BATU-EXAM

Mechanics & Basic Electrical & Electronics

20/08/23

Mechanics

Definition:-

It is the branch of applied science which deals with laws and principles of mechanics along with their application to engineering problem.

Divisions of Engineering Mechanics.

- Statics (physical science of bodies at rest)
- Dynamics (Physical Science of bodies in motion)
  - Kinematics (independent of forces acting on bodies)
  - Kinetics (Considering forces acting)

* Statics:

- It is the branch of eng. mechanics which deals with forces & their effect while acting upon at rest.

* Dynamics:

- It is the branch of engg. mechanics which deals with forces & their effect while acting upon the bodies in motion. It is further divided into Kinematics and Kinetics.

(I) Kinematics:

- It is the branch of dynamics which deals with bodies in motion without any reference to forces which are responsible for motion.
- eg. Projectile.

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Kinetics:

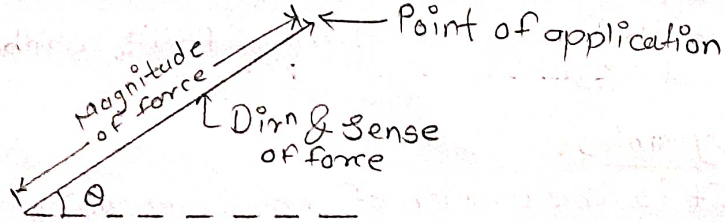
It is the branch of dynamics which deals with bodies in motion due to application of forces.

Forces:

- The force is defined as an agent which produces or tends to produce, destory or tend to destory motion.

(IMP) Characteristics of forces:-

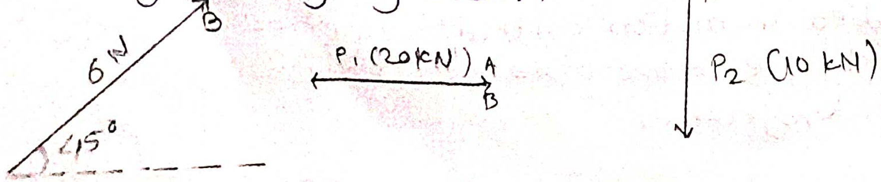
1. Magnitude of force (i.e. 100 N, 50 N, etc)
2. The direction of line along which force act. it is also known as line of action of force.
3. Nature of force (whether force is Pull or Push). This denoted by placing an arrow on the line of action of forces.
4. The point at which the force act on the body.



Representation of forces.

* ~~Fore~~ Forces may be represented by methods

1. Vector representation - This method represents a force graphically by vector.



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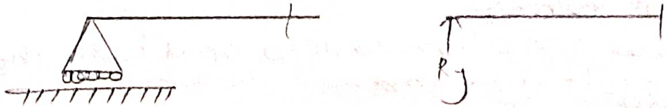
2. Bow's Notation - It is method of representing a force by writing two capital letters ... either side of the force.

Types of Support:

1. Pin or Hinge

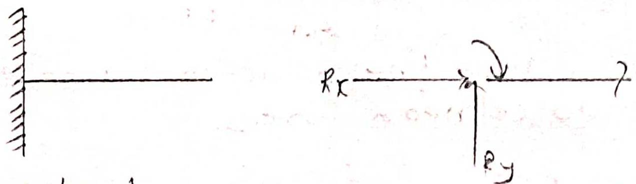
It prevents translation along x & y.

2. Roller -



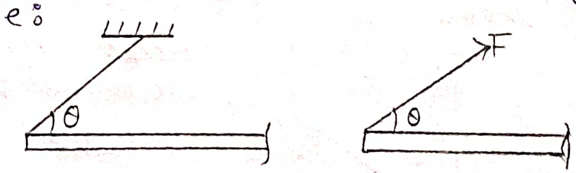
It is prevents translation along the direction prependicular to the roller surface.

3. Fixed:



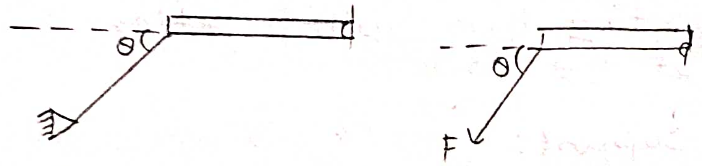
It prevents translation along x and y direction. It is also prevents rotation of body.

4. Cable:



Tension force acts along direction of cable away from body.

5) Link.



Reaction acts along the link away towards the body.

Idealisation Of Engineering Problems:

1) Strategy 2) Modeling 3) Analysis
4) Reflect & Think.

