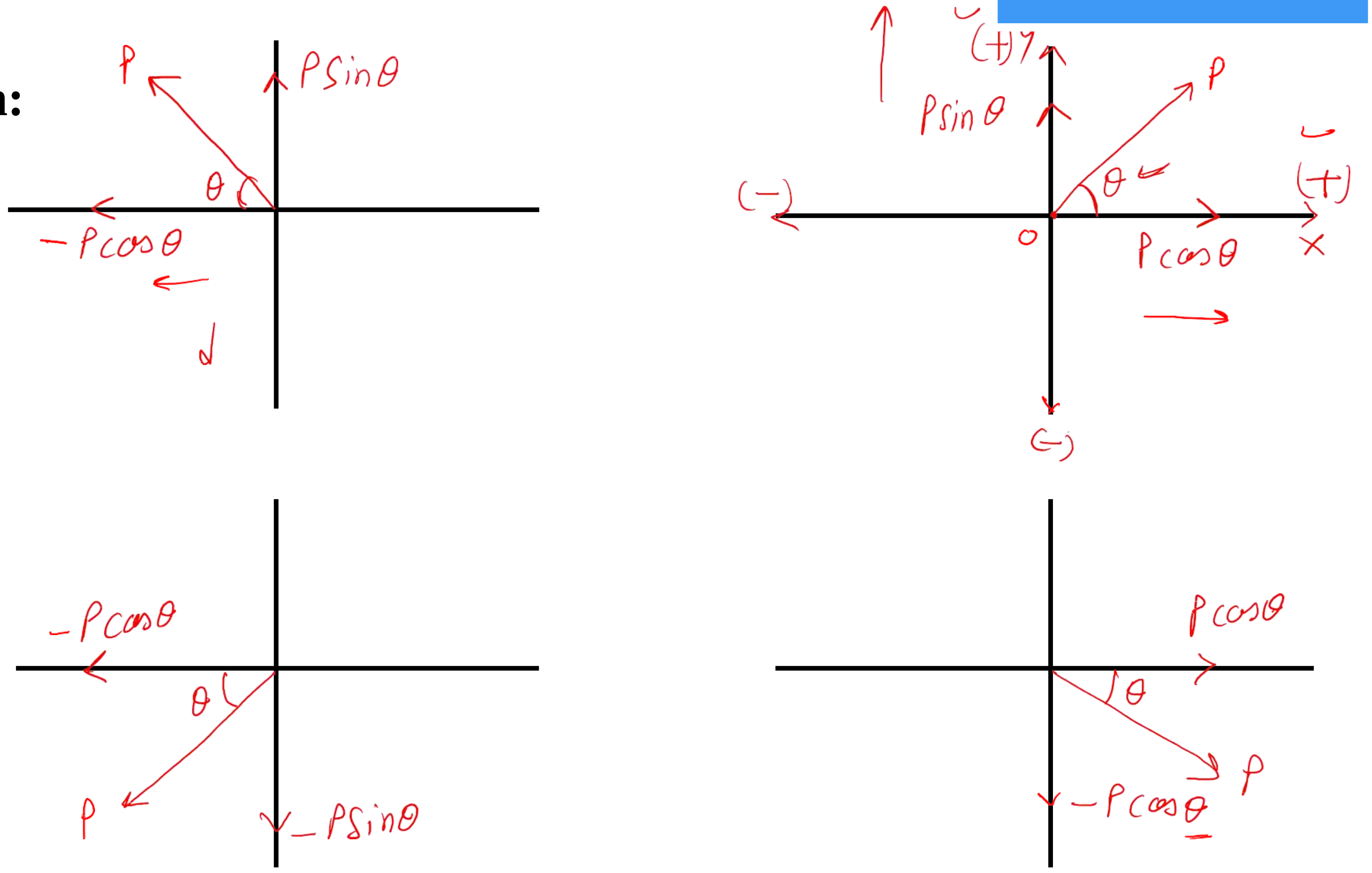
1. **Perpendicular resolution**: Perpendicular resolution is the general method of splitting up a single force into two mutually perpendicular directions. Two perpendicular components are acting along x-axis and y-axis or any two perpendicular axes.

2. **Non-perpendicular resolution:** In non-perpendicular resolution a force is resolved into two directions which are not perpendicular to each other.



Resolution of a Force

- **Perpendicular resolution:**



Resolution of a Force

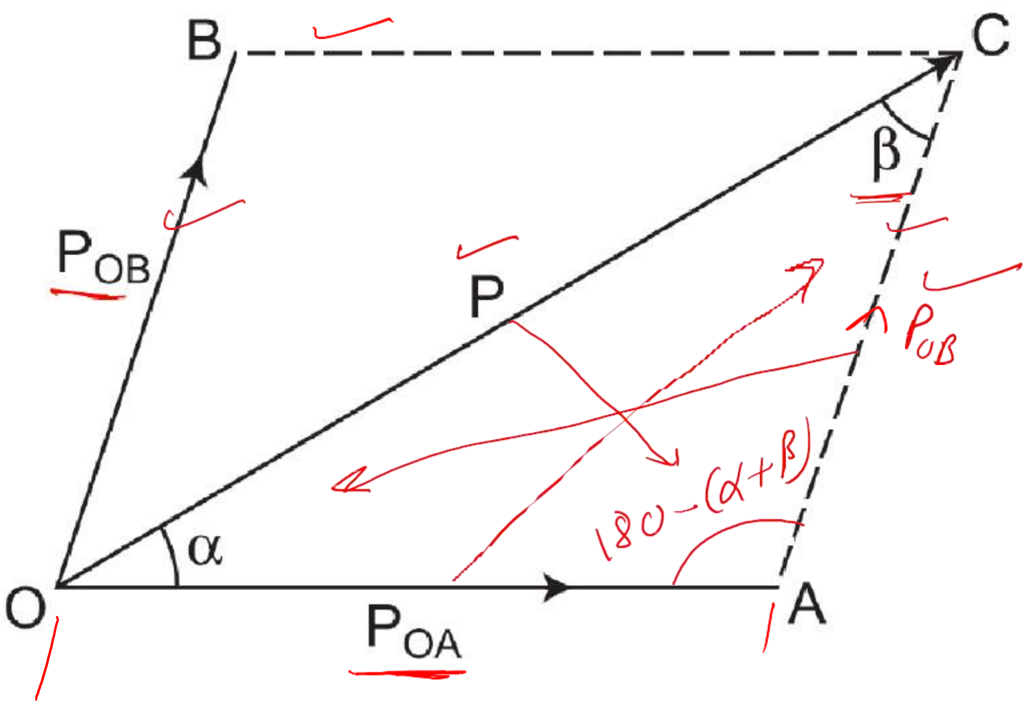
Parallelogram method (graphical method)

- **Non-perpendicular resolution:**

Sine law :-

$$\frac{P_{OA}}{\sin\beta} = \frac{P_{OB}}{\sin\alpha} = \frac{P}{\sin[180-(\alpha+\beta)]} = \frac{P}{\sin(\alpha+\beta)}$$

$$P_{OA} = \frac{P\sin\beta}{\sin(\alpha+\beta)} ; \quad P_{OB} = \frac{P\sin\alpha}{\sin(\alpha+\beta)}$$



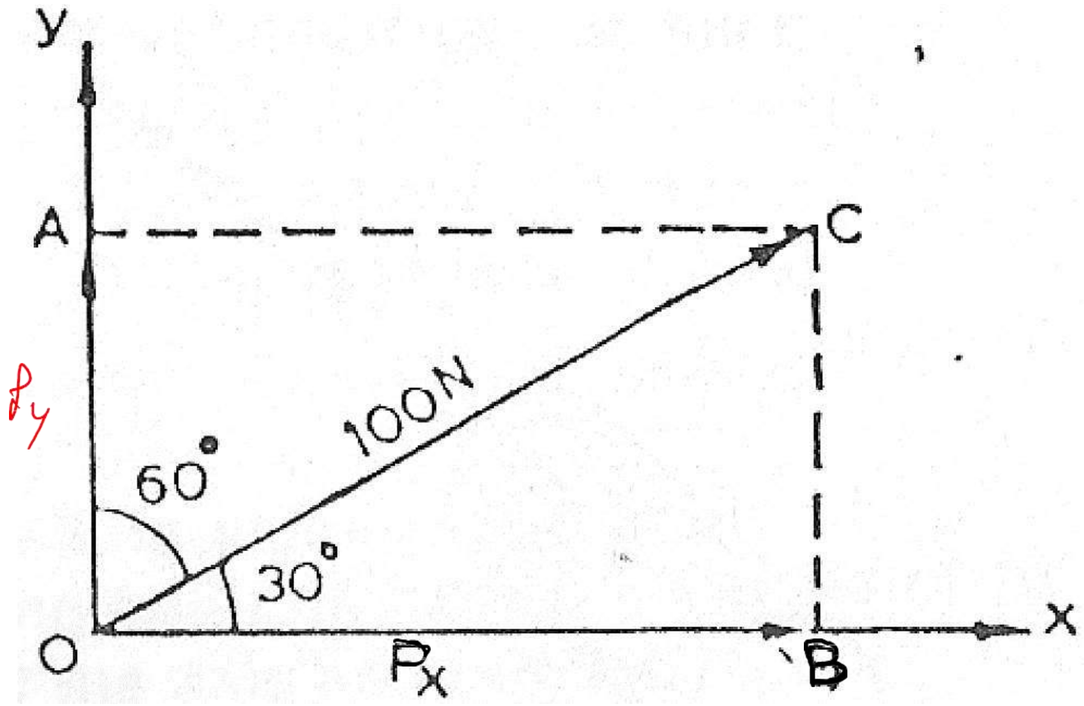
A force of 100 N acts in such a manner to make an angle of 60° with the vertical axis. Resolve the forces into two mutually perpendicular directions.

Sol $P_x = 100 \cos 30$ OR $100 \sin 60$

$= 86.6$ N

$P_y = 100 \cos 60$ or $100 \sin 30$

$= 50$N

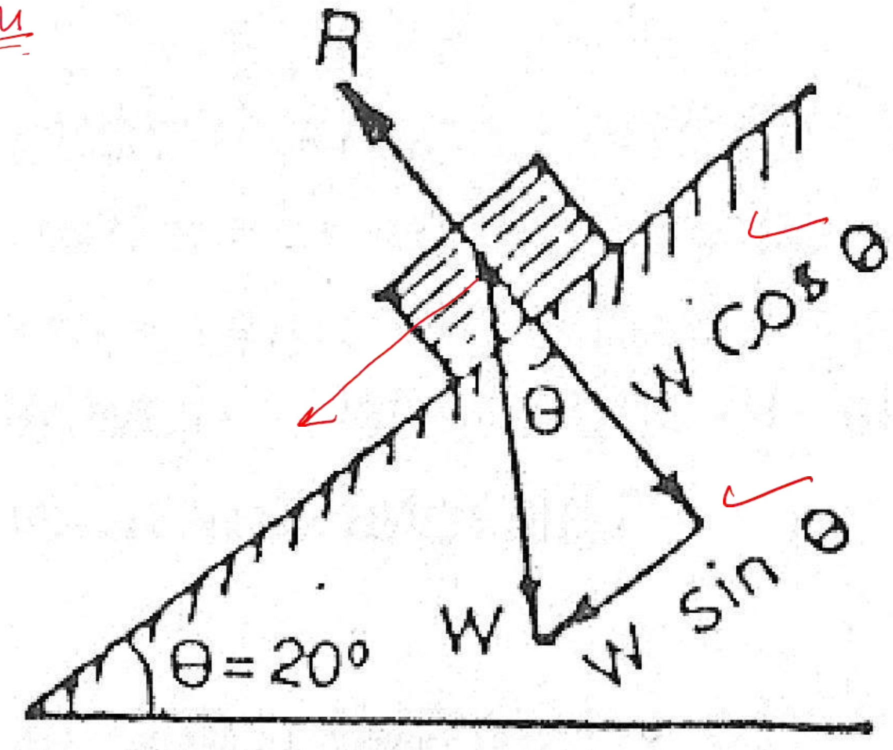


An inclined plane is set an angle of 20° to the horizontal. A weight of 150 N placed on it and is at rest. Calculate the components of this load acting parallel and normal to the plane.

Sol.

