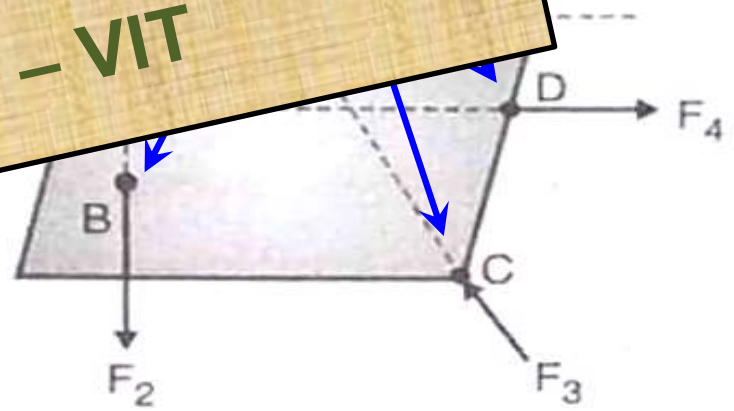
Vishwakarma Institute of Technology

FY - Department of Engineering, Sciences and Humanities

Mechanics – 2.1

Basics of Mechanics

FY – DESH – VIT



NON CONCURRENT FORCES

What is Mechanics ?

It is the study of **behavior of matter under the action of applied Forces.**

It is a science that deals with **study of Physical phenomenon.**

What is Engineering Mechanics ?

It deals with …..

1) **Laws and principles of Mechanics.**

2) Application to the **Engineering problems.**

It helps an Engineer in …..

1) planning 2) designing 3) construction of various types of structures and machines.

e.g. **Robots.**

Roll of CG in Robotics

Empty Bottle

Locate the CG of system of gripper and empty bottle

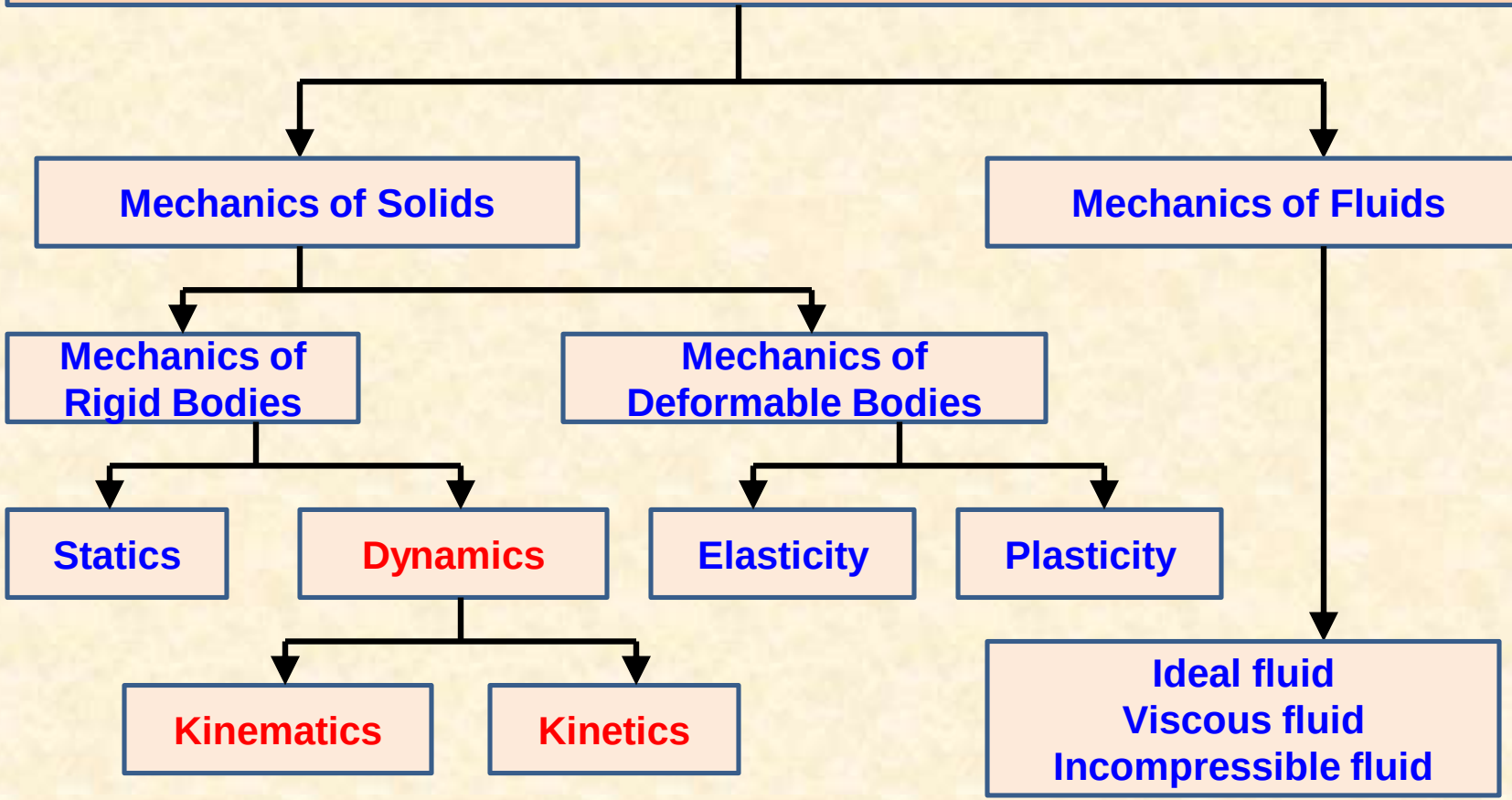
Half filled

Is the CG of system at the same point ?

Turned upside down !

Where is the CG of system now ?