System of forces -

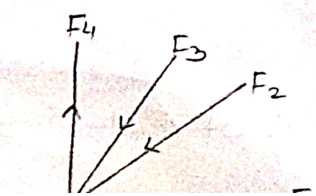
When two or more forces acts on a body they are called as system of forces.

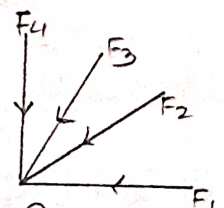
1) Coplanar forces:
The forces whose line of action lie on same plane are known as coplanar forces.

2) Colinear forces:-
The force whose line of action lie on same line are known as colinear forces.

3) Concurrent forces:
- The force which meet at one single point is known as concurrent forces

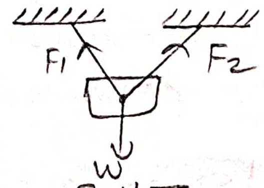
Collinear Force System





Push Type

Concurrent force system



Pull Type

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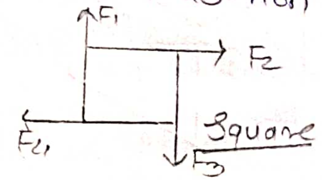
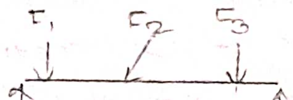
4) Non-Concurrent forces:
- The forces which acts at different point are known as non - concurrent forces.



Square



Beam

5) Parallel Forces:-
- The forces whose line of action are ||el to each others are called as parallel forces.
- They may be classified as:
(I) like ||el forces:- Parallel forces acting in same direction are called like parallel forces.
(II) Un-like parallel forces:- Parallel force acting in opposite direction are called as Un-like....:

Non- Coplanar Force System:-

- If line of action of all forces lie on different plane the system is called as non-Coplanar force system.

Non-Coplanar force System.
↓
Concurrent | Parallel | Non-||el or general force | Non-Concurrent

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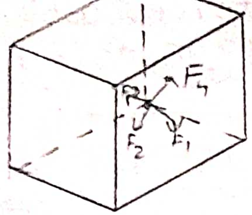
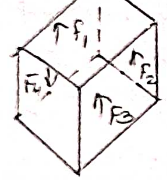
① Non-Coplanar Concurrent:

- The forces lie in different plane. But passes through single point of concurrency 'o' as shown in figure.



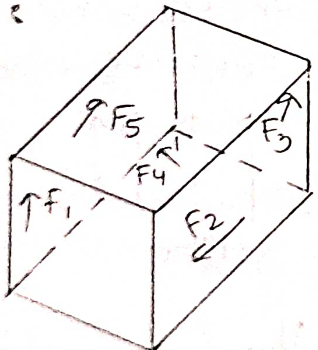
② Non-Coplanar parallel:-

- ~~Non~~ This forces exist in different plane but parallel to each other.



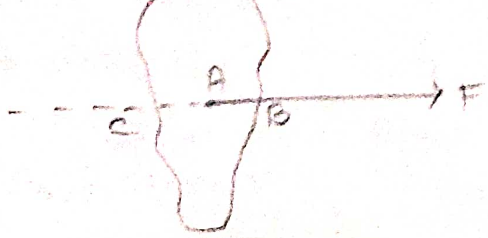
③ Non-Coplanar Non-Concurrent:

- This forces act in different plane and they do not pass through one single point of concurrency as shown in figure.



Principle Of Transmissibility of Forces:-

It states that "If a force acts at any point on a rigid body it may also be considered to act at any other point on its line of action, provided this point is rigidly connected with body.



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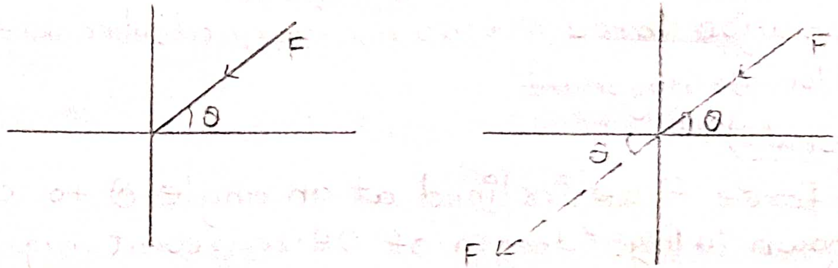
From fig F is the force act at a point A. in the rigid body. The same force will act at any other point on the line BC without change in its magnitude.



As per this priciple if the force is pushed in any quadrant the component can be calculated by extending the line of action of force and making it pull.

Resultant → sum of all the forces acts the body

* Resultant forces:-

- If a number of forces are acting at simultaneously on a point or particle, then it is possible to find out a single force which could replace them i.e, which would produce the same effect as produced by given forces. This single force is called as resultant force & the given forces are called component of forces.