Parall comp. $= W \sin\theta = 150 \sin 20 = 51.3$ N. Ans

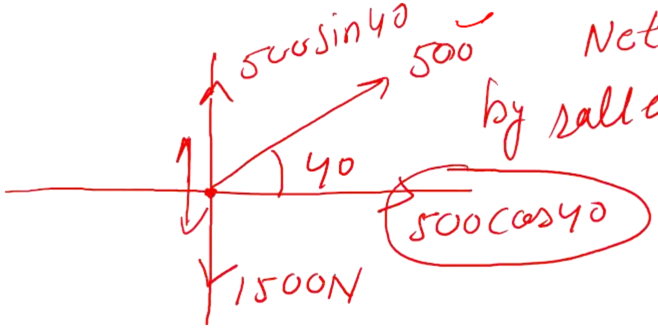
$\perp$ comp. $= W \cos\theta = 150 \cos 20 = 140.95$ N Ans



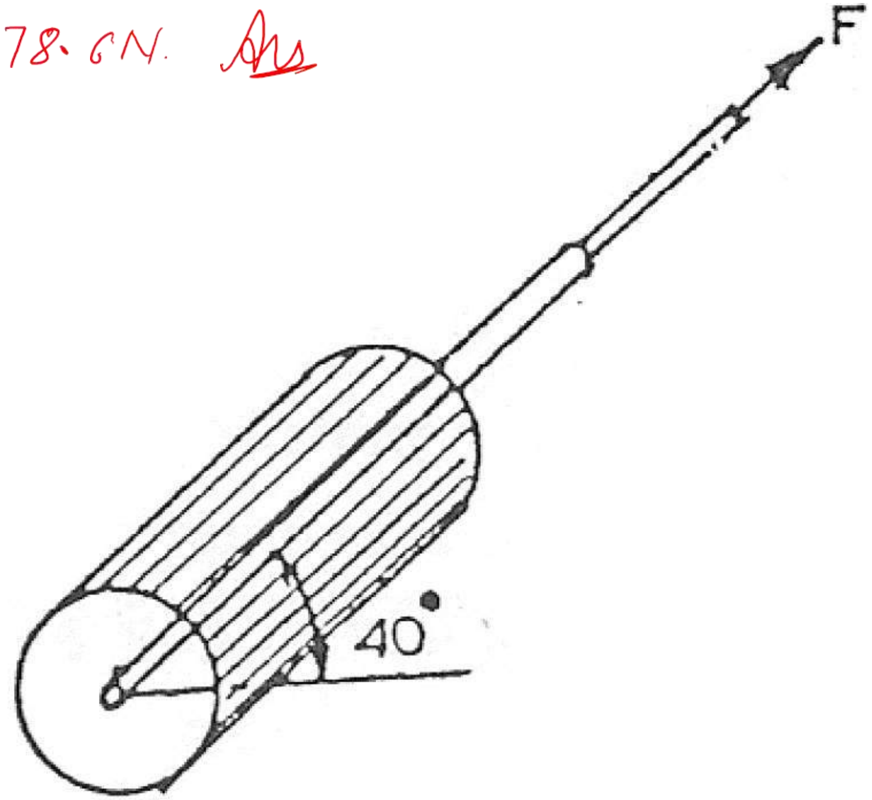
A force of 500 N is applied to the handle of a 1500 N roller at an angle of 40° with horizontal. Calculate the force exerted by the roller on the ground when the roller is (a) pulled; (b) pushed.

Sol.

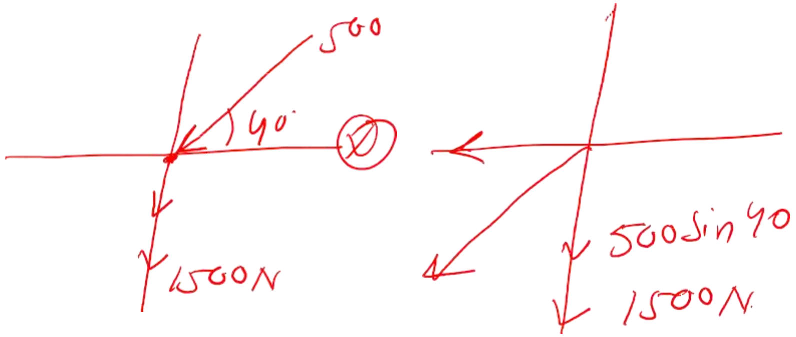
(a)



Net force on ground by roller $500 \sin 40 - 1500 = -1178.6\,N$ Ans



(b)



$-500 \sin 40 - 1500 = -1821.4\,N$

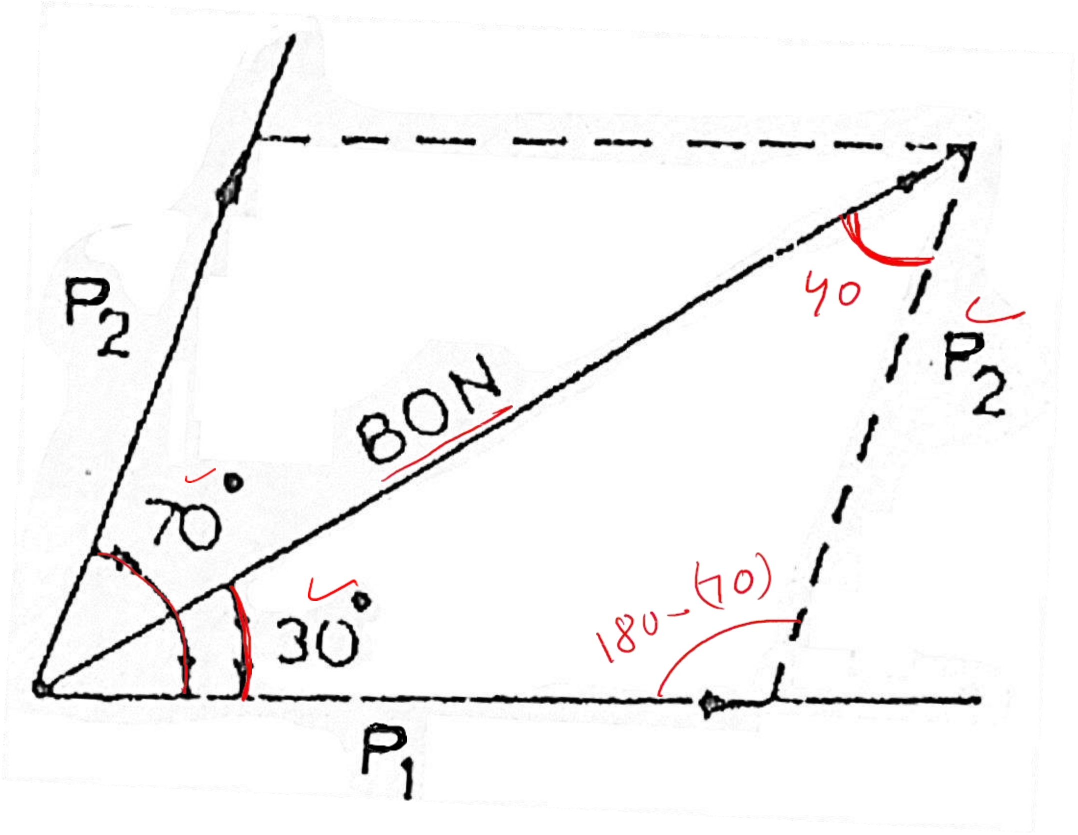
Ans

A force of 80 N is acting at an angle of 30° to the horizontal. Resolve it along two axis having an angle of 70° in between them. Take one of the axis as horizontal.

Sol:

$$P_1 = \frac{80 \sin 40}{\sin 70} = 54.72 \text{ N} \quad \text{Ans}$$

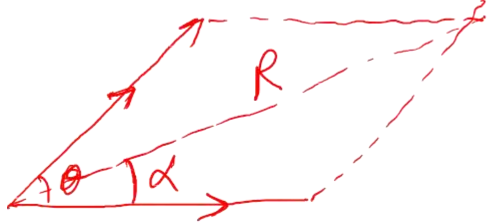
$$P_2 = \frac{P \sin 30}{\sin 70} = 42.57 \text{ N} \quad \text{Ans}$$



Resultant Force

- Resultant is a single force which produces the same effect as produced by number of forces when acting together.
- Resultant force is denoted by R.
- The procedure to find out single resultant force of a system of forces is known as composition of forces.

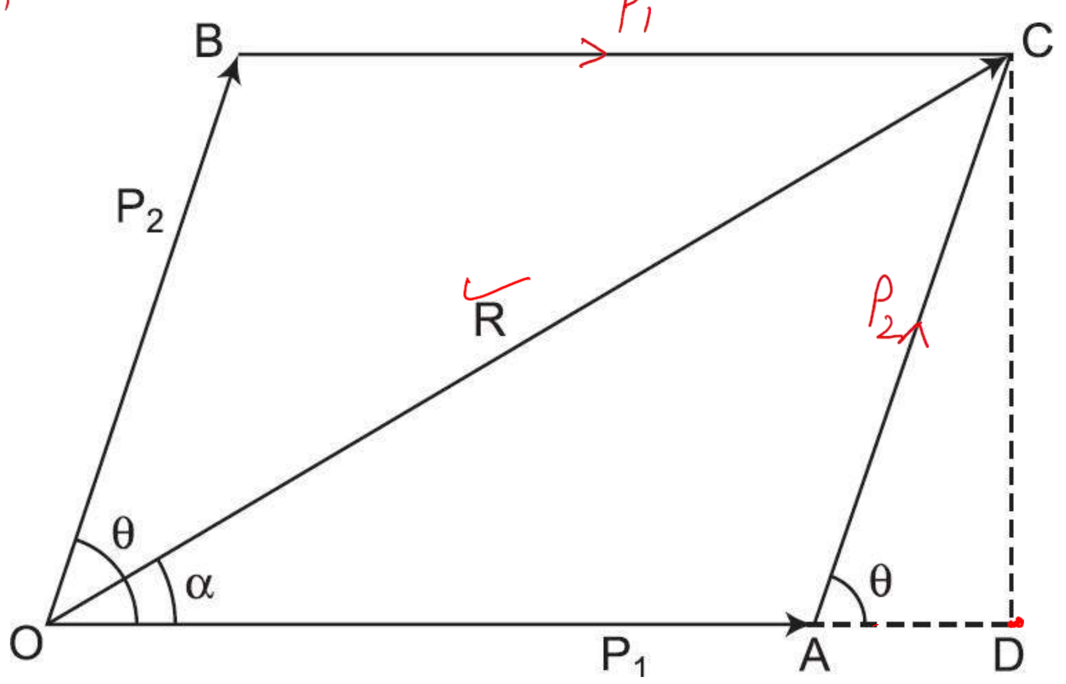
Resultant of Concurrent Forces



10N → 10mm

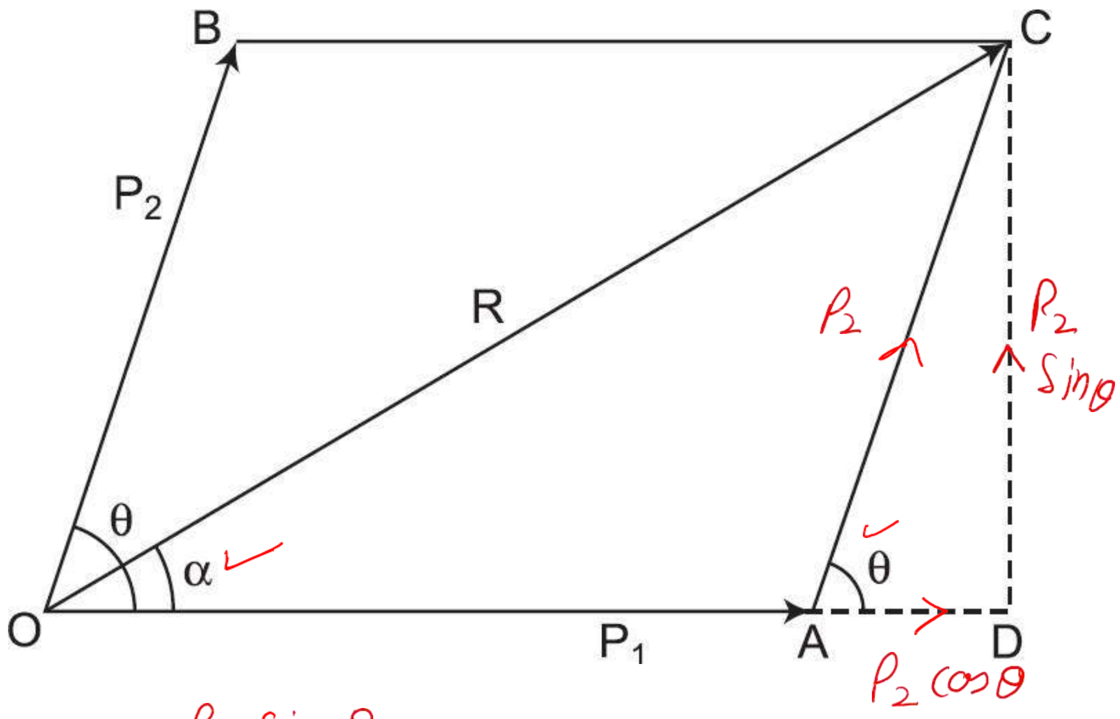
CASE I. Resultant of two concurrent forces:

- **Parallelogram Law of Forces:** *"If two forces acting simultaneously at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant may be represented in magnitude and direction by the diagonal of the parallelogram passing through that point."*



Resultant of Concurrent Forces

- **Parallelogram Law of Forces:** $\triangle ODC$



$$OC^2 = OD^2 + CD^2 = (OA + AD)^2 + CD^2$$

$$R^2 = (P_1 + P_2\cos\theta)^2 + P_2^2\sin^2\theta$$

$$= P_1^2 + P_2^2\cos^2\theta + 2P_1P_2\cos\theta + P_2^2\sin^2\theta$$

$$= P_1^2 + P_2^2(\cos^2\theta + \sin^2\theta) + 2P_1P_2\cos\theta$$

$$= P_1^2 + P_2^2 + 2P_1P_2\cos\theta$$

$$\boxed{R = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta}}$$

Magnitude of Resultant

$$\tan\alpha = \frac{CD}{OD} = \frac{P_2\sin\theta}{P_1 + P_2\cos\theta}$$

$$\alpha = \tan^{-1}\left[\frac{P_2\sin\theta}{P_1 + P_2\cos\theta}\right]$$

Resultant of Concurrent Forces

- **Parallelogram Law of Forces:**

when $\theta = 0 \therefore \cos\theta = 1$ (colinear & like)

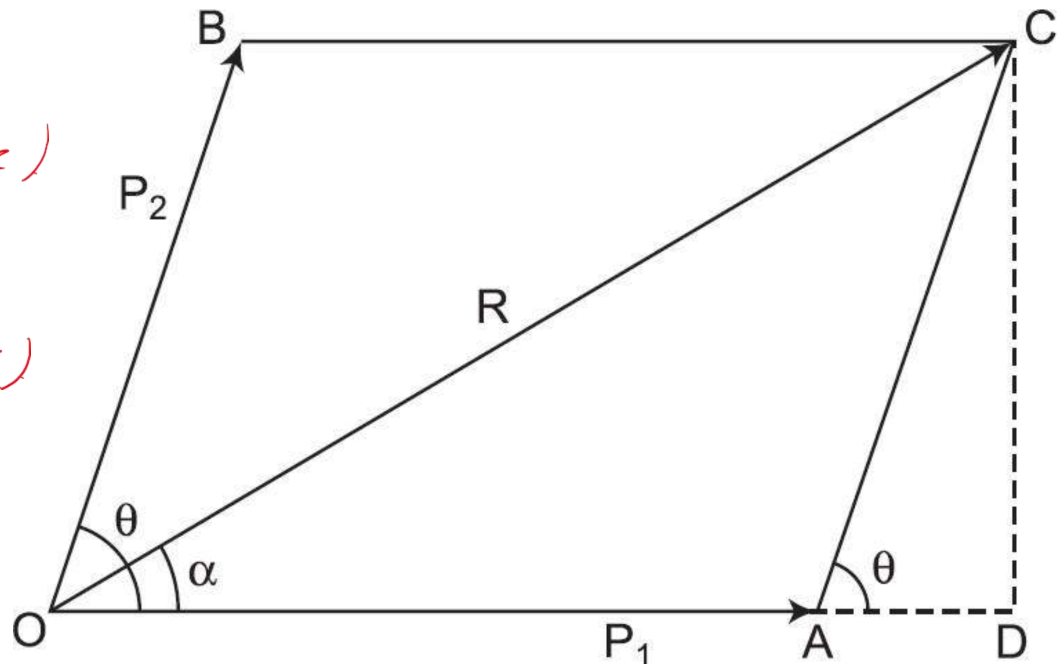
$R = P_1 + P_2$ (max.) ✓

when $\theta = 180 \therefore \cos\theta = -1$ (colinear & unlike)

$R = P_1 - P_2$ (Min.) ✓

when $\theta = 90 \therefore \cos\theta = 0$

$R = \sqrt{P_1^2 + P_2^2}$; $\boxed{\tan\alpha = \frac{P_2}{P_1}}$



Resultant of Concurrent Forces

- **Parallelogram Law of Forces:**

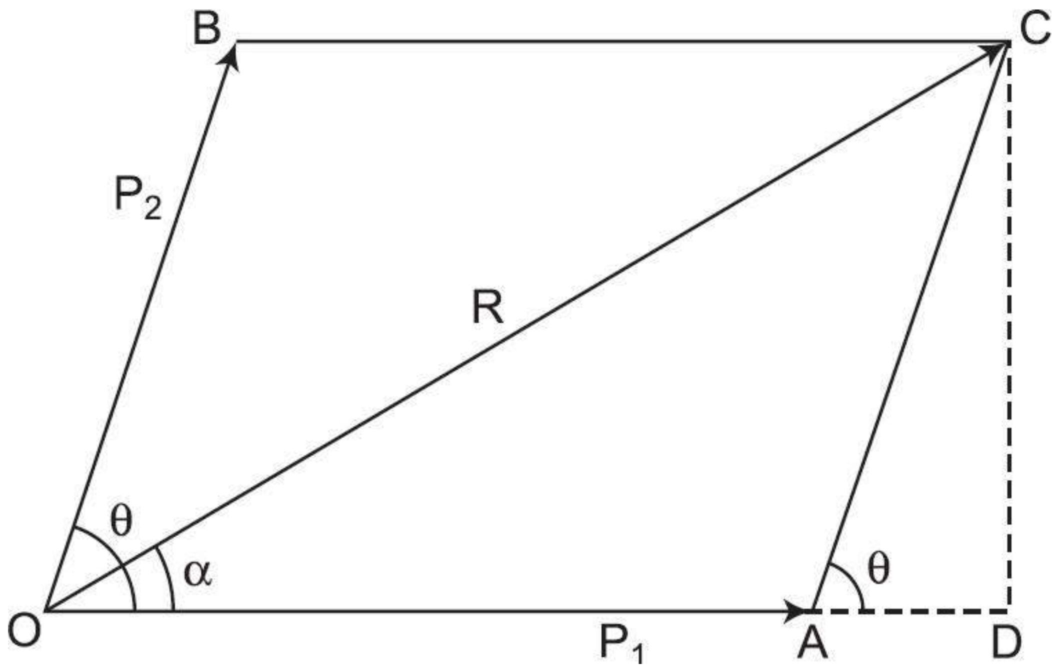
If $P_1 = P_2$

$$R = \sqrt{2P_1^2(1+\cos\theta)} = \sqrt{2P_1^2\, 2\cos^2\theta/2}$$

$$\boxed{R = 2P_1 \cos\theta/2}$$

$$\tan\alpha = \frac{\sin\theta}{1+\cos\theta} = \frac{\cancel{2}\sin\theta/2\,\cancel{\cos\theta/2}}{\cancel{2}\cos^{\cancel{2}}\theta/2}$$

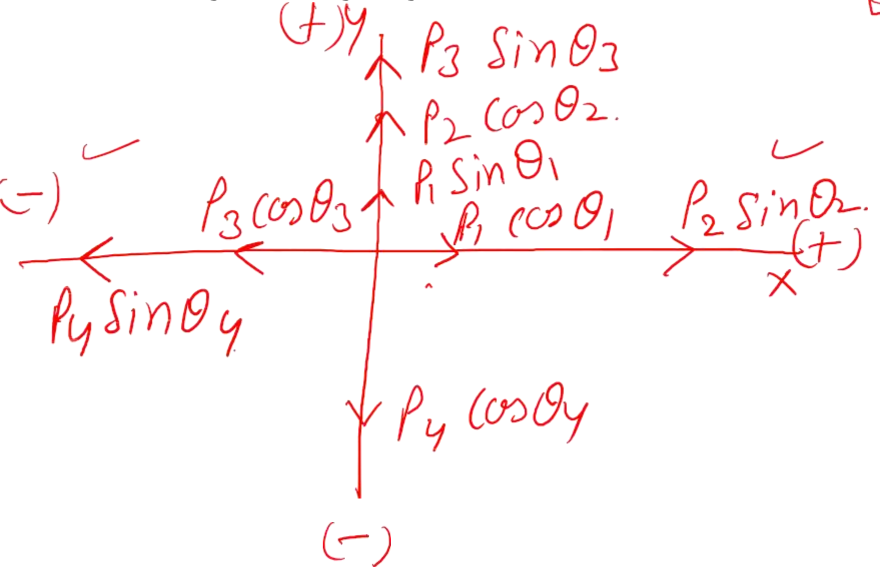
$$\tan\alpha = \tan\frac{\theta}{2} \Rightarrow \boxed{\alpha = \frac{\theta}{2}}$$



Resultant of Concurrent Forces

CASE II. Resultant of more than two concurrent forces:

- If three or more forces are acting at a point then their resultant is found analytically by a method known as rectangular components method.

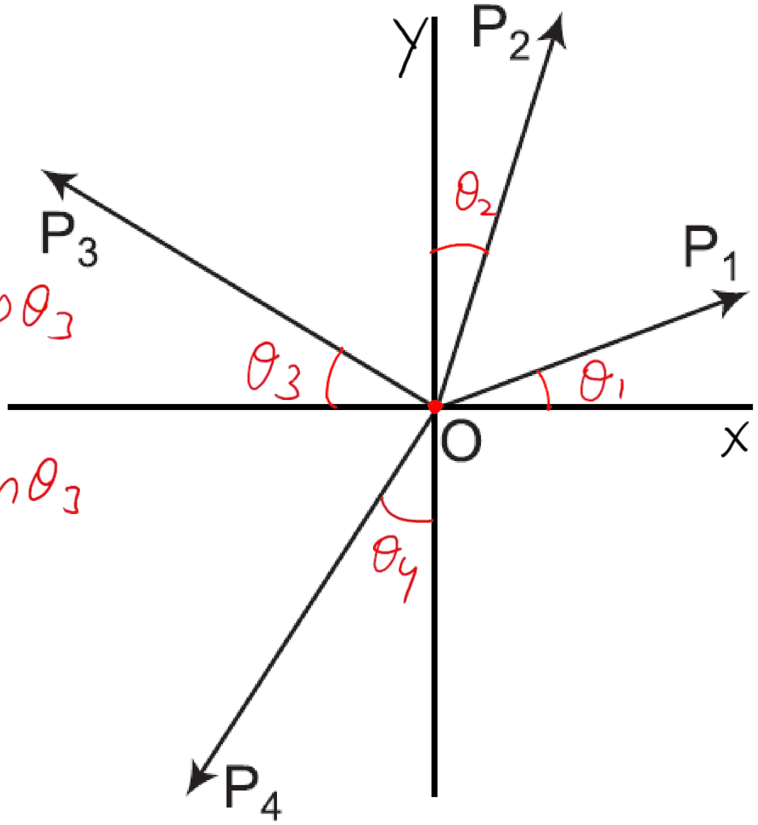


$$\Sigma P_x = P_1 \cos\theta_1 + P_2 \sin\theta_2 - P_3 \cos\theta_3 - P_4 \sin\theta_4 =$$

$$\Sigma P_y = P_1 \sin\theta_1 + P_2 \cos\theta_2 + P_3 \sin\theta_3 - P_4 \cos\theta_4 =$$

$$R = \sqrt{\Sigma P_x^2 + \Sigma P_y^2}$$

$$\alpha = \tan^{-1}\left[\frac{\Sigma P_y}{\Sigma P_x}\right]$$



The maximum resultant of two forces P_1 and P_2 is 1000 N and minimum magnitude is 400 N. Find values of P_1 and P_2.

