MECHANICAL ENGINEERING DEPARTMENT

LECTURE NOTES

FOR

THE SUBJECT

# ENGINEERING MECHANICS

$2^{ND}$ SEMESTER

By

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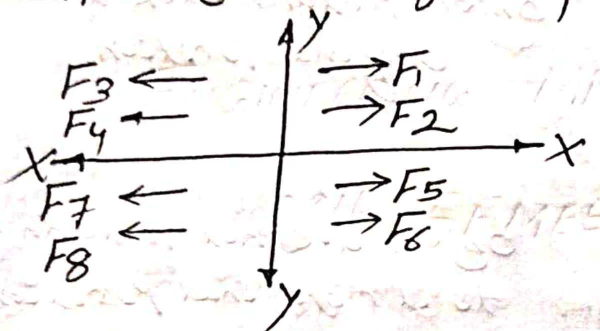
# CHAPTER- 2 : EQUILIBRIUM

## Equillibrium

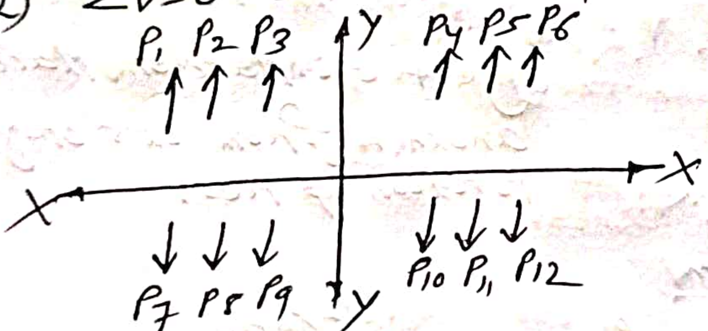
When two or more than two forces act on a body in such a way that body remain in a state of rest or uniform motion, then such system of forces is said to be in equillibrium.

## Condition of Equillibrium

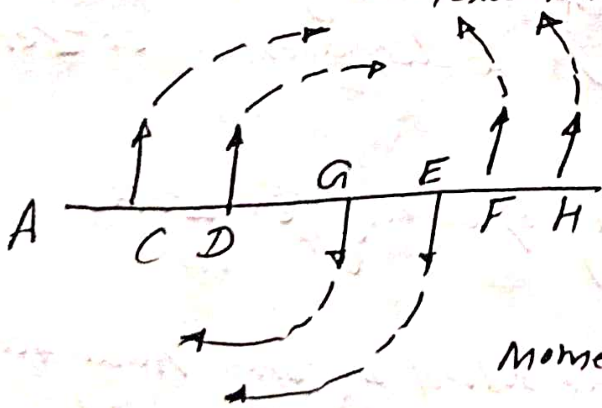
(1) $\Sigma H = 0$ (Total right hand side force = Total Left hand side force).




(2) $\Sigma V = 0$ (Total upward force = Total downward force)




(3) $\Sigma M = 0$ (Total clockwise moment force = Total Anticlockwise moment force).




Moment = Force × perpendicular Distance

## Classification of Equillibrium

1. Static equillibrium
   - (a) stable equillibrium
   - (b) unstable equillibrium
   - (c) Neutral equillibrium
2. Dynamic equillibrium
   - (a) Linear equillibrium
   - (b) Rotational equillibrium.

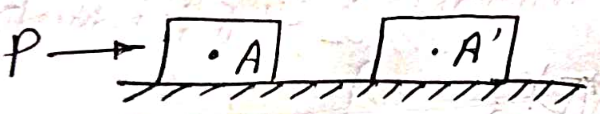
### Stable equillibrium

Object return back to it's original position.

### Unstable equillibrium

Object doesnot return back to it's original position.

### Neutral equillibrium




Object displace one place to another from it's original Position of rest.

### Linear Equillibrium

Where velocity of a body is Zero.

Travelling in a circle (displacement is Zero).