* Resolution Of Force -

- The way of representing a single force into number of forces, without enhancing the effect of the force on the body is called resolution of forces.

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Methods of Resolution - There are two methods of resolution.

① Resolution of two forces x two mutually perpedicular component (Orthogonal)

② Resolution force x two non-perpendicular component (Non-Orthogonal)

(Orthogonal -)

① let a force F be inclined at an angle θ to x-axis as shown in fig. (length of OA represent magnitude of B). we have to resolve it into ~~comp~~ two components F_x along x-axis & F_y along y-axis.

Given : F & θ

To find : F_x & F_y

In $\triangle OAB$, $\cos\theta = \frac{OB}{OA}$

$\therefore OB = F_x = F\cos\theta$ & $\sin\theta = \frac{AB}{OA}$

$\therefore AB = F_y = F\sin\theta$

magnitude of components $F_x = F\cos\theta$ & $F_y = F\sin\theta$

Direction of components is F_x towards right & F_y vertically upward,

Different cases of resolution of force.

−, +	+, +
−, −	+, −

Part{I} : Resolution when the force is pull in respective quadrant.

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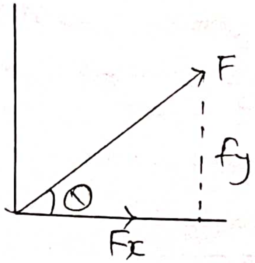
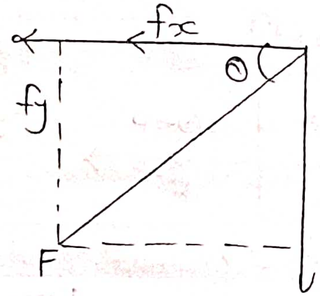
Case (I)



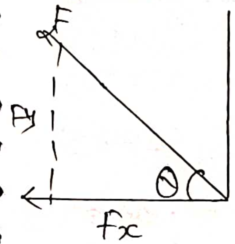
$F_x = F\cos\theta$
$F_y = F\sin\theta$

Case (II)



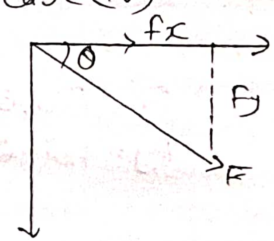
$F_y = -F\sin\theta$
$F_x = -F\cos\theta$

Case (III)



$F_x = -F\cos\theta$
$F_y = F\sin\theta$

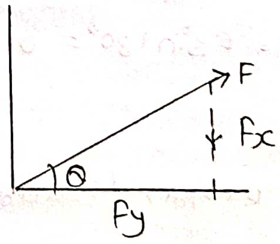
Case (IV)



$F_x = F\cos\theta$
$F_y = -F\sin\theta$

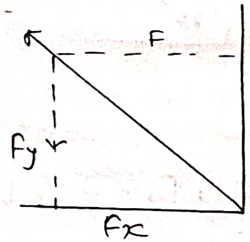
Part (II) - Resolution when force is push in respective quadrant.

Case (I)



$F_x = F\cos\theta$
$F_y = F\sin\theta$

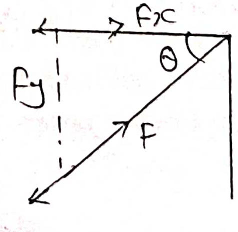
Case (II)



$F_x = F\cos\theta$

$F_y = \cancel{-F\cos}$ $-F\sin\theta$

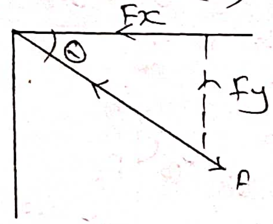
Case (III)



$F_x = F\cos\theta$

$F_y = F\sin\theta$

Case (IV)

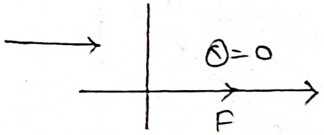


$F_x = -F\cos\theta$

$F_y = F\sin\theta$

Part (III): Resolution when force lies on x and y axis.

