Engineering Mechanics

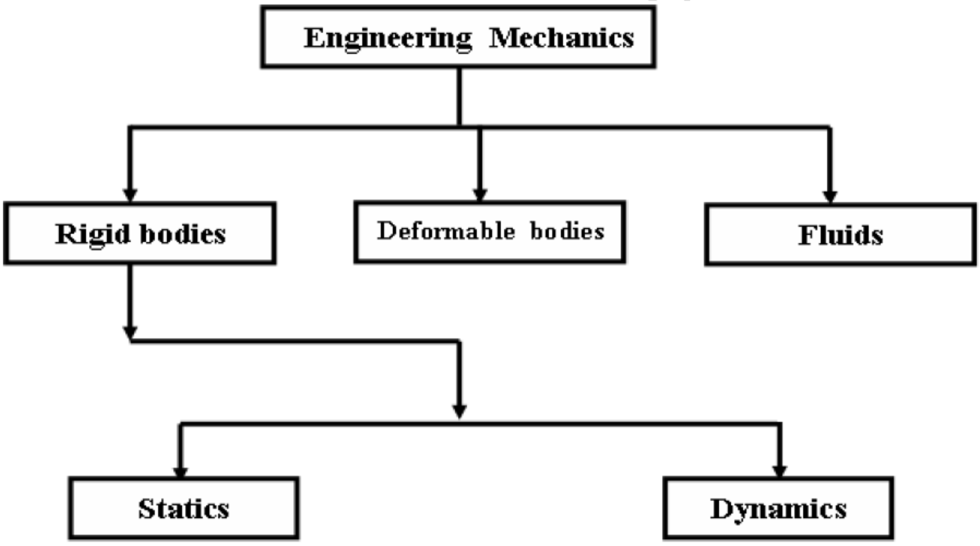
Introduction:

Definitions: -

Mechanics: - Can be defined as that branch of the physical science deals with the state of "rest" or "motion" of bodies that are subjected to the action of forces.

It is divided into three parts: mechanics of *rigid bodies*, mechanics of *deformable bodies*, and mechanics of *fluids*.

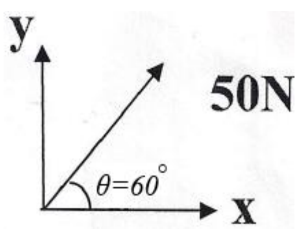
The mechanics of rigid bodies is subdivided into *statics* and *dynamics*, (*Static* dealing with bodies at rest), (*Dynamic* dealing with bodies in motion).



Force: - is an action that changes, or tends to change, the state of motion of the body upon which it acts, or (Is the action exerted by one body upon other).It is a vector quantity that can be represented either mathematically or graphically.

A complete description of a force must include its:

1. Magnitude
2. Direction and sense
3. Point of action (location of its effect point)



***Particle:* -** A particle may be defined as an object which has only mass and no size. When a body is treated as a particle in analysis of the problem, it has a mass but its "size" can be neglected.

***Rigid body:* -** When a body treated as a rigid body, it has mass and size but its deformation is negligible.

Rigid body mechanics is divided into two branches: -

1- *Statics:* - It deals with the equilibrium of bodies, that is, those that are either at rest or move with a constant velocity (acceleration, a = 0).
2- *Dynamics:* - It deals with accelerated motion of bodies.

<u>Units of measurements:</u>

1- ***International System of Units (S.I units) (meter, kg, N)***
2- ***English System of Units (U.S) (FPS) (foot, Ib_m, Ib_f)***

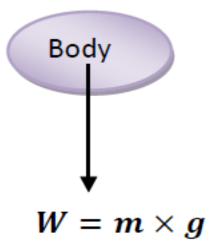
Basic units (Length "L", Mass "m", Force "F", Time "t", Temperature "T")

1- *International system of units (S.I) (m, kg, N)*

Quantity	***Symbol***	***Unit***
Length	L, l, …….etc.	m , (meter)
Force	F, P,Q,….etc.	N , (Newton)
mass	m	Kg , (kilogram)
Weight	W	N (Newton)
Moment	M	N.m , (Newton * meter)
time	t	s, (second)
velocity	v	m/s
acceleration	a	m/s^2

Weight: the weight of a body is given by the relation :

$$W = m \times g$$



Where: -

W:the weight of the body. (N)

m:- the mass of the body. (kg)

g: the gravitational acceleration. (m/s^2), ($g = 9.81\ m/s^2$, S.I) ($g = 32.2\ ft/s^2$, FPS) (Constant)

Example: **-** if the mass of a body is 25 kg, what is the weight of that body?

