

MECHANICAL ENGINEERING DEPARTMENT

LECTURE NOTES

FOR

THE SUBJECT

ENGINEERING MECHANICS

2ND SEMESTER

By

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FACULTY (MECHANICAL)

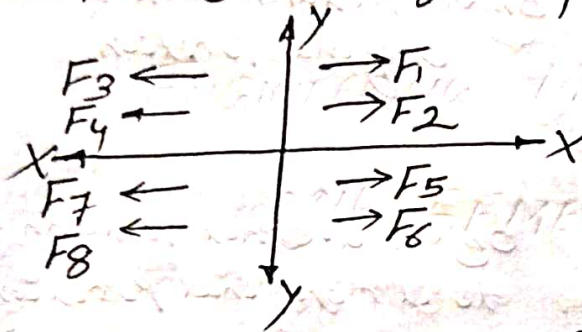
CHAPTER-2: EQUILIBRIUM

Equilibrium

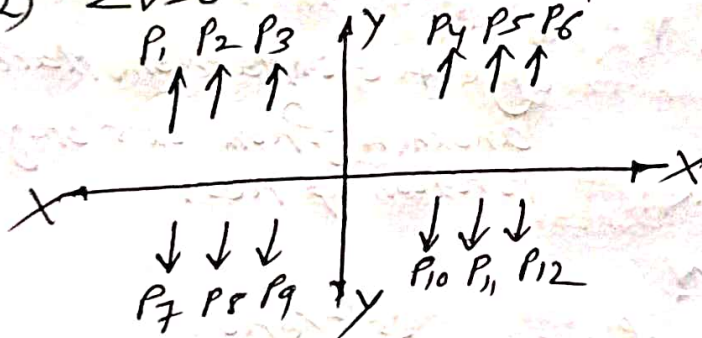
When two or more than two forces act on a body in such a way that body remain in a state of rest or uniform motion, then such system of forces is said to be in equilibrium.

Condition of Equilibrium

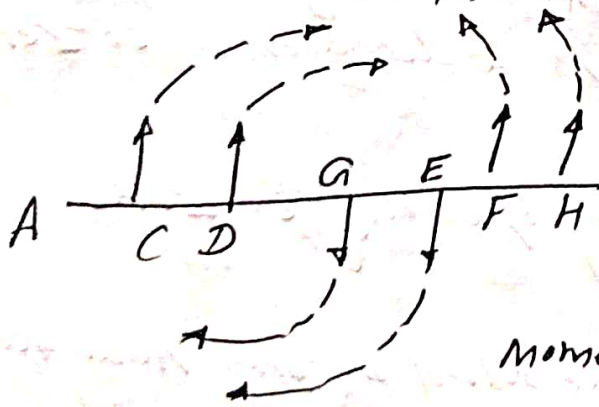
(1) $\Sigma H = 0$ (Total right hand side force = Total Left hand side force)



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



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



Moment = Force $\times$ perpendicular Distance

Classification of Equilibrium

① Static equilibrium

- (a) stable equilibrium
- (b) unstable equilibrium
- (c) Neutral equilibrium

② Dynamic equilibrium

- (a) Linear equilibrium
- (b) Rotational equilibrium

Stable equilibrium



Object return back to it's original position.

Unstable equilibrium



Object doesnot return back to it's original position.

Neutral equilibrium



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

Linear Equilibrium

Where velocity of a body is Zero.



Travelling in a circle.
(displacement is Zero).

Rotational Equilibrium

Where Angular Velocity of a body is Zero.

Note Equilibrium problems are solved by only Analytical method for exam point of view.

STATEMENT OF LAMIS THEOREM

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

Mathematically

$$P \propto \sin \alpha$$
$$\Rightarrow P = K \cdot \sin \alpha \quad (K = \text{const.})$$

$$\Rightarrow \frac{P}{\sin \alpha} = K \quad \text{--- (1)}$$

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

$$\Rightarrow \frac{P}{\sin \beta} = K \quad \text{--- (2)}$$

$$P \propto \sin \gamma$$

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

$$\Rightarrow \frac{P}{\sin \gamma} = K \quad \text{--- (3)}$$

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

Prove

→ consider 3 coplanar forces P, Q, R acting at a point O . Let the opposite angle to three forces be α, β, γ as shown in figure.

Now, complete the parallelogram $A O B C$.