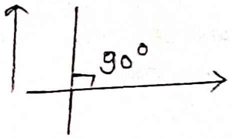
Case (I)



$F_x = F\cos\theta = F\cos 0 = F$

$F_y = F\sin\theta = F\sin 0 = 0$

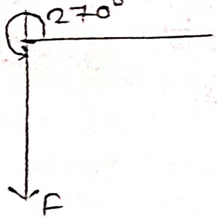
Case (II)



$F_x = F\cos\theta = F\cos 90^\circ = 0$

$F_y = F\sin\theta = F\sin 90^\circ = 1$

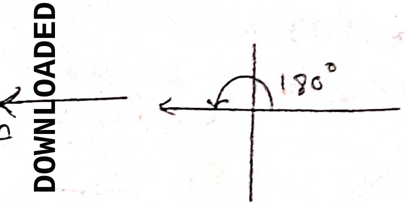
Case (III)



$F_x = F\cos\theta = F\cos 270^\circ = 0$

$F_y = F\sin\theta = F\sin 270^\circ = -F$

Case (IV)

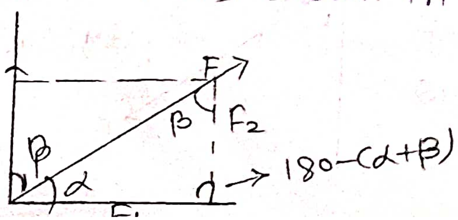


$F_x = F\cos\theta = F\cos 180^\circ = -F$

$F_y = F\sin\theta = F\sin 180^\circ = 0$

- Resolution of a force into two Non-perpendicular Component (Non-orthogonal) -

Let F_1 and F_2 be component of F along axis α and β with F as shown in fig.



In $\triangle$ OAB

$$\frac{F_1}{\sin\beta} = \frac{F_2}{\sin\alpha} = \frac{F}{\sin[180^\circ-(\alpha+\beta)]}$$

$$F_1 = \frac{F\sin\beta}{\sin[180^\circ-(\alpha+\beta)]}$$

$$F_2 = \frac{F\sin\alpha}{\sin[180^\circ-(\alpha+\beta)]}$$

Composition of forces -

- The process of finding out resultant force of number of given forces is called composition of forces. The resultant of a force system can be determined by any one of the following method:-

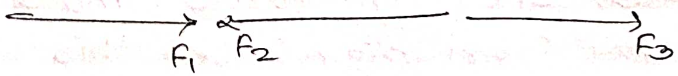
(I) Analytical Method (II) Graphical.

(I) Analytical Method:

(A) Resultant of Coplanar, collinear Forces:-

- Let us consider collinear forces F_1, F_2, F_3, as show in fig for finding their resultant analytically take, algebric sum of their sense & get net value which will give the resultant.

The direction of resultant depends upon their magnitude.



(B) Resultant of coplanar, concurrent forces:-

(I) Method of Resolution:-

(i) Resolve all the forces horizontally & vertically and find algebric sum of all Horizontally and Vertically Component i.e, ΣF_x & ΣF_y.

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The resultant (R) will be given by

$$R = \sqrt{\Sigma(fx)^2 + \Sigma(fy)^2}$$

Let θ be acute angle made by resultant with horizontal then $\tan\theta = \frac{\Sigma fy}{\Sigma fx}$

$$\theta = \tan^{-1}\left(\frac{\Sigma fy}{\Sigma fx}\right) \text{ ——— direction}$$

$$\boxed{R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2}} \text{ ——— magnitude}$$

Parallelogram law Of forces :-

Parallelogram laws of forces state that "if two forces acting simultaneously on a particle be represented in magnitude and direction by two adjacent sides of Parallelogram then resultant may be represented in magnitude and direction by the diagonal of parallelogram which passes through their point of intersection."

Theorem:

Let us consider two concurrent forces P and Q acting at and away from origin O. Let this two forces be represented in magnitude and direction as two adjacent sides of parallelogram OACB. Thus line joining O & C represent resultant (R) in magnitude & direction according to parallelogram law of forces.

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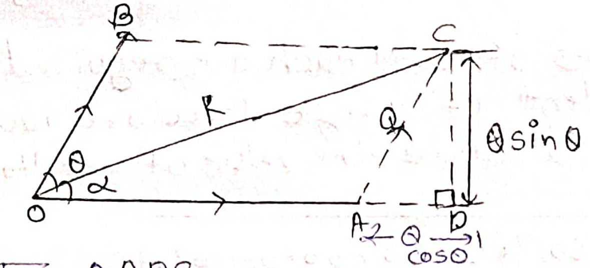

In $\triangle ADC$

$\sin\theta = \frac{CD}{AC}$ $\quad\quad$ $\cos\theta = \frac{AD}{AC}$

$CD = Q\sin\theta$ $\quad\quad$ $AD = Q\cos\theta$

In $\triangle OCD$

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

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

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

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

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

$$\boxed{R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}} \text{ ——— Magnitude.}$$

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

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

* Resultant of coplanar Non-concurrent forces-

$$R = \sqrt{(\Sigma Fx)^2 + (\Sigma Fy)^2}$$

$$\theta = \tan^{-1}\left(\frac{\Sigma Fy}{\Sigma Fx}\right)$$

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* Que: ① If two forces of 60 N each are required to be equivalent of a single force are having angle 120°. Calculate the value of resultant.