Solution / $W = m * g \Longrightarrow W = 25 * 9.81 = 245.25\ N$

Note:- *In english system of units (FPS), the units of force is "Pound, (lb)", length is "Foot, (Ft)".*

TABLE 1–1 Systems of Units

Name	Length	Time	Mass	Force
International System of Units SI	meter m	second s	kilogram kg	newton* N $\left(\frac{kg \cdot m}{s^2}\right)$
U.S. Customary FPS	foot ft	second s	slug* $\left(\frac{lb \cdot s^2}{ft}\right)$	pound lb

*Derived unit.

Note:-

- 1m =100 cm = 10^2 cm
- 1m = 1000 mm =10^3 mm
- 1cm = 10 mm
- 1lb = 0.453 kg = 4.45 N (1kg = 2.225 lb)
- 1 Slug = 14.59 kg
- 1ft = 0.305 m = 12 in
- 1 in = 2.54 cm
- 1 GN = 1000 MN = 10^3MN
- 1 GN = 1000000 KN = 10^6 KN
- 1 GN = 1000000000 N = 10^9 N
- 1 MN = 1000 KN
- 1 KN = 1000 N

The table below shows the units for other various quantities in ***SI*** system units.

Quantity	*Unit*	*Notation*
Area	Square metre	m^2
Volume	Cubic metre	m^3
Velocity	metre per second	m/sec
Acceleration	metre per second per second	m/sec^2

Example1: - Convert the force *F* = 4000000 ***N*** into ***KN*** and into ***MN***.

Sol: $4000000\,\cancel{N} * \frac{1KN}{1000\,\cancel{N}} = 4000$ KN, $\quad 4000000\,\cancel{N} * \frac{1\ \text{MN}}{1000000\,\cancel{N}} = 4$ MN

Example 2: - Convert the force *P* = 3.5 ***KN*** into ***N***.

Sol: 3.5 KN * 1000 = 3500 N

Example 3: - Convert the force R = 3520000 ***N*** into ***KN*** and ***MN***.

Sol: 3520000 / 10^3 = 3520 N, 3520000/ 10^6 = 3.52 MN

Example 4: - Convert the length L= 3 m into cm and into mm.

Sol: $3\,\cancel{m} * \frac{100\ cm}{1\,\cancel{m}}$ = *300 cm*, *3 m *1000 = 3000 mm*

Example 5: - Convert 2 km/hr into m/s. How many ft/s is this?

Sol: 1 km = 1000 m, 1hr = 3600 sec

$$2\,\frac{\cancel{km}}{\cancel{hr}} * \frac{1000\ m}{1\cancel{km}} * \frac{1\,\cancel{hr}}{3600\ s} = 0.556\ m/s$$

$$0.556\ \frac{\cancel{m}}{s} * \frac{1\ ft}{0.305\,\cancel{m}} = 1.82\ ft/s$$

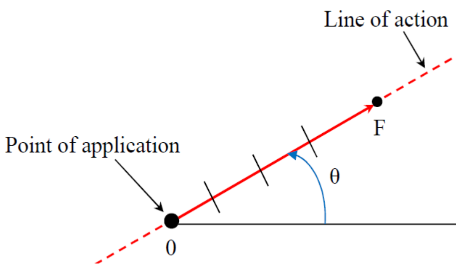
Scalars and Vectors: - most of physical quantities in mechanics can be expressed mathematically by means of "scalars & vectors".

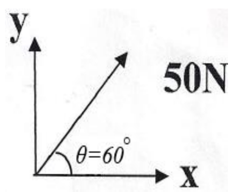
Scalar quantity: - It is a quantity has "*magnitude*" only, for example :(mass, volume, time, distance and length).

Vector quantity: - It is a quantity has both "*a magnitude*" and "*a direction*" (e.g. Force, Velocity, weight….etc.). Vector quantity is generally represented by a letter with an arrow written over it, such as ($\vec{F}$. $\vec{V}$).