Facets of Engineering Mechanics : A Glance



Statics And Dynamics

Statics – Study of behavior of rigid bodies under the action of applied forces when they are at **Rest**

Dynamics – Study of behavior of rigid bodies under the action of applied forces when they are in **Motion**

- **Kinetics –** Study of the Motion of the bodies **due to the application of forces.**
- **Kinematics –** Study of motion of the bodies **without considering the forces**

Dynamics - Example

Rollercoaster

Kinetics –

Which forces ?
What direction ?

Kinematics –

How fast ??
How far ??
How long ??

Can you make a list of different physical quantities associated with this system ??

Importance of Statics and Dynamics in Robotics

A Robot is a rigid body. **(What is a Rigid Body ?)**

- A Robot is acted by forces at **rest** and in **motion.**
- A Robot needs to have …..
  - Coordination
  - Synchronization
  - Stability
  - Balance

within its structural parts at **rest** and in **motion** as well.

∴ Sound knowledge of **Statics** and **Dynamics** is necessary !

Particle – Body – Rigidity – Deformation

- A particle occupies a point in space with negligible dimensions and has no size and shape.
- A body is composed of infinite number of particles.
- A body has definite size and shape.
- A body is always limited in all directions.
- In a Rigid body the distance between its particles does not change under the action of the forces.
- Rigid body is an idealized concept as there is no body in the Universe which is 100% Rigid.
- Every body always suffers from deformation. However, if it is extremely small, can be neglected and will not change its overall dimensions.

Rigid Body		Deformable Body
Negligible	Deformation	Considerable
Negligible change	Distance between particles	Considerable change
Maintained	Equilibrium	Disturbed
No Motion	Motion	Motion takes place
No change	Size and Shape	Changes

What is a Force?

Force is the capacity to do work.

Force produces motion in the body.

Force is a vector quantity, SI unit is Newton ($Kg.m/s^2$)

Force causes…. 1) Translation or 2) Rotation or 3) both.

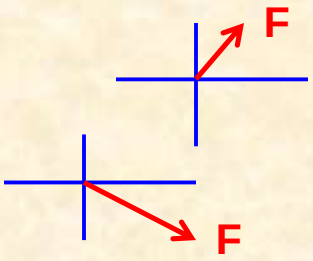
A Force has ……..

Magnitude – for e.g. 100 Newtons.

Direction – angle made with + X axis. For e.g….

$\theta 1 = +50^0$ i.e. CCW (1^{st} Quadrant)

$\theta 2 = -40^0$ i.e. CW (4^{th} Quadrant)



Sense – either a Push or a Pull.

Point of Application of Force – It is the point on the body at which the force can be assumed to be concentrated.

Line of Action of Force – The line in which the force tends to move the body.

Force System

A **"Force System"** consists of multiple forces acting on a body at a point.

Types of Force system are …..

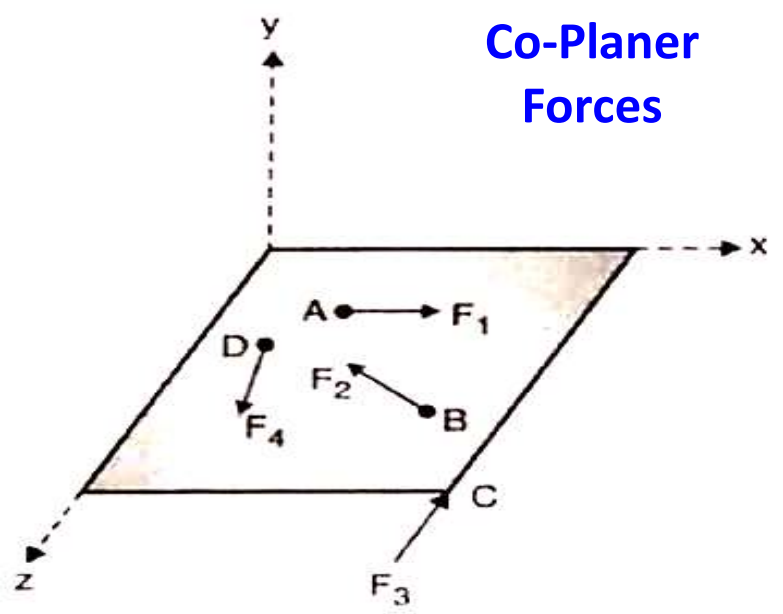
1) Co-planar and Non-Coplanar Force system

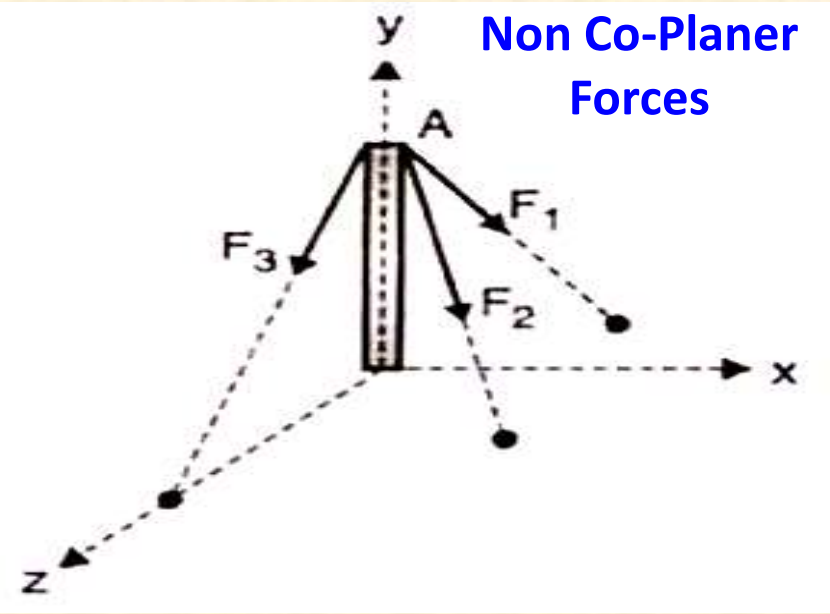
2) Concurrent and Non-Concurrent Force system

