MODUE → I.

UNIT → 2.

INTRODUCTION To Engg. Mechanics :→

It may be defined as a physical science which deals with the behaviour of a body under the action of forces when body is at rest or in motion

Engineering Mechanics is an application of laws and principles of Mechanics to the engineering problems or actual problems. It basically includes analysis design and understanding the behaviour of all engineering structures and machines

Mechanics → Fluid Mechanics.
→ Strength of Metarials
→ Mechanics of Rigid body

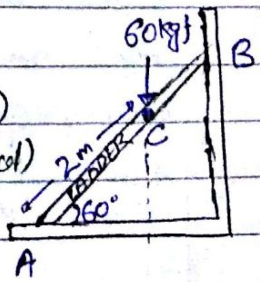
→ Strength of materials :→ Behavior of objects under stress and strain

→ Mechanics of rigid body :→ Static : Under Rest
Dynamic: Under Motion

FORCE :→ It may be defined as an agent which produces or tends to produce, destroy or tends to destroy a motion i.e. it tends to change the state of uniform motion of a body. (Force is a Vector qty)

→ Characteristics of Force:

→ Direction of a force (↓)
→ Magnitude of a force (60 kgf)
→ Point of application of force (C)
→ Line of Action of force (Vertical)
→ in line with Gravity.



→ Classification of forces:→

1) Coplanar forces :→ Forces acting on the same plane.

2) Non-coplanar forces:→ Force acting in different planes.

3) Con-current forces:→
→ Co-planar Concurrent forces
→ Non-co-planar concurrent forces

(4) Non-Concurrent forces:→
→ Planar Non-Concurrent forces
→ Non-Planer Non-Conconcurrent forces

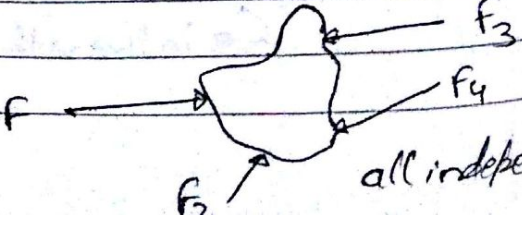
5) Collinear forces:→ Forces acting on the same single line of action

6) Non-Collinear forces → Forces acting in different line of action

(7) Parallel forces →
→ Parallel like forces
→ Parallel Unlike forces

→ Principle and Laws of forces:

(1) Principle of physical independence :→ Action of a force on the body will not be affected by action of another force on the same body i.e. when two or more forces act on a body, every force produces its own effect on the body independent of remaining forces.



all independent

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Principle of Superposition of forces:→

It states that the action of given system of forces on a rigid body will noway change if we add or subtract from them with another system of forces in equilibrium.

It also mean that if two or more forces act on an object then combined effect due to all the forces is a vector of all the individual forces. If forces $\vec{F_1}, \vec{F_2}, \vec{F_3}, \vec{F_4}$ etc act on an object then net effect can be represented by a single force called Resultant force i.e. $F_R = \vec{F_1} + \vec{F_2} + \vec{F_3} + \vec{F_4}$

→ Principle of Transmissionability:→

It states that the state of rest or motion of the body is unaltered if a force acting on a rigid body is replaced by another force of the same magnitude and in the same direction but acting anyway on the body along the line of action of the replaced force.

This is applicable only for rigid bodies and holds good for external forces applied. It cannot be considered for the bodies considered in the strength of materials as deformable bodies.

→ Resolution of forces:→

It is a method of splitting of a single force into two or more forces known as component forces which together produces the same effect as produced by a single force.

Therotically a force can be resolved into any numbers of components but mostly forces are resolved into two components that are Perpendicular to each other. (Horizontal & Vertical).

~~In the resolution~~

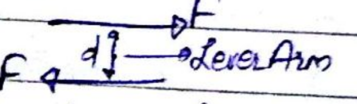
→ Composition of forces / Compounding or Combining)

↳ The method of finding out the resultant force of number of given forces is called composition of forces.

↳ In the resolution or composition of forces. The following Laws can be followed

① Parallelogram Law
② Triangle Law
③ Polygon Law.

→ COUPLE :→ Two parallel unlike forces with equal magnitude seperated by a definite is said to form a couple. It has a tendency to rotate the body on which it is acting. The perpendicular distance b/w these ∥ forces is known as lever arm or arm of a couple. or moment arm. The sum of the forces in any couple in any direction is zero.



Example :→ This figure shows a body subjected to two parallel forces which are acting in opposite direction but equal in magnitude F at a perpendicular distance d. These two forces constitute a couple.

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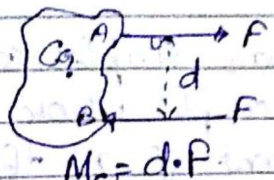
Moment of a Couple:→ The moment of a couple is the product of either one of the forces and the ⊥ distance b/w the forces. Example:→



$\underline{M_C = d \cdot F}$

Let F be the force acting at A or B and d be the lever Arm then the moment of a couple is given by

$M_C = d \cdot F$

units of Mc are → N-m or N-mm or kN-m.

→ Characteristics of Couple:→

① It has two parallel unlike forces with the same or equal magnitude at a distance d

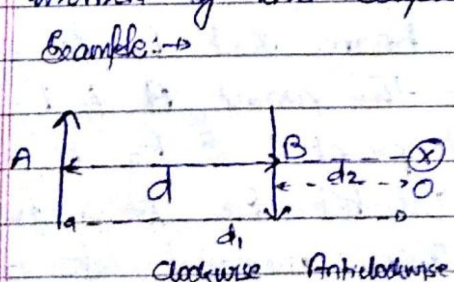
② Sum (algebraic) of forces constituting a couple will be Zero.

③ Translatory effect of a couple on a body is Zero

④ The rotational effect of a couple about any point is a constant and it is equal to the product of either one of the forces and the perpendicular distance b/w the forces

⑤ Algebraic Sum of moment of force constitute the couple about any point is equal to the moment of the couple itself

Example:→



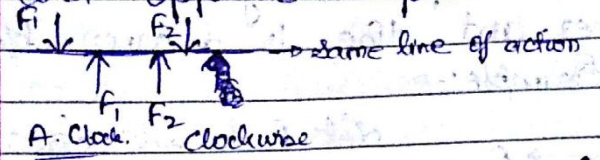
Taking the moment about the point O as shown in figure then:→

$M_O = +F_A d_1 - F_B \cdot d_2$

$\Rightarrow F(d_1 - d_2)$

$\boxed{M_O \Rightarrow F \cdot d \Rightarrow M_C}$

⑥ A couple can be balanced only by equal and opposite couple in the same plane.

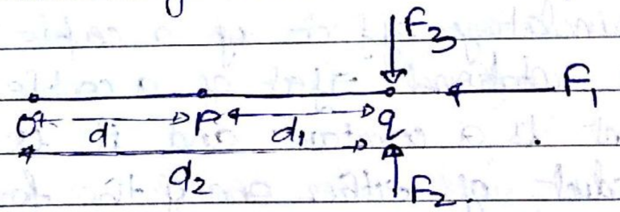


⑦ Any number of coplanar couples can be reduced to a single couple whose magnitude will be equal to moment of all the couples

⑧ Any two couples whose moments are equal and of same sign then they are equal.

⑨ The moment of a couple is constant for any point chosen in a plane.

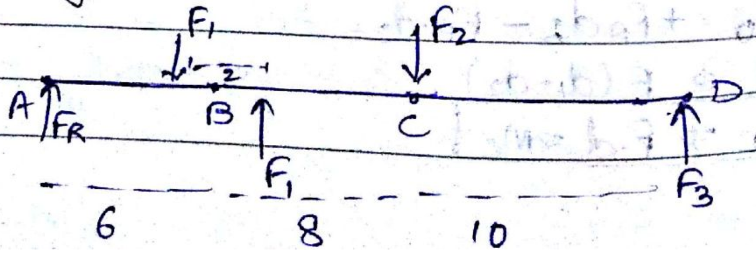
Moment: It is the ~~perpen~~ product of force acting and the distance between its line of action to the point of reference



∴

$$M_O = F_1 \times 0 - F_2 \times d_2 + F_3 \times d_2$$
$$M_P = F_1 \times 0 - F_2 \times d_1 + F_3 \times d_1$$

→ Let ABCD be a beam. Let F_1 be a couple acting at the point B & F_2 be a force acting at point C & F_3 be a force acting at D let F_R be a force acting at A. Then moment at A = ?



Anticlockwise Couple.

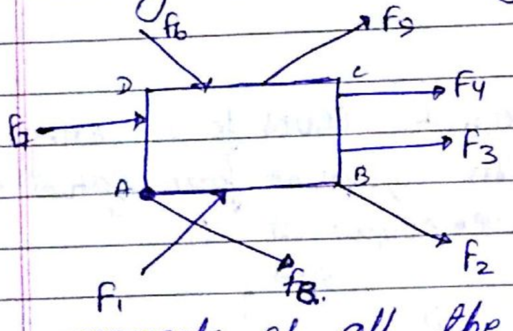
$$M_A = F_R \cdot 0 - F_1(2) + F_2(14) - F_3(24)$$
$$M_B = +F_R(6) - F_1(2) + F_2(8) - F_3(18)$$
$$M_C = +F_R(14) - F_1(2) + F_2(0) - F_3(10)$$
$$M_D = +F_R(24) - F_1(2) - F_2(10) - F_3(0)$$

Equivalent forces Couple Systems :→

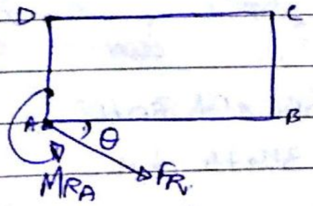
→ A single Resultant force passing through a given pt. which is a combination of all forces acting on the body, Moment about that point which is sum of moments of all the force about that point

Note :→ This is applicable for coplanar forces.

Example :→ Considered a body with no. of forces acting on the body as shown in figure.

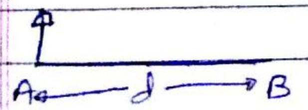


The equivalent force couple system about point A is given in the following figure as the resultant force & moment of all the forces.

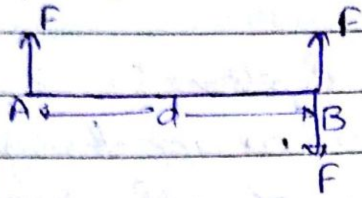


→ Equivalent force-couple system at point A.

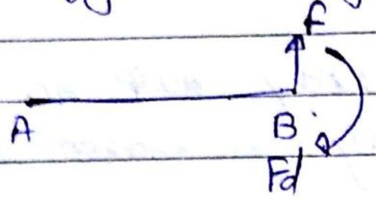
Example 2: Considered a rigid body with two point AB and a force acting at A as shown in figure 1.



→ Apply an equal and opposite force system of magnitude F at B. The system will not be disturbed due to the addition of forces at B as shown in fig 2.

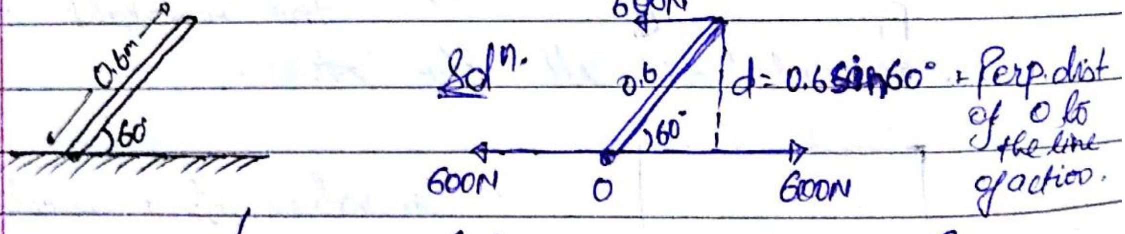


Now force at A & force at B in the opp. direction will form a couple & the couple can be replaced by (F×d). The force F at A is replaced by force at B and a moment of magnitude Fd as added at shown in fig ③ leaving behind F at B.



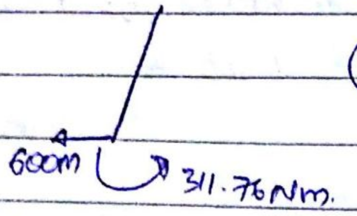
Problems :→

1. Replace the horizontal 600N force acting on a lever arm by an equivalent force system consisting of a force and a couple at O.



$M_O = 600 \times 0.6 \sin 60°$

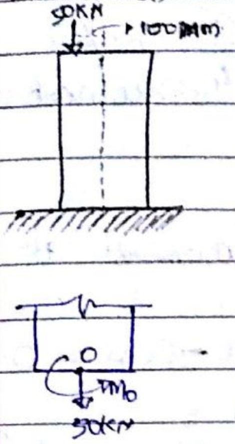
$\Rightarrow 311.76$ N-m

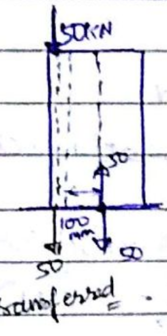


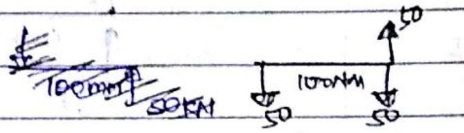
Taking moment of the couple at point O.

$M_O = F \times d = 600 \times 0.6 \cos 30 = 311.76$ N-m

8 A concrete column is carrying a force (load) of 50KN as shown in the figure. Replace the system of forces by force couple system.





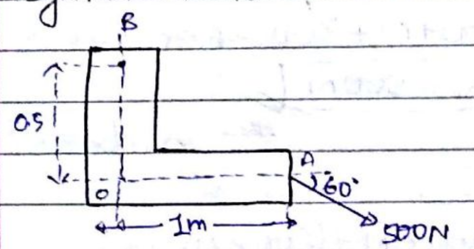


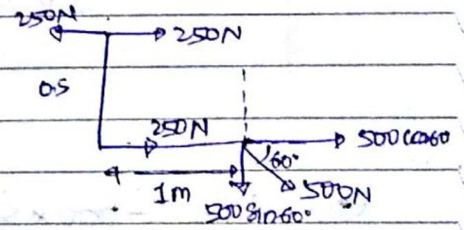
$\therefore M_O = 50\times100$

$= 5KN\text{-}m$

$F_O = 50KN\downarrow$

(3) A 500N force is applied to point A of a L shaped plate. Find the equivalent force couple system at B.





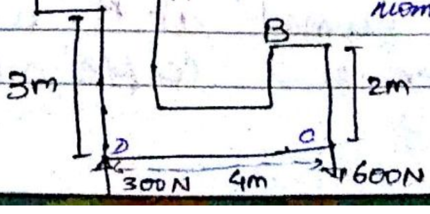
$M_B = -500\cos60^\circ\times0.5 + 500\sin60^\circ\times1$

$\Rightarrow +308.01\ NM$

F_B:

↳ The resultant of force will be 500 N acting at an angle of 60° since there is only one force acting at point A.

2 Replace the system of forces acting on a frame shown in figure by a resultant R through A and a couple acting horizontally through B and C. Also calculate the moments at A, B, C & D



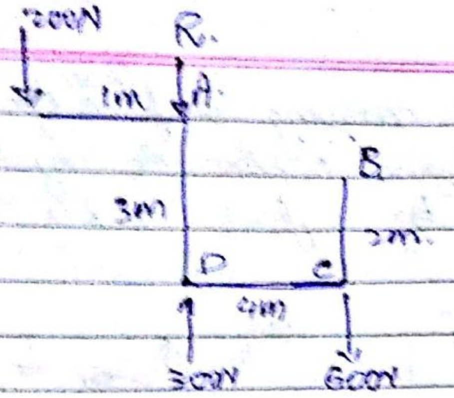
10 marks

anticlock wise (−) (+) clockwise

Sign Convention

−ve ← → +ve

Soln:



① Resultant @ A
② Couple @ B
③ Couple @ C
④ Moment @ D.

① Assume a force R acting downward at A.

in equilibrium

$\therefore \sum Y_{force} \Rightarrow -200 - R + 300 - 600 = 0$

$\therefore R = -500N$

↳ 500N downwards (✗)

−ve indicates assumption is wrong.

Let Assume R in upward direction

$\sum V = -200 + R + 300 - 600 = 0$

$\therefore \boxed{R = 500N}$ in upward dir.

② $M_B = (-200 \times 5) + (300 \times 4) + (600 \times 0)$

$\Rightarrow 200 Nm$

Equilibrium of Couple - Calculation of moment

③ $M_C = (-200 \times 5) + (300 \times 4) + 600 \times 0$

$= 200 N\text{-}m$

④ $M_A = -200(1) + 300(0) + 600(4)$

$\Rightarrow 2200 N\text{-}m = M_A$

⇒ If the forces acting at B and C form a couple then the couple is given by

Couple = F × (BC) — ①

The moment at A is calculated as 2200 N-m which is a couple acting at same eq. at A ↳ ②

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From ① & ② $F \times BC = 2200$

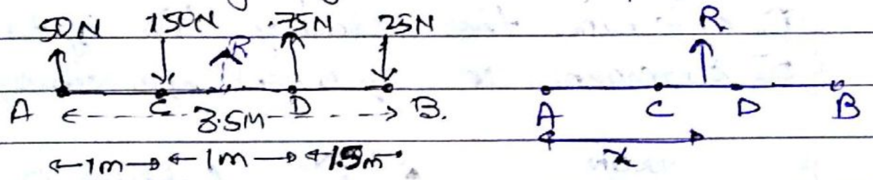
$\therefore F = \frac{2200}{2} = 1100\,N$

Q A system of forces acting on a rigid body as shown in the figure. Reduce this system into ① A single force system

12 marks Question

② Single force & a couple at B

③ Single force & a couple at A.



a) Single force System :→ All the forces are acting vertically. Hence the resultant will be vertical & that resultant is given by:

$$\Sigma V = +R + 50 - 150 + 75 - 25 = 0$$

$$\therefore R = 50\,N.$$

Let x be the distance from A to resultant as shown in figure. Taking the moments about A by applying Varignon's theorem → moment of Resultants is equal to algebraic sum of moment of forces

∴ Taking any end point supposing at A.

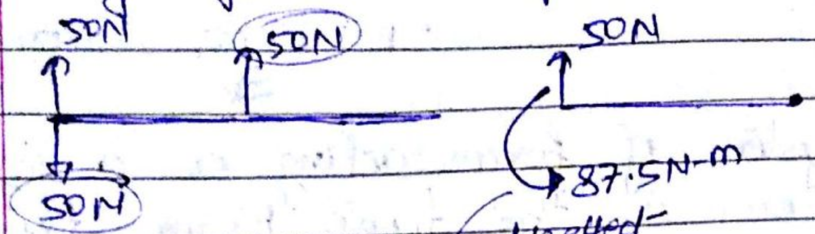
$$+50(x) = 150(1) - 75(2) + 25(3.5)$$

$$x \Rightarrow 1.75\,m \text{ from } A.$$

ⓑ Single force & couple @ B :→ Applying two equal & opp forces at B

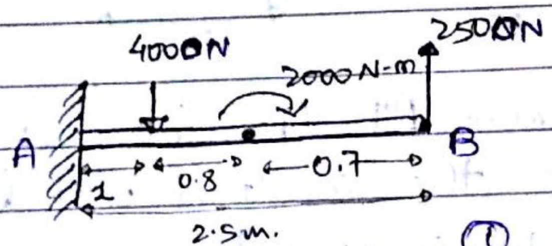
$\therefore M_B = 87.5\,N\text{-}m$

(c) Single force & couple at A :



completed

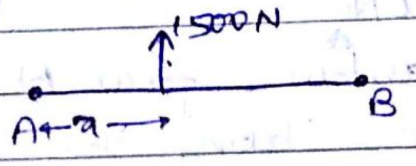
Q. A figure shown is a cantilever beam with two forces and a couple
(1) Determine the result of the system
(2) Determine an equivalent sys. through A



Cantilever Beam:-
Support at A &
a free end at B.

(1) $R = 4000 - 2500 = 1500\,N$

→ By Varignons theorem,



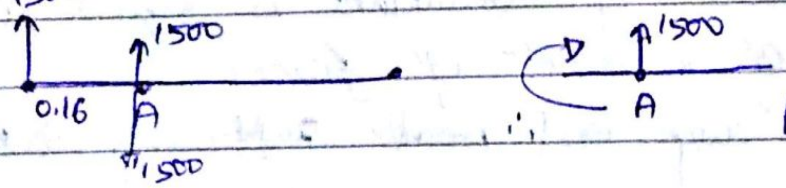
at Support A.

$1500(x) = 4000(1) + 2000 - 2500 \times 2.5$

$\therefore x = -0.16$ meter

i.e. x is left of A

(2)



$M_A = 1500\,(0.16)$
$= 240\,N\text{-}m$

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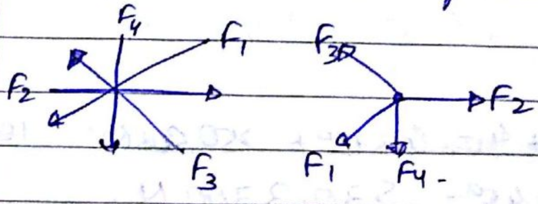
fields of CE

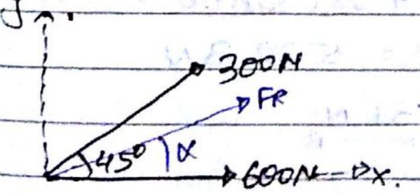
1. Surveying 2. Building Construction
3. Geo-Technical Engineering (deals with the soil)
4. Geology (Study of rock & rock mechanics)
5. EarthQuake Study: (How, why, when)
6. Structural Engineering (Design of a building)
7. Water resource Engineers (Location of water for boring)
8. Hydrology Engineer (Study of Surface water, dams)
9. Environmental Engineers (Waste managements)
10. Traffic. & Highway Engineers
11. Infrastructural Engineer (Requirements inside the ~~bu~~ build)

☆ Module 2:→ Analysis of force System, Concurrent force System and Non-Concurrent force System.

① Concurrent force System: A force System in which all the forces are passing through a single point of reference on a given plane is called concurrent planar force System.



Q Calculate the resultant force and the angle with the horizontal with the resultant in following force System



$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

$= \sqrt{600^2 + 300^2 + 2(600)(300)\cos45^\circ}$

$= 839.404$ N

$\alpha = \tan^{-1}\left(\frac{F_2}{F_1}\right) = \tan^{-1}\left(\frac{1}{2}\right)$

$= 26.5^\circ$

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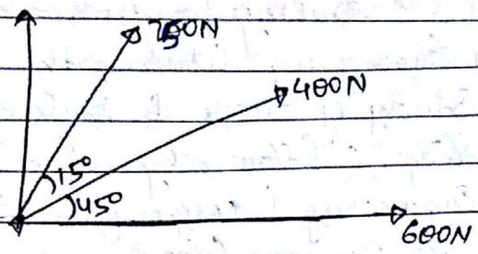
Q



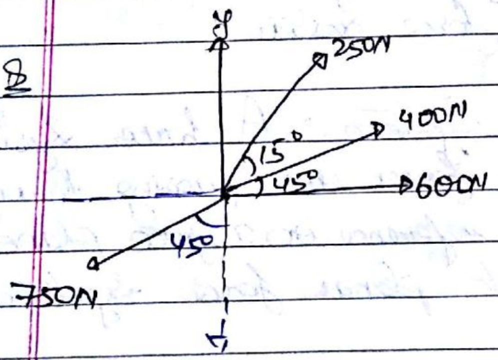
$F_x = 600 + 400\cos 45^\circ + 250\cos 60^\circ = 1007.8\,N$

$F_y = 250\sin 60^\circ + 400\sin 45^\circ = 499.34\,N$

$F_R = \sqrt{F_x^2 + F_y^2} = \underline{1124.77\,N}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \underline{26.36^\circ}$

Q



Calculate F_R & angle with horizontal.

$F_{+x} = 600 + 400\cos 45^\circ + 250\cos 60^\circ = 1007.8\,N$

$F_{-x} = 750\sin 45^\circ = 530.3300\,N$.

$\therefore$ Net $F_{(+x)} = \underline{477.5\,N}$.

$F_{+y} = 400\sin 45^\circ + 250\sin 60^\circ = 499.34\,N$

$F_{-y} = 750\cos 45^\circ = 530.3\,N$.

$\therefore$ Net $F_{(y)} = \underline{-31\,N}$.

$\therefore Net = \sqrt{F_x^2 + F_y^2} = \sqrt{4} \quad = 478.51\,N$.

$\therefore$ $\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \underline{356.28^\circ}$.

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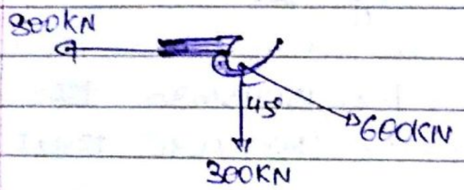
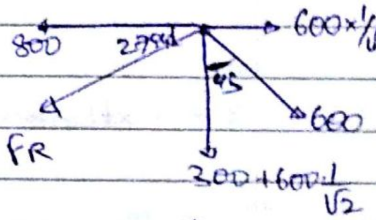
Q A hook has been hanged over a 300KN concrete block which is acting perpendicularly down. Another pull of force 600 KN is happening at the hook edge due to the crane load. The self pullback of the hook is 800 KN as shown in figure. Calculate the Resultant & the direction of the resultant of hook.





$\Rightarrow$

$V_x = 800 - 424.26$

$\Rightarrow 375.73$ KN

$V_y \Rightarrow 300 + 424.26$

$\Rightarrow 724.26$ KN

$\therefore$ Resultant: $F_R = \sqrt{(375.73)^2 + (724.26)^2}$

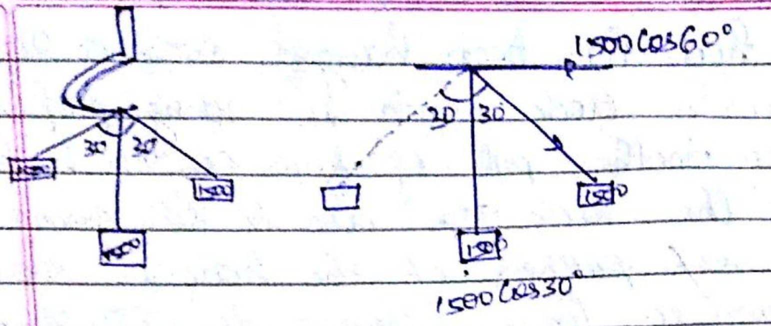
$= \underline{815.92 \text{ KN}}$

$\therefore \theta = \tan^{-1}\left(\frac{724.26}{375.73}\right) = \underline{62.61°}$

$\Rightarrow 180 + 62.61$

$= \underline{242.61°}$

Q A crane hook has been hanged with 1500KN weight blocks and it is being lifted up ground to an height of 18ms. Due to the wind press. the blocks stated swinging. The angle of swing from its mean position is 30° either side. Calculate the max force applied on the hook and also the direction in which it's applied.



@ mean position $F_x = 0$ $F_R = \sqrt{1500^2} = 1500\,kN$

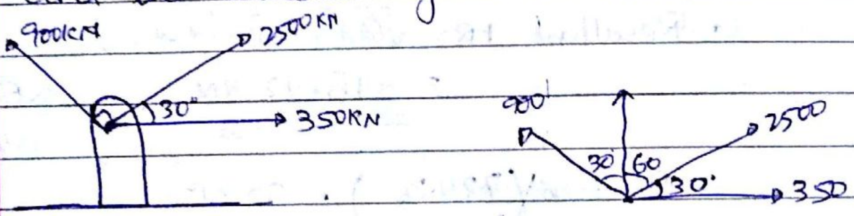
$F_y = 1500$

@ Extreme (30°) = $F_x = 1500\sin 30 = 750$

$F_y = 1500\cos 30° = 1299.03$.

$F_R = \underline{1500\ kN}$.

Q. A winch on a ground has been applied with forces as shown in figure. Calculate the resultant and the direction of the resultant



$V_x = 350 + 2500\cos 30° - 900\sin 30°$

$= 2065.06\ kN$

$V_y = 900\cos 30° + 2500\cos 60°$

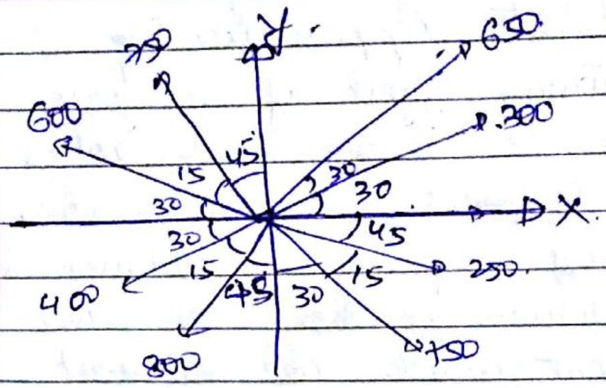
$= 2029.42\ kN$

$\therefore F_R = \sqrt{2065.06^2 + 2029.42^2} = 2895.34\ kN$

$\theta = \tan^{-1}\left(\dfrac{2029.42}{2065.06}\right)$

$\theta = 44.5°$

Sol
(a)



$F_x = 300\cos 30 + 600\cos 60 - 750\cos 45 - 600\cos 30 + 250\cos 45$
$\quad - 400\cos 30 - 800\cos 45 + 750\cos 60$
$= -825.45$ kN

$F_y = 300\sin 30 + 650\sin 60^\circ + 750\cos 45 + 600\cos 60$
$\quad - 400\sin 30 - 800\cos 45 - 750\cos 30 - 250\sin 45$
$= -48.73$ kN

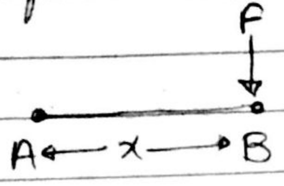
$\therefore F_R = \sqrt{(-825.45)^2 + (-48.73)^2} = 826.88$ kN

$\theta = \tan^{-1}\left(\frac{48.73}{825.45}\right) = 3.378^\circ$

$\therefore \theta = 180 + 3.378^\circ$
$= 183.38^\circ$

⇒ Moment & its Application :→

The turning effect of a force produced in a body on which it is acting is called a moment. Moment is the product of force and perpendicular distance b/w the line of action of the force and the point about which the moment is ref.



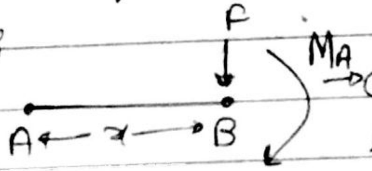
Moment = Force × ⊥r distance

$M_A = F \times x$

Types of Moments :→

① Clockwise Moments : The force's turning effect which tends to rotate the body in the direction in which the hands of a clock move is called a clockwise moment

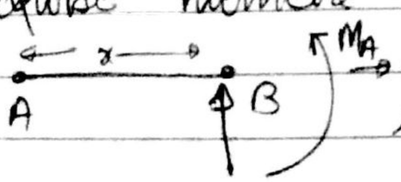
Ex:



→ clockwise moment with refrence to the point A.

② Anticlockwise moment :→ The turning effect of a force which tends to rotate the body in a direction opposite to which the hands of a clock move is called anticlockwise moment

Ex:



→ Anticlockwise moment with refrence to the point A

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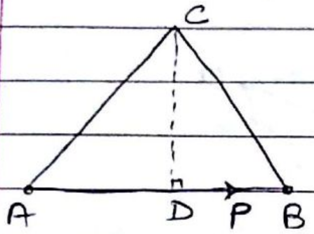
Sign Convention for moments:

Clockwise moment → ↻ +ve

Anticlockwise moment → ↺ −ve

Graphical Representation of a moment.

→ Consider a force P represented by the line AB as shown in the figure. Let C be a point about which the moment of the force P is required to be calculated. Draw a ⊥ line CD onto AB. Join CA, CB



Then, moment of force P about C = force × ⊥ Dis

$= M_C = P \times CD$

$M_C = AB \times CD$ —— ①

Area of the $\Delta = \frac{1}{2} \times base \times height$

$= \frac{1}{2} \times AB \times CD$

$\therefore 2(\text{Area of } \Delta) = AB \times CD$ —— ②.

Comparing ① and ②,

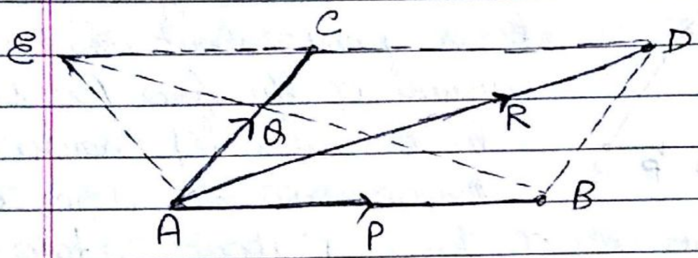
We get: Moment about $C = 2(\text{Area of } \Delta)$

Thus, Moment of a force about any point is equal to the twice the area of the triangle where base represents the line of action of force and Vertex represents the point about which the moment is required

10-12 marks Guaranteed Question

⇒ Varignon's Theorem of Moments :

If no. of coplanar concurrent forces are acting simultaneously on a particle at rest then the algebraic sum of moments of all the forces about any point is equal to the moment of their resultant force about the same point.



Consider two co-planar concurrent forces P & Q represented by the lines AB and AC acting at Point A as shown in the figure. Draw CD ∥ to AB and BD ∥ to AC and complete the parallelogram ABCD. Join the Diagonal AD pointing through the point of intersection of forces P and Q. Hence the Diagonal represents the resultant R of P and Q both in magnitude and direction.

Let E be any point on the same plane of ∥gm ABCD. Join EC, EA, & EB. By the Graphical representation of moment :

Moment about E for force P $= 2[\text{Area of } \triangle ABE]$

Moment about E for force Q $= 2[\text{Area of } \triangle ACE]$

Moment about E for force R = 2[Area of $\triangle ADE$]

Area of $\triangle AED$ is equal to Area of ($\triangle AEC + \triangle ACD$)
But Area of $\triangle ACD$ = Area of $\triangle ADB$

$$\triangle AED = \triangle AEC + \triangle ADB$$

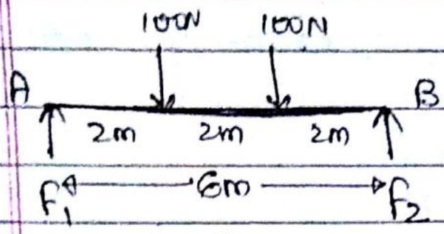
Area of $\triangle ADB = \triangle AEB$.
$\Rightarrow$ 2 (Area of $\triangle AED$) = 2(Area of $\triangle AEC$) + 2(Area of $\triangle AEB$) —— (4)
from (1), (2), (3) & (4)

Moment of force R about E = Moment of force Q about E + Moment of force P abt E.

Thus the algebraic sum of moments of all the forces about any point in the same plane is equal to the moment of their resultant force about the same point.

NON-CONCURRENT FORCE SYSTEM.

1)

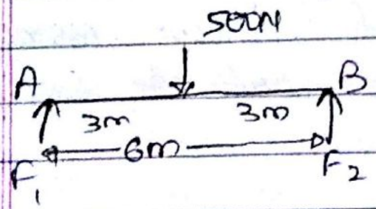


Let us assume AB a beam supported by the forces F_1 and F_2 as shown in the figure. At A & B respectively. The length of the beam is 6m. Two forces 100N each are acting, one at 2m from the left support and another at 2m from the right support.

$$\Sigma V = 0 \Rightarrow F_1 + F_2 - 100 - 100 = 0$$
$$F_1 + F_2 = 200N.$$

$$\Sigma M_A = 0 + (100\times2) + (100\times4) - F_2(6) = 0 \quad \text{for end cond}$$
$$\therefore F_2 = 100\ N.$$
So $F_1 = 100\ N.$

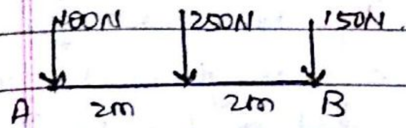
2)



$$\Sigma V = 0$$
$$\therefore F_1 + F_2 - 500 = 0$$
$$\therefore F_1 + F_2 = 500$$

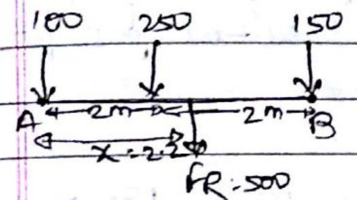
$$\Sigma M_A = 0 + 500(3) - F_2(6) = 0$$
$$\therefore F_2 = 250\,N.$$
$$\therefore F_1 = 250\ N.$$

Q. Find the resultant of the force system given.



$$F_R = \sqrt{F_x^2 + F_y^2}$$
$$= \sqrt{0^2 + (-500)^2} = \underline{500N}.$$

$$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = \tan^{-1}\infty = \underline{90^\circ} \downarrow$$



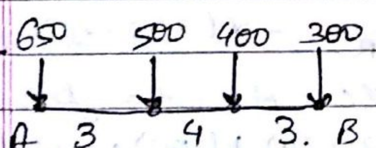
From the principle of Varignon's theorem the moment of a resultant force = Σmoment of all forces.

Let us consider resultant is acting at a distance x meters from the pt. A.

$$M_A = 0 + 250(2) + 150(4) = 500(x)$$

Fr is acting at a distance $x = \frac{1100}{500} = \underline{2.2\,m}$ from A.

Q. Find the resultant of the force system given below & also locate the point of app. of resultant on the line AB.

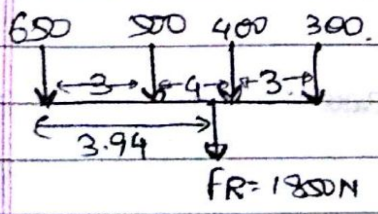


$$F_R = \sqrt{F_x^2 + F_y^2}$$
$$F_R = \sqrt{0^2 + (-1850)^2} = 1850N.$$
$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}(\infty) = 90^\circ \downarrow$$

If FR is acting at x distance.

Apply V.T at A ⇒ $0 + 500(3) + 400(7) + 300(10) = 1850x$

$$\therefore 1850.(x) = 1500 + 2800 + 3000.$$

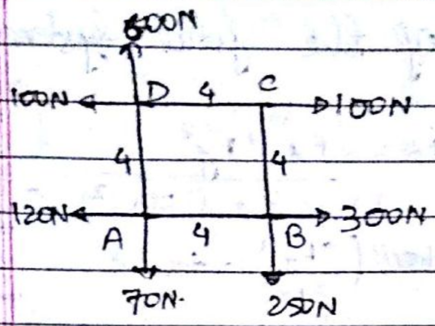


$$x \Rightarrow \frac{7300}{1850} = \underline{3.94\,m} \text{ from A}$$

So the resultant of the forces is acting at a distance 3.94 m from A.

(VI)

Q



Find the resultant of the nonconcurrent force system given and also find position of the resultant from pt A

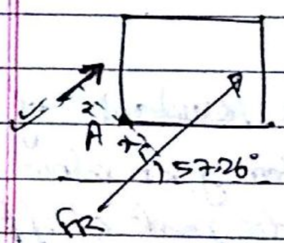
⇒ $\Sigma F_x = -120 + 300 + 100 - 100 = 180\ N$

$\Sigma F_y = -70 - 250 + 600 = 280\ N$

$F_R = \sqrt{F_x^2 + F_y^2}$

$= \sqrt{(180)^2 + (280)^2} = 332.86\ N$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{280}{180}\right) = 57.26°$



Moment about A ~ Resultant

⇒ $M_{A_R} = -x(332.86)$

Moment about A with force system

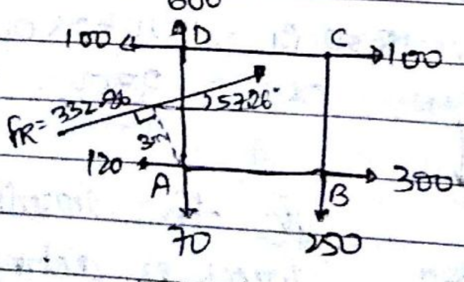
$M_A = +250(4) + (100)4 - 100(4)$

$= 1000\ N\text{-}m$

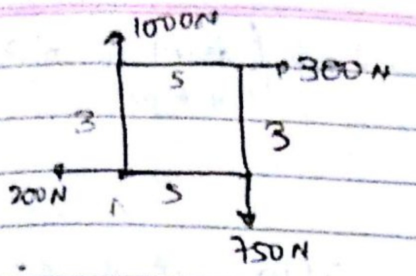
$\therefore x = \frac{1000}{332.86} = 3.004\ m$

in opposite to what we assumed

Show it on figure.



B.



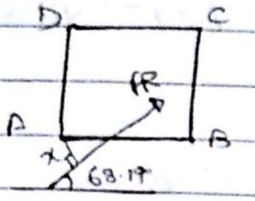
F_R, θ and and d_A = ?

$\Rightarrow \Sigma F_x = -200 + 300 = 100\,N$

$\Sigma F_y = -750 + 1000 = 250\,N$ } $F_R = \sqrt{(F_x)^2 + (F_y)^2} = \sqrt{(100)^2 + (250)^2}$

$\therefore F_R = 269.26\,N.$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{250}{100}\right) = 68.19°.$



Moment about A τ resultant

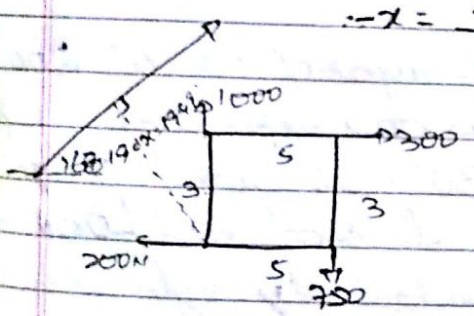
$\therefore M_{AR} = -x(269.26)$

Moment about A with force sys

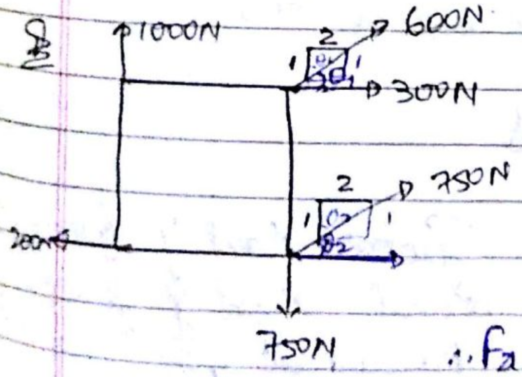
$M_A = 750(5) + 300(3) = 4650$

$\therefore -x = \frac{4650}{269.26} = -17.27\,m.$

opp. to what we assumed.



B



$\tan\theta_1 = \frac{P}{b} = \frac{1}{2} = \underline{26.5°}\ \theta_1$

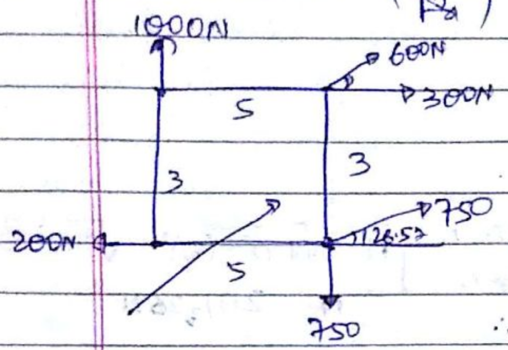
$\tan\theta_2 = \frac{P}{b} = \frac{1}{2} = 26.5°\ \theta_2$

$\therefore F_x = -200 + 750\cos(26.56) + 300 + 600\cos(26.56) + 0 = 1307.52$

$F_y = 0 + 750\sin(26.56) - 750 + 600\sin(26.56) + 1000 = 854.10.$

$\therefore F_R = \sqrt{F_x^2 + F_R^2} = 1561.76\,N.$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{854.1}{1307.52}\right) = 33.15°$



$\therefore M_{AR}$ about $x =$

$\cancel{-x(33.15)}$

$-x(1561.76)$

$\therefore M_A \Rightarrow 750(5) - 750(\sin 26.57)(5) + (3)(300 + 600\cos\ldots)$

$- 600\sin(26.57)(5) + 0 =$

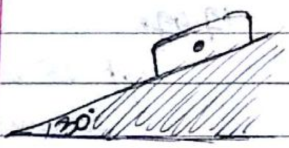
$\Rightarrow 3750 - 1677.34 + 2509.89 - 1341.87$

$\Rightarrow 3240.68$

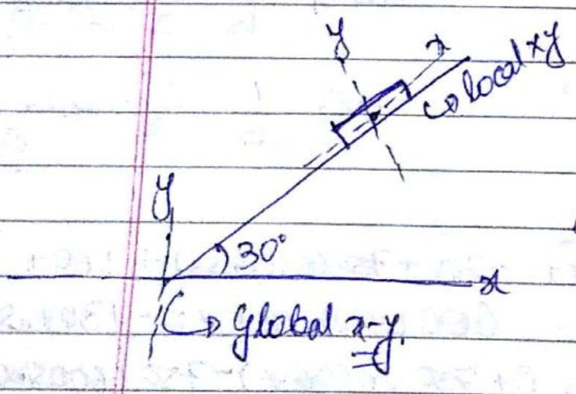
$\therefore$ By VT $\quad -x(1561.76) = 3240.68$

$\therefore \cancel{x = -2.075}$ $\quad \therefore x = -2.075$ m

Q. 12 marks



A object of weight 200 kgs is on a slope with angle 30°. Cal. Global x & y Force components & also find local x & y forces. Cal. Resultant & angle with Resultant is acting wrt x-axis.

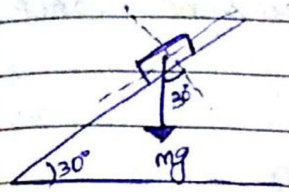


Global x and y forces = ?

Local x and y forces = ?

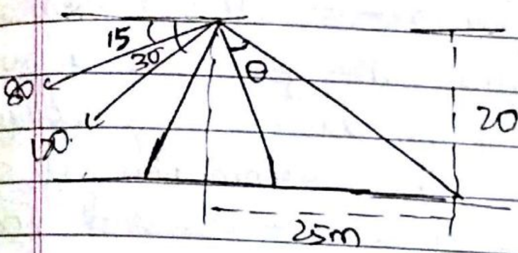
Resultant = ?

Angle with x axis of resultant = ?

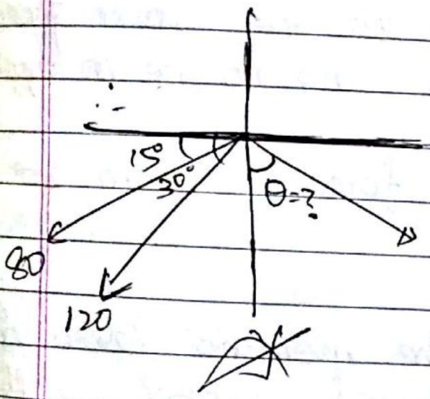


Local y-force = $-mg\cos 30° = -1732$
local x-force = $-mg\sin 30° = -1000$

⇒ Sternak Q.No. 9.



θ could be found by hight



for standing straigh Σf_x must be 0

neglect Σf_y

18-2-2.

Module 3: Equilibrium forces & friction

① Equilibrium of concurrent and non-concurrent forces.

⇒ Condition of Equilibrium

① For concurrent force System :→

(i) $\Sigma V = 0$ i.e. The summation of all the vertical forces — resolved vertical forces is equal to zero in a system which is said to be in equilibrium

(ii) $\Sigma H = 0$ i.e. The summation of all the horizontal forces — resolved horizontal forces is equal to zero in a given system which is said to be in equilibrium

② for non-concurrent force system :→

① $\Sigma V = 0$

② $\Sigma H = 0$

③ $\Sigma m = 0$ i.e. the moments taken at any simply supported section or the moments at any section deviding the given force system ~~into~~ will be equal to zero. The moments at any section ~~at~~ in a force system can be calculated basing on the varignons principle and can be evaluated.

CONCURRENT FORCE SYSTEM.

Date :
Page No :

→ **Equilibrium of Concurrent forces:**

Any system of forces are said to be in equilibrium when the resultant of all forces is zero and algebraic sum of moments of all forces is zero.

→ **Condition of Equilibrium:**

A system of forces is said to be in equilibrium when

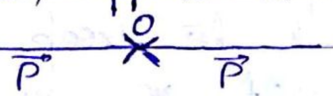
$$F_R = \sqrt{\sum F_x^2 + \sum F_y^2} = 0 \quad \text{and}$$
$$\sum M = 0.$$

That means for a concurrent force system $\sum F_x = 0$ and $\sum F_y = 0$.

For a non-current force system $\sum F_x = 0$, $\sum F_y = 0$ and $\sum M = 0$.

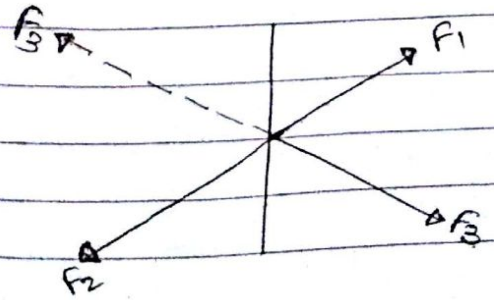
→ **Two Force System :→**

If a body is acted upon two forces then for an equilibrium, the forces must be equal in magnitude, opposite in direction and collinear.



→ **Three force System :→**

If a body is acted upon 3 forces, then for equilibrium, the resultant of any two forces must be equal, opposite and collinear with the third force.



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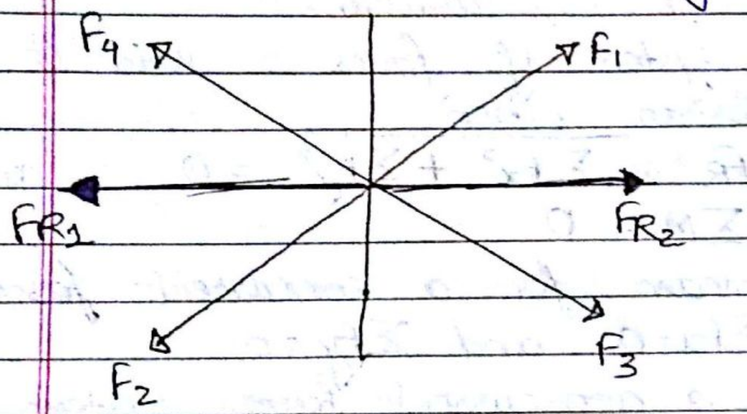
Four Force System:

If a body is acted upon by four forces, then for equilibrium the resultant of any two forces must be equal & opposite and collinear with the resultant of remaining two forces



⟹ Equilibriant :→

An equilibriant is a force equal in magnitude, opposite in direction and collinear with the resultant. It is defined as a force or a moment required to keep the object in equilibrium

If an equilibriant is added to a concurrent force system, then the system is said to be in equilibrium.

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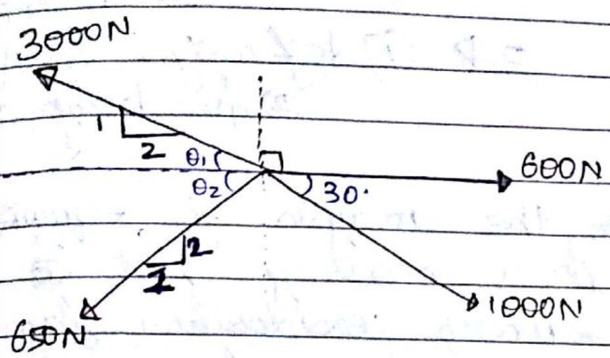
Q Find the equilibriant for given force System

(1)



From figure :→ $\theta_1 = 26.56$

$\theta_2 = 63.43$

$\therefore \Sigma F_x = 600 + 1000\cos 30 - 3000\cos(26.56) - 650\cos(63.43) = -1508.11\,N$

$\Sigma F_y = 0 - 1000\sin 30° - 650\sin(63.43) + 3000\sin(26.56) = 260.05\,N.$

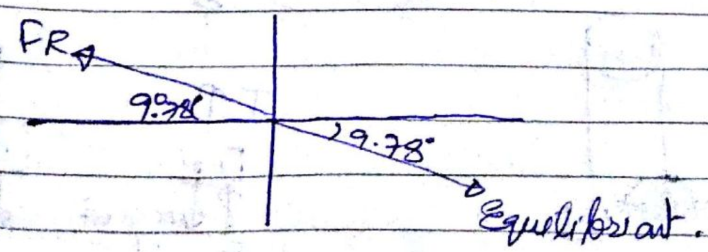
$\therefore F_R = \sqrt{F_x^2 + F_y^2} = 1530.36N$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = -9.78°$

$= 180 - 9.78 = \underline{170.21°}$

$\therefore$ Equilibriant $= -1530.36N.$

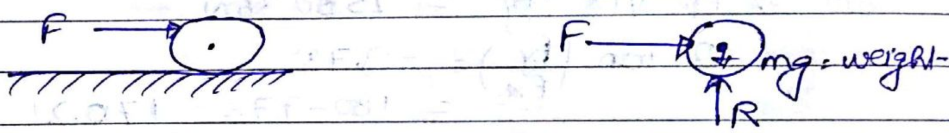
The equilibriant of the given force System is given by the same magnitude of resultant and in the same line of action of resultant but in opp. direction which makes the resultant and the equilibriant in collinear force system.



⇒ You will get notes copy for :→ ① Applied force
② Non-applied force
⇒ ① Self weight ② Reaction
③ free body diagram

fbd :→ for the analysis of equilibrium conditions it is necessary that to isolate the body under consideration from other bodies in contact and draw all the forces acting on the body. This type of diagram of a body in which the body under consideration is freed from all contact surfaces and shown with all forces on it (self wt, Reactions and applied forces) is called free body diagram.

FBD.

①


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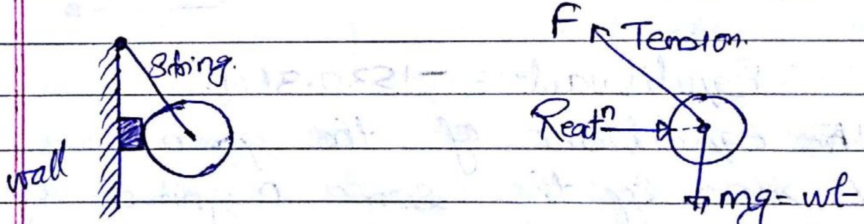

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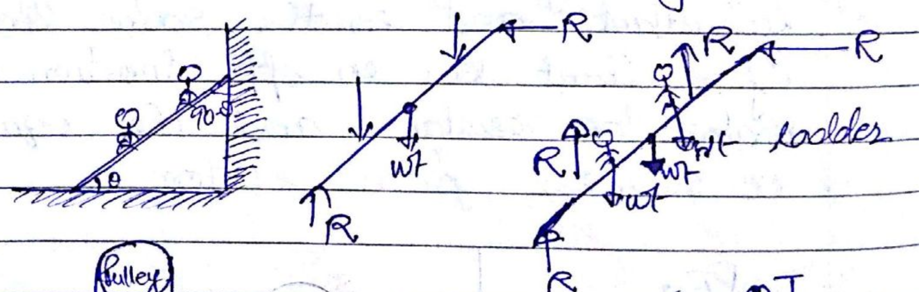
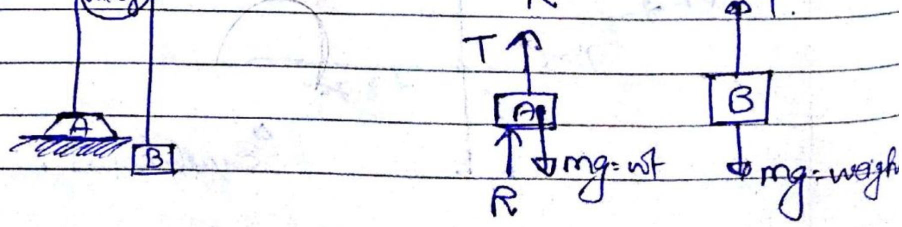
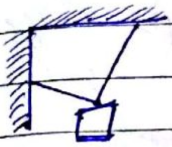
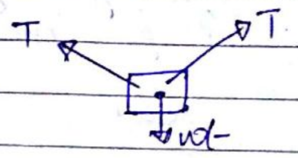


④


Q Write the FBD for the following :-

(1)





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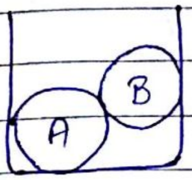
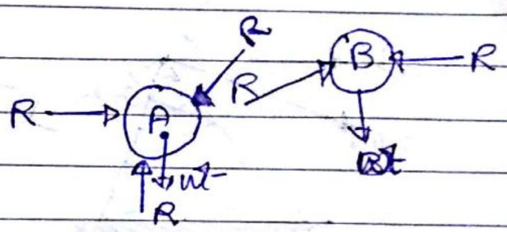
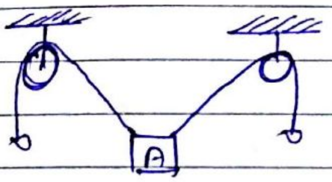
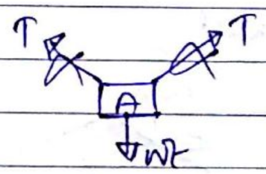




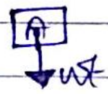
(3)





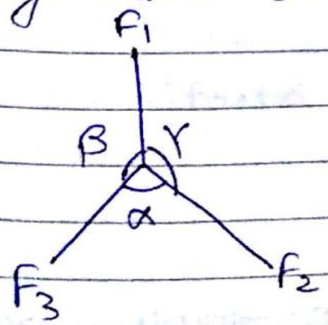
No tension force

only wt (self) ↓ free to move



⇒ LAMIS THEOROM :

If three coplanar forces are acting simultaneously at a point in equilibrium then each force is proportional to sine angle b/w other to forces.



$F_1 \propto \sin\alpha$

$F_2 \propto \sin\beta$

$F_3 \propto \sin\gamma$

$$\therefore \frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

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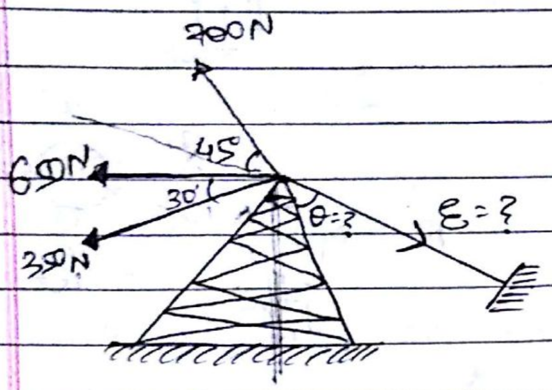
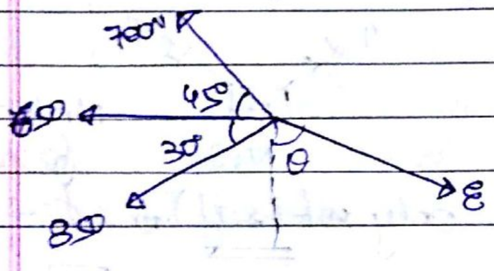
→ Calculate the equilibrant force required for following force system to keep the sys in equilibrium.



⇒



$F_x = -650 - 700\cos 45 - 850\cos 30$
$= -1881.09\ N$

$F_y = 700\sin 45 - 350\sin 30$
$= +69.97\ N$

$\therefore F_R = \sqrt{F_x^2 + F_y^2} = 1882.39\ N.$

$\theta_1 = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 2.13°$

$\theta_1 = 90 - 2.13° = 87.87°$

$\theta_1 = \theta = 87.87°$

Or

$F_x = E\sin\theta - 650 - 700\cos 45 - 850\cos 30 = 0$
$F_y = -E\cos\phi + 700\sin 45 - 350\sin 30 = 0$

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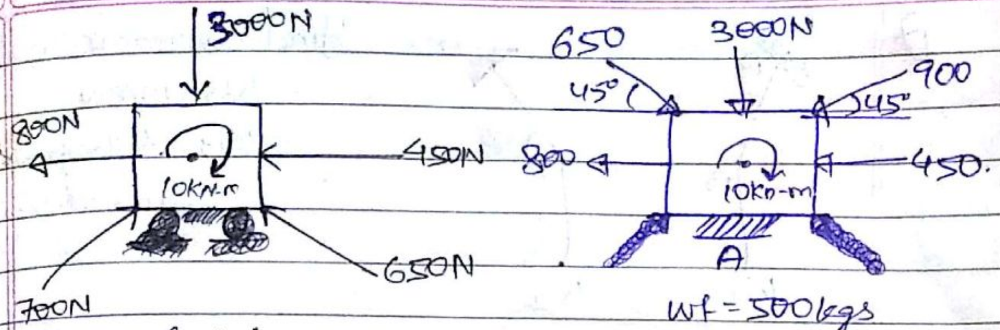
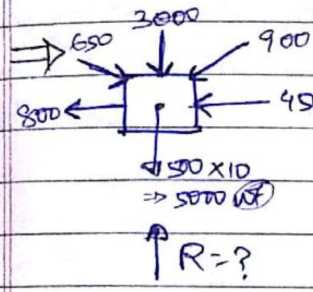
Q 

Calculate the resistance offered by two supports A & B on the vehicle to be in equilibrium.



$\Sigma x = -800 - 450 + 650\cos 45 - 900\cos 45$

$\Sigma y = 3000 + 5000 + 900\sin 45 + 650\sin 45$

$\Sigma x = -1426.77 \qquad \Sigma y = 9096.01$

$\therefore R = 9096.01\ N = \Sigma y$

Q Important points to remember while solving a problem:

- If a number is subjected to a pull then resistance against external force is always from end A & B.
- If a ~~number~~ member AB is subjected to push then resistance against external force is towards the end AB
- Strings, cables, wires, ropes, chain etc. are always subjected to tension only
- A string carrying freely hanging load on one end will be in tension.
- If such string passes through a frictionless pulley then tension on either side of the pulley remains same
- Reactions are directed towards centroid of the body

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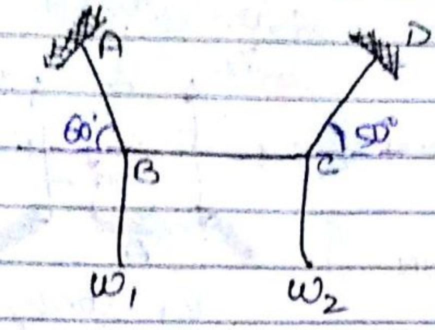
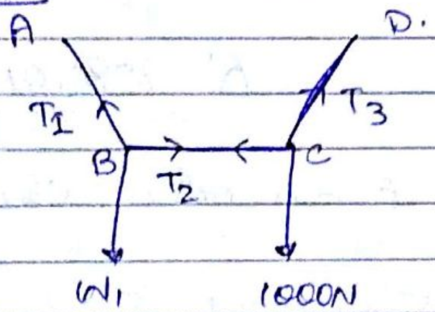
Q.

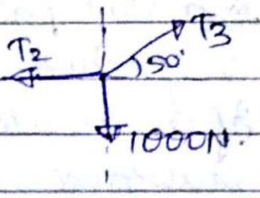


Find tension in wire ABC
$W_2 = 1000N$
W_1 = to keep to sys in equilibrium

Assume T_1 T_2 T_3 be 3 tension forces acting in the cable AB, BC, CD respectively. It is said that the system is in equili. i.e. $\Sigma H = 0$ and $\Sigma V = 0$ then the fbd:



Analysis of joint 'C'



for $\underline{C}$: $F_x: -T_2 + T_3 \cos 50 = 0 \rightarrow T_2 = T_3 \cos 50$

$F_y = -1000 + T_3 \sin 50 = 0 \rightarrow T_3 \sin 50 = 1000$

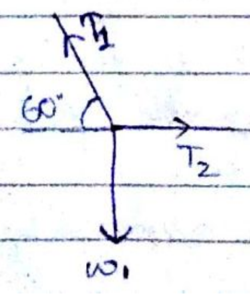
$\therefore T_3 = \frac{1000}{\sin 50} = 1305.40N$

$\therefore T_2 = T_3 \cos 50 = 839.09 \ N.$

for B:

$\Sigma F_x = T_2 - T_1 \cos 60° = 0$

$\Rightarrow \frac{839.1}{\cos 60°} = T_1 = 1678.5 \ N.$



$\Sigma F_y = -W_1 + T_1 \sin 60 = 0$

$\therefore W_1 = T_1 \sin 60$

$= 1453.30N$

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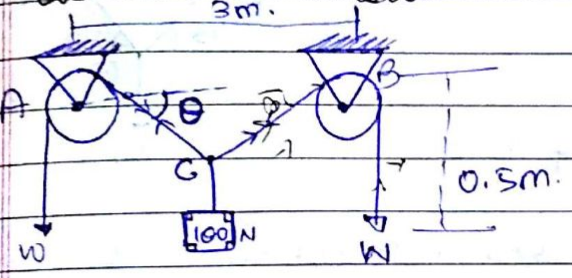
A force $W_1 = 1453.36$ N is acting at joint B vertically downward to keep the sys in equilib. i.e. to keep the cable BC Horizontal.

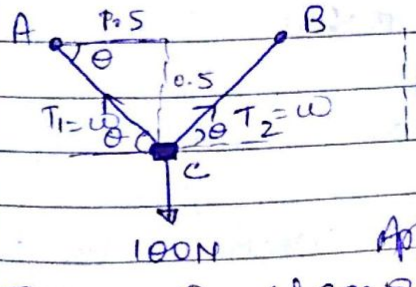
Q Find the value of W which is required to maintain the equilibrium configuration as shown below.



Assume T_1 and T_2 be tension in the strings AC & CB as shown in figure. Assume A & B to be two frictionless pullies. Therefore the tension in the string AC & CB will be equal to the load acting at the other end of the string

i.e. $T_1 = T_2 = W$

fbd.



$\tan\theta = \frac{0.5}{1.5} = \frac{1}{3}$

$\therefore \theta = 18.43°$

Applying eq. condition at C

$\Sigma H = 0 \quad F_x = W\cos 18.43 - W\cos 18.43 = 0$

$\Sigma F_y = 2 \cdot W \sin 18.43 = 100$

$\therefore W = \frac{100}{2 \cdot \sin 18.43} = 158.15$ N.

Or apply

LT

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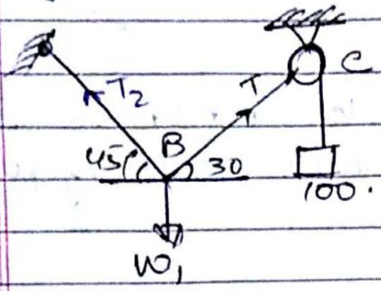
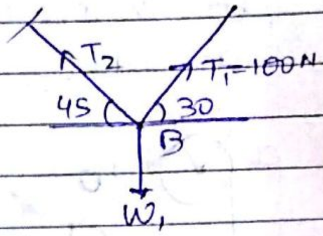
Q. Find the value of W_1 for the equilibrium of the system shown in the figure



fbd

$T = 100N.$



Applying Eq. at B.

$\Sigma F_x: \quad -T_2 \cos 45 + 100 \cos 30 = 0.$

$\therefore \quad T_2 = \dfrac{100 \cos 30}{\cos 45} = 122.47 \text{ N}$

$\Sigma F_y \Rightarrow \quad T_2 \sin 45 + 100 \sin 30 = W_1$

$\Rightarrow 122.47 \sin 45 + 100 \sin 30 = W_1$

$\therefore W_1 = 136.59 N.$

Now Applying Lamis Theorem:

$$\frac{W_1}{\sin(180-75)} = \frac{T_1}{\sin(90+45)} = \frac{T_2}{\sin(90+30)}$$

$$\frac{W_1}{\sin(105)} = \frac{T_1}{\sin 135} = \frac{T_2}{\sin 120}$$

$W = 136.59N \qquad T_1 = 100N \qquad T_2 = 122.47$

2 A sphere weighing 100N is fitted into a right angled notch as shown. If all the contact surfaces are smooth then determine the reactions at A & B.