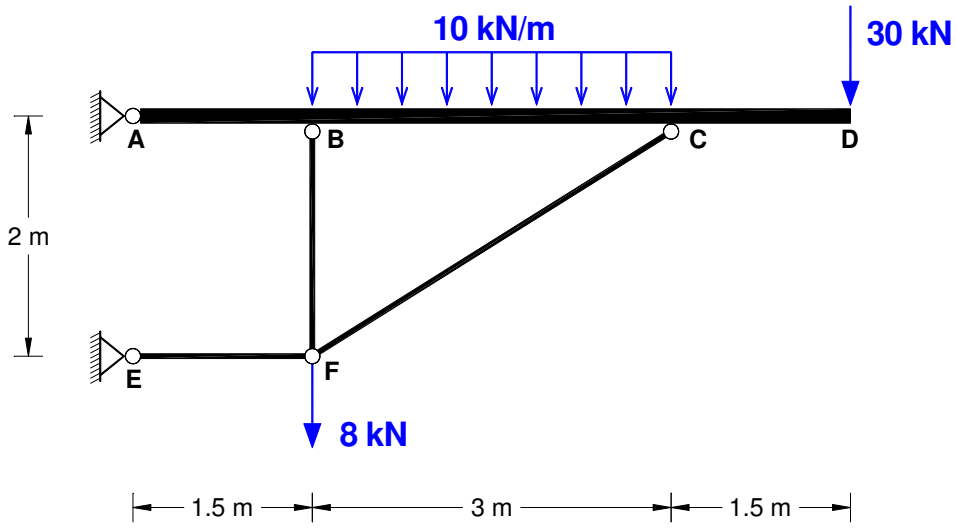
LICENCIATURA EM ENGENHARIA CIVIL

TEORIA DE ESTRUTURAS

TEOREMA DOS TRABALHOS VIRTUAIS

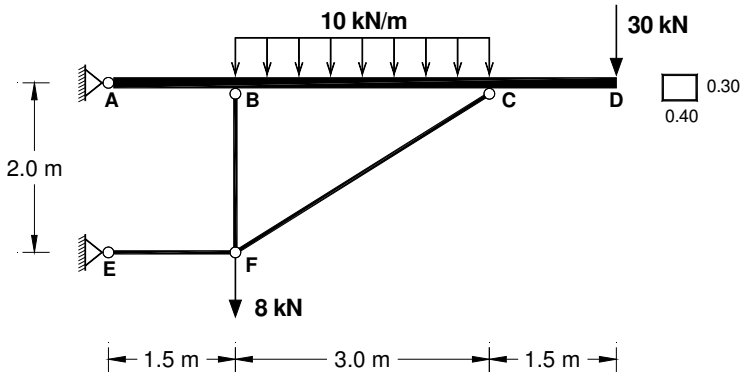


ESTRUTURA MISTA ISOSTÁTICA

ISABEL ALVIM TELES

EXERCÍCIO PROPOSTO

Considere a estrutura representada na figura.



Barras ABCD
Secção: ver figura
Betão: E = 29 GPa

Restantes barras
Perfil tubular:
100 mm x 100 mm
esp = 5 mm
Aço: E = 206 GPa

Responda às alíneas seguintes desprezando a contribuição do esforço transverso.

a) Determine o deslocamento e rotação do ponto **D**;

b) Determine a rotação do ponto **A**;