Characteristics of force: -

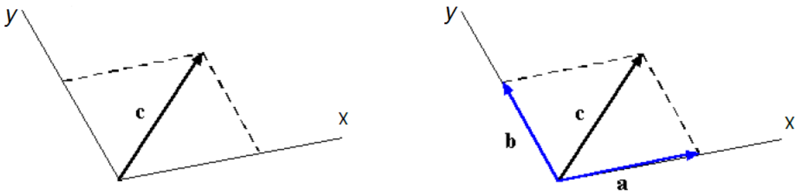
1- Magnitude
2- Direction & sense
3- Location of its effect point



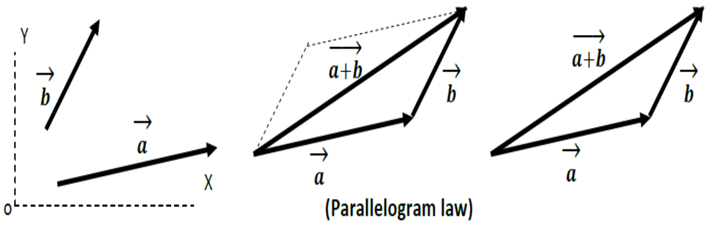


Note:- *Force is measured by Newton (N) or Pound (lb).*

Resolution of a vector: A vector can be resolved along different directions by using the "Parallelogram law". The figure below shows how one resolves vector "c" into two components "a" and "b" which are along the given directions.



Vector addition: *Vector addition follows the parallelogram law described by the figure below:*



(Parallelogram law)

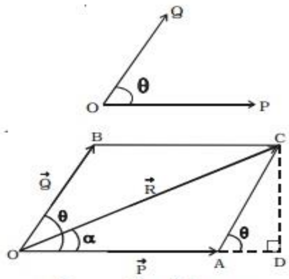


Fig Parallelogram law of forces

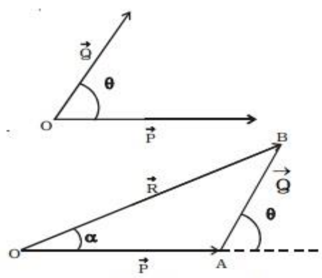


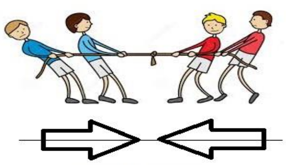
Fig Triangle law of forces

- ***Symbols of angles: θ (Theta), β*** *(Beta)****,*** *α (Alpha), γ (Gamma).*
- ***Units: Degree (°)***

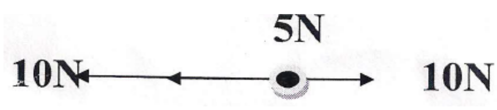
Forces Systems: -

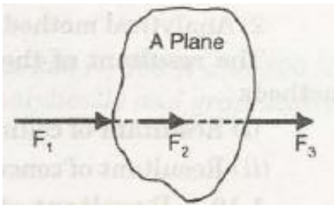
We will classify forces systems using the arrangements of lines of force.

1- Coplanar Collinear forces: The fig. below shows three forces F1 F 2 and F3 acting in a plane. These three forces are in the same line i.e., these three forces are having a common line of action. This system of forces is known as coplanar collinear force system. Hence, in coplanar collinear system of forces, all the forces act in the same plane and have a common line of action. For example (Forces on a rope in tug of war).

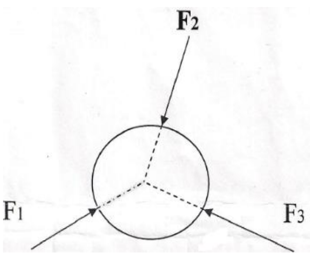


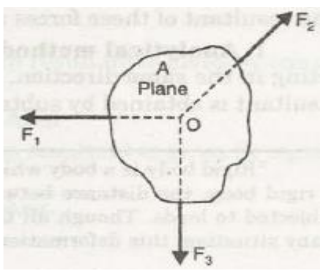
Rope in a tug of war



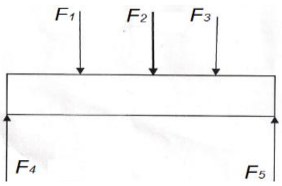


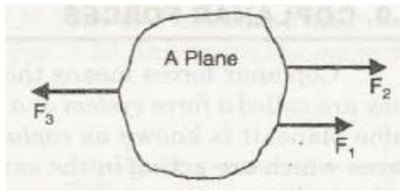
2- Coplanar Concurrent forces: The fig below shows three forces F1 F 2 and F 3 acting in a plane and these forces intersect or meet at a common point o. This system of forces is known as coplanar concurrent force system. Hence, in coplanar concurrent system of forces, all the forces act in the same plane and they intersect at a common point.