3) Parallel and Non-Parallel Force system

4) Collinear and Non-Collinear Force system

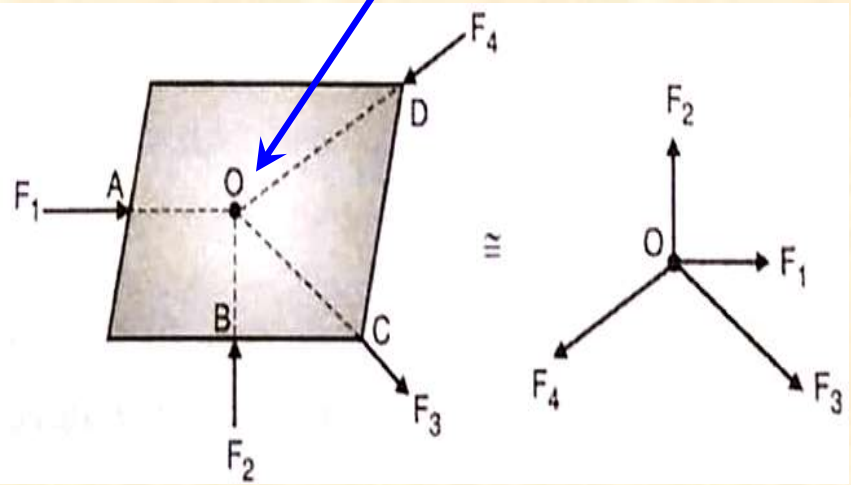
Co-Planar and Non Co-Planar Force system





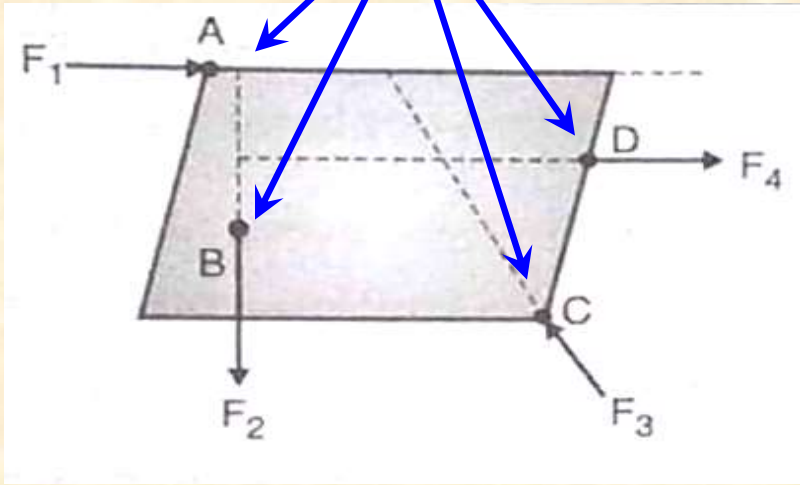
Concurrent and Non-concurrent force system

Lines of action are passing through a common point.



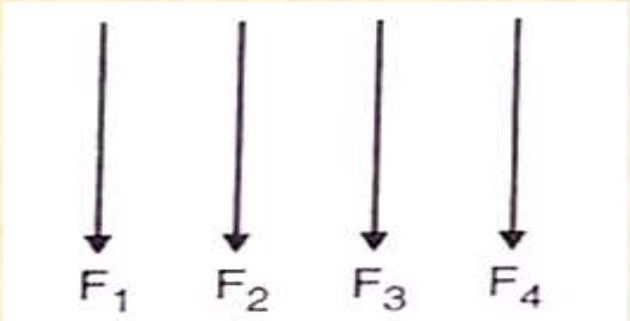
CONCURRENT FORCES

Lines of action are passing through multiple points.

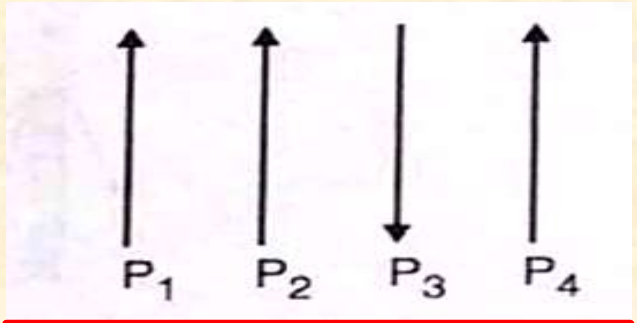


NON CONCURRENT FORCES

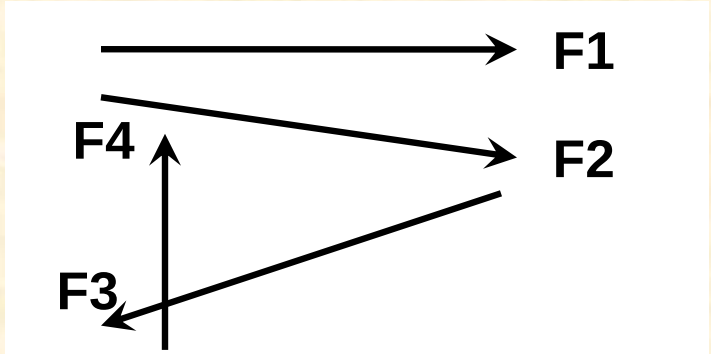
Parallel , Anti Parallel and Non-Parallel Forces