Soln-

$$R = \sqrt{(60)^2 + (60)^2 + 2(60 \times 60 \cos 120°)}$$

$$= \sqrt{3600 + 3600 + 2(3600(-\tfrac{1}{2}))}$$

$$= \sqrt{3600 + 3600 - 3600}$$

$$= \sqrt{3600}$$

$$R = 60$$

$$\tan\alpha = \frac{60 \sin 120°}{60 + 60 \cos 120°}$$

$$\alpha = \tan^{-1}(1.73)$$

$= 60°$ ——— with 60 N force.

② Find angle betn two equal forces P if their resultant is equal to P/2.

→ Soln:- $P = P$, $Q = P$, $R = \frac{P}{2}$, $\theta = ?$

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

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

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

$$\frac{P}{2} = \sqrt{2P^2 \cdot 2\cos^2\frac{\theta}{2}}$$

$$\frac{P}{2} = 4P^2\cos^2\left(\frac{\theta}{2}\right)$$

$$\cos^2\frac{\theta}{2} = \frac{1}{16}$$

$$\cos\frac{\theta}{2} = \frac{1}{4}$$

$$\frac{\theta}{2} = \cos^{-1}\left(\frac{1}{4}\right)$$

$$\frac{\theta}{2} = 75.5°$$

$$\theta = 75.5° \times 2$$

$$\boxed{\theta = 151°}$$

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Q③. Determine the angle betn two forces & a resultant & one of the force.

→ Soln:- Given, $P = 12$ N, $Q = 9$ N, $R = 15$ N.

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

$$15 = \sqrt{(12)^2 + (9)^2 + 2 \times 12 \times 9 \times \cos\theta}$$

$$15 = \sqrt{144 + 81 + 216.\cos\theta}$$

$$15 = \sqrt{225 + 216.\cos\theta}$$

$$225 = 225 + 216.\cos\theta.$$

$$= 216.\cos\theta = 0$$

$$\therefore \cos\theta = 0$$

$$\therefore \theta = \cos^{-1}(0)$$

$$\boxed{\therefore \theta = 90° \text{ or } \theta = 270°}$$

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

$$= \frac{9\sin 90}{12 + 9\cos 90°}$$

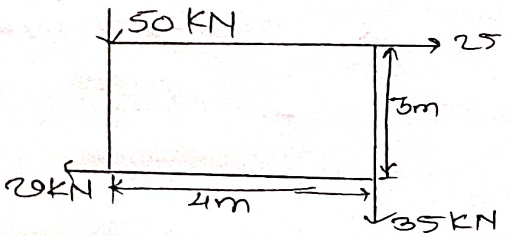
$$= \frac{3}{4}$$

$$\therefore \alpha = \tan^{-1}\left(\frac{3}{4}\right)$$

$= 36.86°$ with 12 N force.

Que. A system of forces are acting at corner of rectangular block as shown in fig. determine magnitude & direction of resultant force.

→ Soln:-



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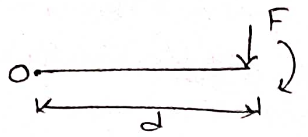
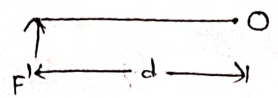
* Classification of moment according to dirⁿ of rotation:-

① Clockwise Moment.



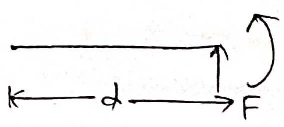
Moment of F about O

$M_O = F \times d$ (↻)

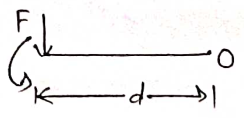


$M_O = F \times d$ (↻)

② Anticlockwise Moment



$M_O = F \times d$ (↺)



$M_O = F \times d$ (↺)

Sign Conventions

Clockwise Moment → +ve

Anticlockwise Moment → −ve

* Law of moment:-

· It states that if a body is in rotational equilibrium under the action of number of forces the sum of clockwise moment is equal to sum of anticlockwise moment of forces about the same point.

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* Varignon's Theorem:-

· It is states the algebric sum of all forces about any point is equal to resultant is equal to moment of resultant about the same point.

$\Sigma M_{FA} = M_{RA}$

i.e, $F_1 x_1 + F_2 x_2 + F_3 x_3 + \dots F_n x_n = R \times X$

where

ΣM_{FA} = Algebric sum of moment of forces about point A

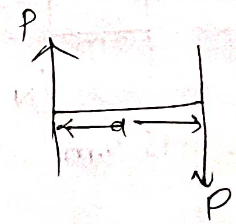
M_{RA} - Moment of resultant about point A

* Couple:-

- Two equal unlike, parallel, non-collinear force, form a Couple. As the forces are equal & opposite their resultant is zero hence couple only produces ~~pure~~ rotary motion without producing linear motion.