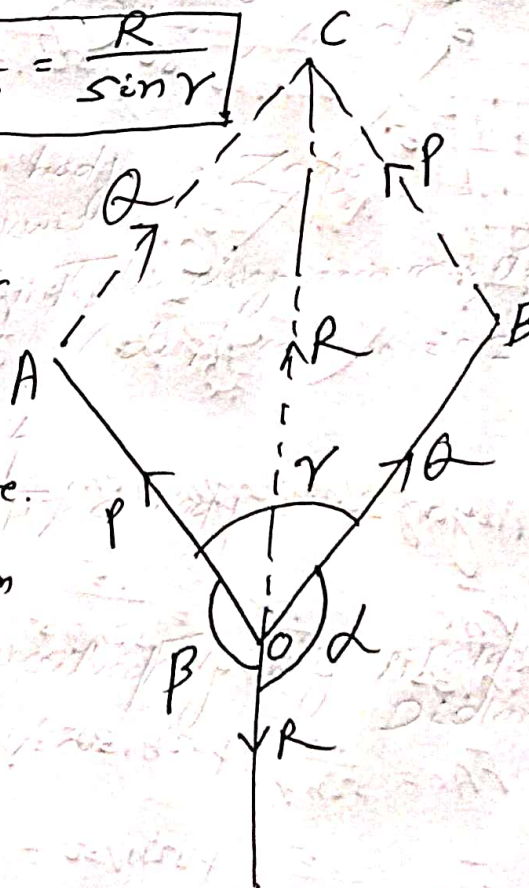
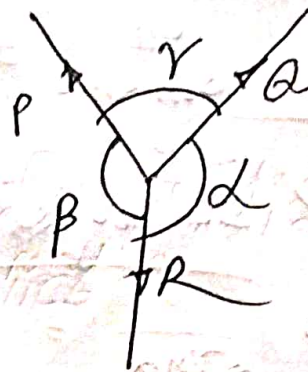
$\Delta A O C$ marked.

$$BC = P, AC = Q$$

$$\angle A O C = 180^\circ - \beta$$

$$\angle A C O = 180^\circ - \alpha = \angle B O C$$

$$\angle C A O = 180^\circ - [\angle A O C + \angle A C O] = \alpha + \beta - 180^\circ$$



$$\text{But } \alpha + \beta + \gamma = 360^\circ$$

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

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

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

We know in ΔAOC , Apply sine rule of theorem.

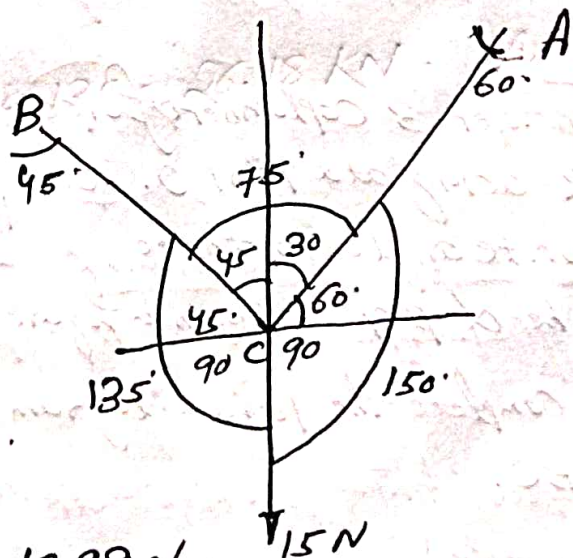
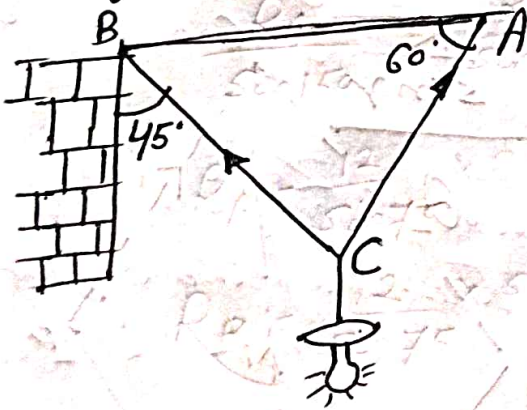
$$\frac{OA}{\sin \angle ACO} = \frac{AC}{\sin \angle AOC} = \frac{OC}{\sin \angle CAO}$$

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

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

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

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

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

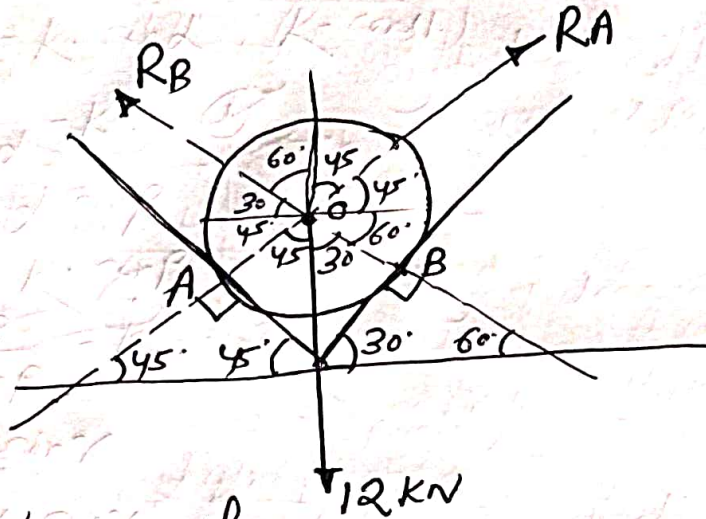
$$\therefore F_{BC} = \frac{15}{\sin 75^\circ} \times \sin 150^\circ = 7.76\text{ N}$$