PARALLEL FORCES

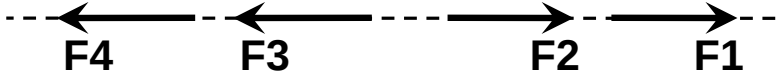


ANTI - PARALLEL FORCES



NON-PARALLEL FORCES

Collinear and Non Collinear force system



CO-LINEAR FORCE SYSTEM

SAFETY FALL NET

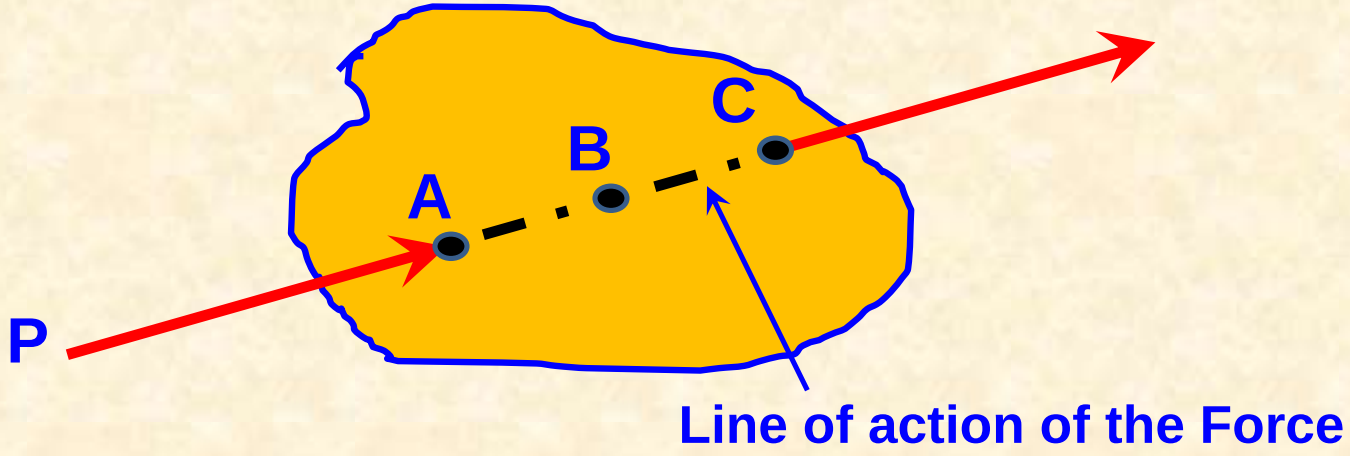
WHAT IS THIS SYSTEM ?

IS IT NON-CONCURRENT ?

IS IT CO-PLANER ?

IS IT PARALLEL ?

Principle of Transmissibility of Force -

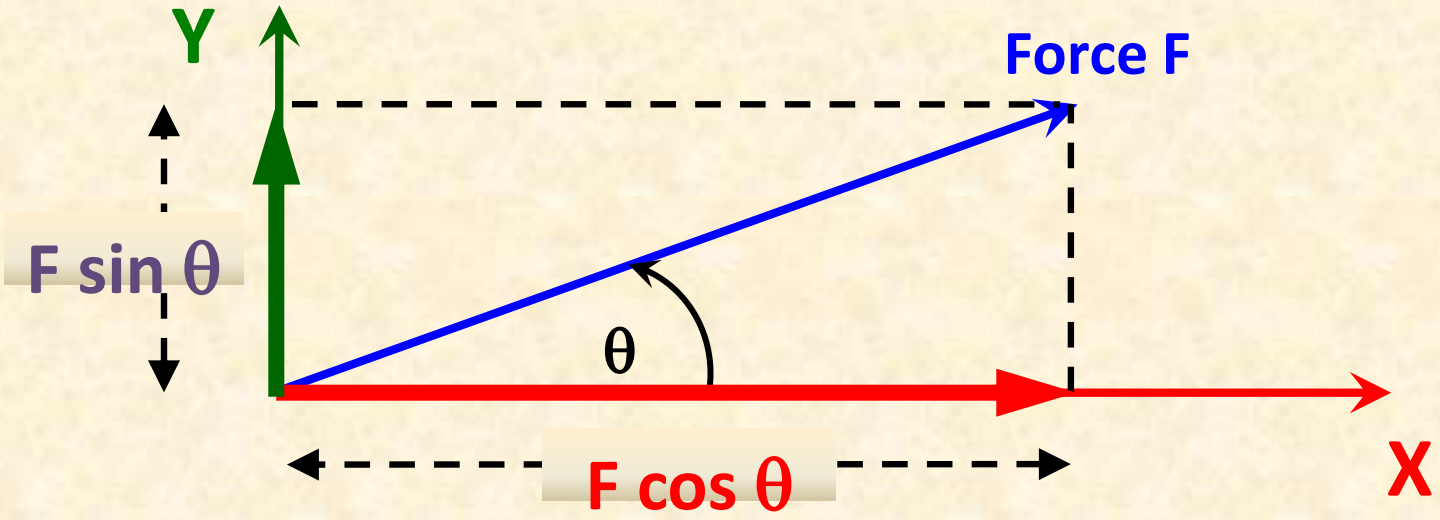


➢ "If a force acts at a point on a rigid body, then it is assumed to **act at any point on the line of action** of force within the body."