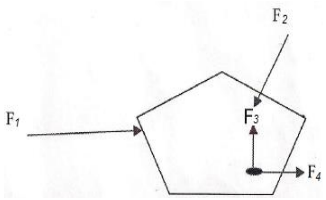


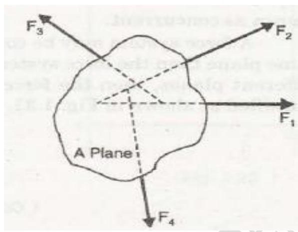
3-Coplanar Parallel forces: The fig. shows three forces F1 F2 and F3 acting in a plane and these forces are parallel. This system of forces is known as coplanar parallel force system. Hence, in coplanar parallel system of forces, all the forces act in the same plane and are parallel.



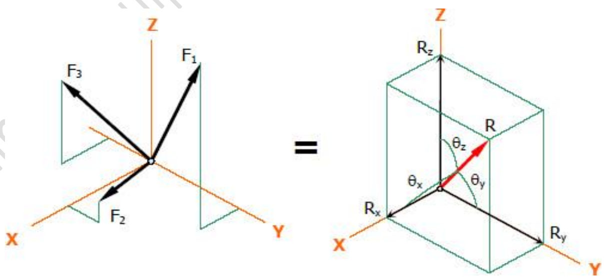


4-Coplanar Non-concurrent Non-parallel forces: The fig. below shows four forces F1, F2 , F3 and F4 acting in a plane. The lines of action of these forces lie in the same plane but they are neither parallel nor meet or intersect at a common point. This system of forces is known as coplanar non-concurrent non-parallel force system. Hence, in coplanar non-concurrent non-parallel system of forces, all the forces act in the same plane but the forces are neither parallel nor meet at a common point. This force system is also known as general system of forces.

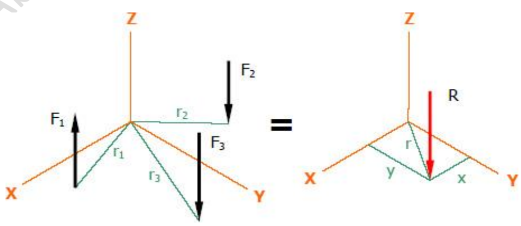




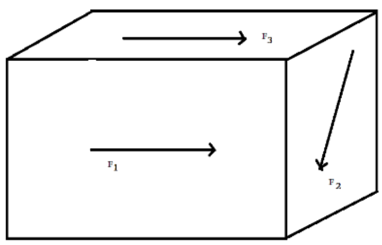
5-Non-Coplanar concurrent forces: - The forces are not lie in the same plane, but their lines of action passes through a single point. For example (A tripod carrying camera).

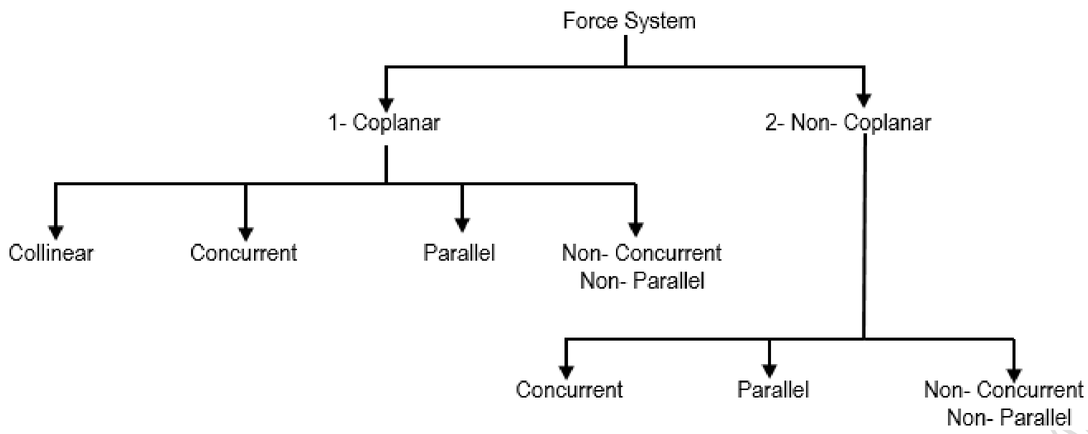


6-Non-coplanar parallel forces: - All the forces are parallel to each other, but not in same plane.