Sol.

$$P_1 + P_2 = 1000\,N \quad -(1)$$

$$P_1 - P_2 = 400\,N. \quad -(2)$$

$$P_1 = 700\,N$$

$$P_2 = 300\,N \quad \underline{\text{Ans}}$$

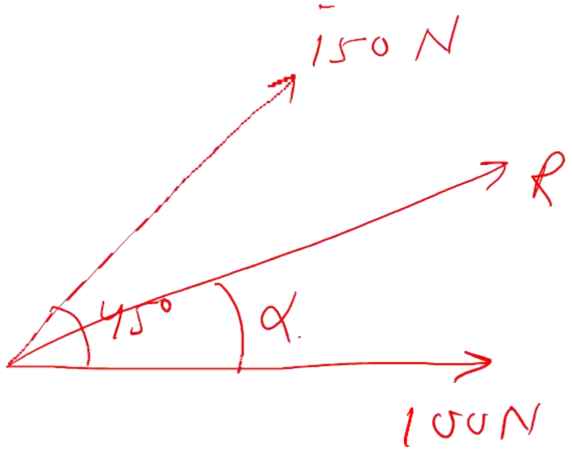
Two forces of 100 N and 150 N are acting simultaneously at a point. What is the resultant of these two forces, if the angle between them is 45°?

Sol:

$$R = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta}$$

$$R = 231.62\ N \quad \text{Ans}$$

$$\alpha = \tan^{-1}\left[\frac{P_2 \sin\theta}{P_1 + P_2\cos\theta}\right] = 27.23^\circ \quad \text{Ans}$$

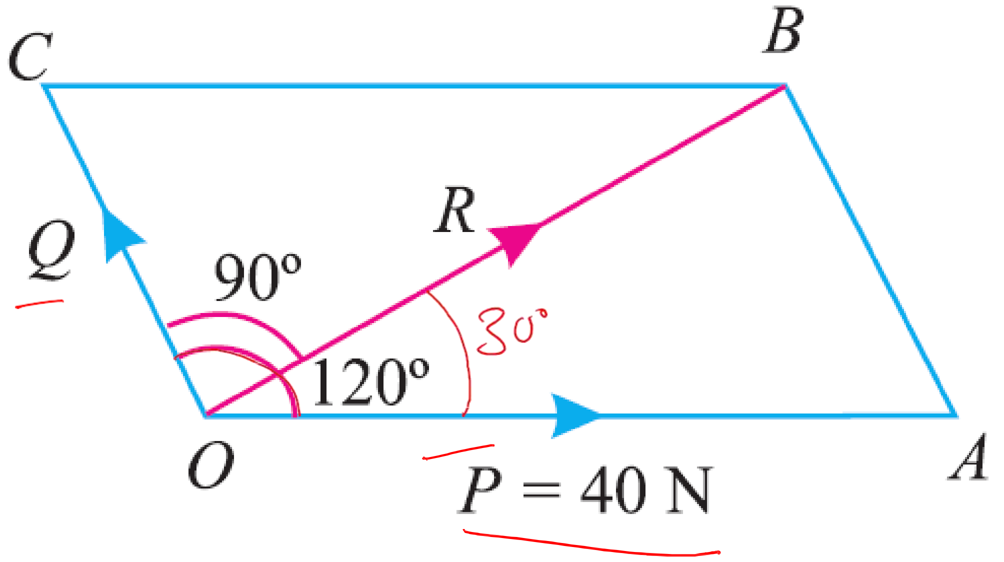


Two forces act at an angle of 120°. The bigger force is of 40 N and the resultant is perpendicular to the smaller one. Find the smaller force.

Sol:

$$\tan 30 = \frac{Q \sin 120}{40 + Q \cos 120}$$

$$\boxed{Q = 20\,N}$$ Ans



Find the magnitude of the two forces, such that if they act at right angles, their resultant is $\sqrt{10}\,N$. *But if they Act at 60°, their resultant is* $\sqrt{13}\,N$.

Sol.

$$\sqrt{P_1^2+P_2^2} = \sqrt{10}\,N \qquad \sqrt{\underbrace{P_1^2+P_2^2}+2P_1P_2\cos 60} = \sqrt{13}\,N.$$

$$P_1^2+P_2^2 = 10 \qquad P_1P_2 = 3\,N.$$

$$(P_1+P_2)^2 = \underbrace{P_1^2+P_2^2}+2\underbrace{P_1P_2} = 16\,N$$

$$P_1+P_2 = 4\,N \quad -(1)$$

$$(P_1-P_2)^2 = P_1^2+P_2^2-2P_1P_2 = 4\,N.$$

$$P_1-P_2 = 2\,N \quad -(2)$$

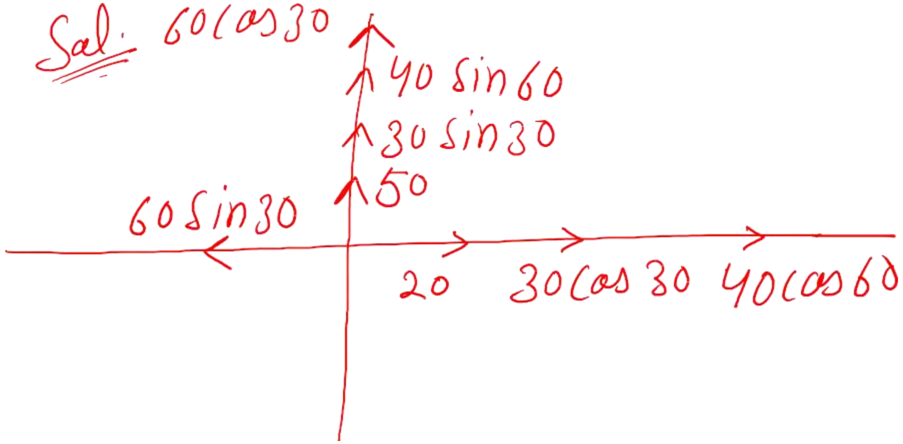
from (1) & (2)

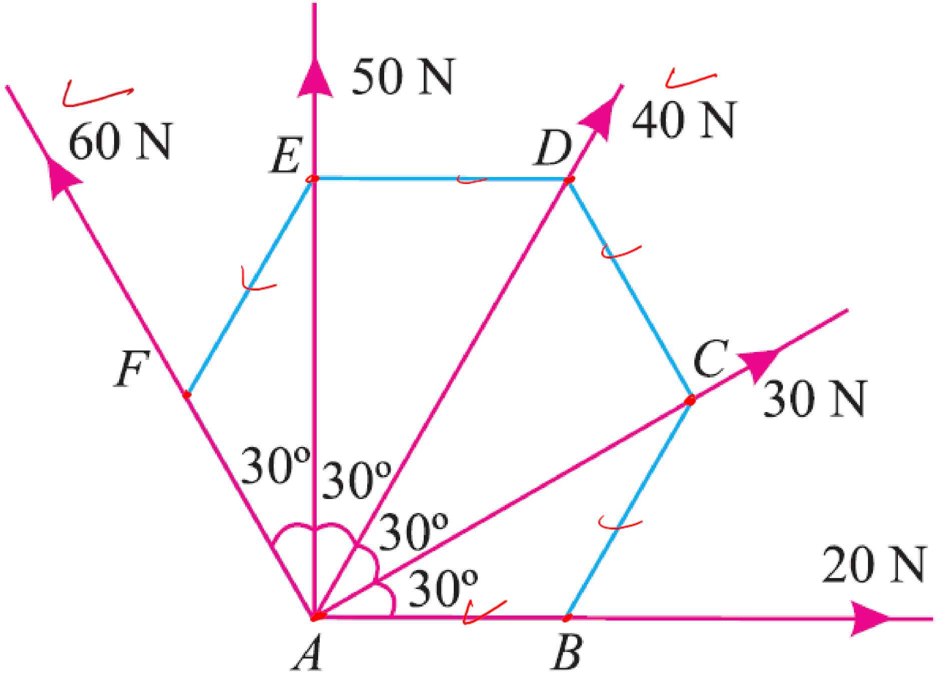
$$P_1 = 3\,N.$$

$$P_2 = 1\,N.$$

The forces 20 N, 30 N, 40 N, 50 N and 60 N are acting at one of the angular points of a regular hexagon, towards the other five angular points, taken in order. Find the magnitude and direction of the resultant force.

Sol.





$$\Sigma P_x = 20 + 30\cos 30 + 40\cos 60 - 60\sin 30 = 36\text{ N}.$$

$$\Sigma P_y = 50 + 30\sin 30 + 40\sin 60 + 60\cos 30 = 151.6\text{ N}.$$

$$R = \sqrt{\Sigma P_x^2 + \Sigma P_y^2} = 155.8\text{ N}$$

$$\alpha = \tan^{-1}\left[\frac{\Sigma P_y}{\Sigma P_x}\right] = 76.64^\circ$$ Ans

The following forces act at a point :

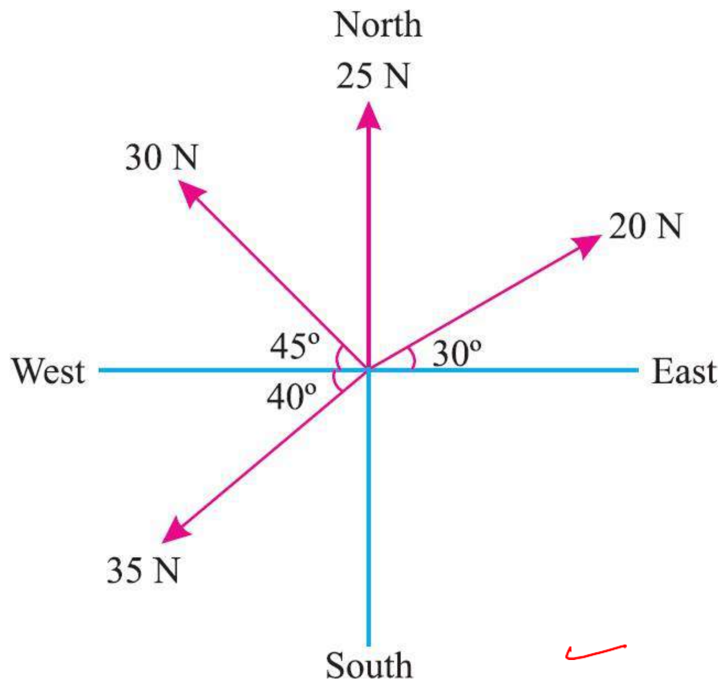
(i) 20 N inclined at 30° towards North of East,

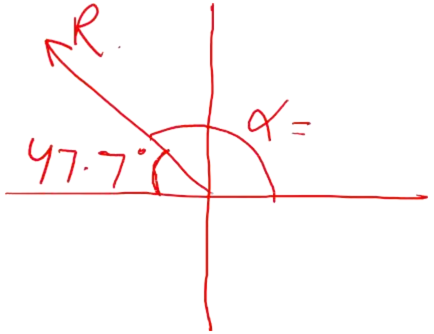
(ii) 25 N towards North,

(iii) 30 N towards North West, and

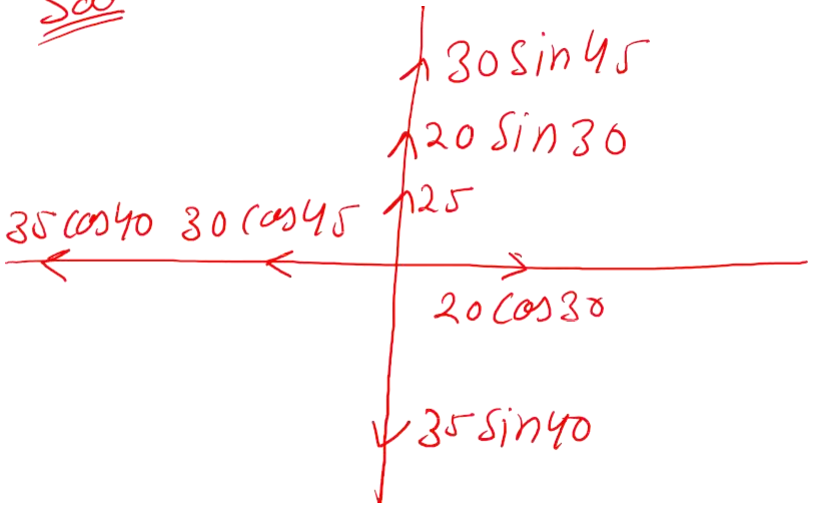
(iv) 35 N inclined at 40° towards South of West.

Find the magnitude and direction of the resultant force.





Sol.



$$\Sigma P_x = 20\cos 30 - 30\cos 45 - 35\cos 40 = -30.7\,N$$

$$\Sigma P_y = 25 + 20\sin 30 + 30\sin 45 - 35\sin 40 = 33.7\,N$$

$$R = \sqrt{\Sigma P_x^2 + \Sigma P_y^2}$$

$$R = 45.6\,N$$

$$\alpha = \tan^{-1}\left[\frac{\Sigma P_y}{\Sigma P_x}\right]$$

$\alpha = -47.7°$ OR $= 132.3°$ Ans

Determine the magnitude and direction of the resultant of the two forces shown.