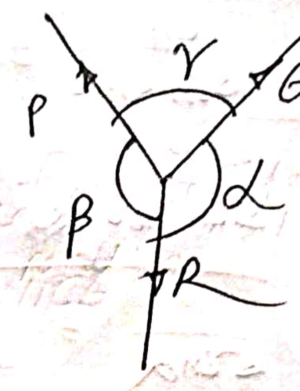
### Rotational Equillibrium

Where Angular velocity of a body is Zero.

**Note** Equillibrium problems are solved by only Analytical method for exam point of View.

## STATEMENT OF LAMI'S THEOREM

It states that "If three coplanner forces acting at a point be in equillibrium, then each force is Propertional to the sine of the Angle between other two."




Mathematically

$P \propto \sin\alpha$

$\Rightarrow P = K \cdot \sin\alpha$ ($K$ = const.)

$\Rightarrow \frac{P}{\sin\alpha} = K$ --- ①

$P \propto \sin\beta$

$\Rightarrow P = K \cdot \sin\beta$

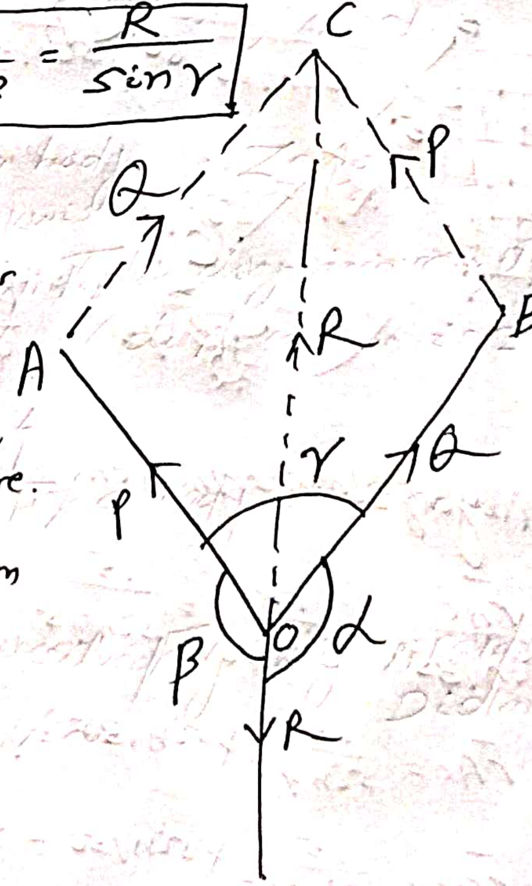
$\Rightarrow \frac{P}{\sin\beta} = K$ --- ②

$P \propto \sin\gamma$

$\Rightarrow P = K \cdot \sin\gamma$

$\Rightarrow \frac{P}{\sin\gamma} = K$ --- ③

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




**Prove**

→ consider 3 coplanner forces P, Q, R acting at a point O. Let the opposite angle to three forces be $\alpha, \beta, \gamma$ as shown in figure.

Now, complete the parallelogram AOBC.

$\Delta AOC$ marked.

$BC = P$, $AC = Q$

$\angle AOC = 180 - \beta$

$\angle ACO = 180 - \alpha = \angle BOC$

$\angle CAO = 180 - [\angle AOC + \angle ACO] = \alpha + \beta - 180$

But $\alpha+\beta+\gamma = 360^\circ$

$\Rightarrow (\alpha+\beta+\gamma)-180 = 360-180$

$\Rightarrow \alpha+\beta-180 = 180-\gamma$

$\Rightarrow \angle CAO = 180-\gamma$

we know in $\Delta AOC$, Apply sine rule of theorem.

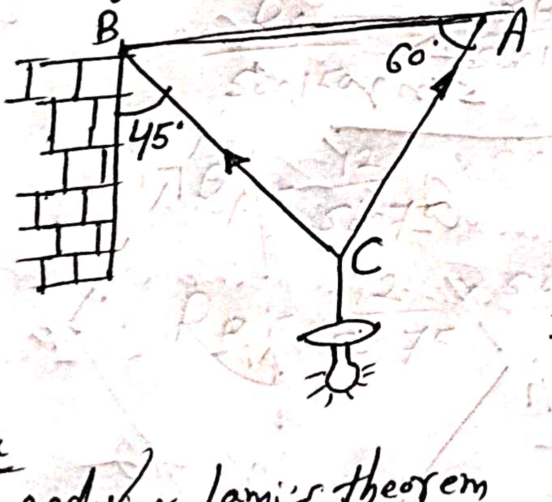
$$\frac{OA}{\sin\angle ACO} = \frac{AC}{\sin\angle AOC} = \frac{OC}{\sin\angle CAO}$$