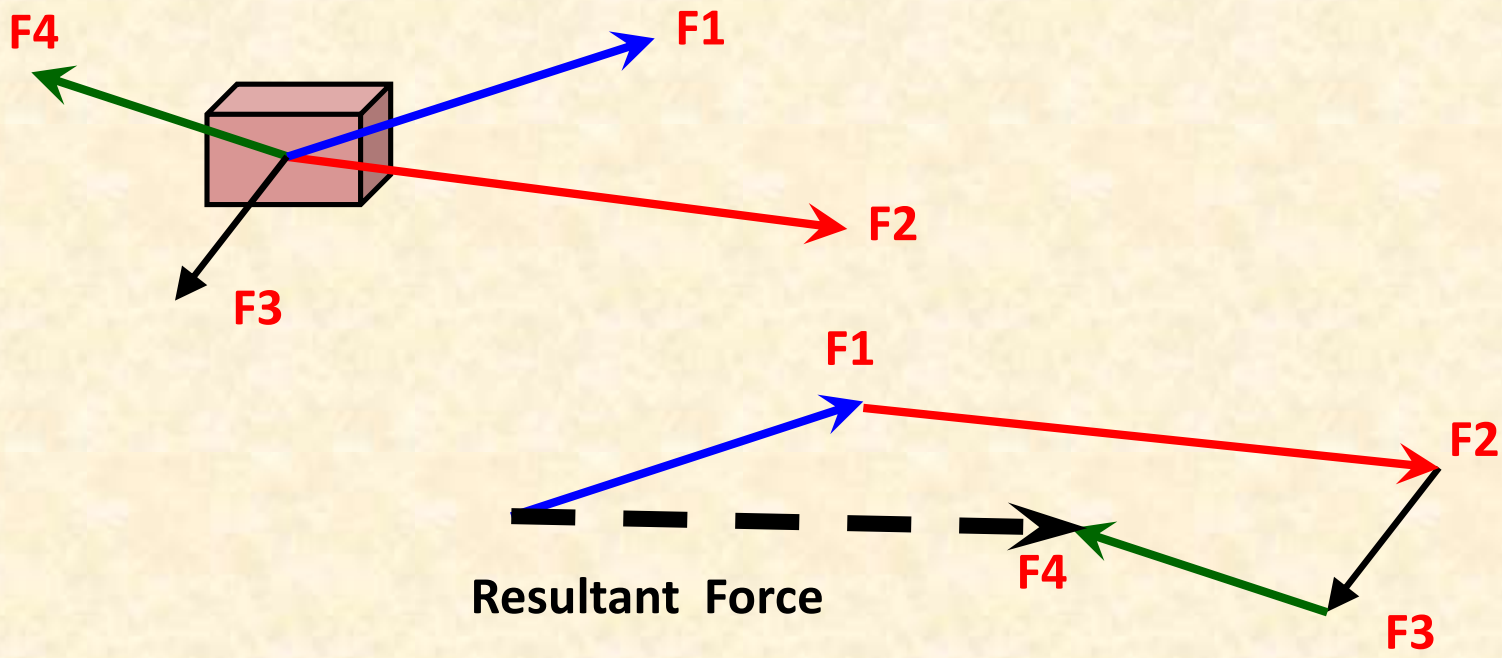
Resolution of a Force -

Force is a vector quantity. So, it can be assumed to be composed of two fictitious components.

Along….. 1) X axis 2) Y axis



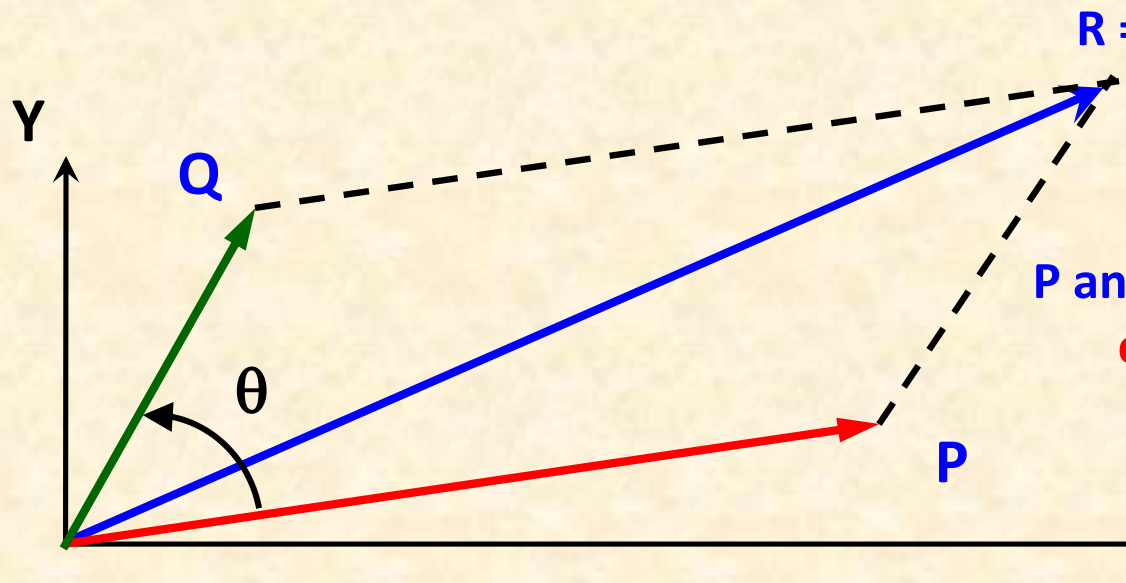
Resultant Force -



Resultant Force = vector sum of all forces.

(algebraic sum)

Law of Parallelogram of Forces -



R = Resultant is the diagonal

P and Q are coplaner and concurrent forces

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

Is Pythagoras theorem related to this ?