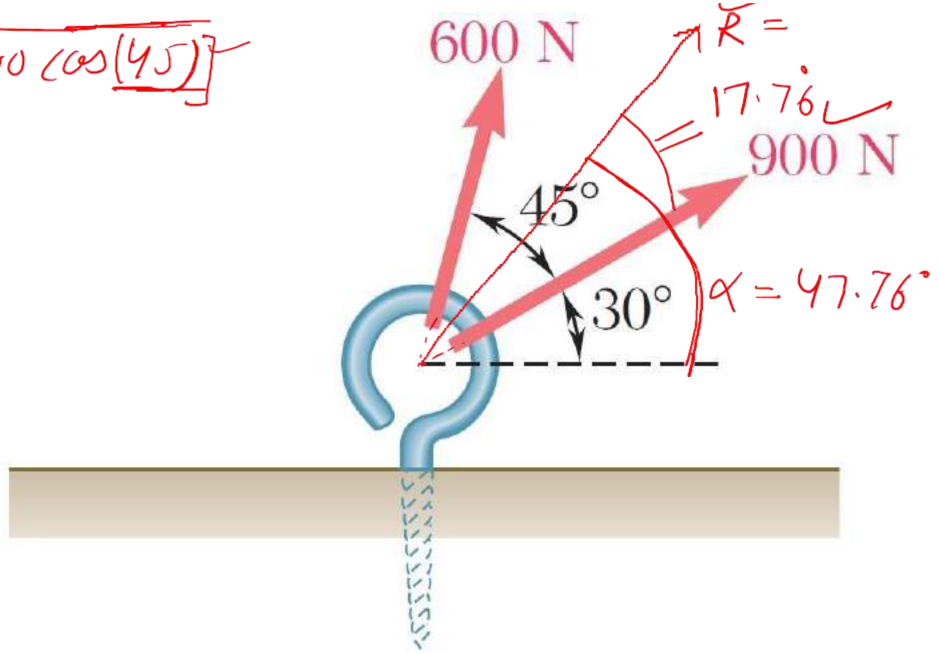
Sol:

$$R = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta} = \sqrt{900^2 + 600^2 + [2 \times 900 \times 600 \cos(45)]}$$

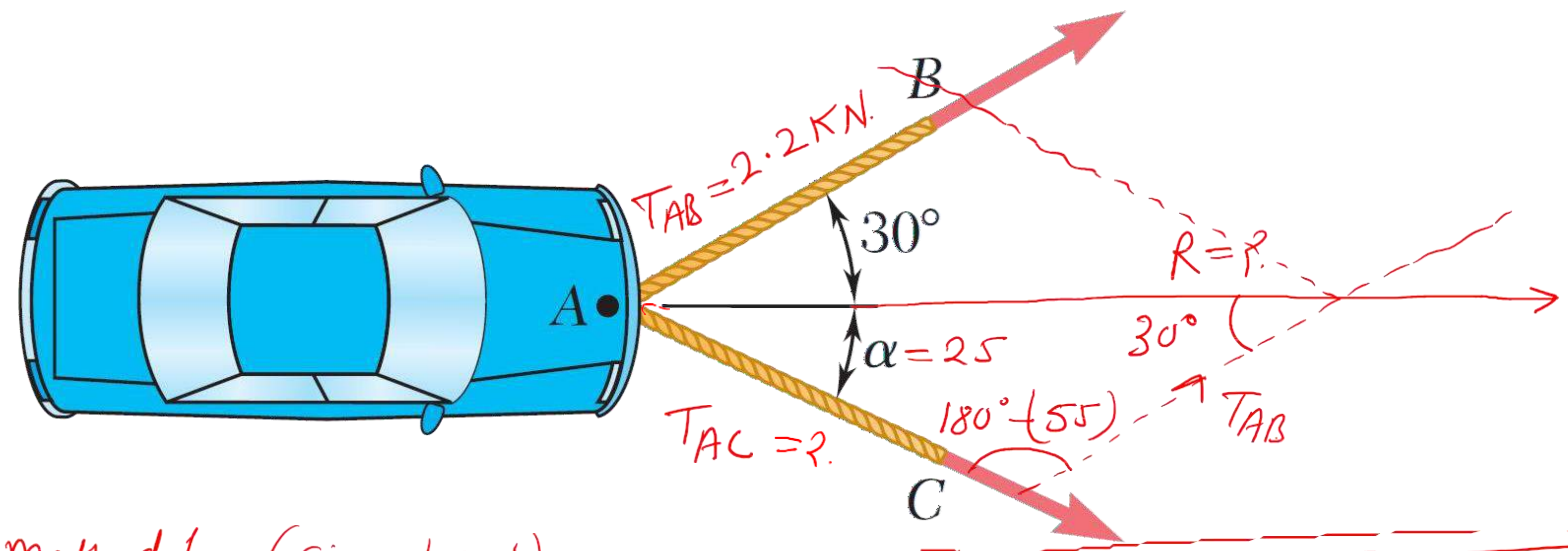
$$\boxed{R = 1390.56\ N}$$ Ans

$$\alpha = \tan^{-1}\left[\frac{600 \sin 45}{900 + 600 \cos 45}\right] + 30$$

$$\boxed{\alpha = 47.76^\circ}$$ Ans



A disabled automobile is pulled by means of two ropes as shown. The tension in rope *AB* is 2.2 kN, and the angle α is 25°. Knowing that the resultant of the two forces applied at *A* is directed along the axis of the automobile, determine (*a*) the tension in rope *AC*, (*b*) the magnitude of the resultant of the two forces applied at *A*.



Method 2

$$\tan 25 = \frac{2.2 \sin 55}{T_{AC} + 2.2 \cos 55}$$

$T_{AC} =$

$$R = \sqrt{T_{AC}^2 + 2.2^2 + 2 \times T_{AC} \times 2.2 \cos 55}$$

$R =$

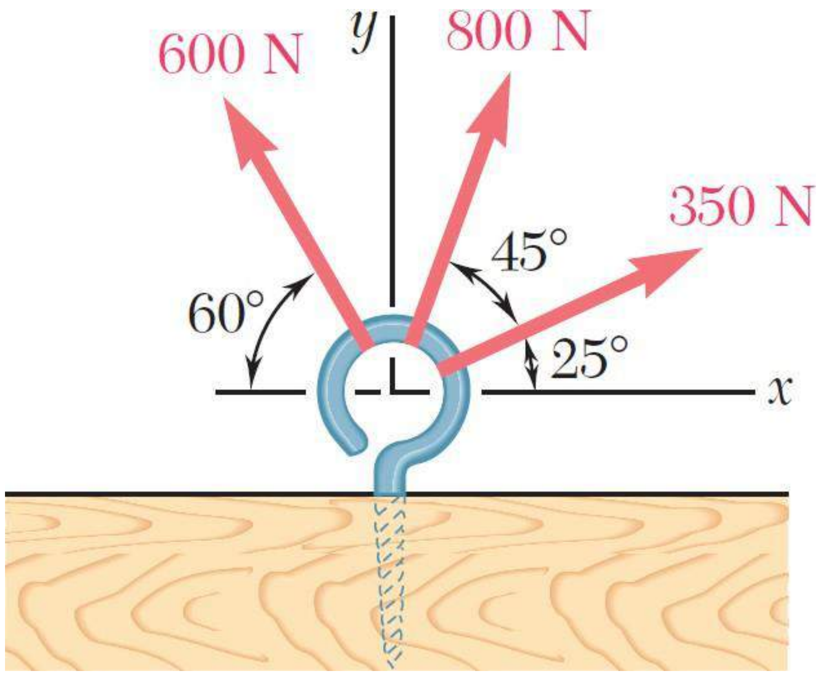
Method 1 (Sine Law)

$$\frac{T_{AC}}{\sin 30} = \frac{T_{AB}}{\sin 25} = \frac{R}{\sin 55°}$$

$T_{AC} = 2.603\,KN.$ Ans

$R = 4.264\,KN$ Ans

Determine the *x* and *y* components of each of the forces shown.



Sol:

Force	x-comp	y-comp
350 N	317.2 N	147.91 N
800 N	273.61 N	751.75 N
600 N	−300 N	519.6 N
	$\Sigma F_x = 290.8\,N$	$\Sigma F_y = 1419.3\,N$

Ans

$$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$$

$$R = 1448.78\ N$$ Ans

$$\alpha = \tan^{-1}\left[\frac{\Sigma F_y}{\Sigma F_x}\right]$$

$$\alpha = 78.41^\circ$$ Ans

Moment of Force

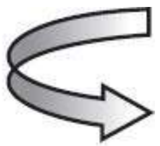
Turning

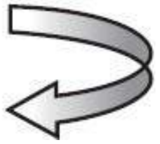
- When a force causes an object to turn, this turning effect is called **Moment**.

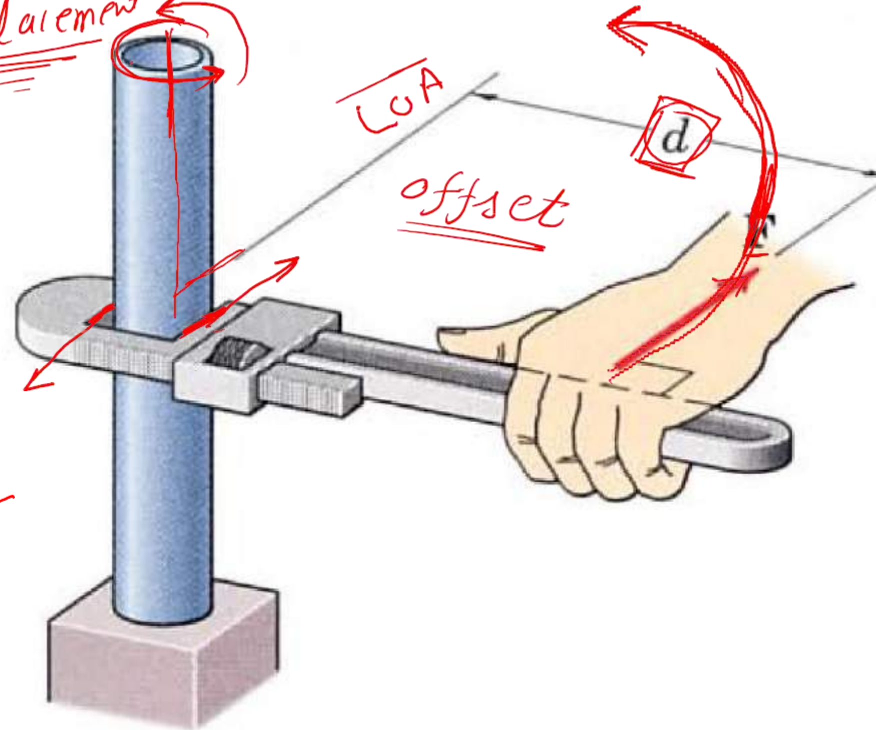
work done = F × d displacement

Moment = Force × Distance

$$M = F \times \perp d$$ [N-m]

Anticlockwise moment ⟶ Positive  (+ve)

Clockwise moment ⟶ Negative  (−ve)



- Moment is the product of the force multiplied by the perpendicular distance from the line of action of the force to the pivot or point where the object will turn.

