ME 165
Basic Mechanical Engineering

Lecture 02

Statics of Particle

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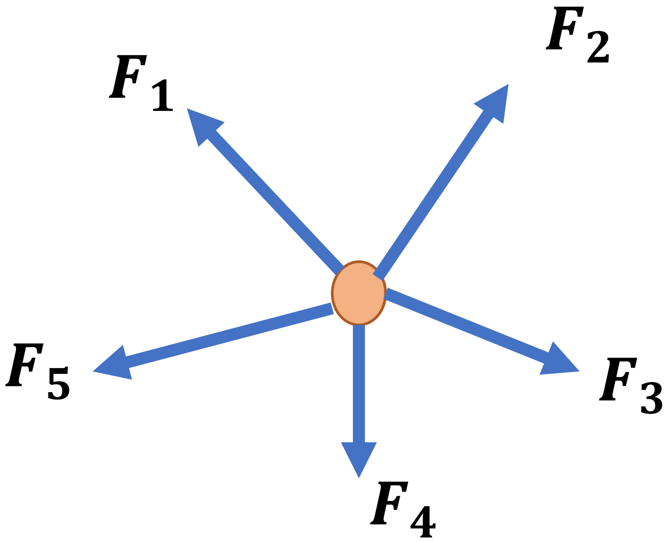
Forces in a Plane

❑ Equilibrium of a Particle:



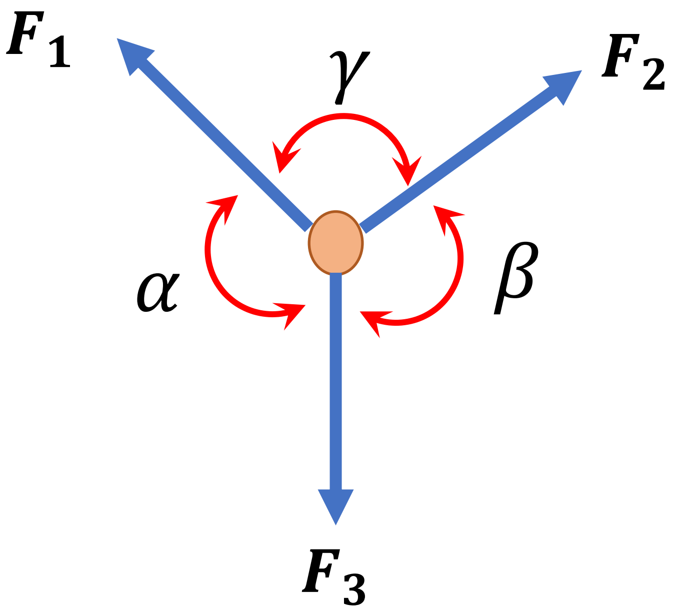
$$\overline{\boldsymbol{R}} = \overline{\boldsymbol{F_1}} + \overline{\boldsymbol{F_2}} + \overline{\boldsymbol{F_3}} + \overline{\boldsymbol{F_4}} + \overline{\boldsymbol{F_5}} + \cdots \overline{\boldsymbol{F_n}}$$

$$R_x\bar{\boldsymbol{i}} + R_y\bar{\boldsymbol{j}} = \left(\sum F_x\right)\bar{\boldsymbol{i}} + \left(\sum F_y\right)\bar{\boldsymbol{j}}$$

$$\left.\begin{aligned} \boldsymbol{R_x} &= \sum \boldsymbol{F_x} = \mathbf{0} \\ \boldsymbol{R_y} &= \sum \boldsymbol{F_y} = \mathbf{0} \end{aligned}\right\} \textbf{Condition for Equilibrium (2D)}$$

