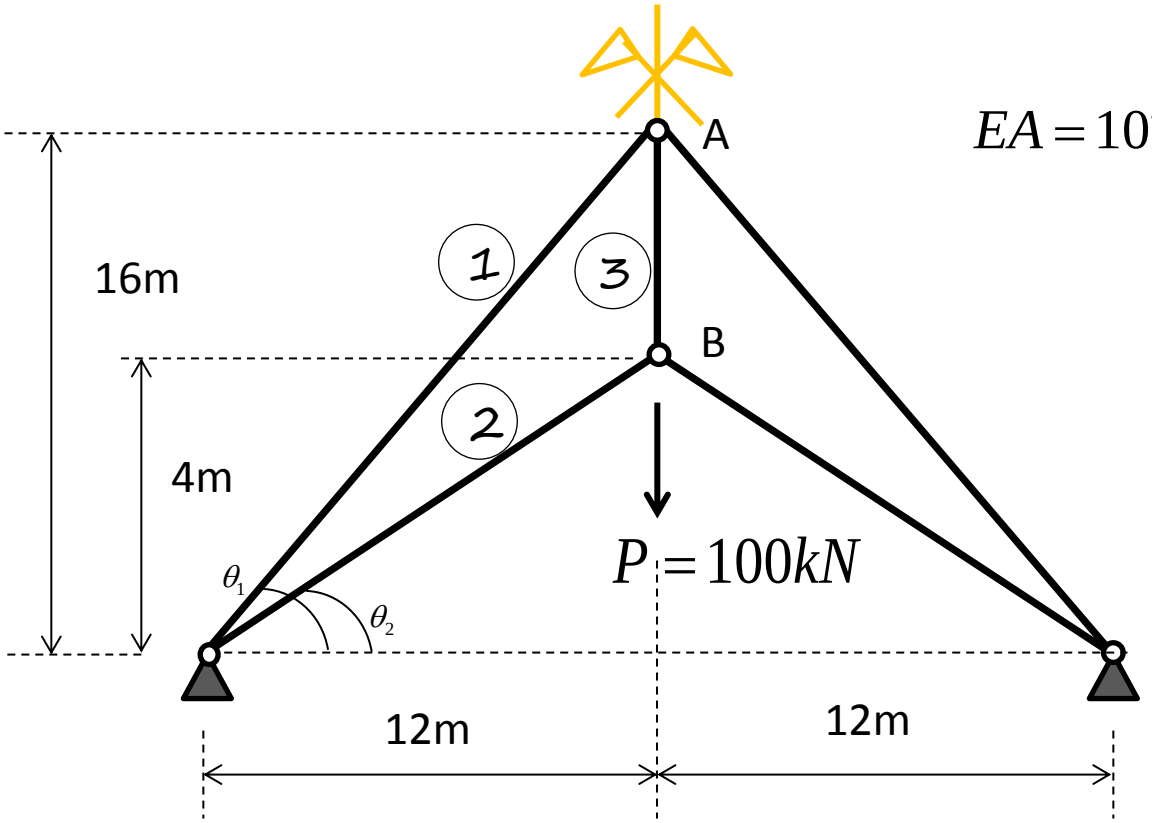
Exercício: Determinar os esforços nas barras da treliça:



$EA = 10^4$

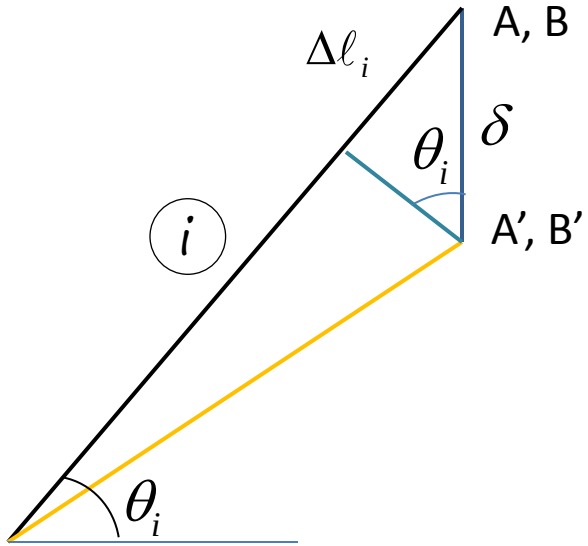
$2n - b \quad < r \quad \therefore$ hiperestática