Resultant Moment

- When two or more than two forces are acting about a point their combined effect is represented by the "Resultant Moment".
- How to Find Resultant Moment: (location of Resultant)

① Find $\underline{R}$ of all the given forces

② Find moments of all given forces about point O

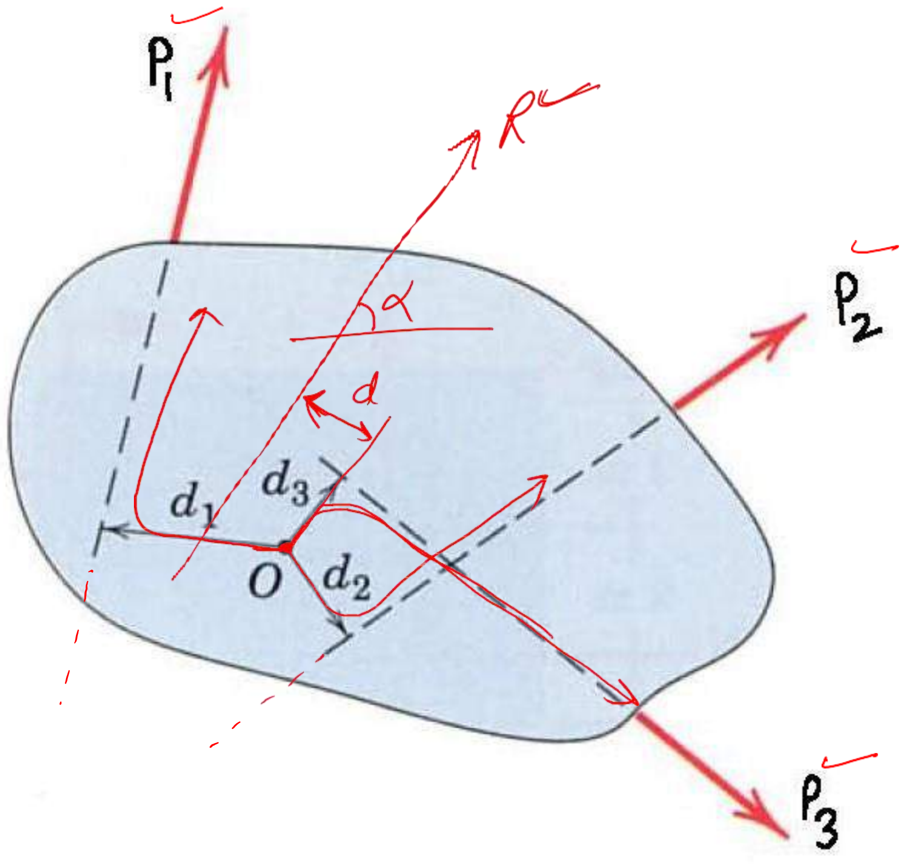
$M_{P_{1_O}} = -P_1 \times d_1$; $M_{P_{2_O}} = P_2 \times d$; $M_{P_{3_O}} = -P_3 \times d_3$

③ $\underline{M_O} = M_{P_{1_O}} + M_{P_{2_O}} + M_{P_{3_O}} + \text{------}$

④ $\underline{R \times d} = M_O = \left[(-P_1 \times d_1) + (P_2 \times d_2) + (-P_3 \times d_3)\right]$

Resultant moment

$$\boxed{d = \frac{M_O}{R}} \rightarrow \text{distance of R from O}$$



Resultant of Parallel Force System

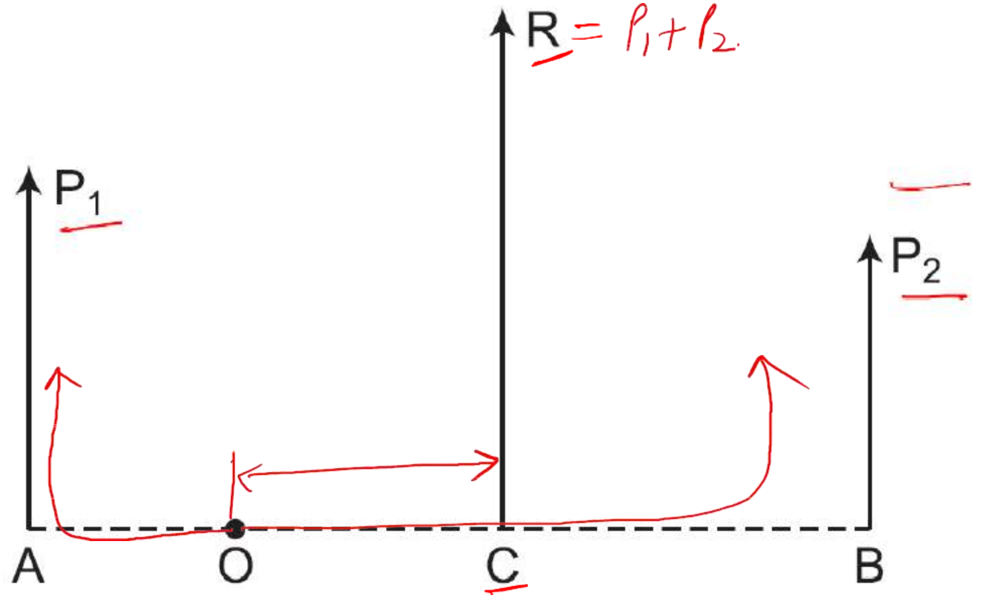
- **Case I:** Like Parallel Forces

① $R = P_1 + P_2$

② $M_{P_{1_O}} = -P_1 \times OA$; $M_{P_{2_O}} = P_2 \times OB$

③ $R \times OC = M_{P_{1_O}} + M_{P_{2_O}}$

④ $$\boxed{OC = \frac{(-P_1 \times OA) + (P_2 \times OB)}{R}}$$



Resultant of Parallel Force System

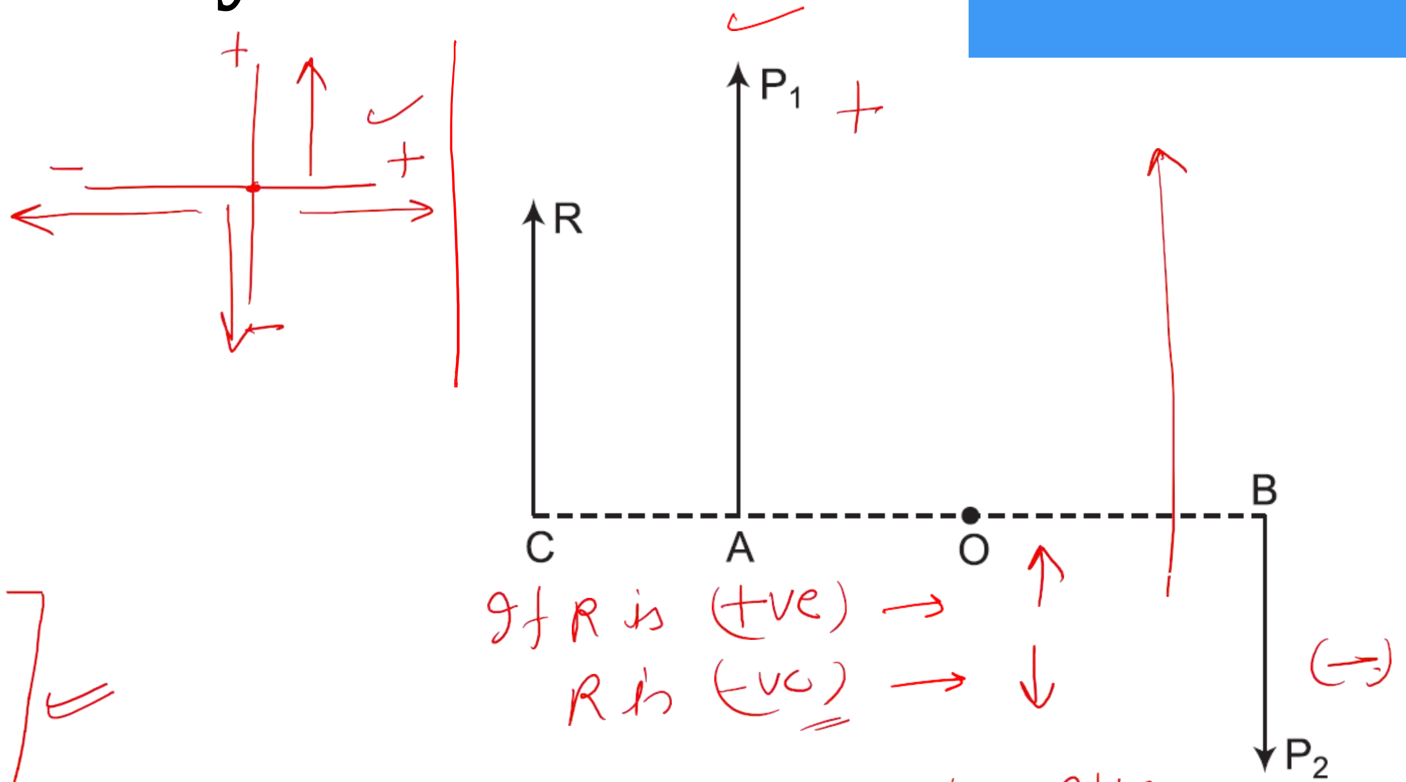
- **Case II:** Unlike Parallel Forces

(1) $R = P_1 - P_2$

(2) $MP_{1_0} = -P_1 \times OA$; $MP_{2_0} = -P_2 \times OB$

(3) $R \times OC = MP_{1_0} + MP_{2_0}$

(4) $$\boxed{OC = \frac{(-P_1 \times OA) + (-P_2 \times OB)}{R}}$$



If R is (+ve) → ↑
R is (−ve) → ↓

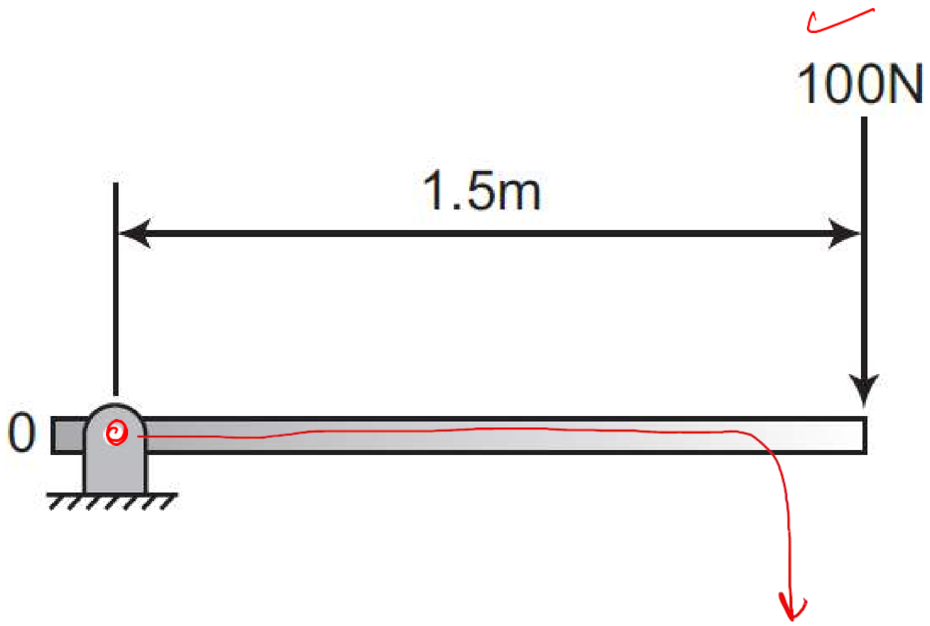
If OC is +ve → then RHS of O
OC is −ve → the LHS of O

Determine the moment of the 100 N force about point O

Sol.

$M_o = -100 \times 1.5$ N-m.

$M_o = -150$ N-m. Ans

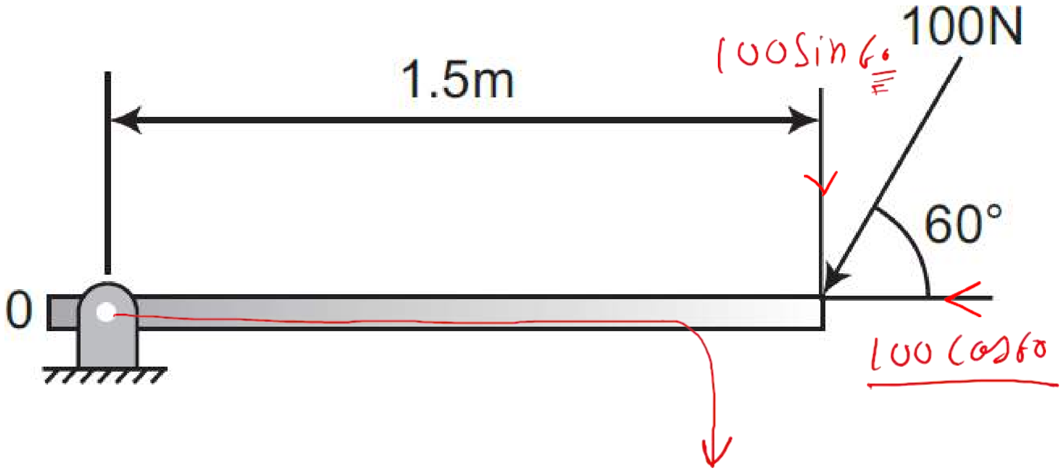


Determine the moment of the 100 N force about point *O*

Sol.

$$M_o = -\ 100 \sin 60 \times 1.5$$

$$\boxed{M_o = -\ 130\ N \cdot m}$$



Equilibrium of System of Forces

No change

- Equilibrium is the state of rest of a body i.e. the body does not move and also does not rotate about any point under the action of forces.
- When object is in equilibrium under the action of system of forces, following conditions are satisfied:

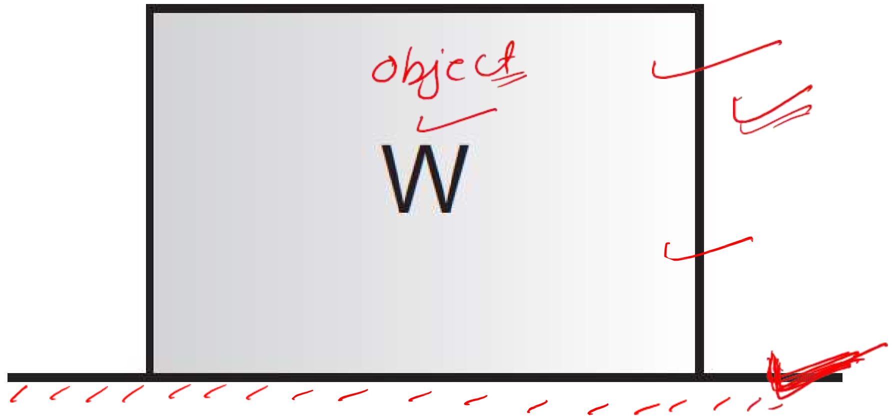
  1. The algebraic sum of the components of the forces in any direction must equal to zero.
  2. The algebraic sum of the moments of the forces about any point must equal zero.