Forces in a Plane

- **Equilibrium of a Particle:**
  - **Special Case (Only Three forces)**

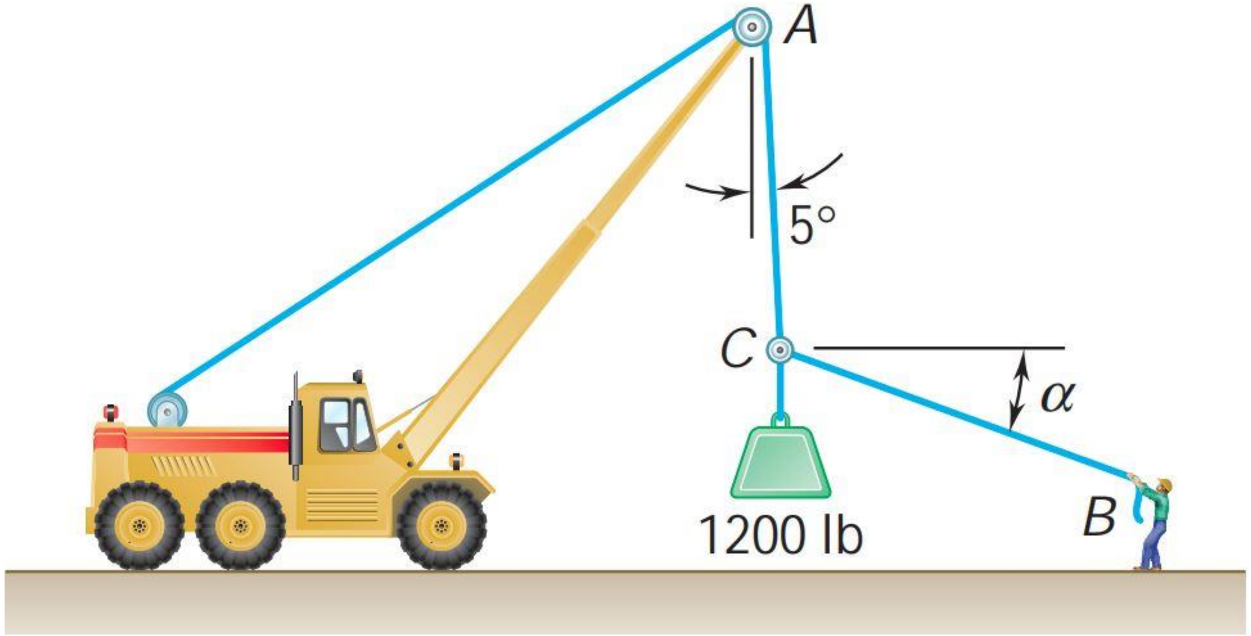


Sine Formula: $$\frac{F_1}{Sin\,\beta} = \frac{F_2}{Sin\,\alpha} = \frac{F_3}{Sin\,\gamma}$$

Forces in a Plane

❑ Problem:

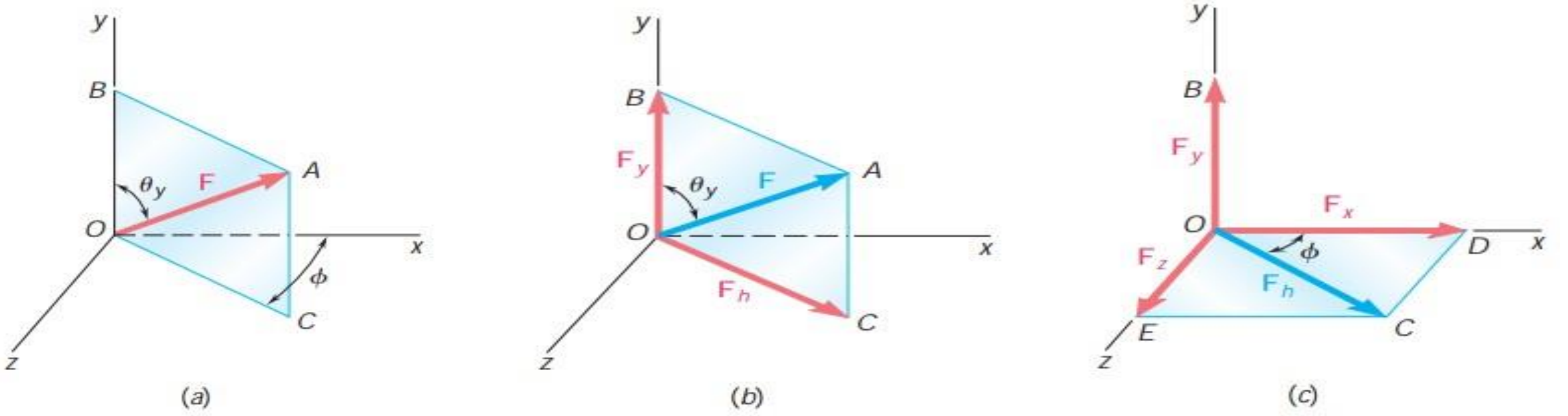
Knowing that $\alpha = 20°$, determine the tension (a) in cable AC, (b) in rope BC. **(Ex. 2.45)**



