

A free body diagram of a joint, represented by a central point. A vertical line passes through the point, with an upward arrow labeled R_{ZA} and a downward arrow labeled R_{XA} . A horizontal arrow labeled M_{ZA} points to the right. A diagonal arrow labeled R_{YA} points up and to the right. A diagonal arrow labeled M_{YA} points down and to the right. A diagonal arrow labeled M_{XA} points down and to the left.

$$\sum \bar{F}_y = 0 \Rightarrow -20 + 20 + R_{yt} = 0 \Rightarrow \boxed{R_{yt} = 0}$$

$$\sum F_y = 0 \Rightarrow -4.10 + 4.10 + R_{2A} = 0 \Rightarrow \underline{R_{2A} = 80 \text{ kN}}$$

$$\sum M_{x_A} = 0 \Rightarrow M_{x_A} + 4.10.4 - 4.10.4 = 0 \Rightarrow \underline{M_{x_A} = 0}$$

$$\sum M_{y/A} = 0 \Rightarrow \boxed{M_{y/A} = 0}$$

$$\sum M_{yA} = 0 \Rightarrow \boxed{M_{yA} = 0}$$

$$\sum M_{zA} = 0 \Rightarrow M_{zA} - 20 \cdot 6 - 20 \cdot 4 - 20 \cdot 6 - 20 \cdot 4 = 0 \Rightarrow M_{zA} = 400 \text{ kNm}$$

A free body diagram of a joint. It shows a central point with several forces acting on it. Upward is force T . To the right is force N . To the left is force S . To the top-right is force V_x . To the bottom-right is force V_y . To the left is force M_{fx} . To the bottom-left is force M_{fy} . At the bottom, there are two upward reaction forces labeled 80 and 400 . To the left of the diagram is a coordinate system with a vertical z -axis and a diagonal axis.

$$\sum F_x = 0 \Rightarrow Y_x = 0$$

$$\sum F_y = 0 \Rightarrow V_g = 0$$

$$\sum \vec{F}_2 = 0 \Rightarrow N + 80 = 0 \Rightarrow \boxed{N = -80 \text{ kN}}$$

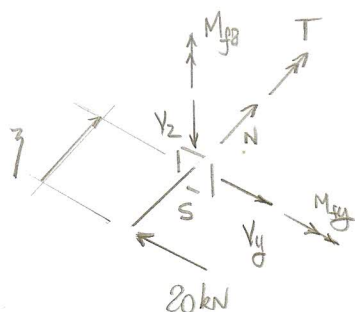
$$\sum M_{x_1} = 0 \Rightarrow \underline{\underline{M_{fx} = 0}}$$

$$\sum M_{y,5} = 0 \Rightarrow \underline{\underline{M_{fy} = 0}}$$

$$\sum M_{y,s} = 0 \Rightarrow \underline{M_y = 0}$$

$$\sum M_{x,s} = 0 \Rightarrow T + 400 = 0 \Rightarrow \underline{T = -400 \text{ kN/m}}$$

Barras JB:



$$\sum F_x = 0 \Rightarrow \boxed{N = 0}$$

$$\sum F_y = 0 \Rightarrow -20 + V_y = 0 \Rightarrow \boxed{V_y = 20 \text{ kN}}$$

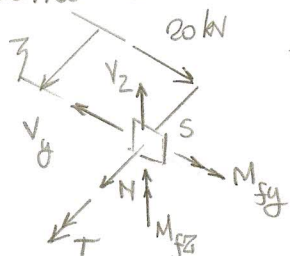
$$\sum F_z = 0 \Rightarrow \boxed{V_z = 0}$$

$$\sum M_{x,S} = 0 \Rightarrow \boxed{T = 0}$$

$$\sum M_{y,S} = 0 \Rightarrow \boxed{M_{fy} = 0}$$

$$\sum M_{z,S} = 0 \Rightarrow M_{fz} - 20 \cdot 3 = 0 \Rightarrow \boxed{M_{fz} = 20 \cdot 3} \quad (\oplus \text{ lado direito})$$

Barras KB:



$$\sum F_x = 0 \Rightarrow \boxed{N = 0}$$

$$\sum F_y = 0 \Rightarrow -V_y + 20 = 0 \Rightarrow \boxed{V_y = 20 \text{ kN}}$$

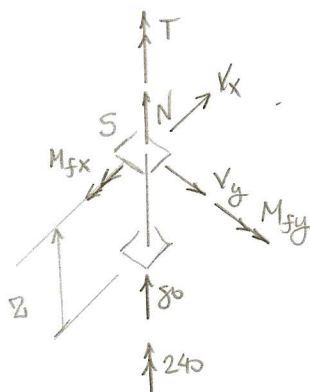
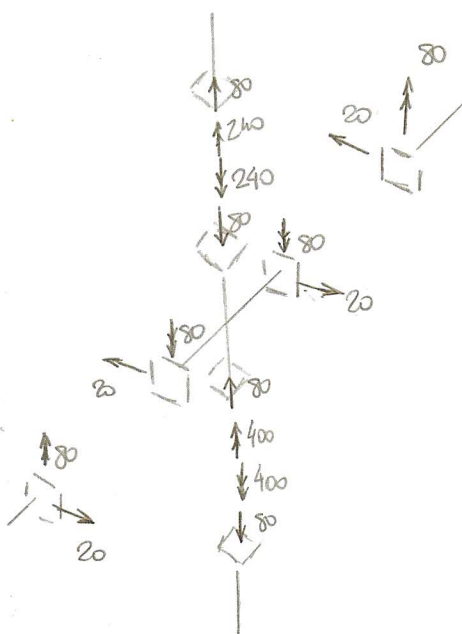
$$\sum F_z = 0 \Rightarrow \boxed{V_z = 0}$$

$$\sum M_{x,S} = 0 \Rightarrow \boxed{T = 0}$$

$$\sum M_{y,S} = 0 \Rightarrow \boxed{M_{fy} = 0}$$

$$\sum M_{z,S} = 0 \Rightarrow M_{fz} - 20 \cdot 3 = 0 \Rightarrow \boxed{M_{fz} = 20 \cdot 3} \quad (\oplus \text{ lado esquerdo})$$

Barras BC:



$$\sum F_x = 0 \Rightarrow \boxed{V_x = 0}$$

$$\sum F_y = 0 \Rightarrow \boxed{V_y = 0}$$

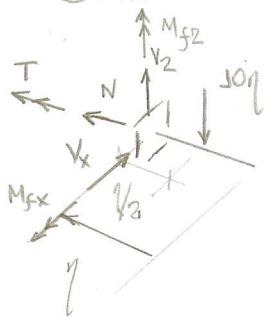
$$\sum F_z = 0 \Rightarrow N + 80 = 0 \Rightarrow \boxed{N = -80 \text{ kN}}$$

$$\sum M_{x,S} = 0 \Rightarrow \boxed{M_{fx} = 0}$$

$$\sum M_{y,S} = 0 \Rightarrow \boxed{M_{fy} = 0}$$

$$\sum M_{z,S} = 0 \Rightarrow T + 240 = 0 \Rightarrow \boxed{T = -240 \text{ kNm}}$$

Barras EF:



$$\sum F_x = 0 \Rightarrow \boxed{V_x = 0}$$

$$\sum F_y = 0 \Rightarrow \boxed{N = 0}$$

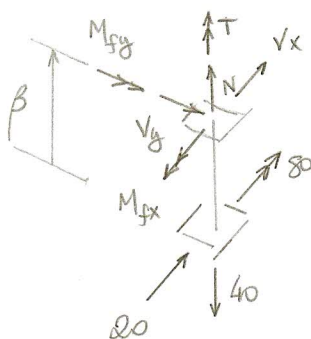
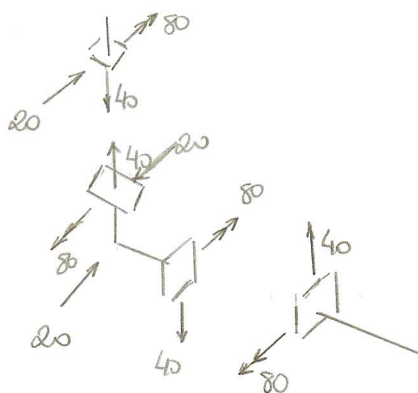
$$\sum F_z = 0 \Rightarrow V_z - 10q = 0 \Rightarrow \boxed{V_z = 10q}$$

$$\sum M_{x,s} = 0 \Rightarrow M_{fx} - 10q \cdot \frac{l}{2} = 0 \Rightarrow \boxed{M_{fx} = 5q l^2} \quad (\oplus \text{ em cima})$$

$$\sum M_{y,s} = 0 \Rightarrow \boxed{T = 0}$$

$$\sum M_{z,s} = 0 \Rightarrow \boxed{M_{fz} = 0}$$

Barras DE:



$$\sum F_x = 0 \Rightarrow -20 + V_x = 0 \Rightarrow \boxed{V_x = -20 \text{ kN}}$$

$$\sum F_y = 0 \Rightarrow \boxed{V_y = 0}$$

$$\sum F_z = 0 \Rightarrow N - 40 = 0 \Rightarrow \boxed{N = 40 \text{ kN}}$$

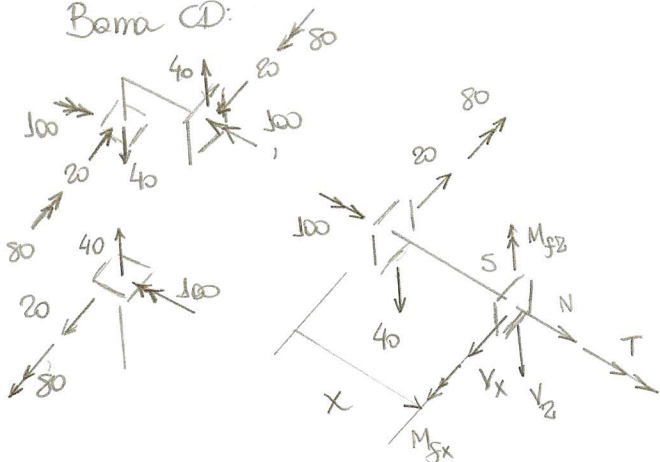
$$\sum M_{x,s} = 0 \Rightarrow M_{fx} - 80 = 0 \Rightarrow \boxed{M_{fx} = 80 \text{ kNm}} \quad (\oplus \text{ lado direito})$$

$$\sum M_{y,s} = 0 \Rightarrow M_{fy} + 20\beta = 0$$

$$\boxed{M_{fy} = -20\beta} \quad (\oplus \text{ o trás})$$

$$\sum M_{z,s} = 0 \Rightarrow \boxed{T = 0}$$

Barras CD:



$$\sum F_x = 0 \Rightarrow V_x - 20 = 0 \Rightarrow \boxed{V_x = 20 \text{ kN}}$$

$$\sum F_z = 0 \Rightarrow -V_z - 40 = 0 \Rightarrow \boxed{V_z = -40 \text{ kN}}$$

$$\sum F_y = 0 \Rightarrow \boxed{N = 0}$$

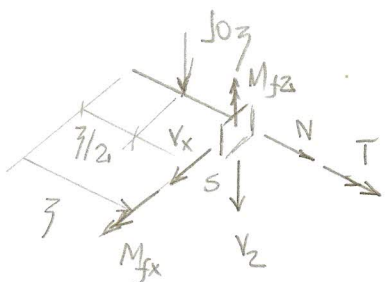
$$\sum M_{x,s} = 0 \Rightarrow M_{fx} + 40x - 80 = 0$$

$$\boxed{M_{fx} = 80 - 40x} \quad (\oplus \text{ em baixo})$$

$$\sum M_{y,s} = 0 \Rightarrow T + 100 = 0 \Rightarrow \boxed{T = -100 \text{ kNm}}$$

$$\sum M_{z,s} = 0 \Rightarrow M_{fz} - 20x = 0 \Rightarrow \boxed{M_{fz} = 20x} \quad (\oplus \text{ na frente})$$

Barra HI:



$$\sum F_x = 0 \Rightarrow \boxed{V_x = 0}$$

$$\sum F_y = 0 \Rightarrow \boxed{N = 0}$$

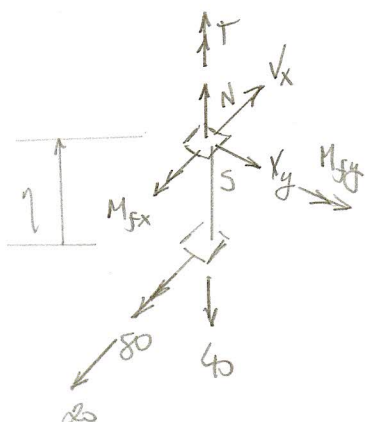
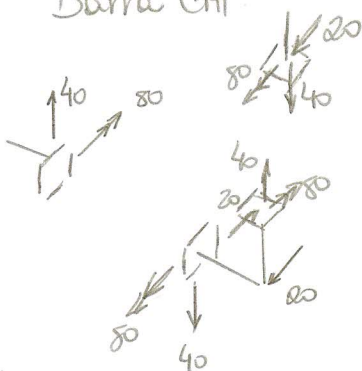
$$\sum F_z = 0 \Rightarrow -V_z - 103 = 0 \Rightarrow \boxed{V_z = -103}$$

$$\sum M_{x,s} = 0 \Rightarrow M_{fx} + 103 \cdot \frac{3}{2} = 0 \Rightarrow \boxed{M_{fx} = -53^2} \quad (\oplus \text{ embaixo})$$

$$\sum M_{y,s} = 0 \Rightarrow \boxed{T = 0}$$

$$\sum M_{z,s} = 0 \Rightarrow \boxed{M_{fz} = 0}$$

Barra GH:



$$\sum F_x = 0 \Rightarrow 20 - V_x = 0 \Rightarrow \boxed{V_x = 20 \text{ kN}}$$

$$\sum F_y = 0 \Rightarrow \boxed{V_y = 0}$$

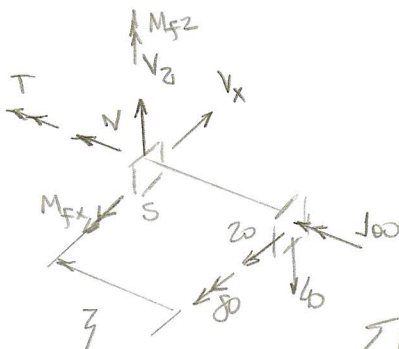
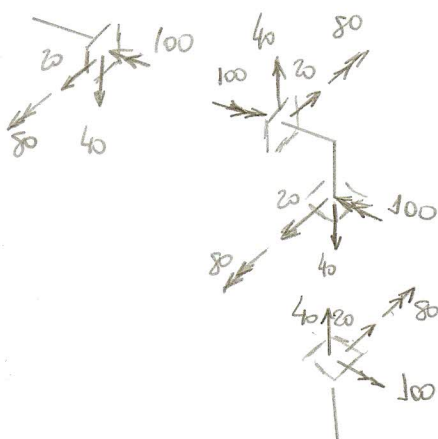
$$\sum F_z = 0 \Rightarrow N - 40 = 0 \Rightarrow \boxed{N = 40 \text{ kN}}$$

$$\sum M_{x,s} = 0 \Rightarrow M_{fx} + 80 = 0 \Rightarrow \boxed{M_{fx} = -80 \text{ kNm}} \quad (\oplus \text{ lado direito})$$

$$\sum M_{y,s} = 0 \Rightarrow M_{fy} - 20 \cdot 1 = 0 \Rightarrow \boxed{M_{fy} = 20 \text{ kNm}} \quad (\oplus \text{ outros})$$

$$\sum M_{z,s} = 0 \Rightarrow \boxed{T = 0}$$

Barra CG:



$$\sum F_x = 0 \Rightarrow -V_x + 20 = 0 \Rightarrow \boxed{V_x = 20 \text{ kN}}$$

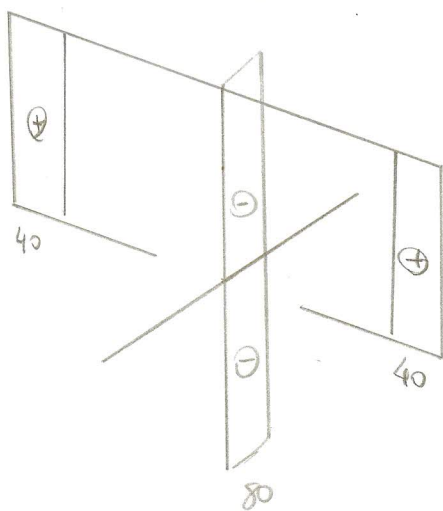
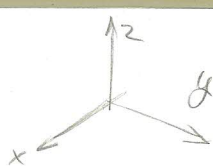
$$\sum F_y = 0 \Rightarrow \boxed{N = 0}$$

$$\sum F_z = 0 \Rightarrow V_z - 40 = 0 \Rightarrow \boxed{V_z = 40 \text{ kN}}$$

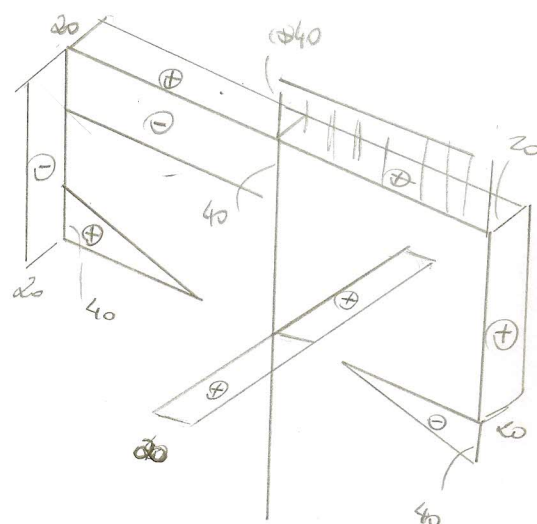
$$\sum M_{x,s} = 0 \Rightarrow M_{fx} - 40 \cdot 3 + 80 = 0 \Rightarrow \boxed{M_{fx} = 40 \cdot 3 - 80} \quad (\oplus \text{ em cima})$$

$$\sum M_{y,s} = 0 \Rightarrow T + 100 = 0 \Rightarrow \boxed{T = -100 \text{ kNm}}$$

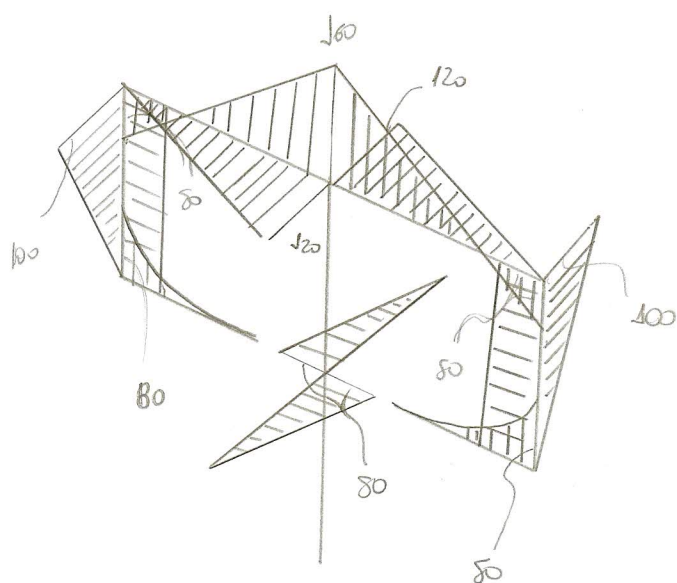
$$\sum M_{z,s} = 0 \Rightarrow M_{fz} - 20 \cdot 3 = 0 \Rightarrow \boxed{M_{fz} = 20 \cdot 3} \quad (\oplus \text{ outros})$$



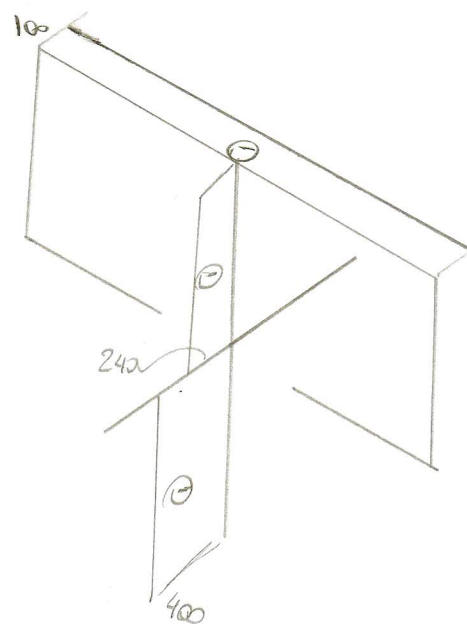
N



V

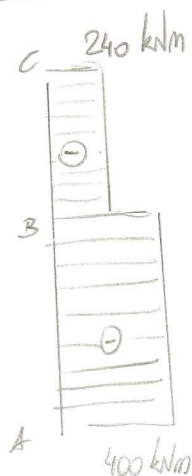


M



T

Na barra AC



Determinar o diâmetro da barra AC (circular, cheia)
sendo $G = 70 \text{ GPa}$, $\tau_R = 150 \text{ MPa}$ e $\theta_{\max}(C) = 0,05 \text{ rad}$ e
 $S = 1,5$.

$$\tau_{\max} = \frac{T \cdot R}{J} = \frac{2}{\pi R^4} \cdot T_{\max} \cdot R \leq \bar{\tau} = \frac{\tau_R}{S} \Rightarrow \frac{2 T_{\max}}{\pi R^3} \leq \frac{\tau_R}{S}$$

$$\frac{\pi R^3}{2 T_{\max}} \geq \frac{S}{\tau_R} \Rightarrow R \geq \sqrt[3]{\frac{2 T_{\max} S}{\pi \tau_R}} \Rightarrow R \geq \sqrt[3]{\frac{2 \cdot 400 \cdot 10^3 \cdot 1,5}{\pi \cdot 150 \cdot 10^6}}$$

$$|R \geq 0,137 \text{ m}|$$



$$\theta_{AC} = \theta_{AB} + \theta_{BC}$$

$$\theta = \frac{T \cdot l}{GJ}$$

$$\theta_{AC} = \frac{T_{AB} l_{AB}}{G \cdot J} + \frac{T_{BC} l_{BC}}{GJ} \quad l_{AB} = l_{BC} = l$$

$$\theta_{AC} = \frac{l}{GJ} (T_{AB} + T_{BC}) \leq \theta_{\max}$$

$$\frac{2l}{G \pi R^4} (T_{AB} + T_{BC}) \leq \theta_{\max} \quad \frac{G \pi R^4}{2l (T_{AB} + T_{BC})} \geq \frac{1}{\theta_{\max}}$$

$$R \geq \sqrt[4]{\frac{2l (T_{AB} + T_{BC})}{\pi G \theta_{\max}}} \Rightarrow R \geq \sqrt[4]{\frac{2 \cdot 5 \cdot (400 + 240) \cdot 10^3}{70 \cdot 10^9 \cdot \pi \cdot 0,05}} \Rightarrow |R \geq 0,155 \text{ m}|$$

$$\text{Logo } |R \geq 0,15 \text{ m}|$$