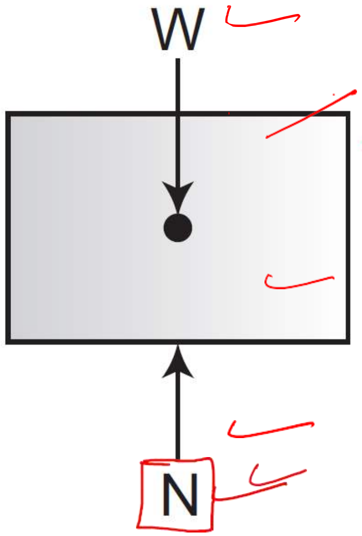
$\Sigma P_x = 0$
$\Sigma P_y = 0$
$\Sigma P_z = 0$

$\boxed{M_o = 0}$ $\boxed{\Sigma M = 0}$

Free Body Diagram (F.B.D.)

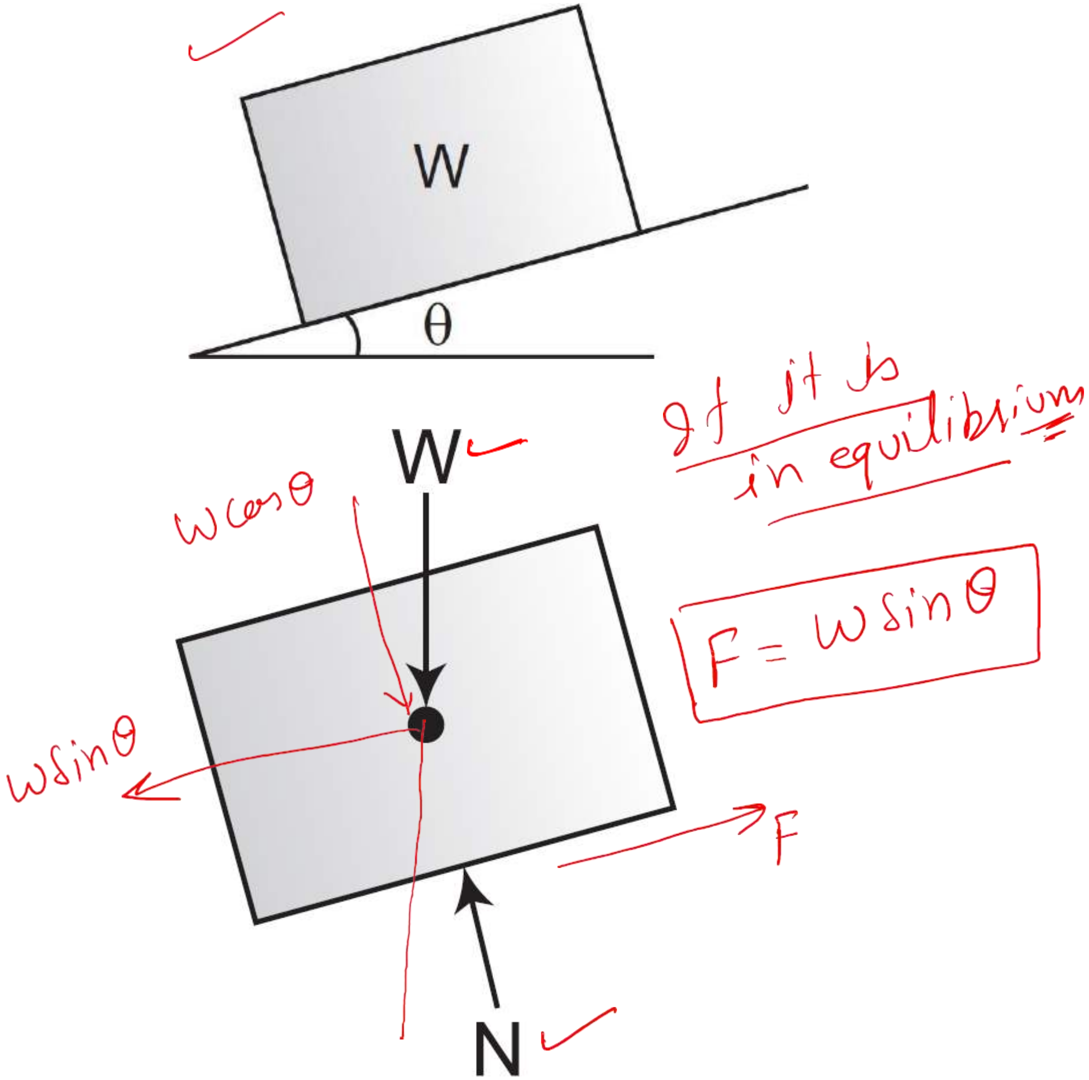
- A free-body diagram of a body is a diagrammatic representation or a sketch of a body in which the body is shown completely separated from all surrounding bodies, including supports.
- The term free implies that all supports have been removed and replaced by the forces (reactions) that they exert on the body.

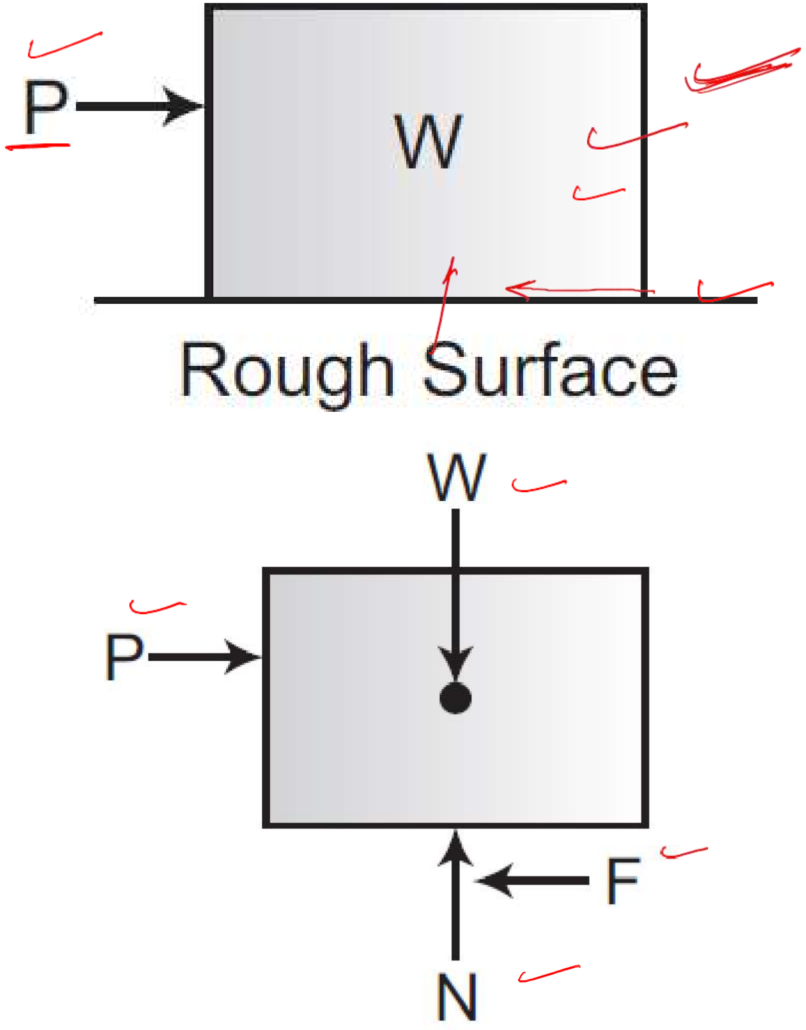




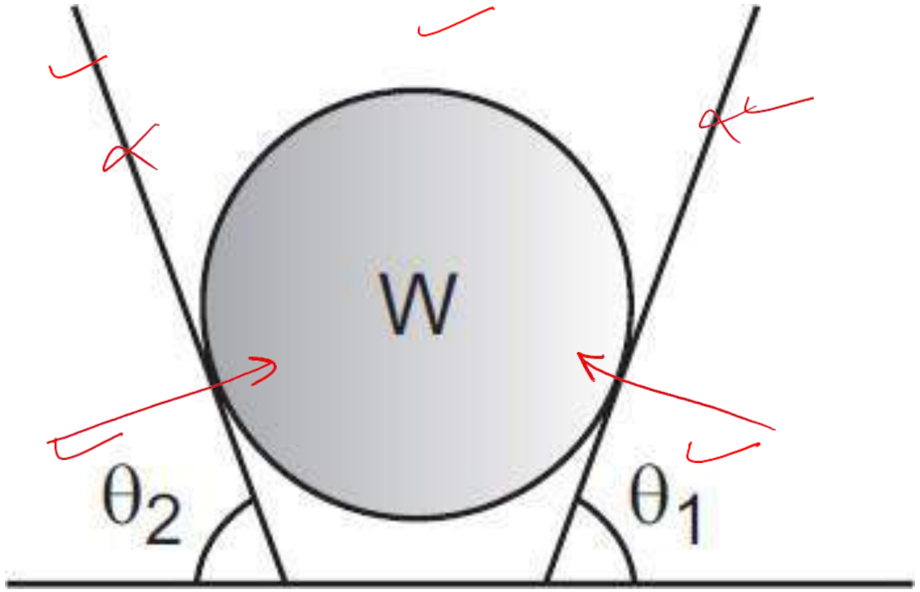
to maintain equilibrium

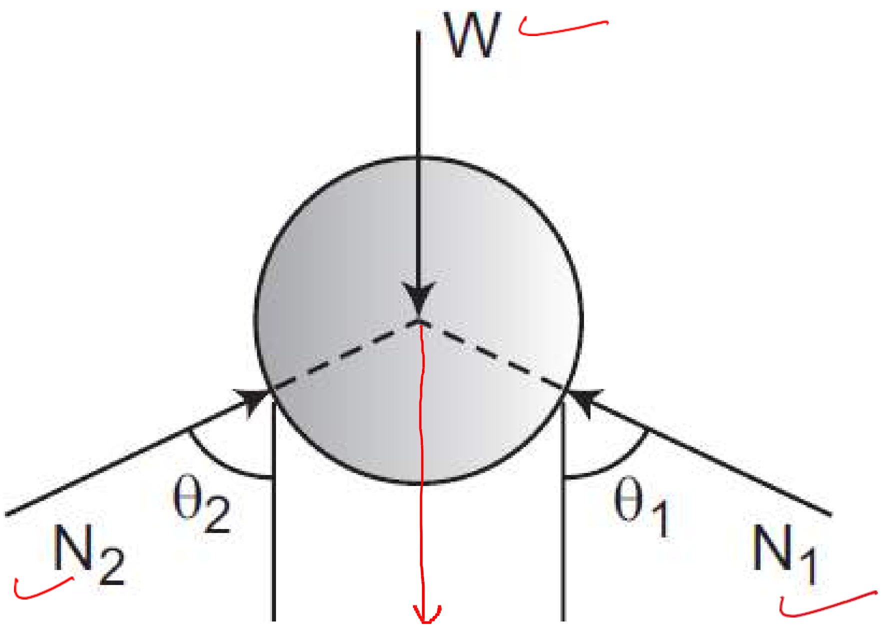
Free Body Diagram (F.B.D.)