Law Of Parallelogram of Forces - Derivation

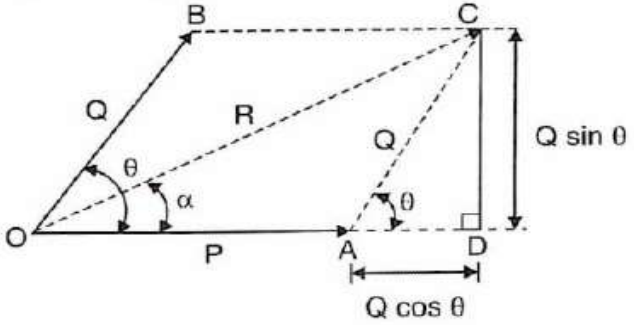
From the ΔADC ;

$$\sin\theta = \frac{CD}{AC} = \frac{CD}{Q}$$

$$\therefore \quad CD = Q \sin\theta$$

$$\cos\theta = \frac{AD}{AC} = \frac{AD}{Q}$$

$$\therefore \quad AD = Q \cos\theta$$



From the ΔODC ;

$$OC^2 = OD^2 + CD^2$$

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

$$(OD = OA + AD = P + Q\cos\theta)$$

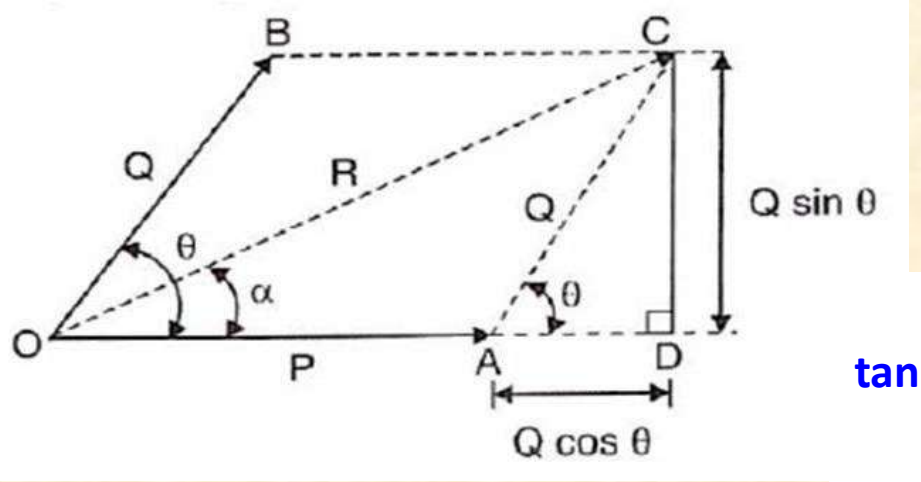
$$\therefore \quad R^2 = p^2 + Q^2\cos^2\theta + 2PQ\cos\theta + Q^2\sin^2\theta$$

$$R2 = P^2 + Q^2 + 2PQ\cos\theta$$

$$(\because \sin^2\theta + \cos^2\theta = 1)$$

$$\therefore \text{ Magnitude of resultant, } R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

Law Of Parallelogram of Forces -



$$\tan\alpha = \frac{CD}{OD} = \frac{CD}{OA + AD} = \frac{Q\sin\theta}{P + Q\cos\theta}$$

$$\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P + Q\cos\theta}\right)$$

IMP Note - α is the angle of the Resultant w.r.t. Force P and not X axis !

Equilibrium -

- A rigid body is said to be in equilibrium, when the resultant of the force system on it is zero.
- The resultant of the force system can be a Force or a Moment.
- If the resultant is zero, it implies that the resultant force (∑ F) and resultant moment (∑ M) both are zero.
- If the resultant force ∑ F = 0, there is No Translation.
- If the resultant moment ∑ M = 0, there is No Rotation.
- Thus the body is said to be in a …….**Complete Static Equilibrium**

Equilibrant = the balancing Force which brings ≡m

Equilibrant is a force which is …..

1) equal in magnitude
2) opposite in direction
3) collinear to the resultant of the force system.

Equilibrium is achieved when, all are satisfied.

1) $\sum Fx = 0$ ….. X components
2) $\sum Fy = 0$ ….. Y components
3) $\sum M = 0$ ….. Moments

Free Body Diagram (F.B.D.) - (Short sketch of the system)

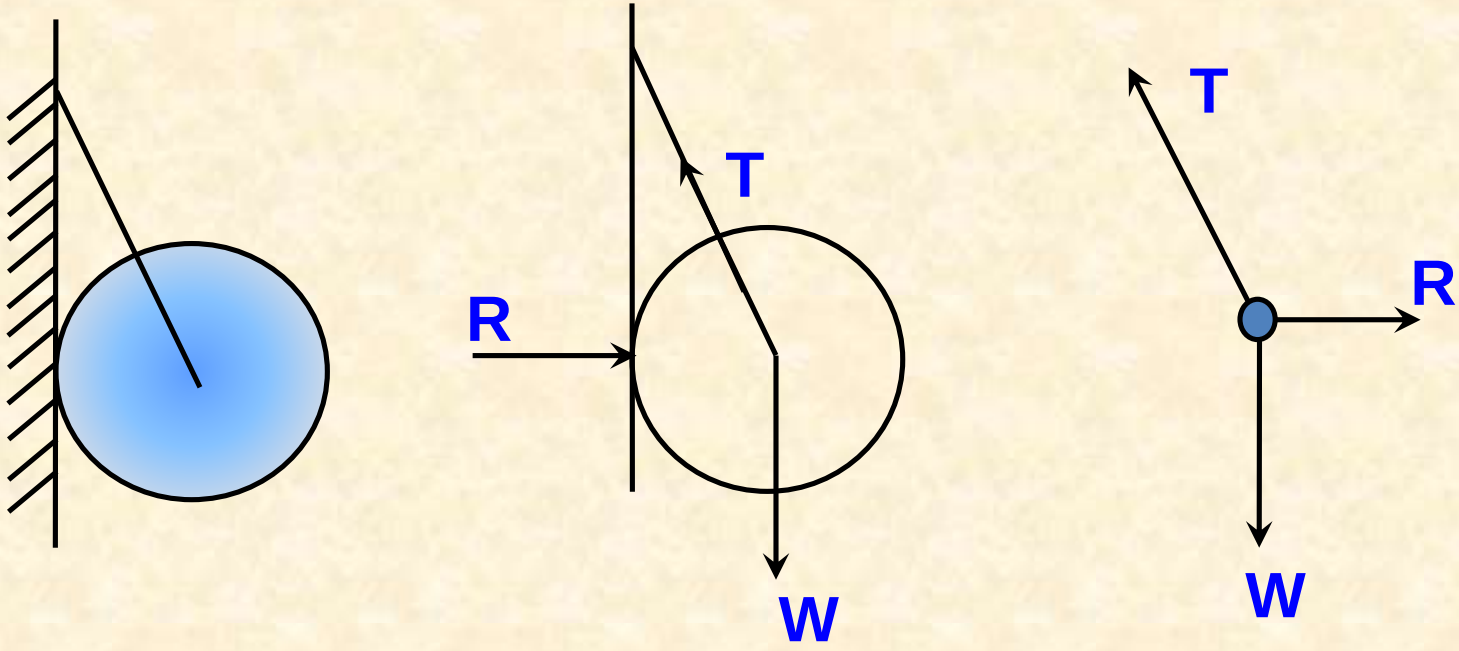
In a physical system, to study the equilibrium, the actual machine parts and structures are replaced by respective active, passive forces, reactions and moments.

