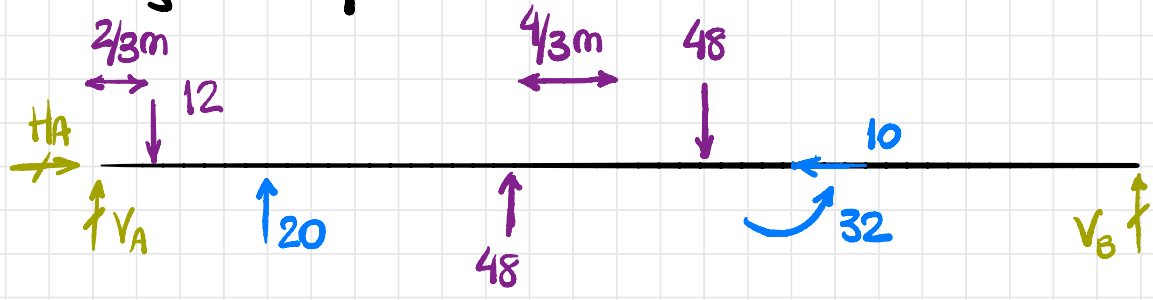


Reações de apoio:



$$\sum F_H = 0: H_A - 10 = 0 \rightarrow H_A = 10 \text{ kN} \quad \text{q1}$$

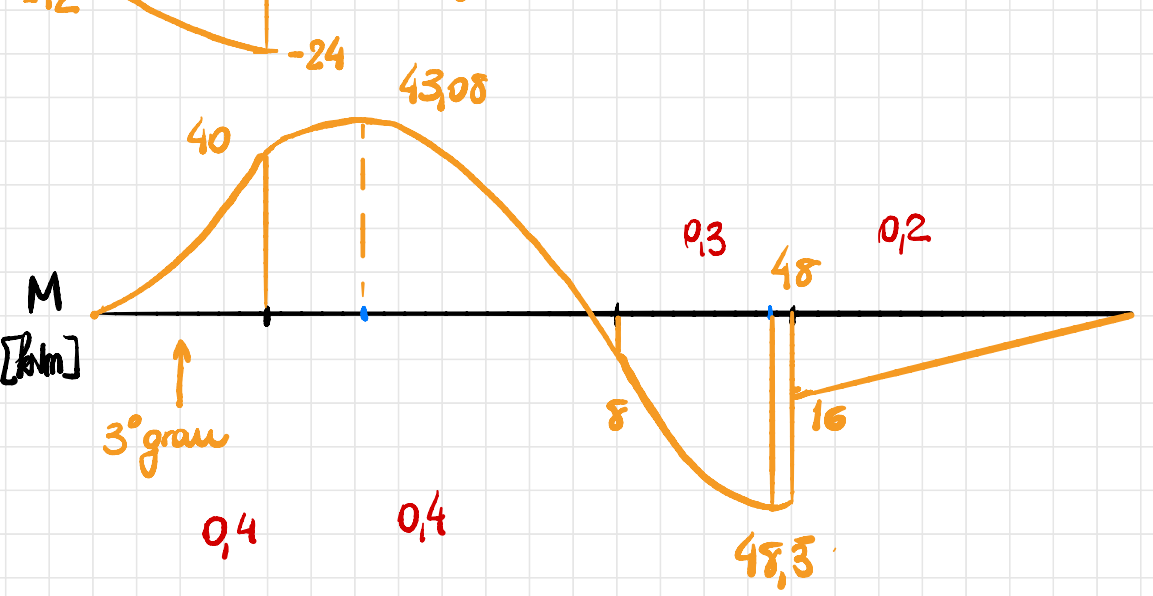
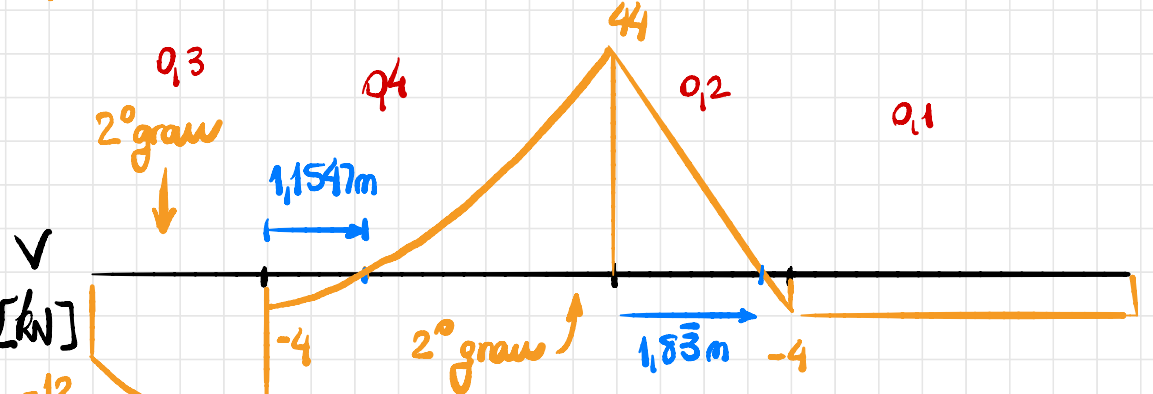
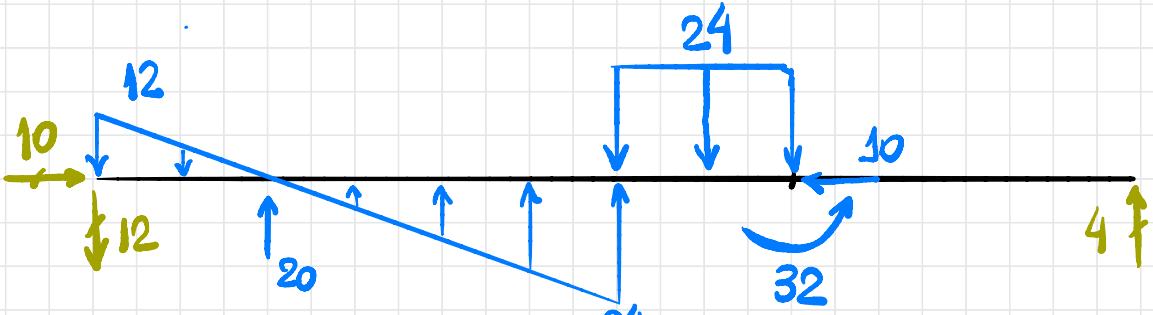
$$\sum F_V = 0: V_A - 12 + 20 + 48 - 48 + V_B = 0 \rightarrow V_A + V_B = -8$$