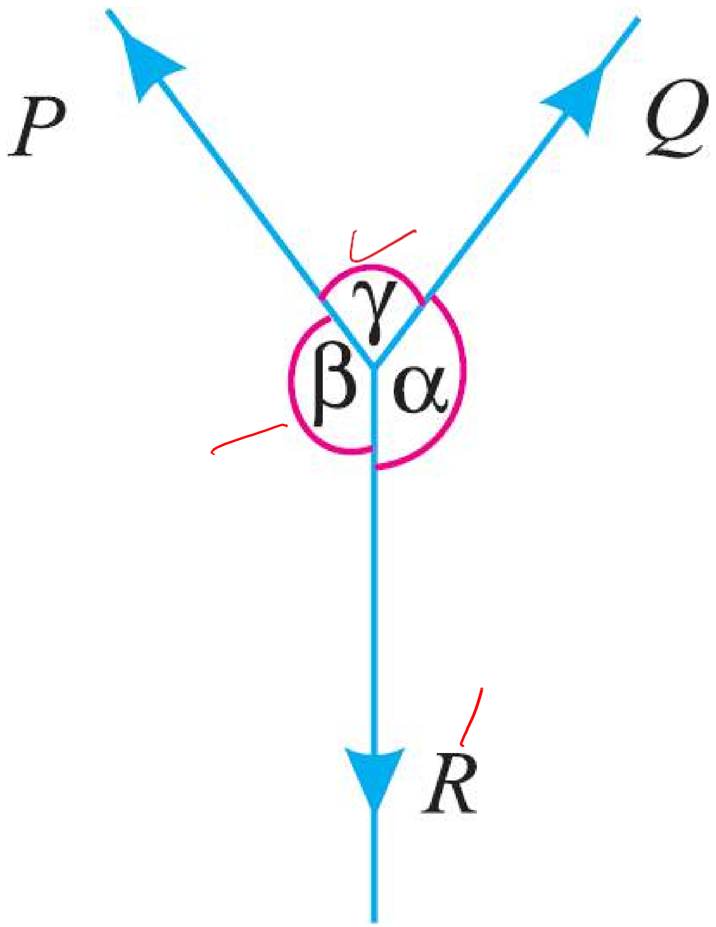
Free Body Diagram (F.B.D.)





EQUILIBRIUM OF COPLANAR FORCES

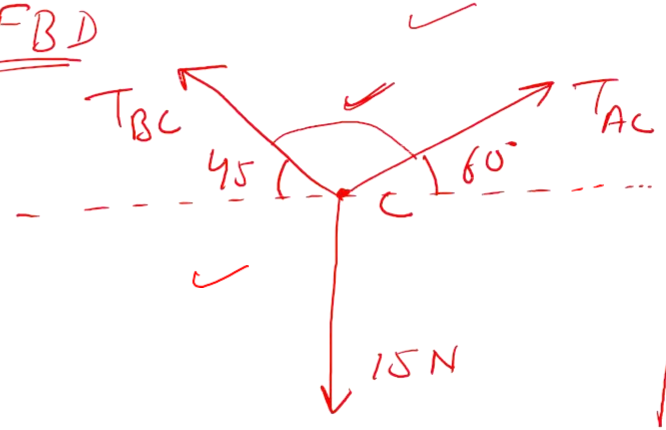
- Lemi's Theorem: If three concurrent forces acting on a body, keep it in equilibrium, then each force is proportional to sine of the angle between the other two.



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

Determine the forces in the strings AC and BC.

(1) FBD

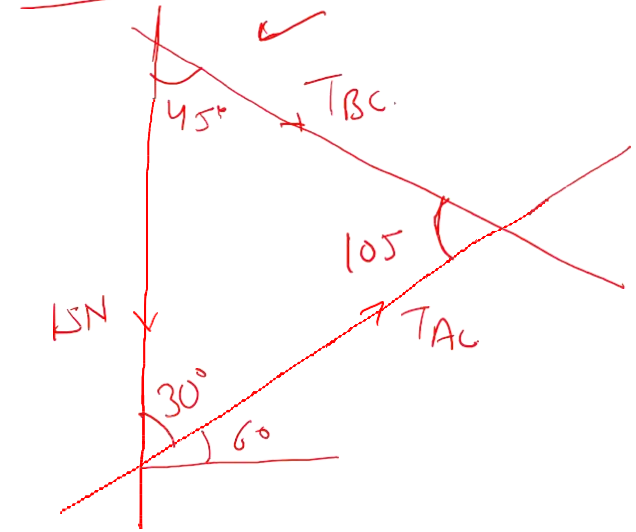


$$\frac{T_{BC}}{\sin 150} = \frac{15}{\sin 75} = \frac{T_{AC}}{\sin 135}$$

$T_{BC} = 7.76\ N$

$T_{AC} = 10.98\ N$ Ans

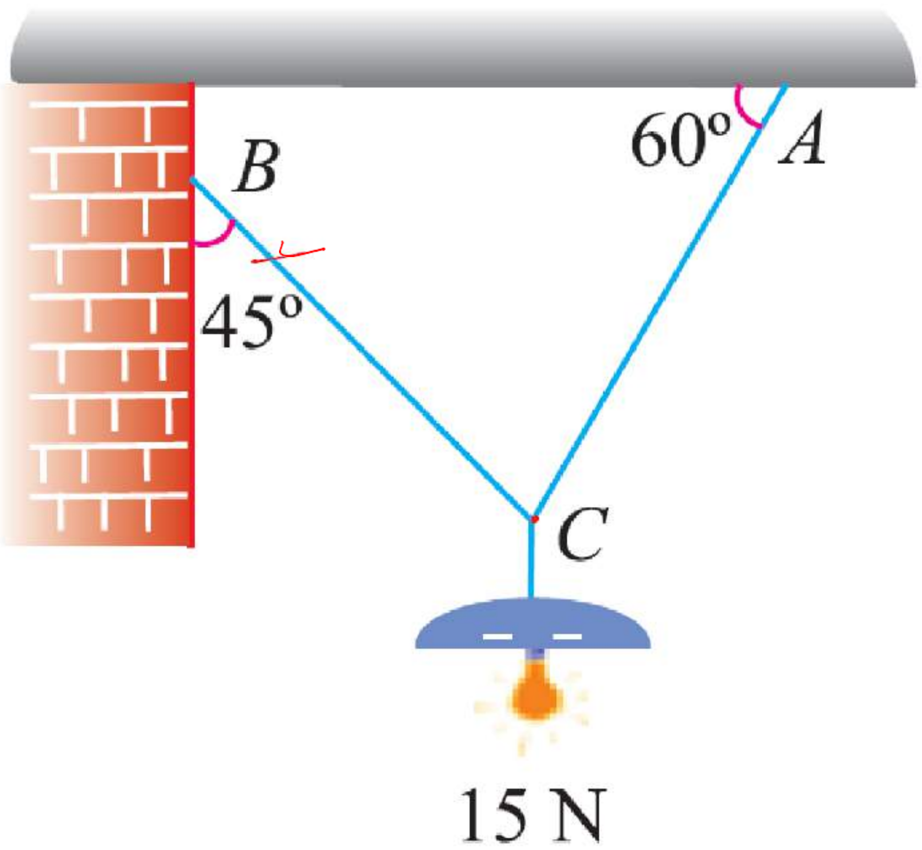
Method-2



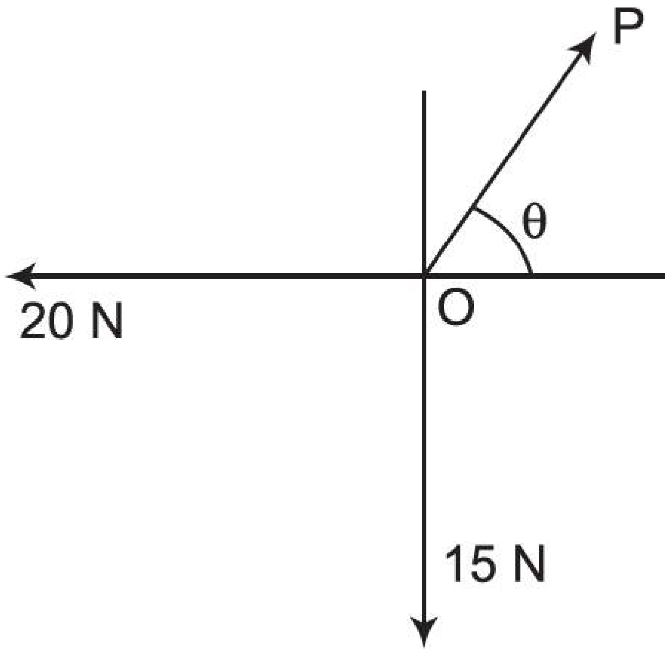
$$\frac{T_{AC}}{\sin 45} = \frac{T_{BC}}{\sin 30} = \frac{15}{\sin 105}$$

$T_{AC} = 10.96\ N$

$T_{BC} = 7.75\ N$



Find out the magnitude of force *P* and angle θ.



Sol.

$$\frac{P}{\sin 90} = \frac{15}{\sin(180-\theta)} = \frac{20}{\sin(90+\theta)}$$

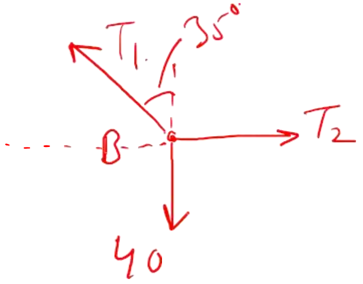
$$\frac{P}{\sin 90} = \frac{15}{\sin \theta} = \frac{20}{\cos\theta}$$

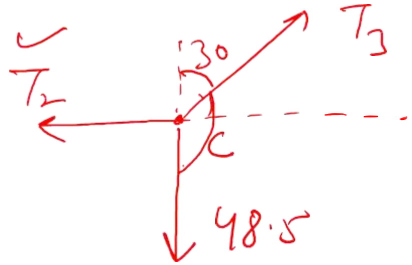
$$\frac{15}{20} = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

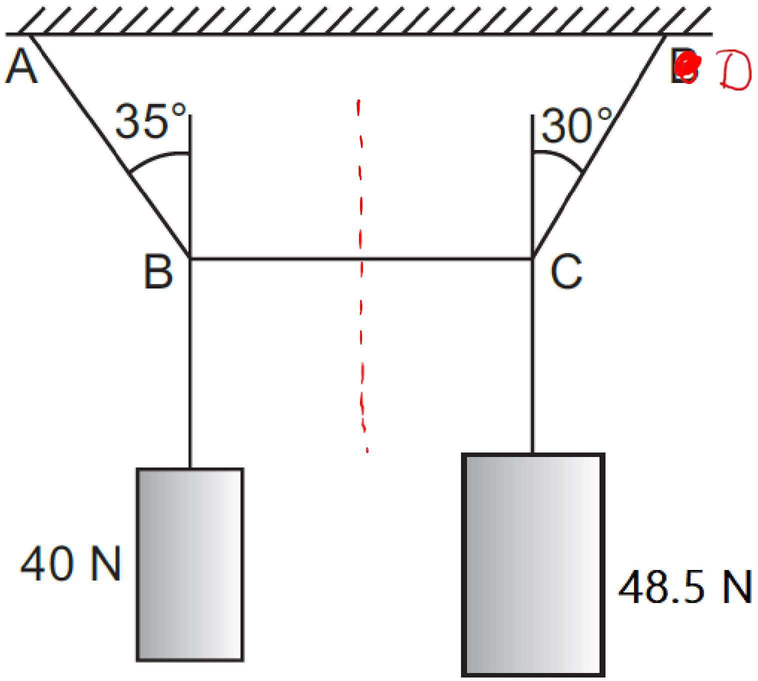
$$\theta = 36.86^\circ$$

$$P = \frac{20 \sin 90}{\cos 36.86} = 24.99\,N \simeq 25N \quad \text{Ans}$$

Determine tension in string *AB* (*T*1), tension in string *BC* (*T*2) and tension in string *CD* (*T*3).







$$\frac{40}{\sin 125} = \frac{T_1}{\sin 90} = \frac{T_2}{\sin 145^\circ}$$

$T_1 = 48.83\ N$

$T_2 = 28\ N$ Ans

$$\frac{28}{\sin 150} = \frac{T_3}{\sin 90}$$

$T_3 = 56\ N$ Ans