Ans: AC 1244 lb, BC 115.4 lb

Do yourself: (Ex. 2.44, 2.48,2.130)

Forces in Space (3D)



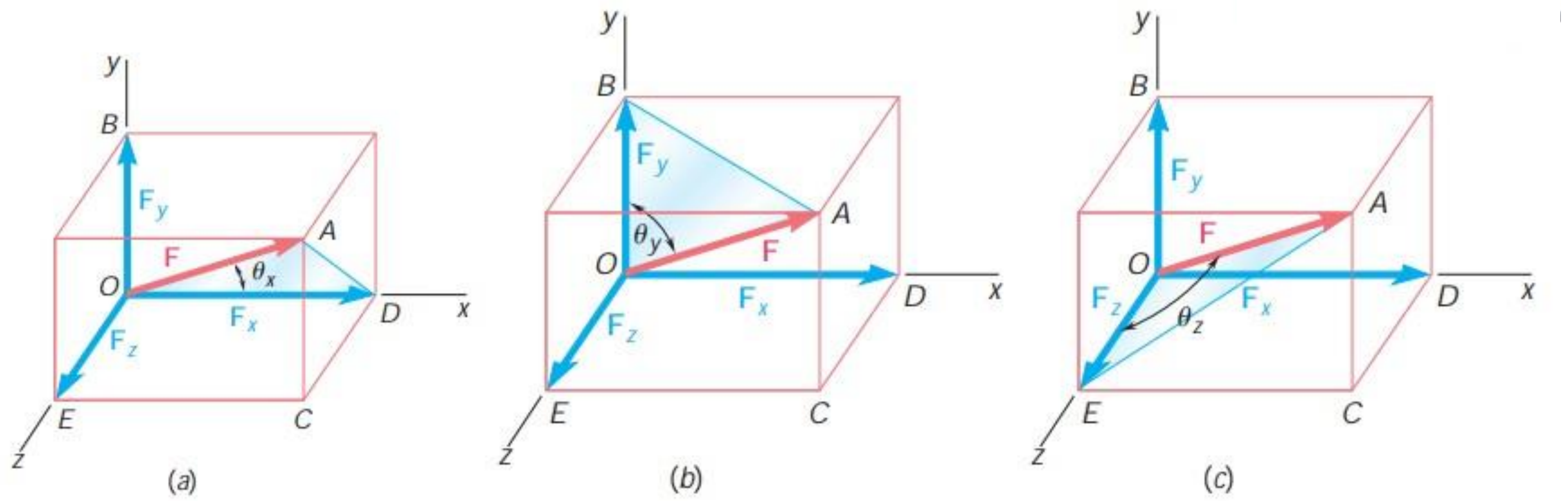
$$F_y = \mathrm{F}\cos\theta_y \qquad \text{and} \qquad F_h = \mathrm{F}\sin\theta_y$$

$$F_x = F_h \cos\emptyset = \mathrm{F}\sin\theta_y \cos\emptyset$$

$$F_z = F_h \sin\emptyset = \mathrm{F}\sin\theta_y \sin\emptyset$$

$$F = \sqrt{F_y^2 + F_h^2} = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

Forces in Space (3D)