7-Non-coplanar non-concurrent non-parallel: - Not all forces lie in the some plane and their lines of action do not pass through a single point





Classification of forces system

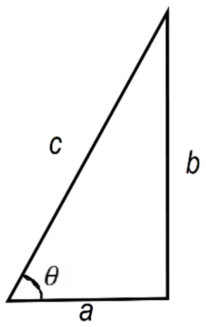
The mathematic you need: -

For the right triangle: -

$Sin\ \theta = \frac{b}{c} \Longrightarrow b = c\ sin\ \theta$

$Cos\ \theta = \frac{a}{c} \Longrightarrow a = c\ cos\ \theta$

$Tan\ \theta = \frac{b}{a} \Longrightarrow \theta = tan^{-1}(\frac{b}{c})$

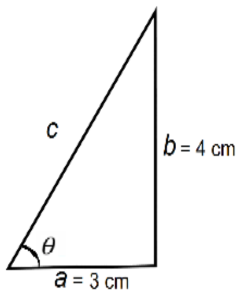


r or C = $\sqrt{(a)^2 + (b)^2}$ (Pythagoras law)

Example: - for the right triangle, find ***C***, and find the angle ***θ***.

$C = \sqrt{(3)^2 + (4)^2} \Longrightarrow C = \sqrt{9 + 16} = 5$ cm

$Tan\ \theta = \frac{4}{3} \Longrightarrow \theta = tan^{-1}(\frac{4}{3}) = 53.2^{\circ}$

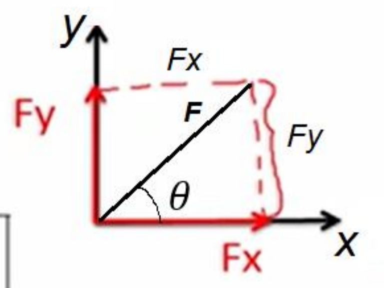


For the general triangle: -

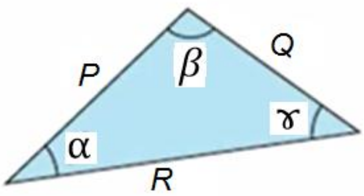
$\alpha + \boldsymbol{\beta} + \gamma = 180^\circ$

$$Fx = F \cos\theta \quad \left(\cos\theta = \frac{Fx}{F}\right)$$

$$Fy = F \sin\theta \quad \left(\sin\theta = \frac{Fy}{F}\right)$$

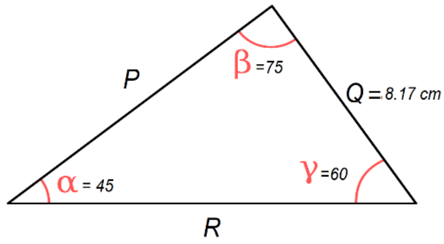


Law of sines	$\frac{P}{Sin\,\gamma} = \frac{Q}{Sin\,\alpha} = \frac{R}{Sin\,\beta}$
Law of cosines	$P = \sqrt{Q^2 + R^2 - 2\,Q\,R\cos\gamma}$ $Q = \sqrt{R^2 + P^2 - 2\,R\,P\cos\alpha}$ $R = \sqrt{P^2 + Q^2 - 2\,P\,Q\cos\beta}$



Example: - for the triangle below, find ***P*** and ***R*** .using law of sines & law of cosines.

Sol:



$$\frac{P}{Sin\,\gamma} = \frac{Q}{Sin\,\alpha} \Rightarrow \frac{P}{Sin\,60} = \frac{8.17}{Sin45}$$

$$P \sin 45 = 8.17 \sin 60 \Rightarrow P = 10 \text{ cm}$$

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

$$R = \sqrt{(10)^2 + (8.17)^2 - 2 * 10 * 8.17\cos 75} \qquad = 11.16 \text{ cm}$$