$$\textcircled{+} \sum M_A = 0: -12 \cdot \frac{2}{3} + 20 \cdot 2 + 48 \cdot \frac{14}{3} - 48 \cdot 7 + 32 + 12 \cdot V_B = 0$$

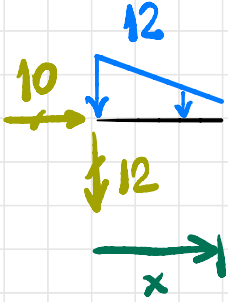
$$12V_B - 48 = 0 \rightarrow V_B = 4 \text{ kN} \rightarrow V_A = -12 \text{ kN}$$

q1

q1



Trecho AC:



$$q(x) = 12 - 6x \quad \left\{ \begin{array}{l} q(0) = 12 \\ q(2) = 0 \end{array} \right.$$

$$\frac{dV}{dx} = -q(x) = 6x - 12, \quad V(0) = -12$$

$$V(x) = 3x^2 - 12x - 12$$

$$\frac{dM}{dx} = v(x) = 3x^2 - 12x - 12, \quad M(0) = 0$$

$$M(x) = x^3 - 6x^2 - 12x$$

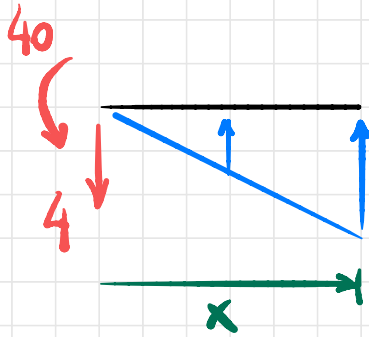
$$V(x) = 0 \rightarrow x^2 - 4x - 4 = 0 \rightarrow x = \frac{4 \pm \sqrt{16 - 4 \cdot 1 \cdot (-4)}}{2}$$

$$x = \frac{4 \pm 4\sqrt{2}}{2} \rightarrow x = 2 \pm 2\sqrt{2}$$

(ambas fora do intervalo $[0, 2]$)

Trecho CD:

-transporte para C:



$$q(x) = -6x \quad \begin{cases} q(0) = 0 \\ q(4) = -24 \end{cases}$$

$$\frac{dV}{dx} = -q(x) = 6x, \quad V(0) = -4$$

$$V(x) = 3x^2 - 4$$

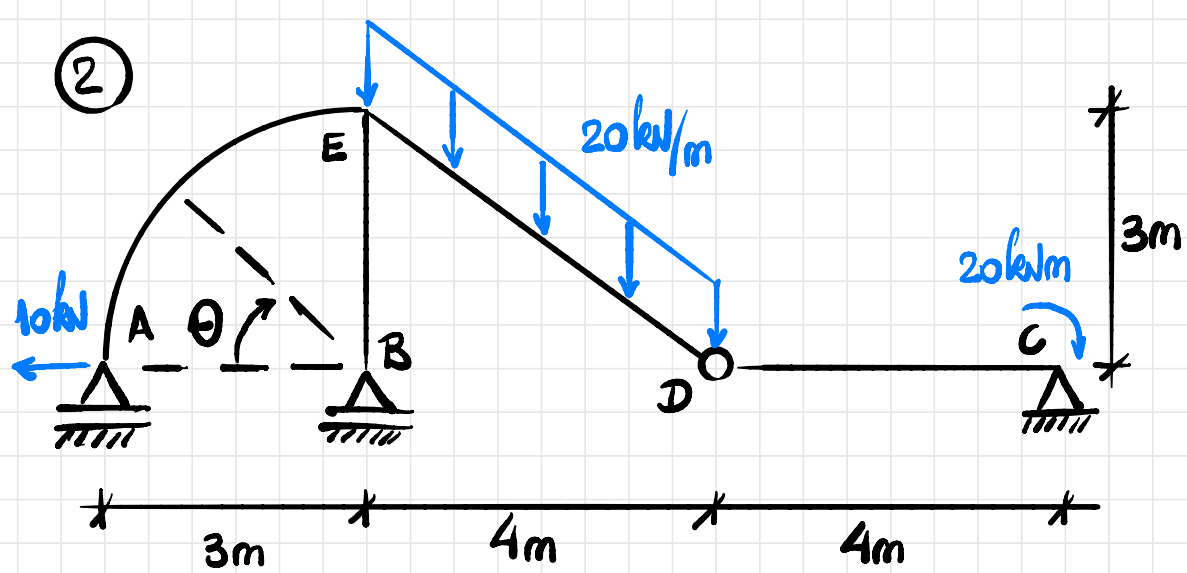
$$\frac{dM}{dx} = V(x) = 3x^2 - 4, \quad M(0) = -40$$

$$M(x) = x^3 - 4x - 40$$

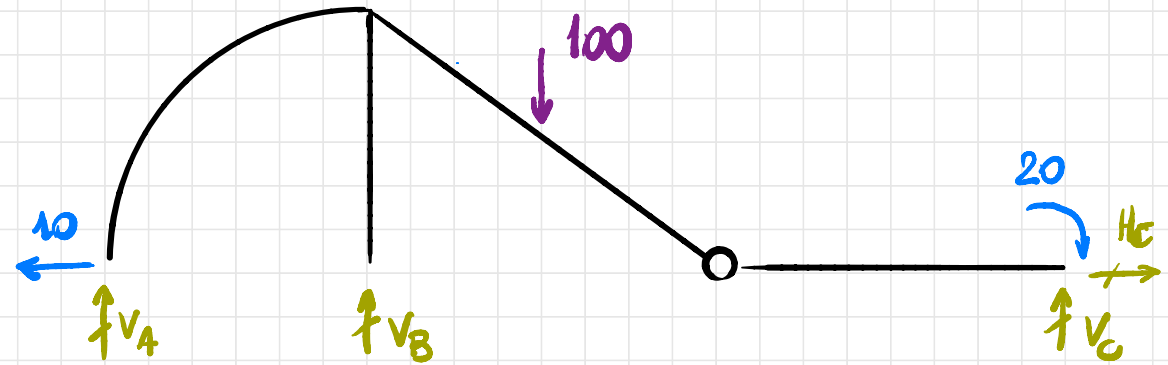
$$V(x) = 0 \rightarrow x = \pm \sqrt{\frac{4}{3}} = \pm 1,1547 \text{ m}$$

$$M(1,1547) = -43,08 \text{ kNm}$$

②



Reações de apoio:



$$\sum F_H = 0: -10 + H_C = 0 \rightarrow H_C = 10 \text{ kN} \quad q_1$$

$$\sum F_V = 0: V_A + V_B + V_C = 100$$

$$\text{A) } \sum M_A = 0: V_B \cdot 3 - 100 \cdot 5 - 20 + V_C \cdot 11 = 0$$

$$3V_B + 11V_C = 520$$

Fazendo um corte em D:



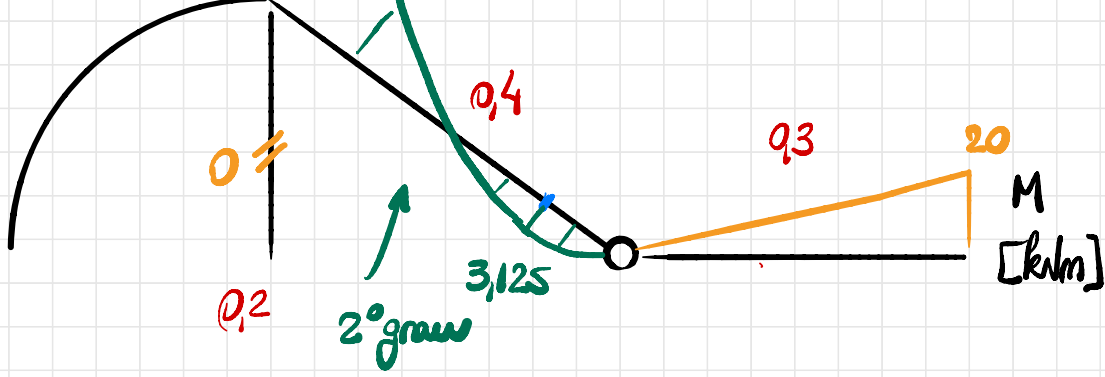
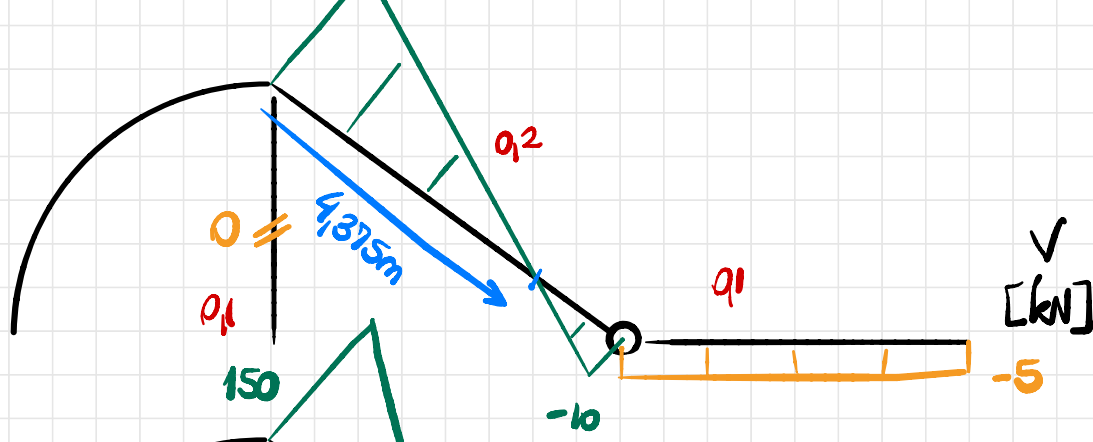
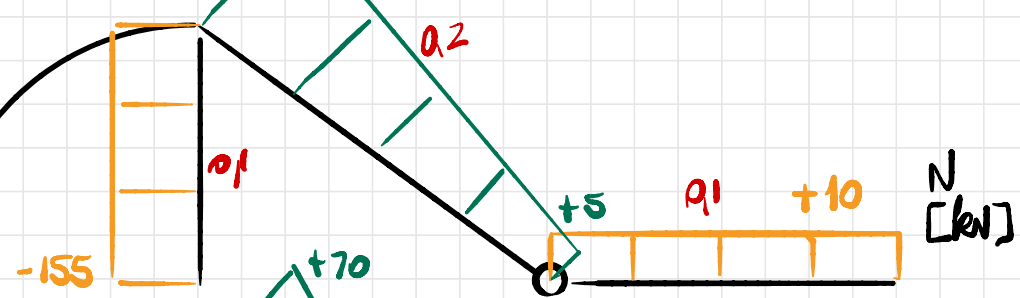
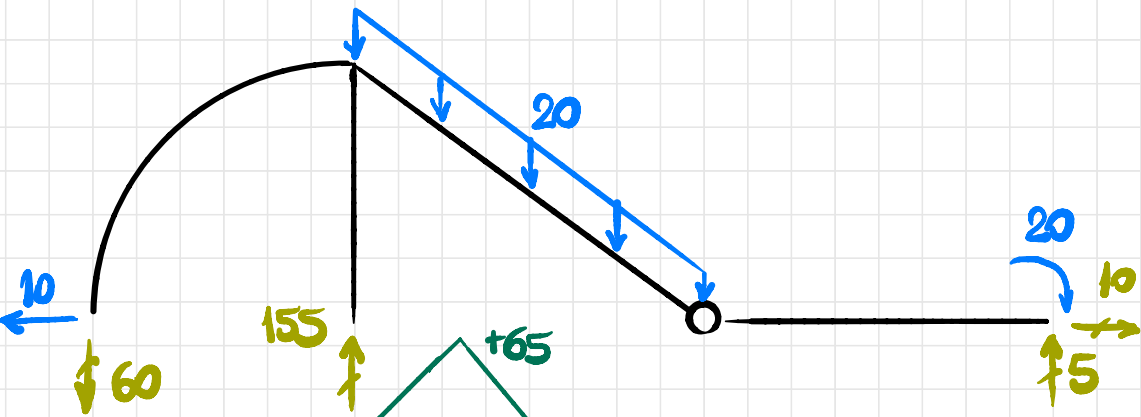
$$\curvearrowright \sum M_D = 0: V_C \cdot 4 - 20 = 0 \rightarrow V_C = 5 \text{ kN} \quad q1$$

$$3V_B = 520 - 11V_C = 520 - 11 \cdot 5$$

$$V_B = 155 \text{ kN} \quad q1$$

$$V_A = 100 - V_B - V_C = 100 - 155 - 5$$

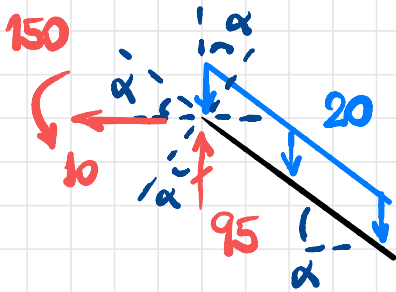
$$V_A = -60 \text{ kN} \quad q1$$



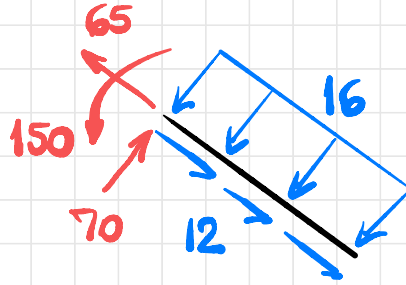
Transparência para E:

$$\sin \alpha = \frac{3}{5}$$

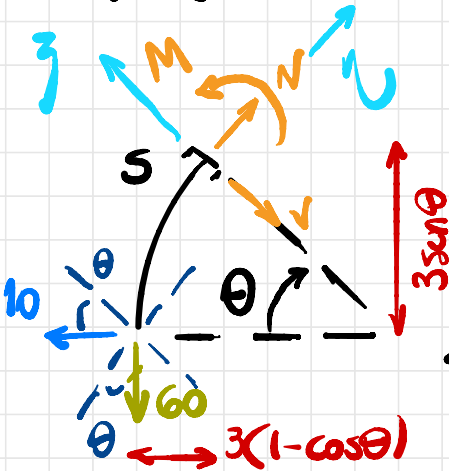
$$\cos \alpha = \frac{4}{5}$$



≡



Equações do trecho curvo:



$$\sum F_y = 0: N - 10 \sin \theta - 60 \cos \theta = 0$$

$$N = 10 \sin \theta + 60 \cos \theta \quad 0,3$$

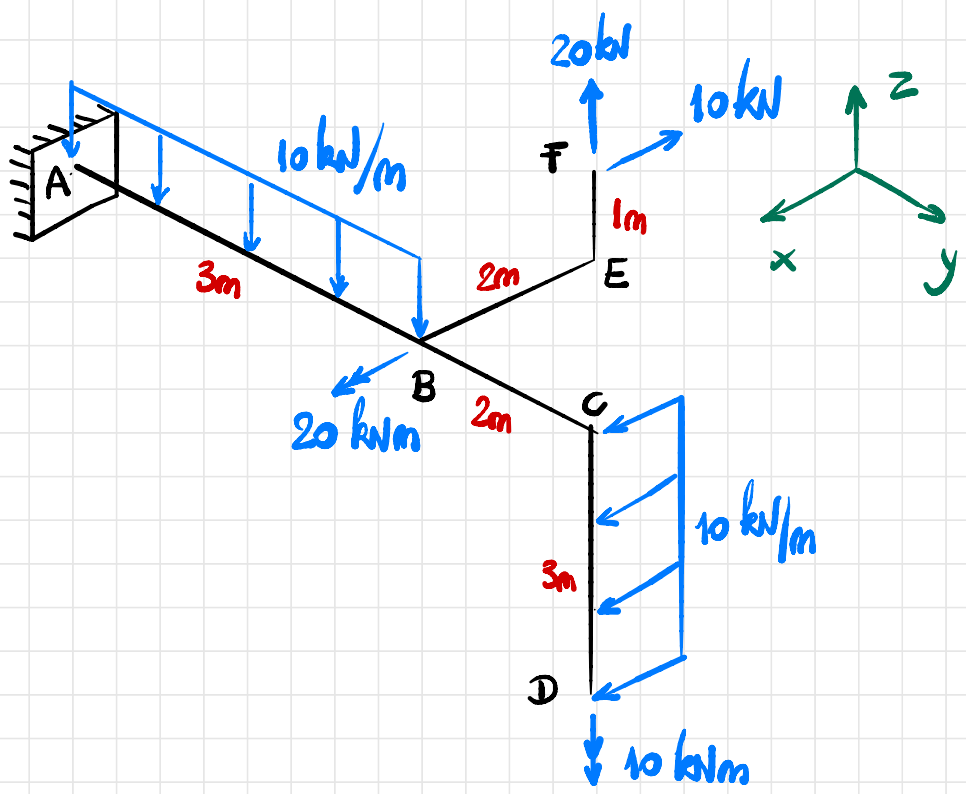
$$\sum F_x = 0: -V + 10 \cos \theta - 60 \sin \theta = 0$$

$$V = 10 \cos \theta - 60 \sin \theta \quad 0,3$$

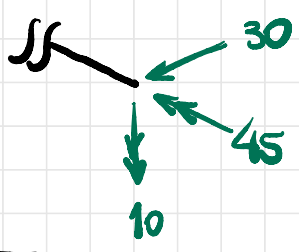
$$\text{vt) } \sum M_s = 0: M - 10 \cdot 3 \sin \theta + 60 \cdot 3(1 - \cos \theta) = 0$$

$$M = 30 \sin \theta + 180 \cos \theta - 180 \quad 0,3$$

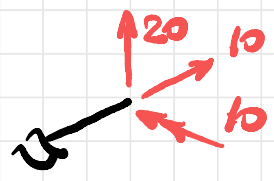
3



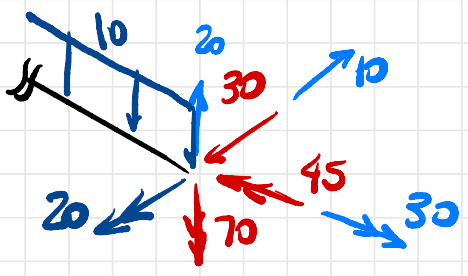
Transporte para C:



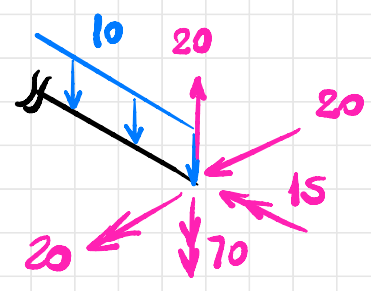
Transporte para E

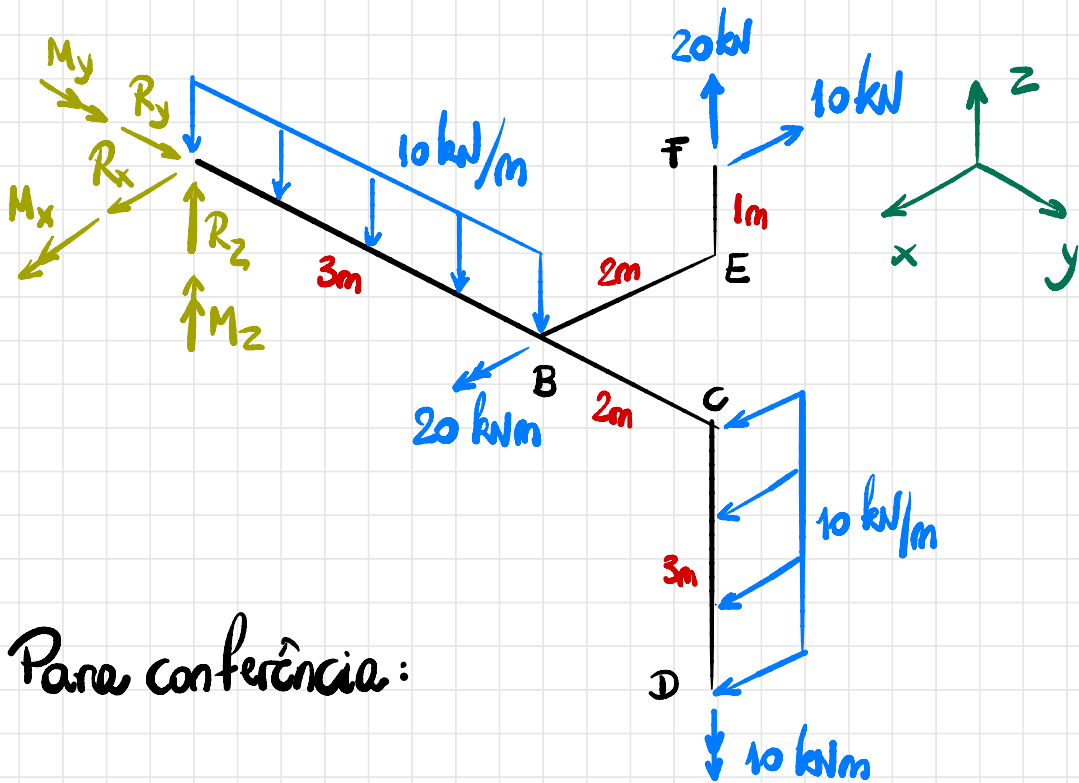


Transporte para B:



≡





Para conferência:

$$\sum F_x = 0: R_x = -20 \text{ kN}$$

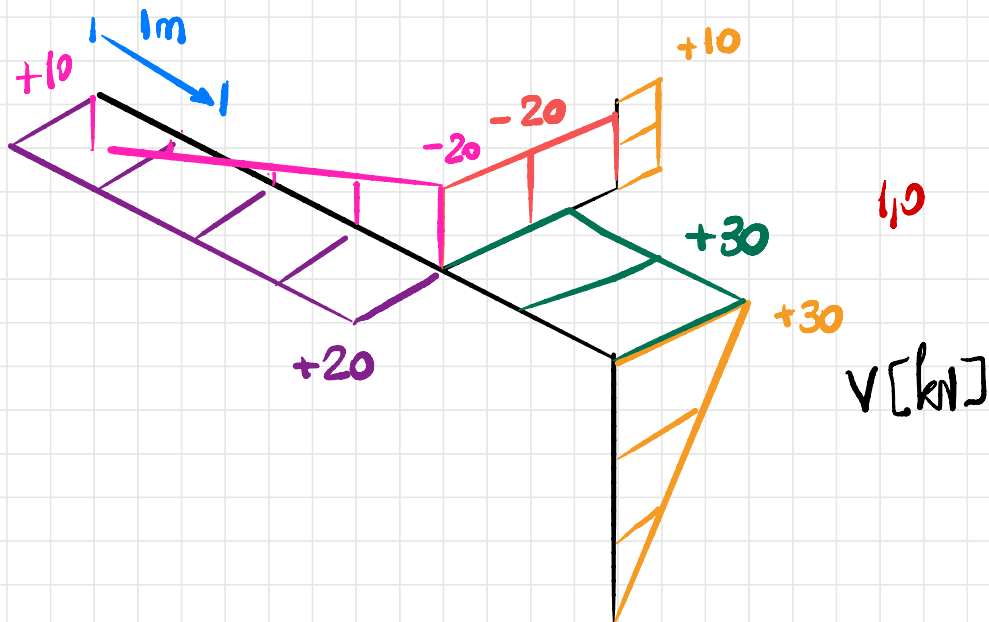
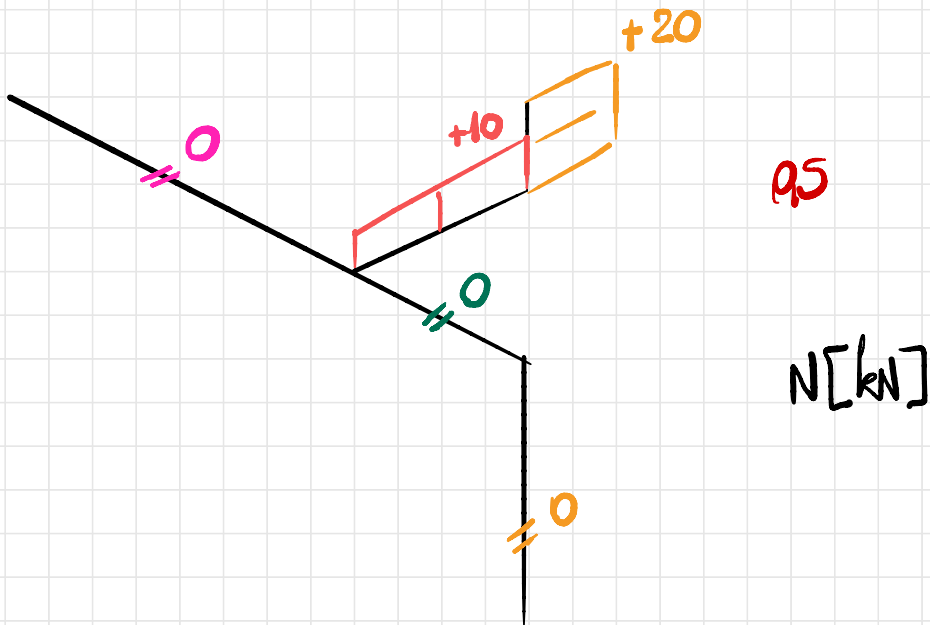
$$\sum F_y = 0: R_y = 0$$

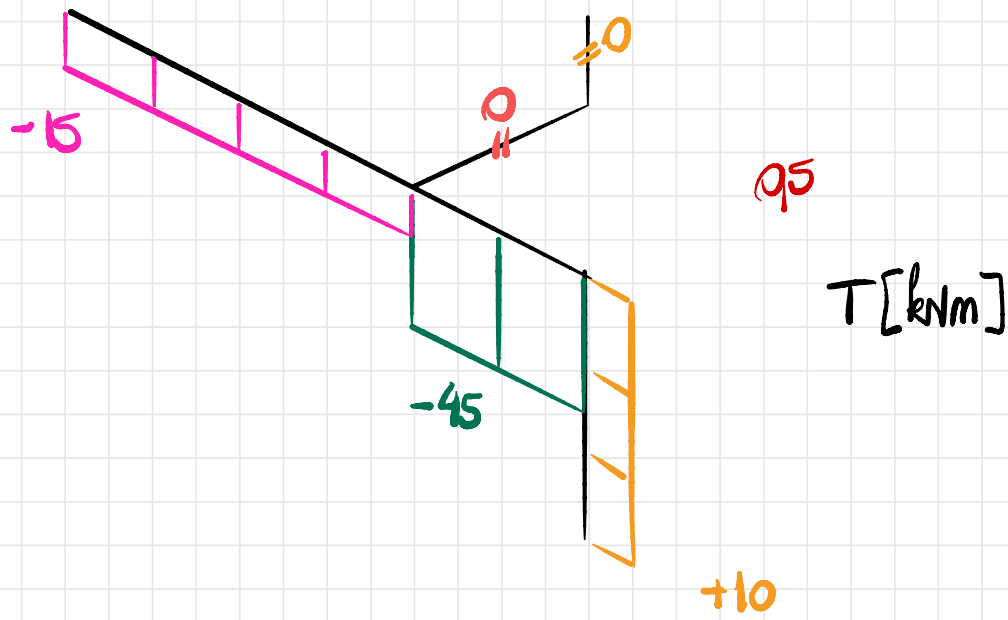
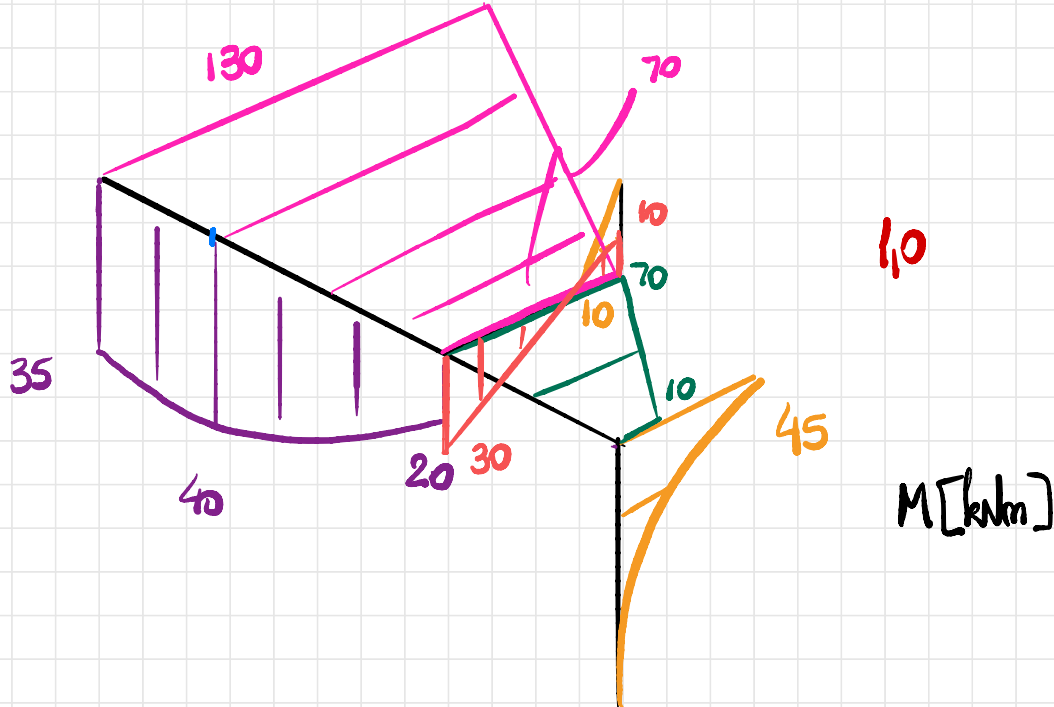
$$\sum F_z = 0: R_2 = 10 \text{ kN}$$

$$\sum M_{A,x} = 0: M_x - 30 \cdot 1,5 + 20 \cdot 3 + 20 = 0 \rightarrow M_x = -35 \text{ kNm}$$

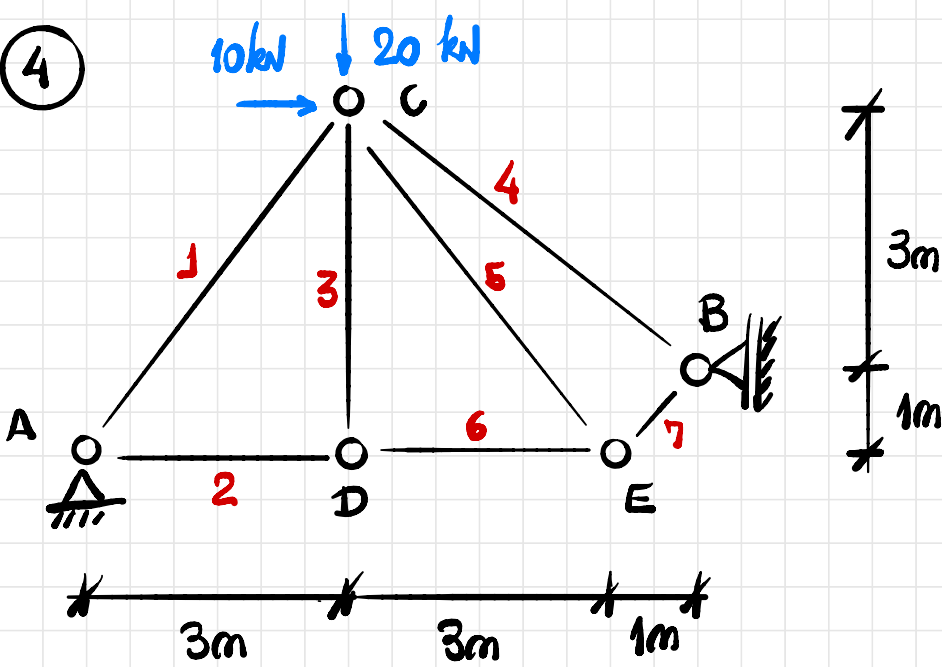
$$\sum M_{A,y} = 0: M_y + 20 \cdot 2 - 10 \cdot 1 - 30 \cdot 1,5 = 0 \rightarrow M_y = 15 \text{ kNm}$$

$$\sum M_{A,z} = 0: M_2 - 10 + 10 \cdot 3 - 30 \cdot 5 = 0 \rightarrow M_2 = 130 \text{ kNm}$$