$\quad = r \quad \therefore$ isostática

$\quad > r \quad \therefore$ hipostática

$2 \cdot 4 - 5 = 3 < 4 \quad 1 \times$ hiper

Compatibilidade de deformações



$$\Delta\ell_i \approx \delta_i \sin\theta_i \quad \Rightarrow \quad \Delta\ell_i = \frac{N_i \ell_i}{EA}$$

$$\Delta\ell_1 \approx \delta_1 \sin\theta_1 \quad \Rightarrow \quad \Delta\ell_1 = \frac{N_1 \ell_1}{EA} = \delta_1 \sin\theta_1$$

$$\boxed{N_1 = -\frac{EA}{\ell_1}\delta_1 \sin\theta_1}$$

$$\Delta\ell_2 \approx \delta_2 \sin\theta_2 \quad \Rightarrow \quad \Delta\ell_2 = \frac{N_2 \ell_2}{EA} = \delta_2 \sin\theta_2$$

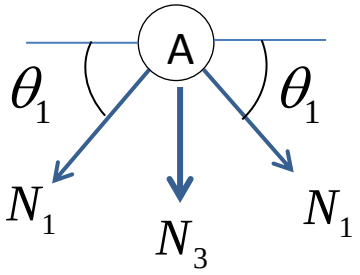
$$\boxed{N_2 = -\frac{EA}{\ell_2}\delta_2 \sin\theta_2}$$

$$\Delta\ell_3 = \delta_2 - \delta_1$$

$$\frac{N_3 \ell_3}{EA} = \delta_2 - \delta_1$$

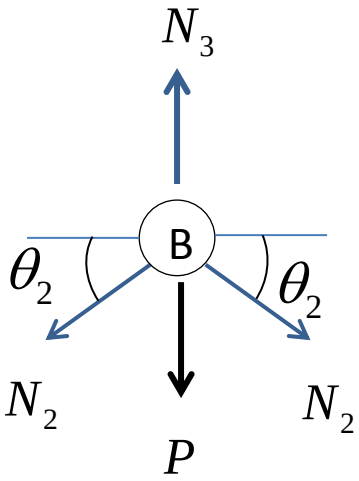
$$\boxed{N_3 = \frac{EA}{\ell_3}(\delta_2 - \delta_1)}$$

Equilíbrio:



$$\sum F_Y = 0 \quad \therefore \quad 2N_1 \sin\theta_1 + N_3 = 0$$

$$N_3 = -2N_1 \sin\theta_1 \qquad (1)$$



$$\sum F_Y = 0 \quad \therefore \quad 2N_2 \sin\theta_2 - N_3 = P \qquad (2)$$

Substituindo (1) em (2), temos:

$$2N_2 \sin\theta_2 + 2N_1 \sin\theta_1 = P$$

$$2(N_2 \sin\theta_2 + N_1 \sin\theta_1) = P \qquad (3)$$

$$l_1 = \sqrt{12^2 + 16^2} = 20m$$

$$l_2 = \sqrt{12^2 + 4^2} = \sqrt{160}m$$

$$l_3 = \sqrt{160}m = 12m$$

$$sin\theta_1 = \frac{16}{20} = 0.8$$

$$sin\theta_2 = \frac{4}{\sqrt{160}} = 0.316$$

$$N_1 = -\frac{10^4}{20}\delta_1 0.8 = -400\delta_1 \quad (4)$$

$$N_2 = -\frac{10^4}{\sqrt{160}}\delta_2 0.316 = -248.82\delta_2 \quad (5)$$

$$N_3 = \frac{10^4}{12}(\delta_2 - \delta_1) = 833.33(\delta_2 - \delta_1) \quad (6)$$

Substituindo (4) e (5) em (3), temos:

$$2(N_2 \sin\theta_2 + N_1 \sin\theta_1) = P$$

$$2(-248.82\delta_2 0.316 - 400\delta_1 0.8) = -100$$

$$(157.25\delta_2 + 640\delta_1) = 100 \quad (7)$$

Substituindo (4) e (6) em (1), temos:

$$833.33(\delta_2 - \delta_1) - 640\delta_1 = 0$$

$$\boxed{\delta_2 = 1.768\delta_1} \quad (8)$$

Finalmente, substituindo (8) em (7), temos:

$$(278\delta_1 + 640\delta_1) = 100 \qquad \boxed{\delta_1 = 0.1089m} \qquad \boxed{\delta_2 = 0.1926m} \qquad (9)$$

Substituindo δ_1 e δ_2 em (4), (5) e (6) temos:

$$N_1 = -400\delta_1 = -43.56\text{kN}$$

$$\boxed{N_1 = -43.56\text{kN}}$$

$$N_2 = -\frac{10^4}{\sqrt{160}}\delta_2 0.316 = -48.12kN$$

$$\boxed{N_2 = -48.12\text{kN}}$$

$$N_3 = \frac{10^4}{12}(\delta_2 - \delta_1) = 69.75kN$$

$$\boxed{N_3 = 69.75\text{kN}}$$