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



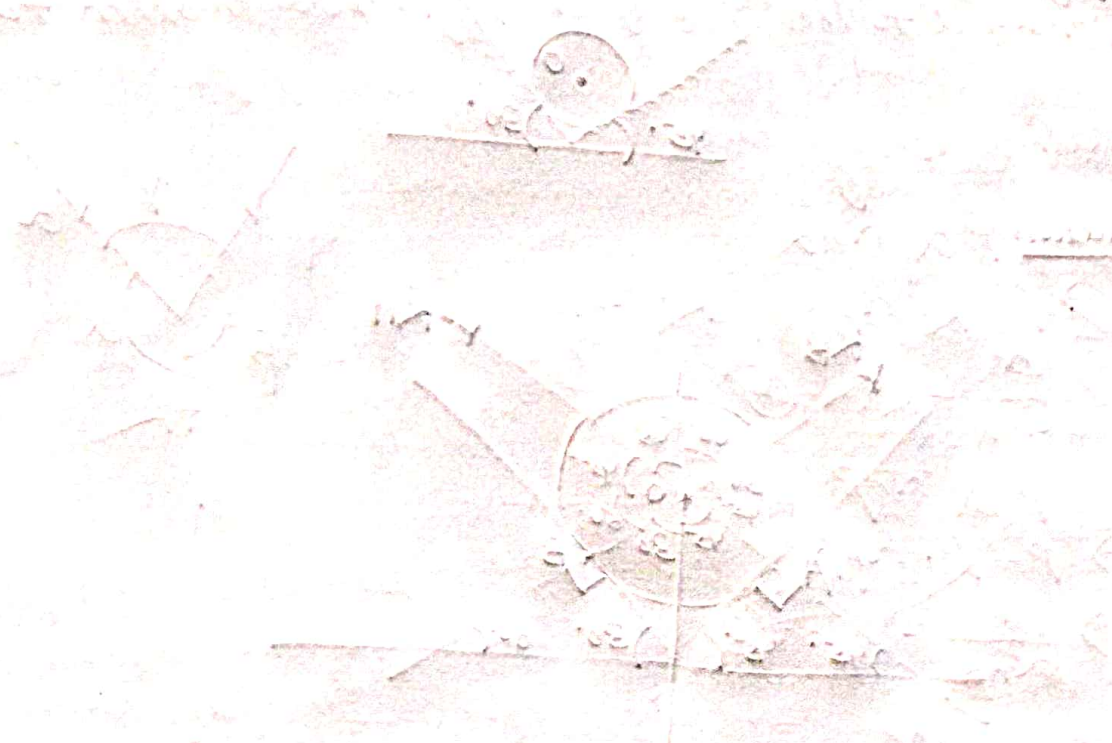
Applying Lami's theorem

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

$$\therefore R_A = \frac{12}{\sin 75^\circ} \times \sin 150^\circ = 22.12 \text{ kN}$$

$$\therefore R_B = \frac{12}{\sin 75^\circ} \times \sin 135^\circ = 26.18 \text{ kN} \quad (\text{Ans})$$

The first part of the paper is devoted to a discussion of the general properties of the system. It is shown that the system is stable and that the solution is unique. The second part of the paper is devoted to a discussion of the numerical solution of the system. It is shown that the numerical solution is stable and that the error is small.



The third part of the paper is devoted to a discussion of the physical interpretation of the results. It is shown that the results are in good agreement with the experimental data. The fourth part of the paper is devoted to a discussion of the conclusions. It is concluded that the system is stable and that the numerical solution is accurate.

The following table gives the values of the various quantities calculated in the paper.

Quantity	Value
$\frac{dV}{dt}$	0.001
$\frac{dV}{dt}$	0.002
$\frac{dV}{dt}$	0.003
$\frac{dV}{dt}$	0.004
$\frac{dV}{dt}$	0.005
$\frac{dV}{dt}$	0.006
$\frac{dV}{dt}$	0.007
$\frac{dV}{dt}$	0.008
$\frac{dV}{dt}$	0.009
$\frac{dV}{dt}$	0.010

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