* Lever Arm:

- The dist. betⁿ two forces of couple is known as lever arm. (unit : Nm)



a = lever arm or arm of Couple

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* Properties Of Couple :

① Resultant of forces of couple is zero.
$(R = P - P = 0)$

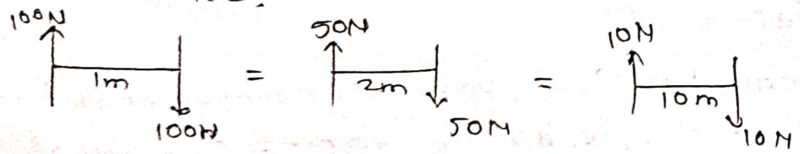
② The moment of couple is equal to the product of one of forces and arm of the couple

$M = P \times a$

③ Moment of couple at any point is constant.

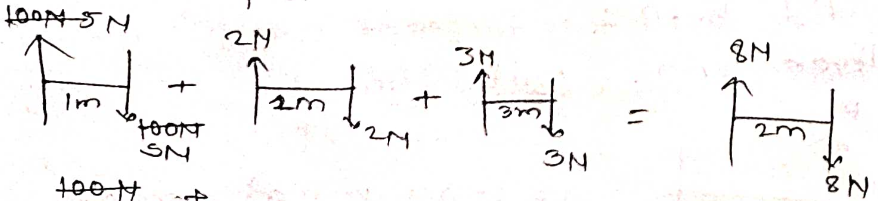
④ A Couple can be balance by another couple of equal and opposite moment.

⑤ Two or more are said to be equal ~~mean~~ when they have same sence.



100 N.m   100 N.m   100 N.m

⑥ Any ~~planar~~ number of coplanar couple can be presented by a single couple. The moment of which is equal to algebric sum of moment of all couple.



~~100N~~ 5 N.m + 2 N.m + 9 N.m = 16 N.m

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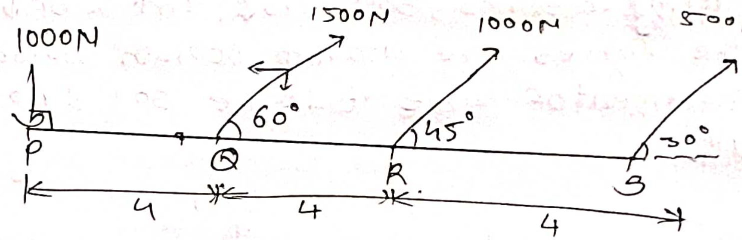
Eqn. A horizontal line PQRS is 12m long where $PQ = QR = RS = 4m$ process of 1000 N, 1500 N, 1000 N, & 500 N at P, Q, R, S resp. with downward direction the line of action of the process make angle of $90°$, $60°$, $45°$, & $30°$ resp. with PS find magnitude direction and position of resultant force.

→



$\Sigma F_x = -1000 \cos 90° - 1500 \cos 60° - 1000 \cos 45° - 500 \cos 30°$

$= -1890.11\ N$

$\Sigma F_y = -1000 \sin 90° - 1500 \sin 60° - 1000 \sin 45° - 500 \sin 30°$

$= -3256.14\ N.$

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

$= 3764.96\ N$

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

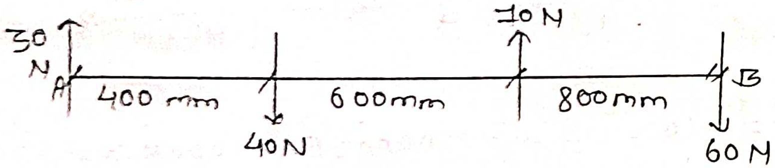
$\boxed{= 59.8°}$

By applying Varignon's theorem

$$\Sigma M_{FP} = M_{RP}$$

Problem: four force of 30 N, 70 N acting upward are balance by force 60 N & 40 N acting downward. Force acting in series 30↑, 40↓, 70↑ & 60↓ dist betn the forces are 400 mm 600 mm 800 mm resp. Find movement of couple at force 30 N & 60 N.