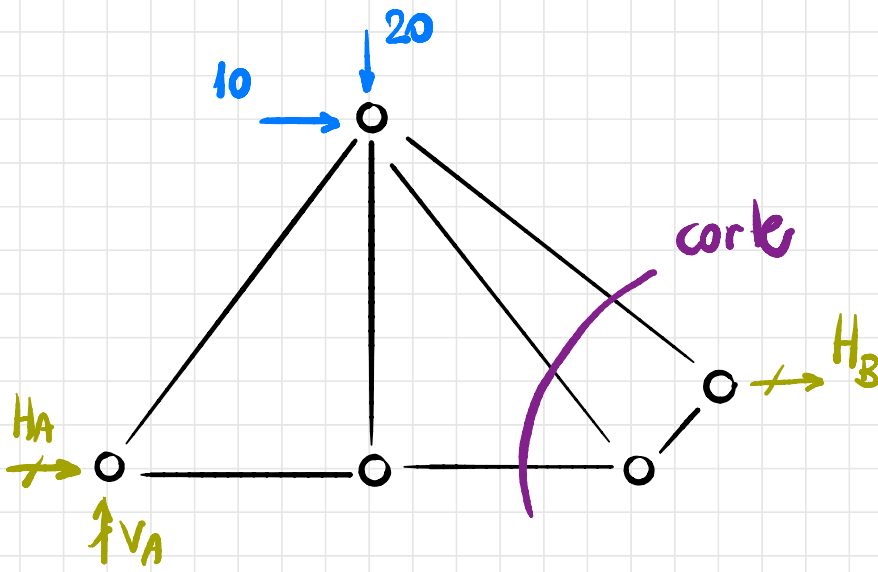




4



barra	N [kN]
4	$-\frac{500}{7}$ (-71,429)
5	$\frac{375}{7}$ (53,571)
6	-75
7	$-\frac{300\sqrt{2}}{7}$ (-60,609)



$$\sum F_H = 0: H_A + H_B + 10 = 0$$

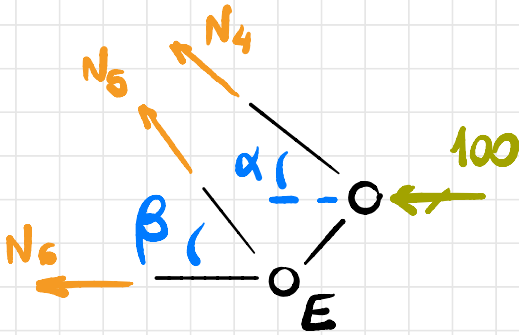
$$\sum F_V = 0: V_A = 20 \text{ kN}$$

$$\textcircled{+} \sum M_A = 0: -10 \cdot 4 - 20 \cdot 3 - H_B \cdot 1 = 0$$

$$H_B = -100 \text{ kN}$$

$$H_A = 90 \text{ kN}$$

Fazendo o corte:



$$\sin \alpha = \cos \beta = \frac{3}{5}$$

$$\cos \alpha = \sin \beta = \frac{4}{5}$$

$$\sum F_H = 0: -N_6 - N_5 \cos \beta - N_4 \cos \alpha - 100 = 0$$

$$\sum F_V = 0: N_5 \sin \beta + N_4 \sin \alpha = 0$$

$$\text{v)} \sum M_C = 0: -N_6 \cdot 4 - 100 \cdot 3 = 0$$

$$\therefore N_6 = -75 \text{ kN}$$

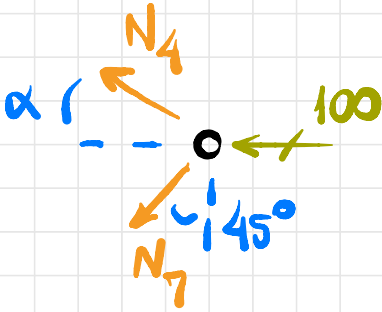
$$\begin{cases} \frac{4}{5} N_4 + \frac{3}{5} N_5 = -25 \\ \frac{3}{5} N_4 + \frac{4}{5} N_5 = 0 \end{cases} \rightarrow \begin{cases} 4 N_4 + 3 N_5 = -125 \\ N_5 = -\frac{3}{4} N_4 \end{cases}$$

$$\left[4 + 3 \left(-\frac{3}{4} \right) \right] N_4 = -125 \rightarrow \frac{7}{4} N_4 = -125$$

$$N_4 = -\frac{500}{7} \text{ kN} \quad (71,429 \text{ kN})$$

$$N_5 = -\frac{3}{4} N_4 \rightarrow N_5 = \frac{375}{7} \text{ kN} \quad (53,571 \text{ kN})$$

No B:



$$\sum F_V = 0: -N_7 \cos 45^\circ + N_4 \cdot \sin \alpha = 0$$

$$\frac{N_7}{\sqrt{2}} = -\frac{500}{7} \cdot \frac{3}{5}$$

$$N_7 = -\frac{300\sqrt{2}}{7} \text{ kN} \quad (-60,609 \text{ kN})$$