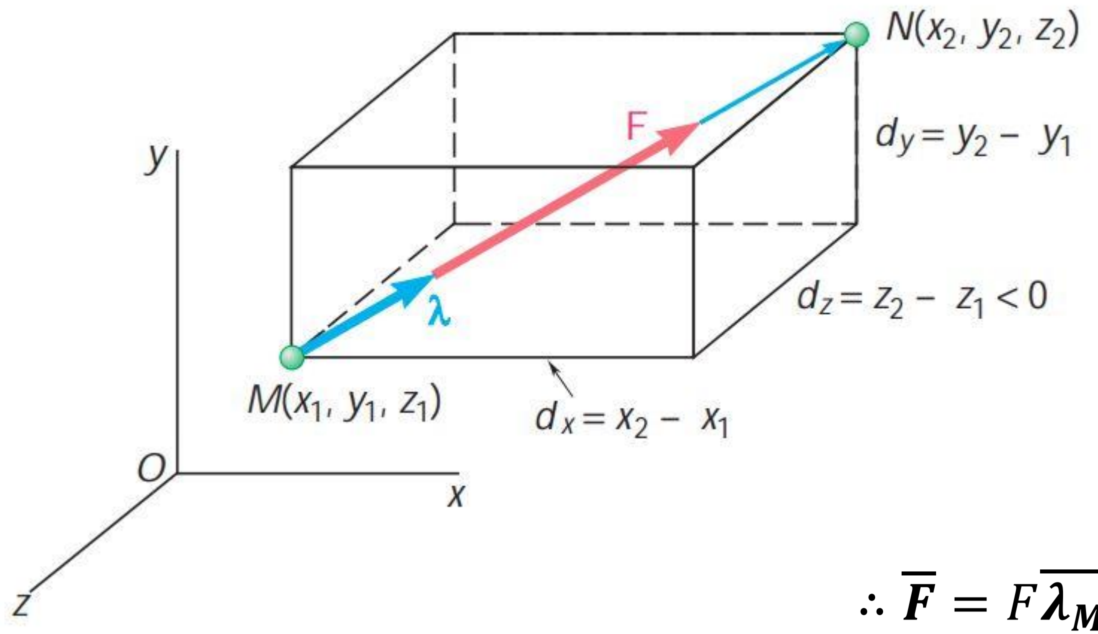
$$F_x = F\cos\theta_x \qquad F_y = F\cos\theta_y \qquad F_z = F\cos\theta_z$$

$$\overline{\boldsymbol{F}} = F_x\,\overline{\boldsymbol{i}} + F_y\overline{\boldsymbol{j}} + F_z\overline{k} = F\,(\cos\theta_x\overline{\boldsymbol{i}} + \cos\theta_y\overline{\boldsymbol{j}} + \cos\theta_z\overline{k}) = F\overline{\lambda}$$

So, $\overline{\boldsymbol{\lambda}} = \cos\theta_x\overline{\boldsymbol{i}} + \cos\theta_y\overline{\boldsymbol{j}} + \cos\theta_z\overline{k}$

Forces in Space (3D)

❑ Force Defined by its Magnitude and Two Points on its Line of Action:



Position vector,

$$\overline{\boldsymbol{MN}} = (x_2 - x_1)\bar{\boldsymbol{i}} + (y_2 - y_1)\bar{\boldsymbol{j}} + (z_2 - z_1)\bar{\boldsymbol{k}}$$

$$\overline{\boldsymbol{MN}} = d_x\bar{\boldsymbol{i}} + d_y\bar{\boldsymbol{j}} + d_z\bar{\boldsymbol{k}}$$

$$\therefore MN = \left|\overline{\boldsymbol{MN}}\right| = d = \sqrt{d_x^2 + d_y^2 + d_z^2}$$

Unit vector along MN,

$$\overline{\boldsymbol{\lambda_{MN}}} = \frac{\overline{\boldsymbol{MN}}}{\left|\overline{\boldsymbol{MN}}\right|} = \frac{1}{d}(d_x\bar{\boldsymbol{i}} + d_y\bar{\boldsymbol{j}} + d_z\bar{\boldsymbol{k}})$$

$$\therefore \overline{\boldsymbol{F}} = F\overline{\boldsymbol{\lambda_{MN}}} = \frac{F}{d}(d_x\bar{\boldsymbol{i}} + d_y\bar{\boldsymbol{j}} + d_z\bar{\boldsymbol{k}})$$

Component of forces:

$$F_x = F\cos\theta_x = \frac{d_x}{d} \qquad \therefore \cos\theta_x = \frac{F_x}{F} = \frac{d_x}{d}$$