→ Soln:-



$M_A = +40 \times 400 - 70 \times (400+600) + 60 \times (400+600+800)$

$= \boxed{54000 \text{ N.mm } (\circlearrowright)}$

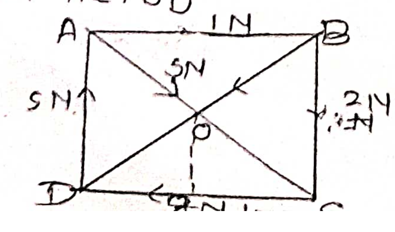
$M_B = 70 \times 800 - 40 \times (800+600) + 30 \times (800+600+400)$

$= 54000$ N.mm $(\circlearrowright)$

② ABCD is square of 2 meters side. Forces having magnitude 1N, 2N, 8N, 5N, are acting along the side of AB, BC, CD, DA resp. In addn this force 5N, 2N, are acting along AC, DB resp. Caln the moment at the point of intersection of AC, BD

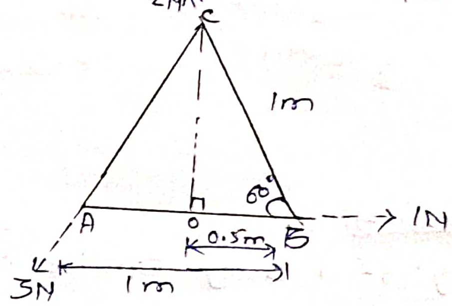
→ Soln.

?



Q. Three forces 1N, 2N, 3N, are acting the side of equilateral triangle of side 1m along AB, BC, & CA. Find algebric sum of moment of all forces about point C

→ Soln



(PGT)

$(1)^2 = (0.5)^2 + OC$

$OC = 1^2 - 0.5^2$

$OC = 0.866$ m.

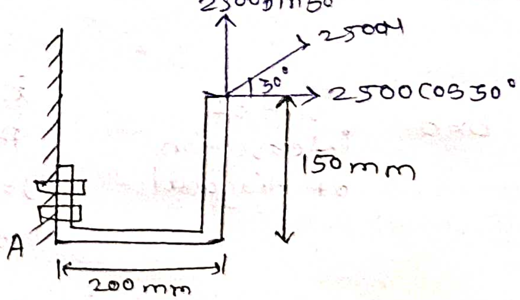
$M_C = -1 \times 0.866$

$= -0.866$ Nm

$= 0.866$ Nm $(\circlearrowleft)$

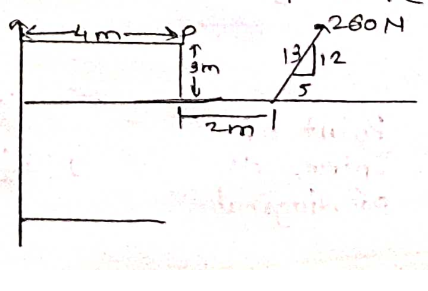
Q. A force 2500 N acts of bracket as shown in fig find moment of this force at point A.

→



Q Determine magnitude & directional sense of resultant moment of force about point P.

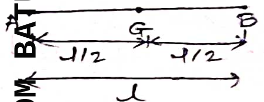
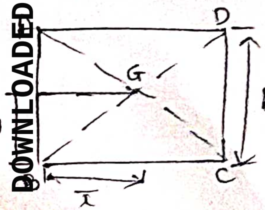
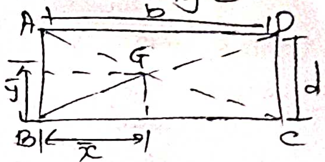
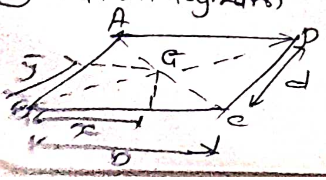
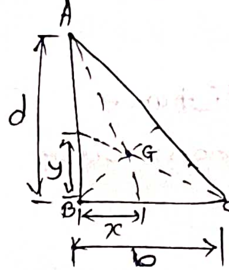
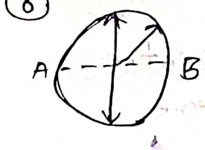
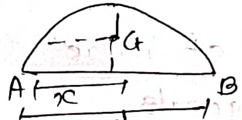
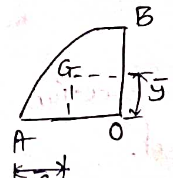
→



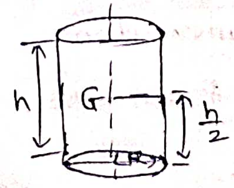
?

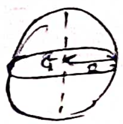
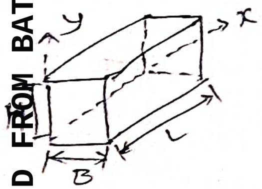
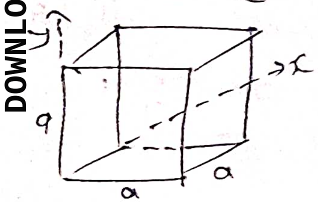
* Centre of Gravity:

Centre of gravity of a body can be define as point through which whole weight of body is assume to act. irrespective of position of body.

