# INDIAN INSTITUTE OF TECHNOLOGY HYDERABAD

## Department of Mechanical and Aersoapce Engineering

*Take Home-1*

**Instructor: Dr. M. Ramji** **ME1050: Basics of Mechanical Engg (2021-22)**
**Date: 14-12-21**

**1.** Determine the *x*-, *y*- and *z*-components of force **F** which acts on the tetrahedron as shown in Fig. 1. The quantities *a*, *b*, *c* and *F* are known and *M* is the mid-point of edge *AB*.

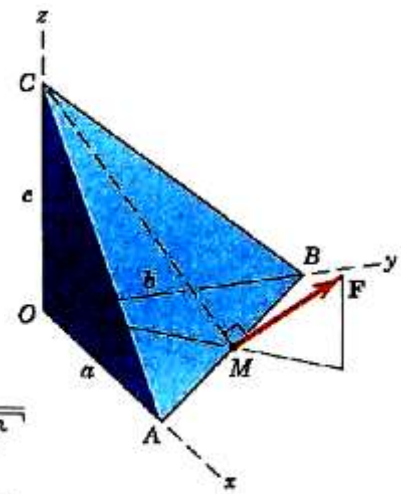



**Fig. 1** Tetrahedron

**Solution**

Finally,

$$F_x = F \frac{2c}{\sqrt{a^2+b^2+4c^2}} \frac{a}{\sqrt{a^2+b^2}} = \frac{2acF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

$$F_y = F \frac{2c}{\sqrt{a^2+b^2+4c^2}} \frac{b}{\sqrt{a^2+b^2}} = \frac{2bcF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

$$F_z = F\sqrt{\frac{a^2+b^2}{a^2+b^2+4c^2}}$$

**2.** The tension in the supporting cable *BC* is 800 N (Fig. 2). Write the force which this cable exerts on the boom *OAB* as a vector **T**. Determine the angles $\theta_x$, $\theta_y$ and $\theta_z$ which the line of action of **T** forms with the positive *x*-, *y*- and *z*-axes.

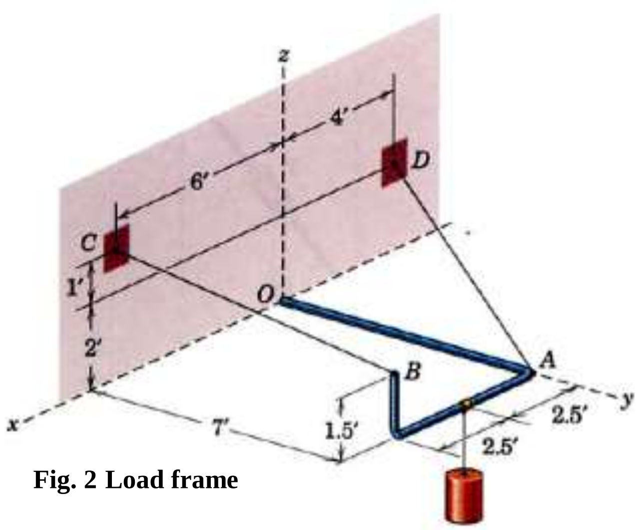



**Fig. 2 Load frame**

**Solution**

$$\underline{T} = T\underline{n}_{BC}$$

$$\underline{T} = 800\left[\frac{+1\underline{i} - 7\underline{j} + 1.5\underline{k}}{\sqrt{1^2+7^2+1.5^2}}\right]$$

$$= +110.7\underline{i} - 775\underline{j} + 166.0\underline{k} \quad \text{lb}$$

$\cos\theta_x = \frac{+1}{7.23}$, $\theta_x = 82.0°$

$\cos\theta_y = \frac{-7}{7.23}$, $\theta_y = 165.6°$

$\cos\theta_z = \frac{1.5}{7.23}$, $\theta_z = 78.0°$

**3.** The wing of the jet aircraft is subjected to a thrust of $T$ = 8 kN from its engine and the resultant lift force $L$ = 45 kN (Fig. 3). If the mass of the wing is 21 kN and the mass center is at ***G***, determine the *x, y, z* components of reaction where the wing is fixed to the fuselage at *A*.

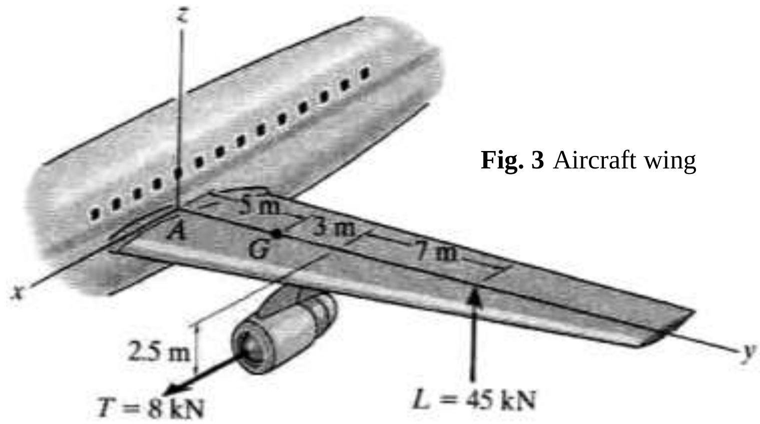



**Fig. 3** Aircraft wing

**4.** The jib crane shown in Fig.4 is subjected to three coplanar forces. Replace this loading by an equivalent resultant force and specify where the resultant's line of action intersects the column *AB* and boom *BC.*

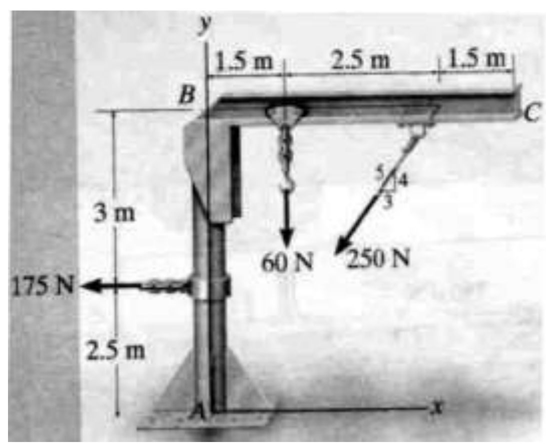
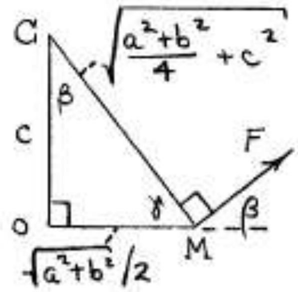
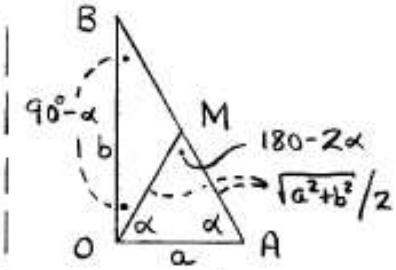



**Fig. 4** Jib crane arrangement

Soln. 1.



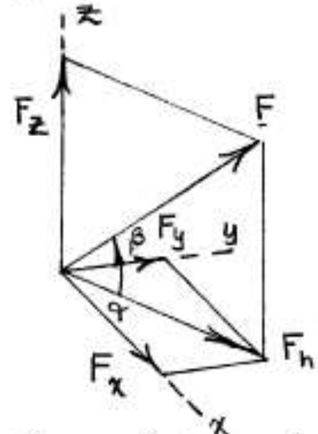

$$\tan\gamma = \frac{c}{\sqrt{a^2+b^2}/2} = \frac{2c}{\sqrt{a^2+b^2}}$$

$$\gamma + 90° + \beta = 180°$$

$$\beta = 90° - \gamma = 90° - \tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}$$

$$\tan\alpha = \frac{b}{a}$$

$$\begin{cases} \cos\alpha = \dfrac{a}{\sqrt{a^2+b^2}} \\ \sin\alpha = \dfrac{b}{\sqrt{a^2+b^2}} \end{cases}$$




$$\begin{cases} F_z = F\sin\beta \\ F_h = F\cos\beta \\ F_x = F_h\cos\alpha = F\cos\beta\cos\alpha \\ F_y = F_h\sin\alpha = F\cos\beta\sin\alpha \end{cases}$$

Now simplify $\sin\beta$ & $\cos\beta$ expressions:

$$\sin\beta = \sin\left[90° - \tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right]$$

$$= \sin 90° \cos\left[\tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right] - \overset{0}{\cos 90°}\sin\left[\tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right]$$

$$= \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+4c^2}} \quad (\text{Also see that } \sin\beta = \cos\gamma\,!)$$

$$\cos\beta = \sin\gamma = \frac{c}{\sqrt{\frac{a^2+b^2}{4}+c^2}} = \frac{2c}{\sqrt{a^2+b^2+4c^2}}$$

Finally,

$$F_x = F\frac{2c}{\sqrt{a^2+b^2+4c^2}}\frac{a}{\sqrt{a^2+b^2}} = \frac{2acF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

$$F_y = F\frac{2c}{\sqrt{a^2+b^2+4c^2}}\frac{b}{\sqrt{a^2+b^2}} = \frac{2bcF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

$$F_z = F\sqrt{\frac{a^2+b^2}{a^2+b^2+4c^2}}$$

Soln. 3

Given:

$T = 8$ kN

$L = 45$ kN

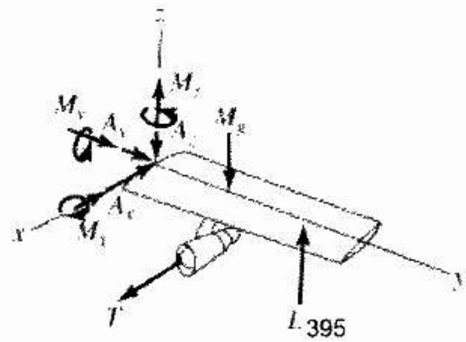
$M = 2.1$ Mg

$a = 2.5$ m

$b = 5$ m

$c = 3$ m

$d = 7$ m




Solution:

$\Sigma F_x = 0;\quad -A_x + T = 0$

$A_x = T \qquad A_x = 8\,\text{kN}$

$\Sigma F_y = 0;\quad A_y = 0 \qquad A_y = 0$

$\Sigma F_z = 0;\quad -A_z - M\,g + L = 0$

$A_z = L - M\,g \qquad A_z = 24.4\,\text{kN}$

$\Sigma M_y = 0;\quad M_y - T(a) = 0$

$M_y = T\,a \qquad M_y = 20.0\,\text{kN}\cdot\text{m}$

$\Sigma M_x = 0;\quad L(b + c + d) - M\,g\,b - M_x = 0$

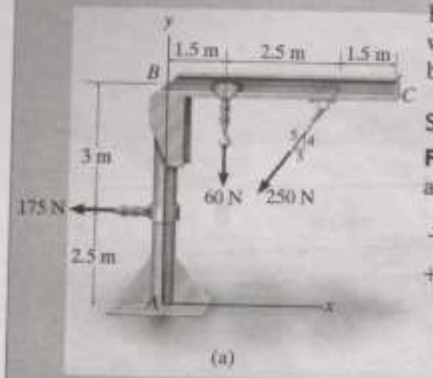
$M_x = L(b + c + d) - M\,g\,b \qquad M_x = 572\,\text{kN}\cdot\text{m}$

$\Sigma M_z = 0;\quad M_z - T(b + c) = 0$

$M_z = T(b + c) \qquad M_z = 64.0\,\text{kN}\cdot\text{m}$

Soln. 4

## EXAMPLE 4.17




(a)

The jib crane shown in Fig. 4–44$a$ is subjected to three coplanar for... Replace this loading by an equivalent resultant force and sp... where the resultant's line of action intersects the column $AB$ an... boom $BC$.

### SOLUTION

**Force Summation.** Resolving the 250 N force into $x$ and $y$ compon... and summing the force components yields

$$\xrightarrow{+} F_{R_x} = \Sigma F_x;\ F_{R_x} = -250\ \text{N}\left(\tfrac{3}{5}\right) - 175\ \text{N} = -325\ \text{N} = 325\ \text{N} \leftarrow$$

$$+\uparrow F_{R_y} = \Sigma F_y;\ F_{R_y} = -250\ \text{N}\left(\tfrac{4}{5}\right) - 60\ \text{N} = -260\ \text{N} = 260\ \text{N}\downarrow$$

As shown by the vector addition in Fig. 4–44$b$,

$$F_R = \sqrt{(325)^2 + (260)^2} = 416\ \text{N}$$

$$\theta = \tan^{-1}\left(\frac{260}{325}\right) = 38.7^\circ$$

**Moment Summation.** Moments will be summed about the arbitrary point $A$. Assuming the line of action of $\mathbf{F}_R$ *intersects* $AB$, Fig. 4–44$b$, we require the moment of the components of $\mathbf{F}_R$ in Fig. 4–44$b$ about $A$ to equal the moments of the force system in Fig. 4–44$a$ about $A$; i.e.,

$$\circlearrowleft + M_{R_A} = \Sigma M_A; \quad 325\ \text{N}\,(y) + 260\ \text{N}\,(0)$$

$$= 175\ \text{N}\,(2.5\text{m}) - 60\ \text{N}\,(1.5\text{m}) + 250\ \text{N}\left(\tfrac{3}{5}\right)(5.5\text{m}) - 250\ \text{N}\left(\tfrac{4}{5}\right)(4\text{m})$$

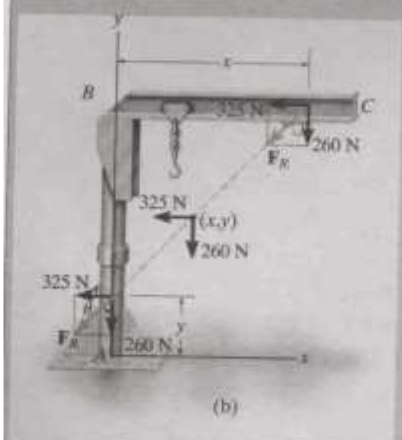
$$y = 1.146\ \text{m}$$

By the principle of transmissibility, $\mathbf{F}_R$ can also be treated as intersecting $BC$, Fig. 4–44$b$, in which case we have

$$\circlearrowleft + M_{R_A} = \Sigma M_A; \quad 325\ \text{N}\,(5.5\ \text{m}) - 260\ \text{N}\,(x)$$

$$= 175\ \text{N}\,(2.5\ \text{m}) - 60\ \text{N}\,(1.5\ \text{m}) + 250\ \text{N}\left(\tfrac{3}{5}\right)(5.5\ \text{m}) - 250\ \text{N}\left(\tfrac{4}{5}\right)(4\ \text{m})$$

$$x = 5.45\ \text{m}$$




(b)

**Fig. 4–44**

**NOTE:** We can also solve for these positions by assuming $\mathbf{F}_R$ acts at the arbitrary point $(x, y)$ on its line of action, Fig. 4–44$b$. Summing moments about point $A$ yields

$$\circlearrowleft + M_{R_A} = \Sigma M_A; 325\ \text{N}\,(y) - 260\ \text{N}\,(x)$$

$$= 175\ \text{N}\,(2.5\ \text{m}) - 60\ \text{N}\,(1.5\ \text{m}) + 250\ \text{N}\left(\tfrac{3}{5}\right)(5.5\ \text{m}) - 250\ \text{N}\left(\tfrac{4}{5}\right)(4\ \text{m})$$

$$325y - 260x = 372.5$$

which is the equation of the colored dashed line in Fig. 4–44$b$. To find the points of intersection with the crane along $AB$, set $x = 0$, then $y = 1.146$ m, and along $BC$ set $y = 5.5$ m, then $x = 5.45$ m.