FBD features ….

1) It is a sketch of a body of interest only.
2) All the surrounding bodies are removed.
3) All of the forces acting on the body are considered and shown.
4) All of the forces acted by the body on other bodies are NOT considered.

How to draw Free Body Diagram ? -

A sphere of weight W is resting on a rigid wall and is held by a string as shown……
Draw the FBD of the sphere.



Lami's Theorem -

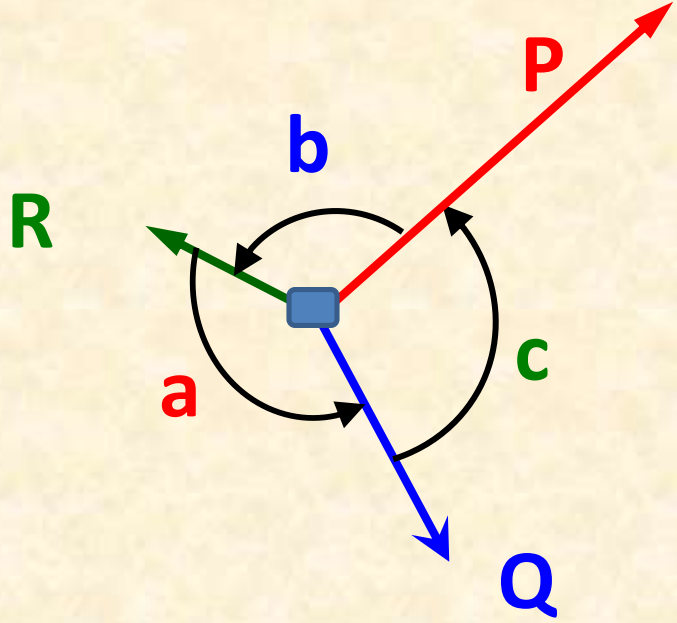
If there are a few forces acting on a body and the body is in a static equilibrium, then according to Lami's Theorem …….

P, Q and R are the 3 forces keeping the body in equilibrium.

a, b and c are the respective angles.

$$\frac{P}{\sin a} = \frac{Q}{\sin b} = \frac{R}{\sin c}$$

Also called as law of sines.



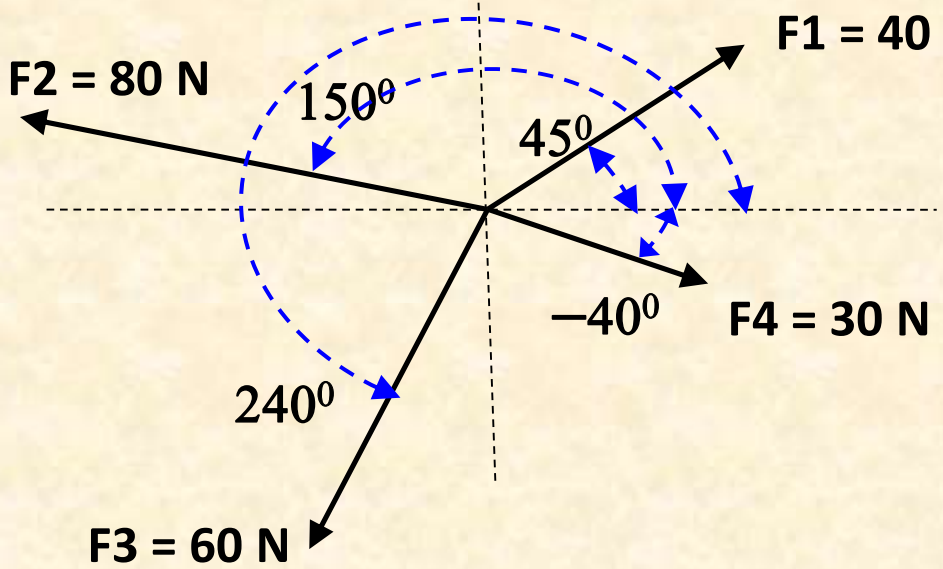
Numerical Example 1 -

Find the resultant Force R if .....

F1 = 40 N, F2 = 80 N, F3 = 60 N and F4 = 30 N

and the respective angles are .....

$\theta 1 = 45^0$, $\theta 2 = 150^0$, $\theta 3 = 240^0$, $\theta 4 = -40^0$



IMP Note - All angles are measured from +ve X axis.