	Area	Position	Centroid
① Straight line 	-	Midpoint	$\frac{l}{2}$ from A or B
② Square 	b×b	Point of intersection of diagonal	$\bar{x} = \frac{b}{2}$ from AB; $\bar{y} = \frac{b}{2}$ from BC
③ Rectangle 	b×d	Point of intersecⁿ of diagonal	$\bar{x} = \frac{b}{2}$ from AB; $\bar{y} = \frac{d}{2}$ = from BC
④ Parallelogram 	b×d	Point of intersectⁿ of diagonal	$\bar{x} = \frac{b}{2}$; $\bar{y} = \frac{d}{2}$
⑤ Triangle 	$\frac{1}{2}$ b×d	Point of intersectⁿ of ~~medains~~ medians	$\bar{x} = \frac{1}{3} b$ from AB; $\bar{y} = \frac{1}{3} h$ from BC
⑥ Circle 	πr^2 or $\frac{\pi}{4} d^2$	Centre of Circle	$\bar{x} = \bar{y} = \bar{r} = \frac{d}{2}$
⑦ Semicircle 	$\frac{\pi r^2}{2}$ or $\frac{\pi d^2}{8}$	At dist. $\frac{4r}{3\pi}$ from AB	$\bar{x} = r$ from A; $\bar{y} = \frac{4r}{3\pi}$ from AB
⑧ Quarter Circle 	$\frac{\pi}{16} d^2$ or $\frac{\pi r^2}{4}$	At dist. of $\frac{4r}{3\pi}$ from boundary axis AO & BO	$\bar{x} = r - \frac{4r}{3\pi}$ from A; $\bar{y} = \frac{4r}{3\pi}$ from AO

* Centre Of

	Volume	Position of G
① Cylinder 	$\pi R^2 h$	At a distanse $\frac{h}{2}$ from base Axis

	Volume	Position of G
② Right Circular Cone 	$\frac{1}{3}\pi R^2 h$	At a distance h/4 from base axis
③ Sphere 	$\frac{4}{3}\pi R^3$	At the centre of sphere
④ Solid Rectangular Block 	$L \times B \times H$	Point of interen of diagonals
⑤ Solid Cube 	a^3	Point of intersection of diagonal.
⑥ Hemisphere 	$\frac{2}{3}\pi R^3$	At of intersection of $\frac{3R}{8}$ from base of axis.

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* **Centroid for composite Plane figures:-**

$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3 + \dots a_nx_n}{a_1 + a_2 + a_3 + \dots a_n}$$

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3 + \dots a_ny_n}{a_1 + a_2 + a_3 + \dots a_n}$$

* **Centre of Gravity of composite Solids:-**

$$\bar{x} = \frac{V_1x_1 + V_2x_2 + V_3x_3 + \dots V_nx_n}{V_1 + V_2 + \dots V_n}$$

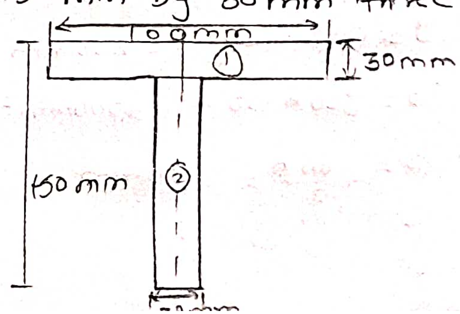
$$\bar{y} = \frac{V_1y_1 + V_2y_2 + V_3y_3 + \dots V_ny_n}{V_1 + V_2 + \dots V_n}$$

where $\rightarrow V_1, V_2, V_3 \dots V_n \rightarrow$ Volume of different Solids.

* **Centroid / C.G areas/ Solids with cutout Sections-**

C.G for Cutout Plane areas	C.G for cutout Solids.
$\bar{x} = \frac{a_1x_1 - a_2x_2}{a_1 - a_2}$	$\bar{x} = \frac{V_1x_1 - V_2x_2}{V_1 - V_2}$
$\bar{y} = \frac{a_1y_1 - a_2y_2}{a_1 - a_2}$	$\bar{y} = \frac{V_1y_1 - V_2y_2}{V_1 - V_2}$

Que. find C.G of 100mm by 150mm by 30mm ~~three~~ 'T' section as shown figure.



→ Solnº- we have

$a_1 = 100 \times 30$

$= 3000\ mm^2$

$y_1 = \left(150 - \frac{30}{2}\right) = 135\ mm$

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$a_2 = 30 \times 120$

$= 3600\ mm^2$

$y_2 = \frac{120}{2} = 60\ mm$

$y = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$

$= \frac{3000 \times 135 + 3600 \times 60}{(3000 + 3600)}$

$= \boxed{94.09\ mm}$

Que: