Date 18/07/25

Engineering mechanics Essentials

Static

Dynamics

- Kinematics → only considering motion
- Kinetics → both motion & force

21st July

☆ Mass & Weight

mass → mass of a body is the total quantity of matter contained in the body. mass is denoted by letter 'm'. generally measured in 'kg'.

weight → weight of a body is the force with which the body is attracted towards the centre of earth.

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Mass	Weight
① copy defination	copy defination
② - It is scalar (no dirⁿ only magnitude)	- It is vector qty (has both magnitude and direction)
③ remains same at all places	varies from place to place due to variation in gravity.
④ It resists motion	It produces motion in body.
⑤ measured by an ordinary balance.	measured by a spring balance.

✶ Rigid body & Elastic body.

→ A body is said to be rigid if it does not undergo deformation whatever force may be applied to the body. In actual practice, there is no body which can be said to be rigid in true sense of terms.

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→ A body is said to be elastic if it undergoes deformation under the action of force. All bodies are more or less elastic.

☆ Scalar & Vector

	Scalar	Vector
①	magnitude only	magnitude & direction
②	normal rules of algebra used	vector algebra used.
③	change in terms of magnitude only.	change in terms of either magnitude or its direction of application.
④	Scalar ± Scalar = Scalar	vector ± vector = scalar / vector
⑤	eg: length, area, vol., speed, mass, density, pressure, temp., energy, entropy, time, work, power, etc.	eg: displacement, velocity, acceleration, momentum, force, lift, drag, thrust, weight, etc.

Laws of Mechanics

fundamentals of mechanics :

- → Newton's laws of motion
- → law of universal gravitation.
- → law of parallelogram of forces.
- → Law of transmissibility.
- → law of triangle of forces.
- → lami theorem.

① Newton's laws of motion :

- First law : object will remain in rest / motion until external force is applied.

- Second law : $F = ma$

$a = \frac{F}{m}$ ← (from here statement can be formed)

$a \propto F$, $a \propto \frac{1}{m}$

acc^n = a = rate of change of momentum

$\Rightarrow F = ma = \frac{mv - mu}{t} = \frac{m(v-u)}{t} = am = F$

$$\boxed{\frac{v-u}{t} = a}$$

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- Third law : (Action - Reaction)
for every action , there is equal and opposite reaction.

eg:- when bullet is fired gun gets a backward force.

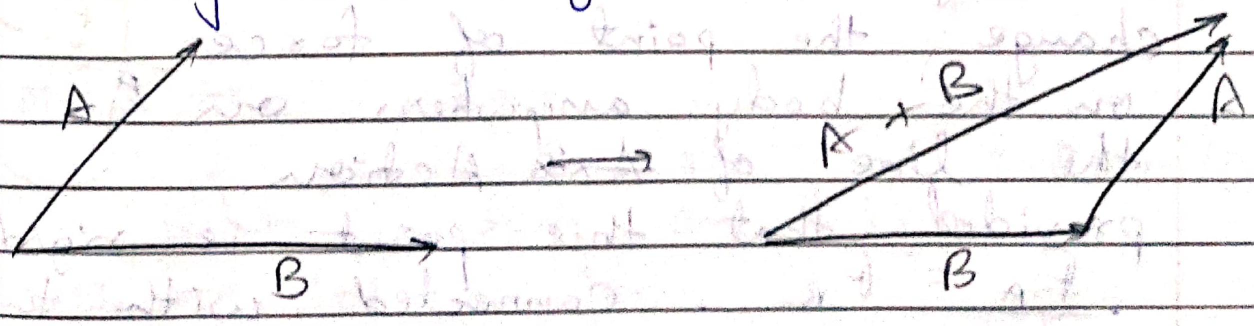
② Newton's law of Gravitational attraction :

$$\boxed{F = \frac{G m_1 m_2}{r^2}} \qquad G = 6.673 \times 10^{-11}\ Nm^2/Kg^2$$

$$w = mg$$

$$\cancel{m}g = w = \frac{G \cancel{m} m_e}{r^2} \Rightarrow g = \frac{G m_e}{r^2} = \boxed{9.81 m/s^2}$$

③ triangle law for resultant vector :-



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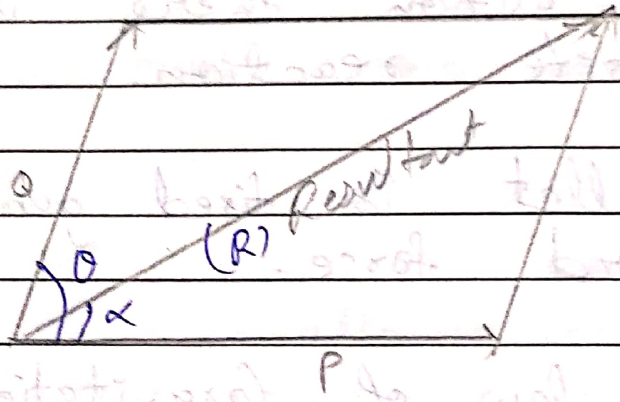
(4) Parallelogram law of ~~mechanics~~ forces



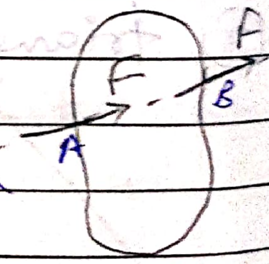
$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

If 2 forces 'Q' & 'P' are there ~~then~~ as sides (adjacent) then the diagonal will be resultant

$\tan\alpha = \dfrac{Q\sin\theta}{P + Q\cos\theta}$ (for direction)

(5) Principle of transmissibility of forces

- It says that we can change the point of force on the body anywhere on the line of ~~Axis~~ Action provided that this point is rigidly connected with the body.



$F_A = F_B$

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Force

- force system:

force is that which changes or tends to change the state of rest or uniform motion of a body along a straight line. It may also deform a body changing its dimen-tions.

mathematically → $\boxed{F = ma}$

Units of force :-

- CGS → (i) Dyne
  (ii) Gramforce (gmf).

one dyne is that force which acting on a mass of one gram produces in it an acceleration of $1\ cm/s^2$

- MKS → (1) kgf
  1 kgf produces acc^n of $9.81\ m/s^2$ when acted on 1 kg.
- S.I. → (1) Newton
  1 Newton when acting on 1 kg mass produces acc^n of $1\ m/s^2$
  $1\ N = 10^5$ dyne

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Effects of force

1. rest to motion (vice versa) or accelerate and decelerate.
2. may retard the forces already acti on a body, thus result in equilib
3. may give rise to internal stresses in the body, on which it acts.
4. A force can change the direction of a moving object.
5. A force can change the shape and size of an object.

☆ CHARACTERISTICS OF A FORCE

1. Magnitude (eg. 20N, 50N)
2. Direction (also known as line of action of the force, eg. 30° North of east)
3. Nature of the force (push, pull)
4. the point at which the force acts on the body.

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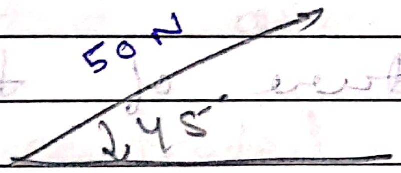
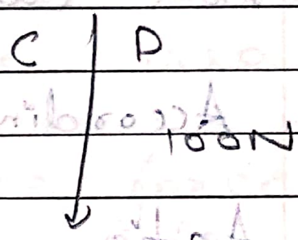
Representation of forces

(1) → vector Representation.
(2) → Bow's notation.

(1) vector - A force can be represented graphically by a vector as shown.



force vector



Bow's notation

(2) Bow's notation - It is a method of representing a force by writing two capital letters, one on either side of the force as shown.

★ Classification of forces

(1) According to the effect produced by the force:

(i) External force: when a force is applied externally to a body it is called external force.

(ii) Internal force: The resistance to deform or change of shape, exerted by the material of a body is called an internal force.

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(iii) Active force : An active force is one which causes a body to move or change its shape.

(iv) Passive force : A force which prevent the motion, reformation of a body is called passive force.

② According to nature of forces:

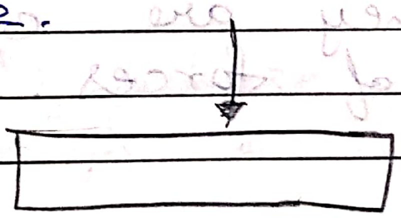
(i) Action and reaction :- whenever there are two bodies in contact, each exerts a force on the other. out of these forces one is called action and other is called reaction.
Action and Reaction are equal & opposite.

(ii) Attraction and repulsion :- These are actually non-contacting forces exerting by one body on another without any visible medium transmission such as magnetic.

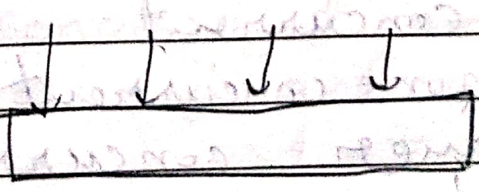
(iii) Tension and Thrust : When a body is dragged with the string the force communicated to the body by the string is called the tension while, if we push the body with a rod, the force exerted on the body its called thrust.

(3) According to the whether the force acts at a point or is distri-buted over a large area.

(i) Concentrated force :- The force whose point of application is so small that it may be considered as a point is called concentrate-d force.



(ii) Distributed force :- A distributed force is one whose place of application is area.



(4) According to whether the forces acts at a distance or by contact

(i) Non-contacting forces or forces at a distance.

Magnetic, electrical and gravitational forces are example of non-contacting forces or forces at a distance.

28th July, 2025

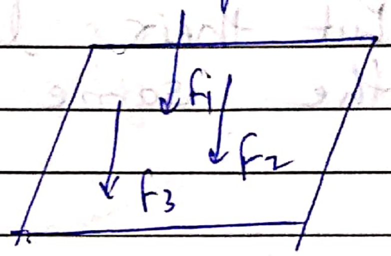
System of Forces

When two or more forces act on a body, they are called to form a system of forces.

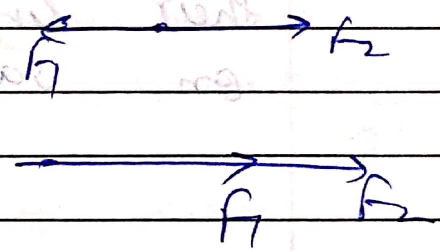
types :-

(I) Co-planer
(II) Collinear
(III) Concurrent
(IV) Coplaner concurrent
(V) Coplaner non-concurrent
(VI) Non-coplaner concurrent
(VII) Non-coplaner non-concurrent.

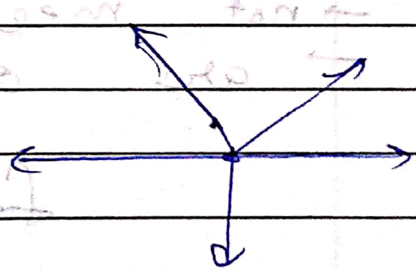
Coplaner :
line of action lie on same plane.



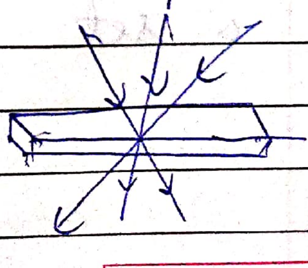
Collinear : line of action on same line



Concurrent: whose line of action pass through a common point.



Co-planer concurrent forces:
whose lines of action lie in the same plane and at the same time pass through a common point.



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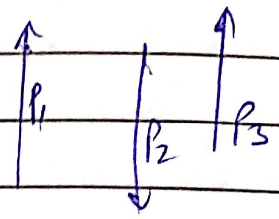
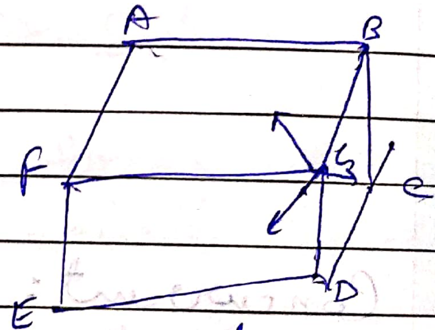
- Coplaner non-concurrent forces :
forces, which do not meet at one point but their line of action lie on the same plane.



- Non-coplaner concurrent :
which meet at one point but their line of action do not lie on same plane.



- Non coplaner, non-concurent ⇒
→ not meet at one point.
→ are on different planes

free body Diagram

A body may consist of more than one element and supports. Each body/support can be isolated from the rest of the system through a set of forces.

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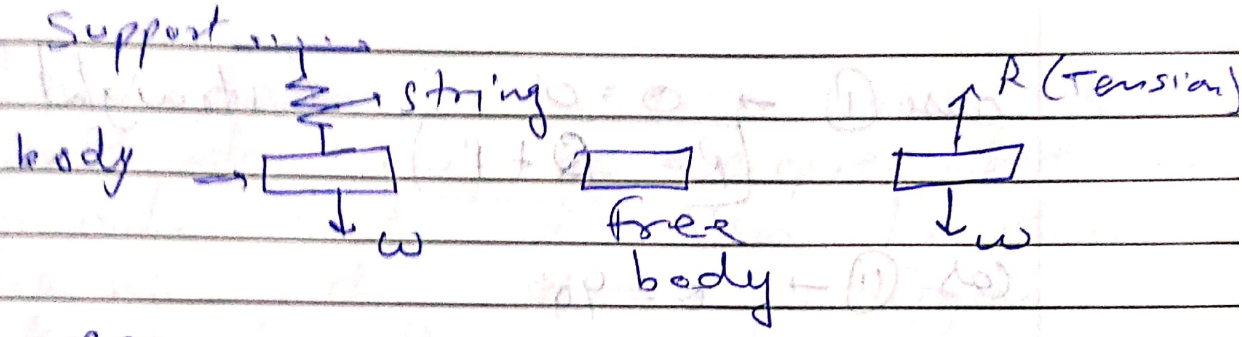
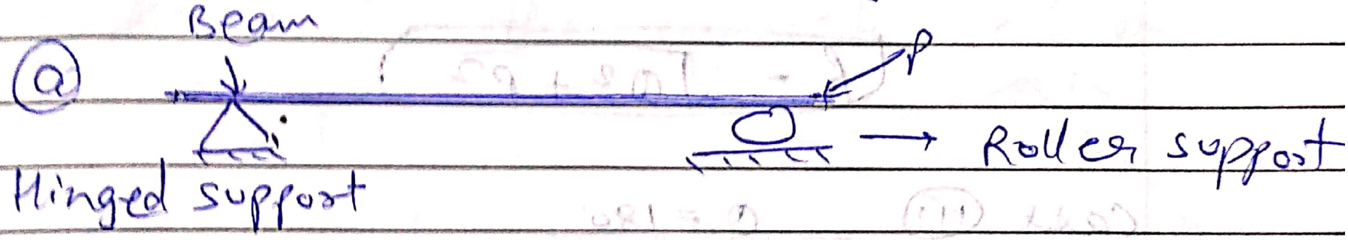
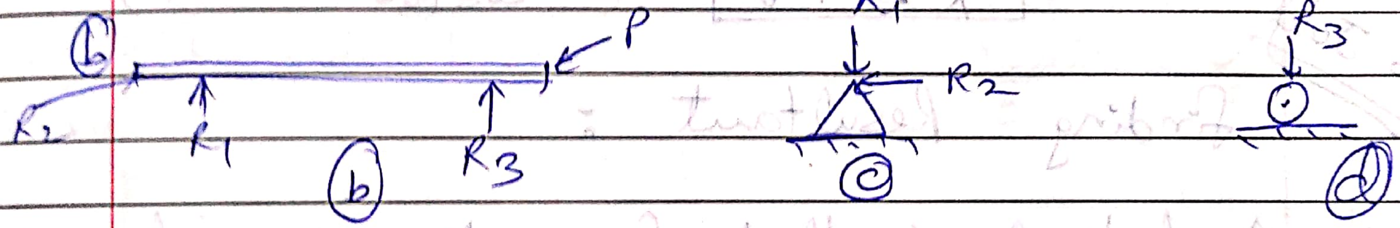
(1)


Support
string
body
ω
free body
R (Tension)
ω

(2) (a)


Beam
P
Hinged support
→ Roller support


(b)
P
R_2
R_1
R_3
(b)
R_1
R_2
(c)
R_3
(d)

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case ① → $\theta = 0°$ (straight).

$\boxed{R = Q + P}$

case ⑪ → $\theta = 90°$

$\boxed{R = \sqrt{Q^2 + P^2}}$

case ⑪ $\theta = 180°$

$\boxed{R = P - Q}$ ($\cos 180° = -1$)

30 July

finding Resultant :

Analytical method from the geometry of triangle oac (fig.).

$\angle coa = \alpha$, $\angle oca = \theta - \alpha$, $\angle cao = 180° - \theta$

$\therefore \frac{oa}{\sin(\theta - \alpha)} = \frac{ac}{\sin\alpha} = \frac{oc}{\sin(180° - \theta)}$

$\Rightarrow \frac{P}{\sin(\theta - \alpha)} = \frac{Q}{\sin\alpha} = \frac{R}{\sin\theta}$

☆ ⇒ Polygon law:
It states that " if a number of coplaner concurrent forces, acting simultaneously on a body are represented in magnitude and direction by the sides of a

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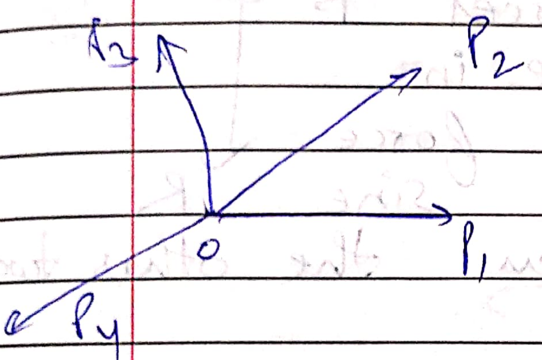
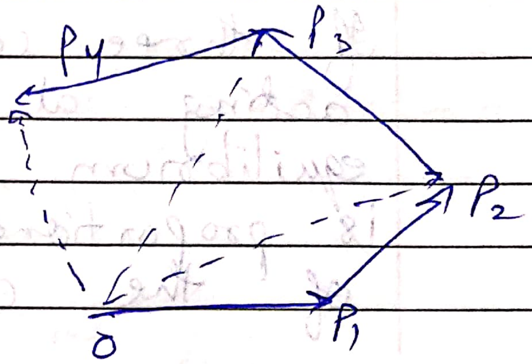
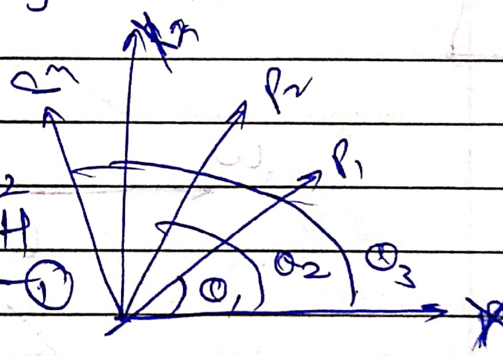
polygon taken in order, then their resultant may be represented in magnitude and direction by the closing side of a polygon, taken in the opposite order.'





→ Resultant by analytical method:



$$R\cos\theta = P_1\cos\theta_1 + P_2\cos\theta_2 + P_3\cos\theta_3 = \Sigma H \quad \text{—(i)}$$

and $$R\sin\theta = P_1\sin\theta_1 + P_2\sin\theta_2 + P_3\sin\theta_3 = \Sigma V \quad \text{—(ii)}$$

Now, by squaring and adding eqns (i) & (ii), we get

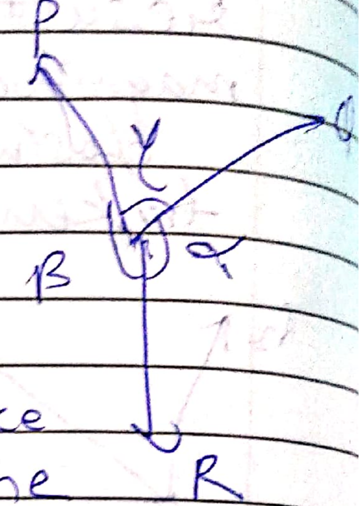
$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2} \quad \text{—(iii)}$$

by dividing (ii)/(i), we get

$$\frac{R\sin\theta}{R\cos\theta} = \tan\theta = \frac{\Sigma V}{\Sigma H} \Rightarrow \theta = \tan^{-1}\left(\frac{\Sigma V}{\Sigma H}\right) \quad \text{—(iv)}$$

→ Lami's theorm.

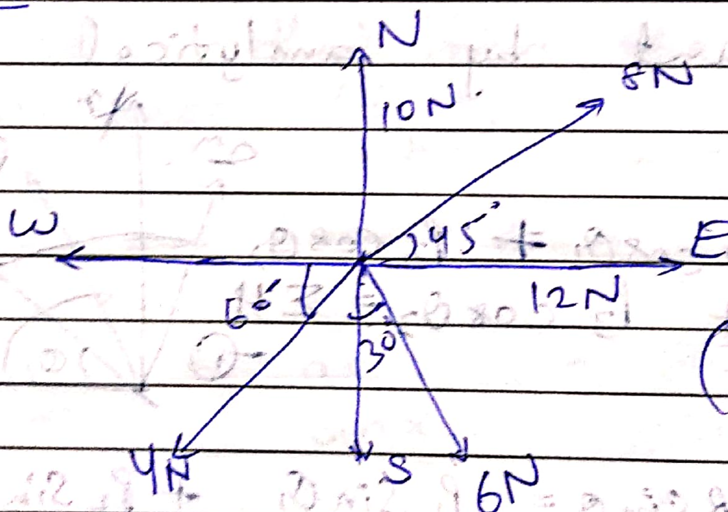
$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$$



If three coplanar forces acting at a point be in equilibrium, then each force is proportional to the sine of the angle between the other two

4th Aug. 2025

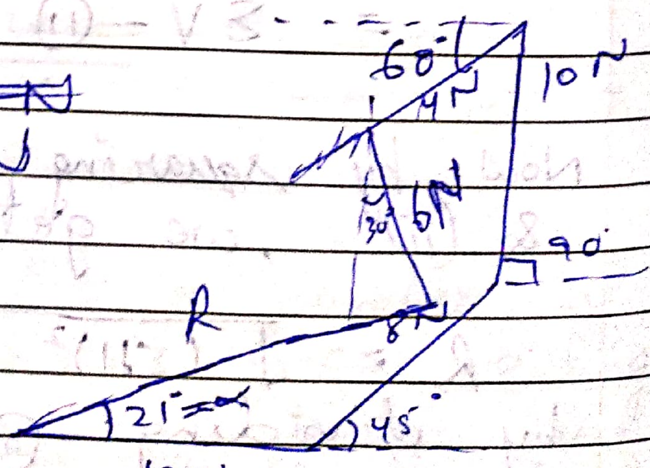
$\boxed{\text{P}-1}$



(space diagram)

⇒ magnitude = ~~40N~~ 20.4N

$\alpha = 21°$



(vector diagram).

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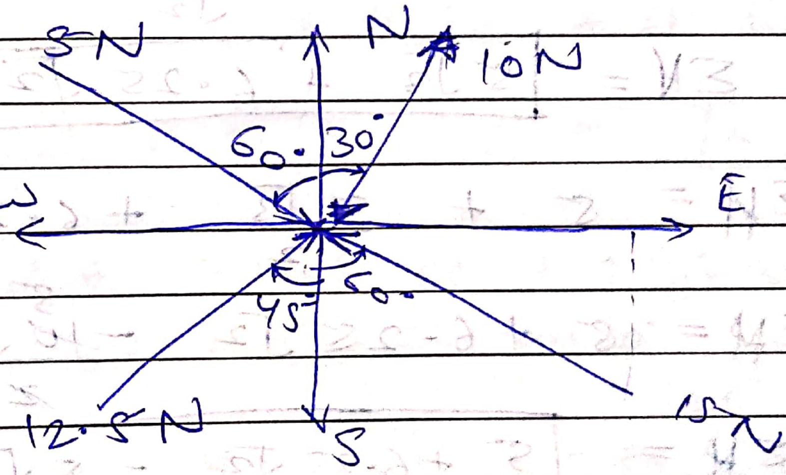
Analytically

[P-2] (i) 10 N push N 30° E
(ii) 12.5 N push S 45° W
(iii) 5N push N 60° W
(iv) 15 N push S 60° E.

Ans $\Sigma H = R\cos\theta = P_1 \cos\theta_1 + P_2 \cos\theta_2 + \dots$

$\Sigma V = R\sin\theta = P_1 \sin\theta_1 + P_2 \sin\theta_2 + \dots$

$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$



$\cancel{\Sigma H = R\cos\theta = 10\cos 30°, + 5\cos 60° + 12.5\cos 45°, + 15\cos 60°}$

$\cancel{= 10\cos 30°, 20\cos 60°, 12.5\cos 45°}$

$\cancel{\Sigma V = R\sin\theta = 10\sin 30° - 5\sin 60° - 12.5\sin 45° - 15\sin 60°}$

$+P_1 \cos\theta_1 = 10\cos 30°$; $+P_1 \sin\theta_1 = 10\sin 30°$

$-P_2 \cos\theta_2 = 5\cos 60°$; $+P_2 \sin\theta_2 = 5\sin 60°$

$+P_3 \cos\theta_3 = 12.5\cos 45°$; $+P_3 \sin\theta_3 = 12.5\sin 45°$

$+P_4 \cos\theta_4 = 15\cos 60°$; $-P_4 \sin\theta_4 = 15\sin 60°$

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$$R\cos\theta = 10\frac{\sqrt{3}}{2} - \frac{5}{2} + 12.5 \times \frac{1}{\sqrt{2}} + \frac{15}{2}$$

$$R\sin\theta = 10\times\frac{1}{2} + 5\times\frac{\sqrt{3}}{2} + 12.5\times\frac{1}{\sqrt{2}} - 15\times\frac{\sqrt{3}}{2}$$

$$R\cos\theta = \Sigma V = 5\sqrt{3} - \frac{5}{2} + \frac{12.5}{\sqrt{2}} + \frac{15}{2}$$

$$= 5\sqrt{3} + \frac{12.5}{\sqrt{2}} + \frac{10}{2}$$

$$\Sigma V = \boxed{5\sqrt{3} + 6.25\sqrt{2} + 5} = \boxed{22.5}$$

$$R\sin\theta = \Sigma H = 5 + \frac{5\sqrt{3}}{2} + 6.25\sqrt{2} - \frac{15\sqrt{3}}{2}$$

$$\Sigma H = 5 + 6.25\sqrt{2} - \frac{\cancel{10}^{5}\sqrt{3}}{\cancel{2}}$$

$$\Sigma H = \boxed{5 + 6.25\sqrt{2} - 5\sqrt{3}} = \boxed{5.18\,N}$$

$$R = \sqrt{(\Sigma V)^2 + (\Sigma H)^2}$$

$$R = \sqrt{(22.5)^2 + (5.18)^2}$$

$$R = \sqrt{506.25 + 26.83}$$

$$R = \sqrt{533.08}$$

$$R = 23.088 \approx \boxed{23.09\,N}$$

$$\tan\alpha = \frac{\Sigma V}{\Sigma H} = \frac{22.5}{5.18} = \boxed{4.34}$$

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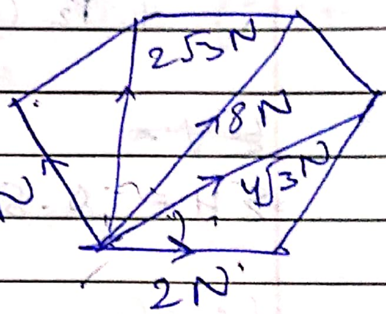
$\alpha = \tan^{-1}(4.34)$

$\alpha = 76.77^\circ \approx \boxed{77^\circ}$

$\boxed{P-3}$ $R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$



$\Sigma H = 4\sqrt{3}\cos 60^\circ + 8\cos 30^\circ + 2\sqrt{3} \times 0 + 4\cos 120^\circ$

$= 4\sqrt{3} \times \frac{1}{2} + 8\frac{\sqrt{3}}{2} + 0 + 4\left(-\frac{1}{2}\right)$

$= 2\sqrt{3} + 4\sqrt{3} - 2 \Rightarrow \boxed{6\sqrt{3} - 2}$

$\Sigma H \Rightarrow 2 + 4\sqrt{3}\sin 60^\circ + 8\sin 30^\circ + 2\sqrt{3}\sin 90^\circ - 4\sin 120^\circ$

$= 2 + 4\sqrt{3} \times \frac{\sqrt{3}}{2} + 8 \times \frac{1}{2} + 2\sqrt{3} \times 1 - 4(-1)$

$= 2 + \frac{4 \times 3}{2} + 4 + 2\sqrt{3} + 4$

$= 2 + 4 + 6 + 2\sqrt{3} + 4$

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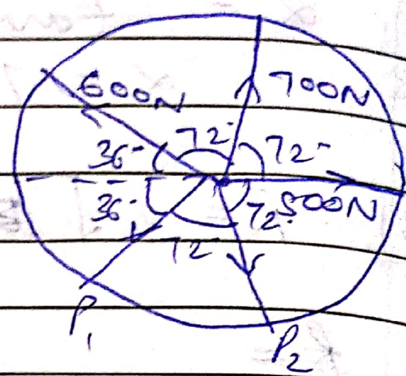
P-5

$$\Sigma H = 500 + 700 \cos 72^\circ - 600 \cos 36^\circ - P_1 \cos 36^\circ + P_2 \cos 72^\circ$$



~~ΣV =~~

$$\Sigma H = 0.809 P_1 - 0.309 P_2 = \boxed{230.9}$$

$(-600 \cos 36^\circ = +600 \cos$

divide both side by 0.809

$$\rightarrow \boxed{P_1 - 0.38 P_2 = 285.4} \text{ — (I)}$$

$$\Sigma V = 700 \sin 72^\circ + 600 \sin 36^\circ - P_1 \sin 36^\circ - P_2 \sin 72^\circ.$$

$$\rightarrow \boxed{P_1 + 1.62 P_2 = 1732.1} \text{ — (II)}$$

Subs → (I) from (II) →

$$2 P_2 = 1446.7$$

$$\boxed{P_2 = 723.3 \text{ N}} \text{ Ans}$$

Put P_2 in (I), we get

$$\boxed{P_1 = 560.2 \text{N}} \text{ Ans}$$

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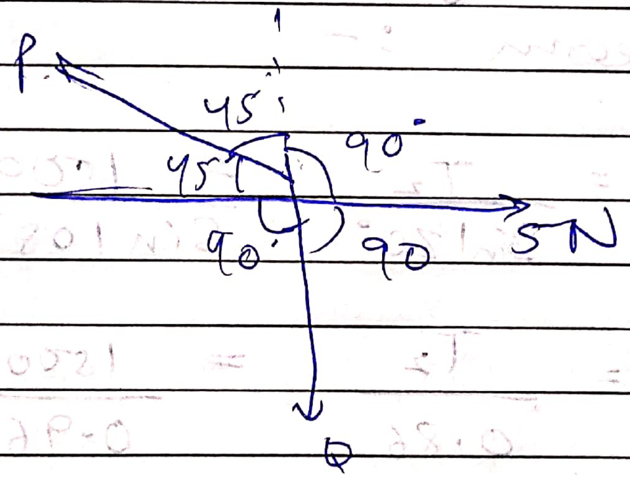
P-6 three forces keep a particle in equilibrium. One acts towards east, another towards north-west and the third towards south. If the first be 5N, find the other two.

→ Applying lami's theorm



$$\frac{5}{\sin 135^\circ} = \frac{P}{\sin 90^\circ} = \frac{Q}{\sin 135^\circ}$$

$$\frac{5}{0.707} = \frac{P}{1}$$

$$P = \frac{5}{0.707} = \boxed{7.07}$$

$$\frac{Q}{0.707} = \frac{5}{0.707} \Rightarrow \boxed{Q = 5}$$

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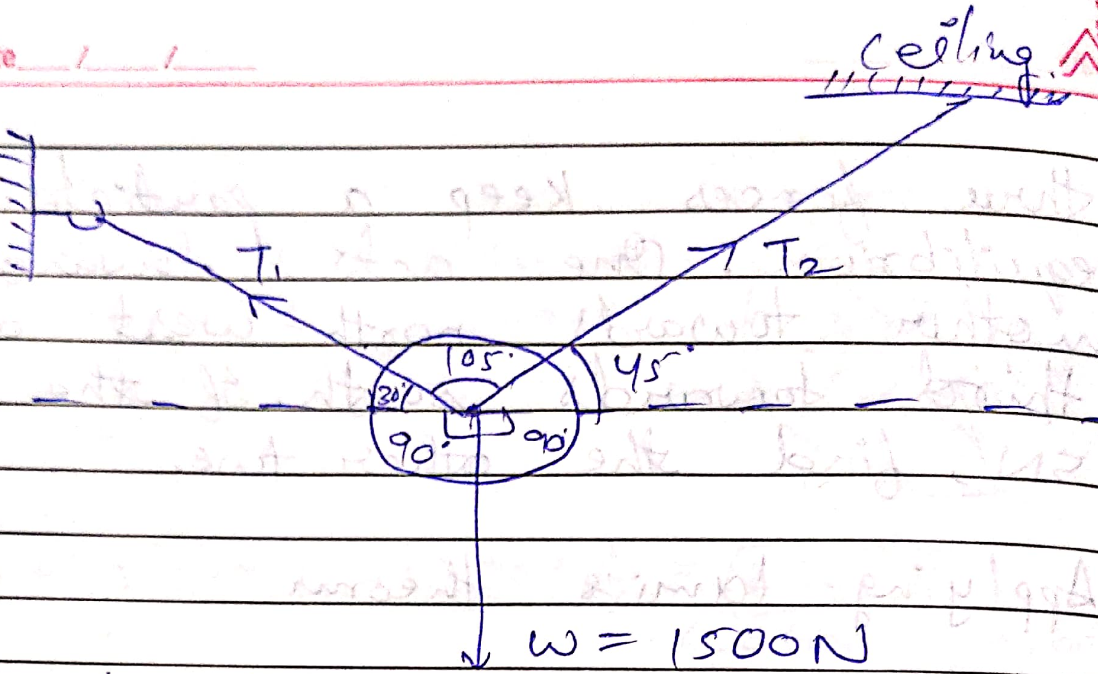
ceiling

P-7



Lami's theorm :-

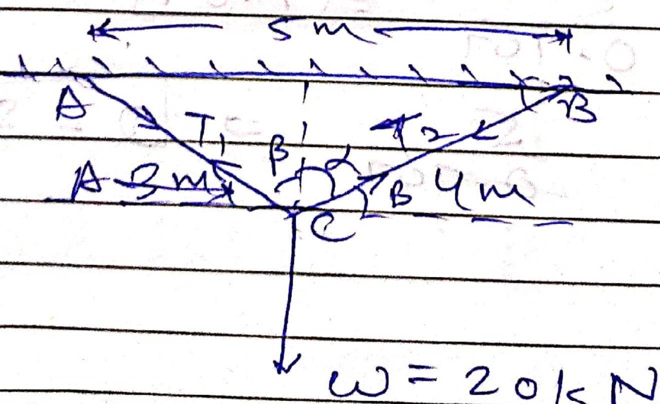
$$\frac{T_1}{\sin 135^\circ} = \frac{T_2}{\sin 120^\circ} = \frac{1500}{\sin 105^\circ}$$

$$\frac{T_1}{0.707} = \frac{T_2}{0.86} = \frac{1500}{0.96}$$

$$\frac{T_1}{0.707} = \frac{1500}{0.96} \Rightarrow \boxed{T_1 = 1104.68\,N}$$

$$\frac{T_2}{0.86} = \frac{1500}{0.96} \Rightarrow \boxed{T_2 = 1343.75\,N}$$

P-8



$$(5)^2 = (3)^2 + (4)^2$$

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So, $\alpha + \beta = 90^\circ$

by sine rule →

$$\frac{3}{\sin\angle B} = \frac{4}{\sin\angle A} = \frac{5}{\sin\angle C}$$

$$\frac{3}{\sin\angle B} = \frac{4}{\sin\angle A} = \frac{5}{\sin 90^\circ} = \frac{5}{1} = \boxed{5}$$

$$\frac{3}{\sin\angle B} = 5 \Rightarrow \boxed{\angle B = 36^\circ 52'}$$

$$\frac{4}{\sin\angle A} = 5 \Rightarrow \boxed{\angle A = 53^\circ 8'}$$

$$\angle\alpha = 90^\circ - \angle B = 53^\circ 8'$$

$$\angle\beta = 90^\circ - \angle A = \boxed{36^\circ 52'}$$

Applying Lami's theorem:-

$$\frac{T_1}{\sin(180 - 53^\circ 8')} = \frac{T_2}{\sin(180 - 36^\circ 52')} = \frac{20\,k}{\alpha + \beta}$$

$$\frac{T_1}{0.8} = \frac{T_2}{0.58} = \frac{20\,k}{1}$$

$$\boxed{T_1 = 16\,kN}$$

$$\boxed{T_2 = 12\,kN}$$

Date ~~8~~ 11, Aug, 2025

P-9 weight of sphere ~~= vol.~~
= vol. of sphere + density of cast iron

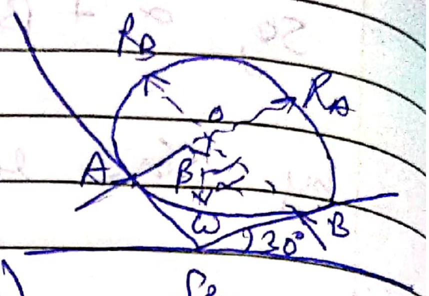


fig.

$$\Rightarrow \frac{4}{3}\pi \times (0.15)^3 \times (72 \times 1000)$$

$$W \Rightarrow 1017.9 \text{ N}$$

$$\frac{R_A}{\sin(180-\alpha)} = \frac{R_B}{\sin(90+\alpha)} = \frac{W}{\sin 90^\circ}$$

$$\Rightarrow \frac{R_A}{\sin\alpha} = \frac{R_B}{\cancel{\sin}\,\cos\alpha} = \frac{1017.9}{1}$$

Now.