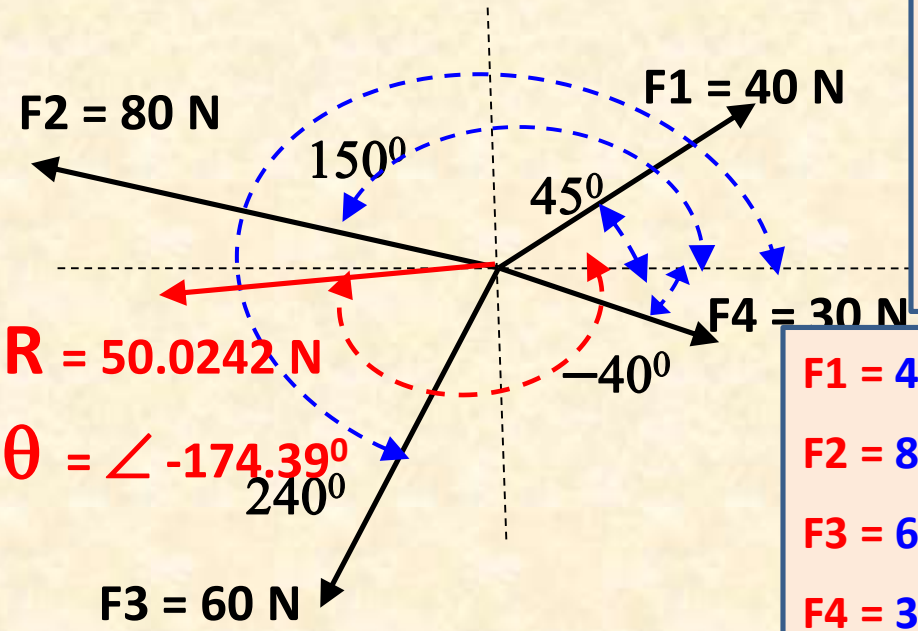
CCW angles are +ve

CW angles are –ve

Thus, $+ 60^0 = - 300^0$

Ex. 1 Solution -

Resolve each Force into X and Y components and sum up.



Note : F1 = 40 N∠45⁰ is the polar format. Convert it to Rectangular (Cartesian) using P to R function on calculator. Pol (+) and Rec (-)

F1 = 40 N ∠45⁰ = (28.2842, 28.2842)

F2 = 80 N ∠150⁰ = (-69.2820, 40)

F3 = 60 N ∠240⁰ = (-30, -51.9615)

F4 = 30 N ∠- 40⁰ = (21.2132, -21.2132)

IMP : All angles are measured from +ve X axis.

CW = – ve and CCW = + ve

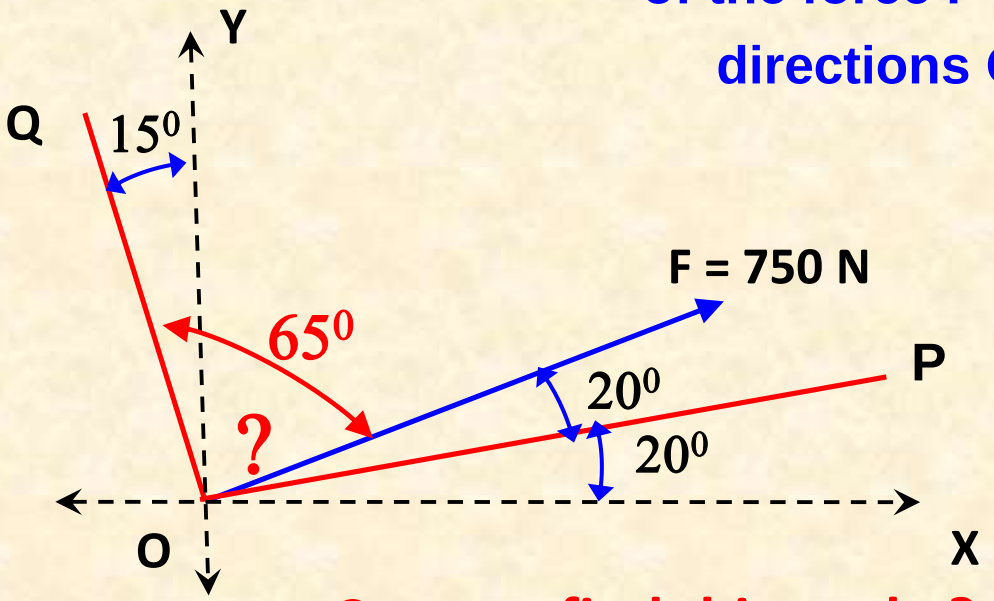
Σ Fx = - 49.7846 , Σ Fy = - 4.8905

Convert to Polar

$\therefore$ R = 50.0242 N ∠ -174.39⁰ … Answer

Numerical Example 2 -

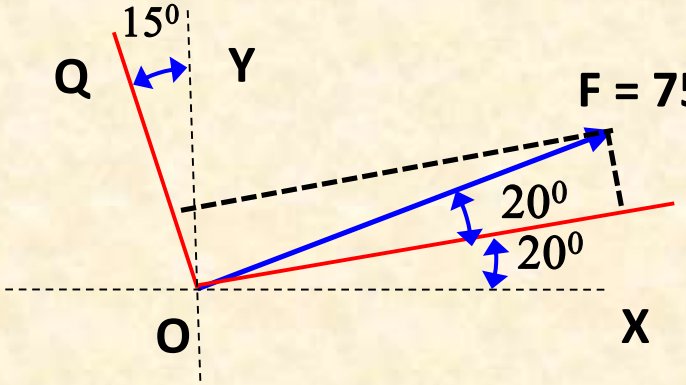
Find the magnitudes of components of the force F of 750 N in the directions OP and OQ.



Can you find this angle ?

What is angle ∠ POQ = ?

Ex. 2 - Solution



This is just opposite to the Parallelogram Law.

Formulae –

F along P = F * [sin FQ / sin (FP + FQ)]

F along Q = F * [sin FP / sin (FP + FQ)]

F_P = F * [sin FQ / sin (FP + FQ)]

= 750 * [sin 65 / sin (65 + 20)]

= 682.3273 N

F_Q = F * [sin FP / sin (FP + FQ)]

= 750 * [sin 20 / sin (65 + 20)]

= 257.4949 N ….. Answer

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Thanks !
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NON CONCURRENT FORCES