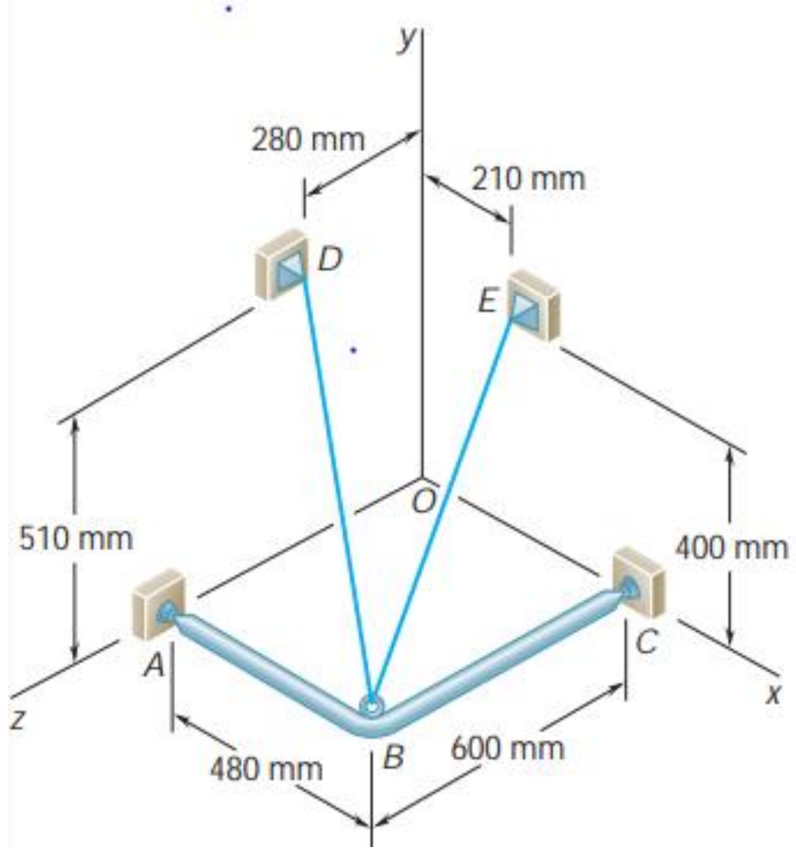
$$F_y = F\cos\theta_y = \frac{d_y}{d} \qquad \therefore \cos\theta_y = \frac{F_y}{F} = \frac{d_y}{d}$$

$$F_z = F\cos\theta_z = \frac{d_z}{d} \qquad \therefore \cos\theta_z = \frac{F_z}{F} = \frac{d_z}{d}$$

Forces in Space (3D)

- **Problem 1:**

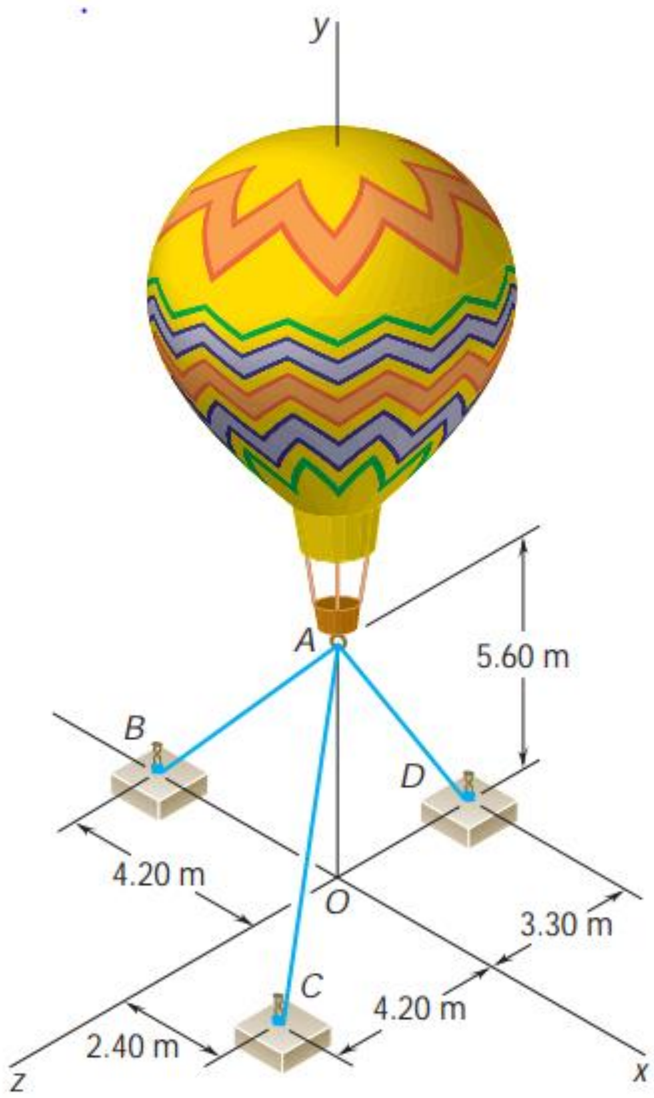
A frame ABC is supported in part by cable DBE that passes through a frictionless ring at B. Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at D.