$$R_A = 1017.9 \sin\alpha$$

$$R_A = 1017.9 \times \frac{1}{2}$$

$\cancel{R_A = 580.9}$, $\boxed{508.9}$ N

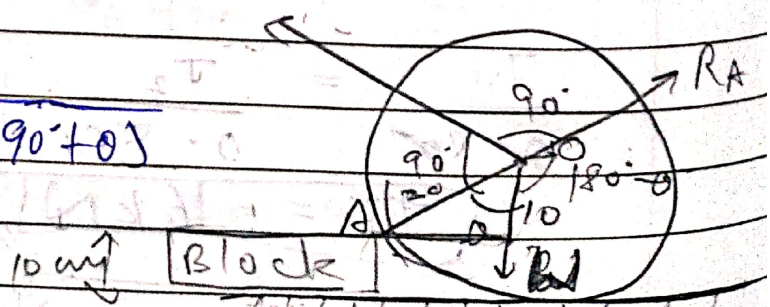
$R_B = \boxed{881.5 \text{ N}}$

using Lami's theorem

$\boxed{\text{P-10}}$ Applying lami's theorem

$$\frac{P}{\sin(180^\circ - \theta)} = \frac{R_A}{\sin(90^\circ + \theta)}$$

$$= \frac{W}{\sin 90^\circ}$$



Date___/___/___

$$\frac{P}{\sin\theta} = \frac{R_A}{\cos\theta} = \frac{800}{1}$$

$$\cos\theta = \frac{B}{H} = \frac{10}{20} = \frac{1}{2}$$

$$\boxed{\theta = 60^\circ}$$

$$\frac{P}{\sin 60^\circ} = 800$$

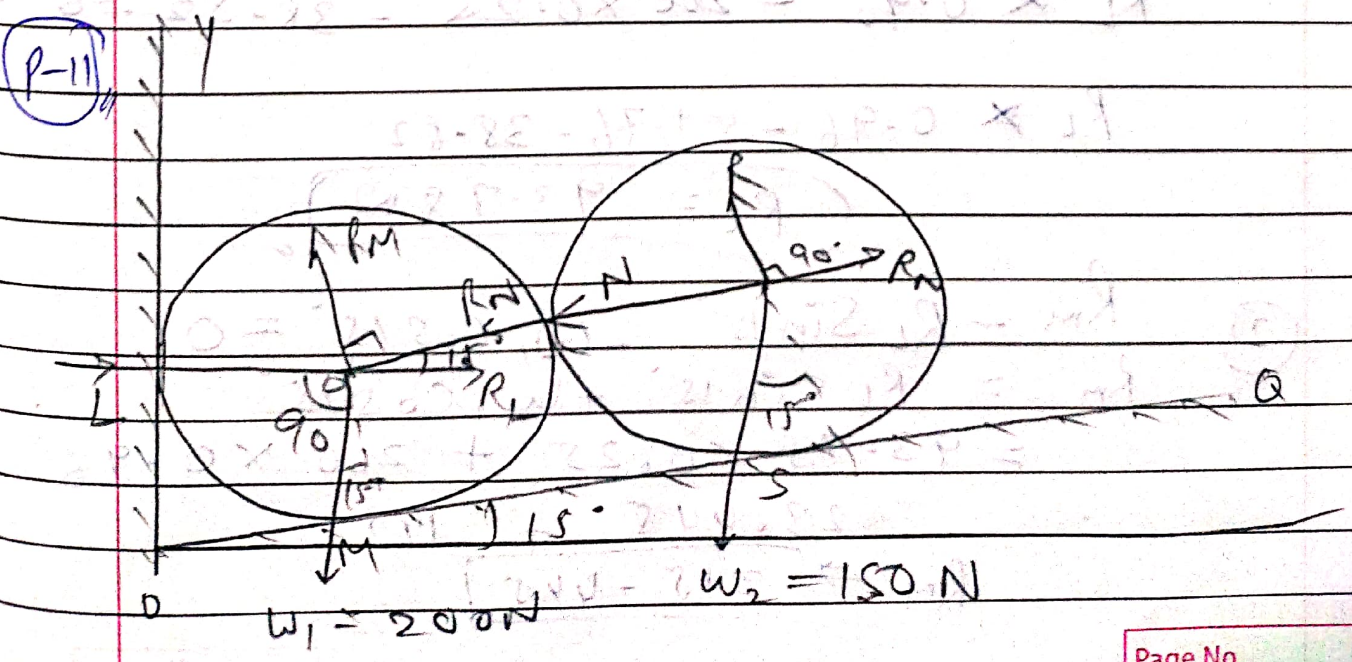
$$P = \cancel{800}^{400} \times \frac{\sqrt{3}}{\cancel{2}} = \boxed{400\sqrt{3}} = P$$

$$R_A = 800 \times \frac{1}{2} = \boxed{400 = R_A}$$

$$\boxed{W = 800}\ N$$

$$\boxed{\begin{aligned} P &= 400\sqrt{3}\ N \\ R_A &= 400\ N \end{aligned}}$$ Ans

(P-11)



Date __/__/__

$$\frac{R_N}{\sin(180-15^\circ)} = \frac{R}{\sin(90+15^\circ)}$$

$$= \frac{W_2}{\sin 90^\circ} = \cancel{150}$$

$$\frac{R_N}{\sin 15^\circ} = \frac{150}{1}$$

$R_N = 150 \times \underset{(0.25)}{\sin 15^\circ} = \boxed{37.5\ N}$

$R = 150 \times \underset{(0.96)}{\cos 15^\circ} = \boxed{144.89\ N}$

By resolving the forces along and $\perp$r to $O_1 O_2$.

along $O_1 O_2 \Rightarrow$ ① $R_L \cos 15^\circ - W_1 \sin 15^\circ - R_N = 0$

$R_L \times 0.96 - 200 \times 0.25 - 38.82 = 0$

$R_L \times 0.96 - 51.76 - 38.82$

$\boxed{R_L = 93.78\ N}$

② $R_M - R_L \sin 15^\circ - W_1 \cos 15^\circ = 0$

$R_M = R_L \sin 15^\circ + W_1 \cos 15^\circ$

$= 93.78 \times 0.25 + 200 \times 0.96$

$23.445 + 192$

$R_M \Rightarrow \boxed{215.445}$