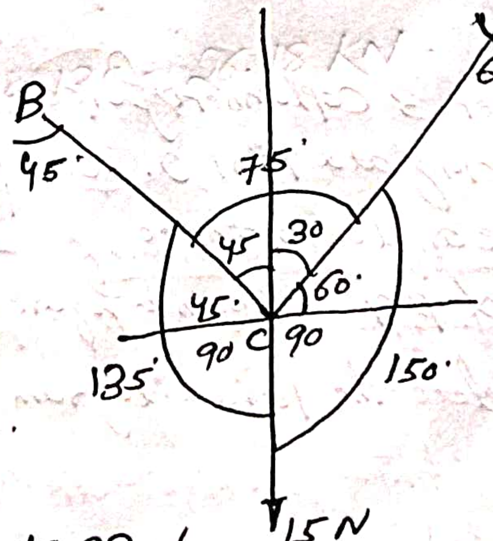
$$\Rightarrow \frac{P}{\sin(180-\alpha)} = \frac{Q}{\sin(180-\beta)} = \frac{R}{\sin(180-\gamma)}$$

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

**Problem-1**

An electric light fixture weighting 15 N hangs from a point C, by two strings AC & BC. The string AC is inclined at 60° to the horizontal & BC is 45° to the horizontal as shown in figure. Determine the forces in the string AC & BC.




**Answer**

Applying Lami's theorem

$$\frac{F_{AC}}{\sin 135^\circ} = \frac{F_{BC}}{\sin 150} = \frac{15}{\sin 75^\circ}$$

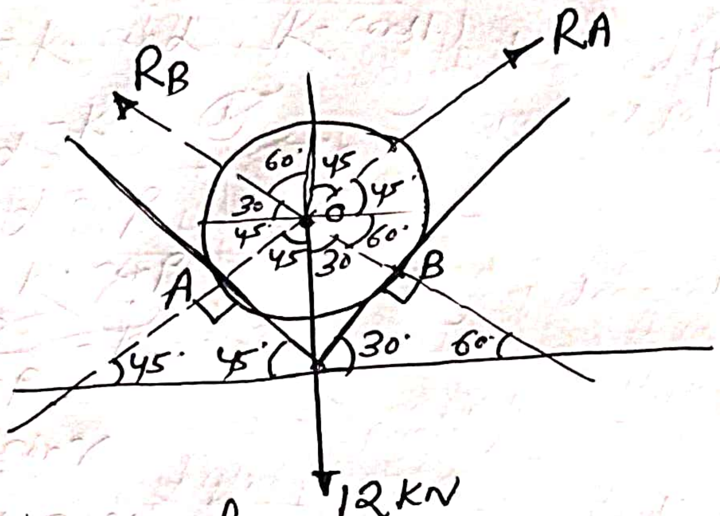
$$\therefore F_{AC} = \frac{15}{\sin 75} \times \sin 135 = 10.98\text{ N}$$

$$\therefore F_{BC} = \frac{15}{\sin 75} \times \sin 150 = 7.76\text{ N}$$

Problem-2

A small sphere of weight 12 KN rest on a V-trench as shown in figure. Find the reaction assuming the contact surfaces to be smooth.


Solution




Applying Lami's theorem

$$\frac{R_A}{\sin 150} = \frac{R_B}{\sin 135} = \frac{12}{\sin 75}$$

$$\therefore\ R_A = \frac{12}{\sin 75} \times \sin 150 = 22.12 \text{ KN}$$

$$\therefore\ R_B = \frac{12}{\sin 75} \times \sin 135 = 26.18 \text{ KN}. \quad \text{(Ans)}$$

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[illegible]