Forces in Space (3D)

❑ Problem 2:

Three cables are used to tether a balloon as shown. Determine the vertical force P exerted by the balloon at A knowing that the tension in cable AD is 481 N.

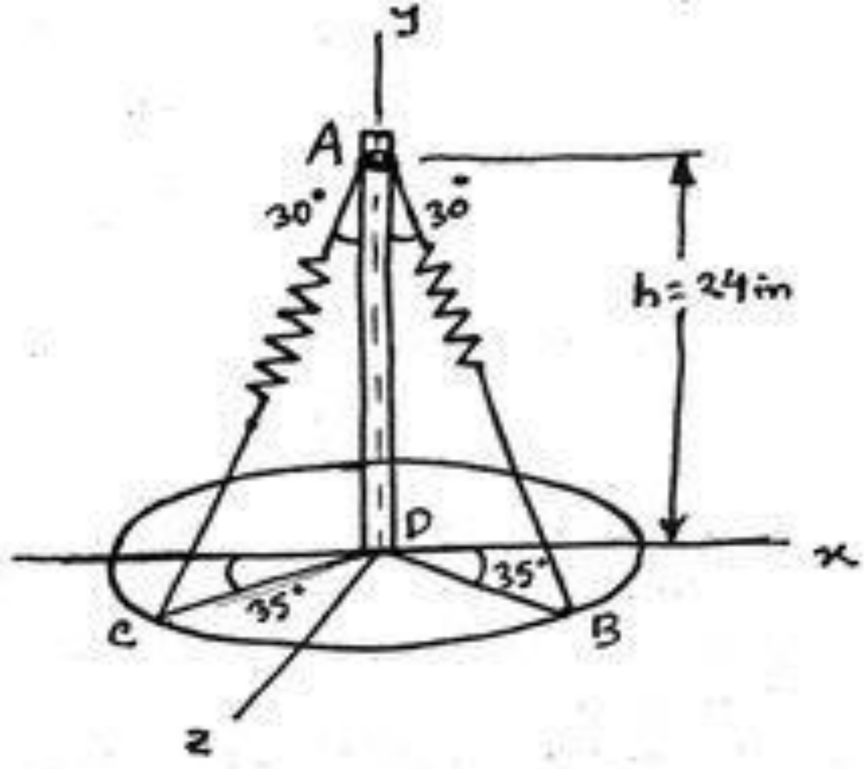


Forces in Space (3D)

❑ Problem 3:

A horizontal circular plate is supported by two springs and a post as shown. Angle between each of springs AB and AC and post DA is 30°. Tension is 50-lb in AB and 40-lb in AC. Determine-

a) Magnitude and direction of the resultant of forces exerted by springs on the post at A; b) The point where resultant intersects the plate.



Ans: $\vec{R} = 4.12\, i — 77.9\, j + 25.8\, k$

Resultant: 82.2 lb

$\boldsymbol{\theta_x = 87.1°}$, $\boldsymbol{\theta_y = 161.5°}$,

$\boldsymbol{\theta_z = 71.7°}$