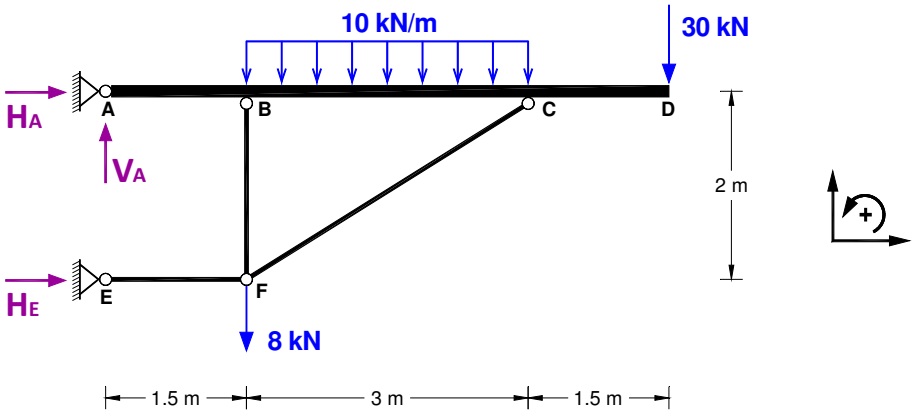
c) Determine o deslocamento relativo dos pontos **E** e **B**;

d) Determine a variação do ângulo formado pelas barras **BF** e **FC**;

e) Confirme com o programa informático FTOOL os resultados obtidos nas alíneas **a**) e **b**).

RESOLUÇÃO

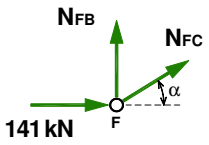
- **Cálculo das reacções e esforços nas barras bi-articuladas**



$$\begin{cases} \sum F_X = 0 \Rightarrow H_A + H_E = 0 \\ \sum F_Y = 0 \Rightarrow V_A - 30 - 10\times 3 - 8 = 0 \\ \sum M_A = 0 \Rightarrow H_E \times 2 - 8\,x\,1{,}5 - 30\,x\,6 - 10\times 3\times 3 = 0 \end{cases} \Rightarrow \begin{cases} H_A = -141 \text{ kN} \leftarrow \\ V_A = 68 \text{ kN} \uparrow \\ H_E = 141 \text{ kN} \rightarrow \end{cases}$$

Nó E Barra EF $\Rightarrow$ N_{EF} = -141 kN (compressão)

Nó F

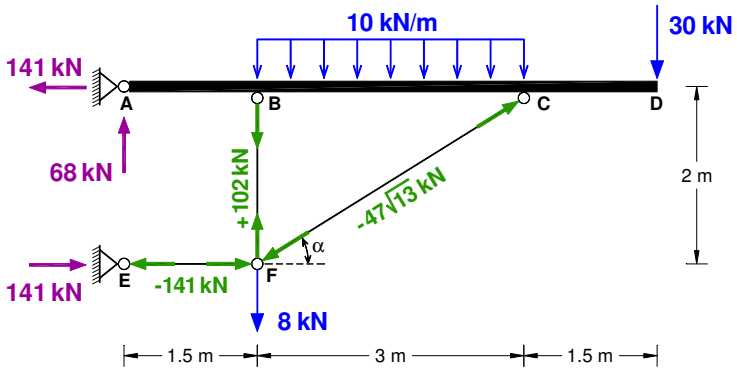


$$\text{tg}\,\alpha = \frac{2}{3} \Rightarrow \alpha = \text{arctg}\,\frac{2}{3} = 33{,}69^\circ \Rightarrow \begin{cases} \cos\alpha = \dfrac{3}{\sqrt{13}} \\ \text{sen}\,\alpha = \dfrac{2}{\sqrt{13}} \end{cases}$$

$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases}$$

$$\begin{cases} N_{FC}\cos\alpha + 141 = 0 \\ N_{FB} + N_{FC}\,\text{sen}\,\alpha = 0 \end{cases}$$

$$\begin{cases} N_{FC} = -47\sqrt{13}\ \text{kN (compressão)} \\ N_{FB} = 102\ \text{kN (tracção)} \end{cases}$$



• Características das barras

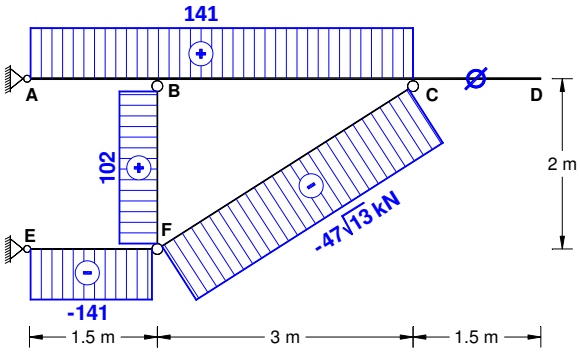
Barras **ABCD**

$$\begin{cases} E = 29\ \text{GPa} = 29\times10^6\ \text{kPa} \\ A = 0{,}40\times0{,}3 = 0{,}12\ \text{m}^2 \\ I = \dfrac{0{,}40\times0{,}30^3}{12} = 9\times10^{-4}\ \text{m}^4 \end{cases}$$

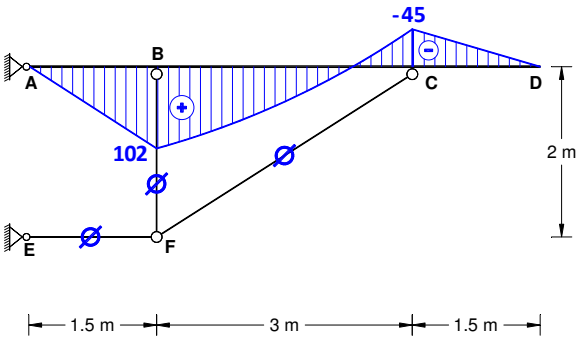
Barras bi-articuladas **EF**, **FB** e **FC**

$$\begin{cases} E = 206\ \text{GPa} = 206\times10^6\ \text{kPa} \\ A = 0{,}10\times0{,}10 - 0{,}09\times0{,}09 = 1{,}9\times10^{-3}\ \text{m}^2 \end{cases}$$

• Diagramas de Esforços – sistema real



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

Barra BC $\Rightarrow$ $M(z) = 102 - 34.z - 5z^2$ kNm

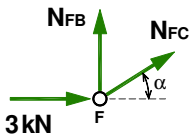
a) DESLOCAMENTO DO PONTO D

a_1) Deslocamento vertical do ponto D

$$\begin{cases} \sum F_X = 0 \Rightarrow H_A + H_E = 0 \\ \sum F_Y = 0 \Rightarrow V_A - 1 = 0 \\ \sum M_A = 0 \Rightarrow H_E \times 2 - 1 \times 6 = 0 \end{cases} \Rightarrow \begin{cases} H_A = -3 \text{ kN} \leftarrow \\ V_A = 1 \text{ kN} \uparrow \\ H_E = 3 \text{ kN} \rightarrow \end{cases}$$

Nó E Barra EF $\Rightarrow$ N_{EF} = -3 kN (compressão)

Nó F

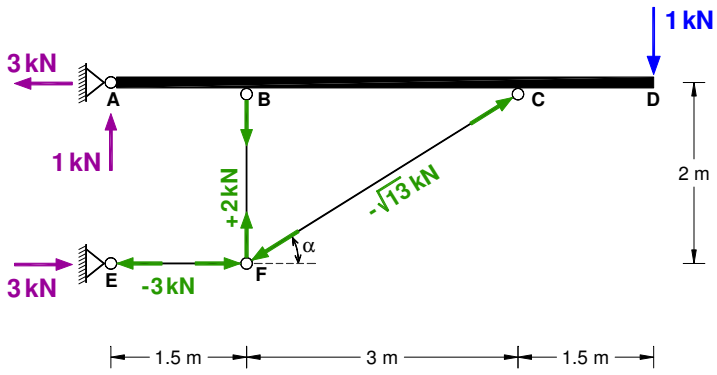


$$\text{tg}\,\alpha = \frac{2}{3} \Rightarrow \alpha = \text{arctg}\,\frac{2}{3} = 33{,}69^\circ \Rightarrow \begin{cases} \cos\alpha = \frac{3}{\sqrt{13}} \\ \text{sen}\,\alpha = \frac{2}{\sqrt{13}} \end{cases}$$

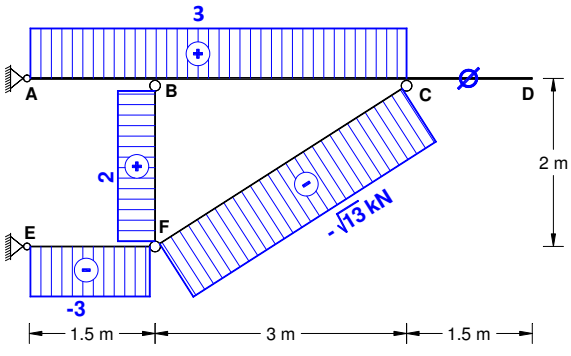
$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases}$$

$$\begin{cases} N_{FC}\cos\alpha + 3 = 0 \\ N_{FB} + N_{FC}\,\text{sen}\,\alpha = 0 \end{cases}$$

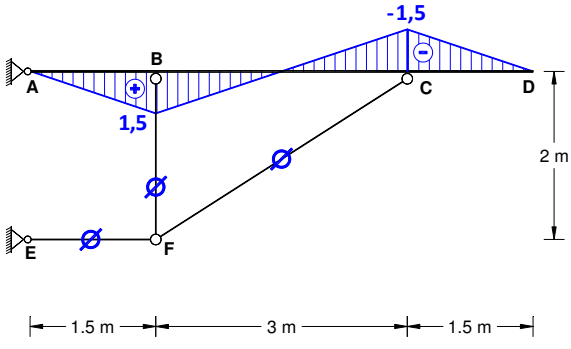
$$\begin{cases} N_{FC} = -\sqrt{13} \text{ kN (compressão)} \\ N_{FB} = 2 \text{ kN (tracção)} \end{cases}$$



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

Barra BC $\Rightarrow$ $M(z) = 1{,}5 - z$ kNm

- **Aplicação do Teorema dos Trabalhos Virtuais (TTV)**

$$\bar{1}\times\delta_D^v = \underbrace{\int \frac{\bar{N}\times N}{E\,A}\,dz + \int \frac{\bar{M}\times M}{E\,I}\,dz}_{\text{barras contínuas}} + \underbrace{\sum \bar{N}\frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int \frac{\bar{N}\times N}{E\,A}\,dz = \frac{1}{29\times10^6\times0{,}12}\times3\times4{,}5\times141 = 5{,}4698\times10^{-4}\ \text{m}$$

$$\int \frac{\bar{M}\times M}{E\,I}\,dz = \frac{1}{29\times10^6\times9\times10^{-4}}\left[\frac{102\times1{,}5}{3}\times1{,}5 + \int_0^3\left[(1{,}5-z)\times(102-34.z-5z^2)\right]dz + \frac{-45\times(-1{,}5)\times1{,}5}{3}\right] =$$

$$= \frac{1}{26100}\left[76{,}5 + \int_0^3 (5z^3+26{,}5z^2-153.z+153)\,dz + 33{,}75\right] =$$

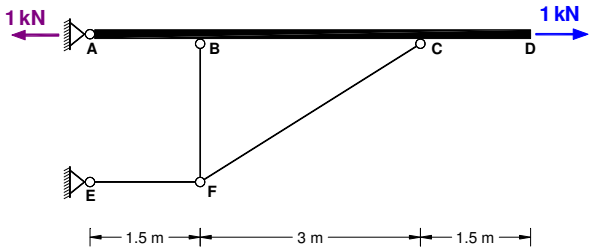
$$= \frac{1}{26100}\left(76{,}5 + \frac{5}{4}3^4 + \frac{26{,}5}{3}3^3 - \frac{153}{2}3^2 + 153\times3 + 33{,}75\right) = 8{,}448\times10^{-3}\ \text{m}$$

$$\sum \bar{N}\frac{N\,L}{E\,A} = \frac{1}{206\times10^6\times1{,}9\times10^{-3}}\left[-141\times(-3)\times1{,}5 + 102\times2\times2 - 47\sqrt{13}\times(-\sqrt{13})\times\sqrt{13}\right] = 8{,}292\times10^{-3}\ \text{m}$$

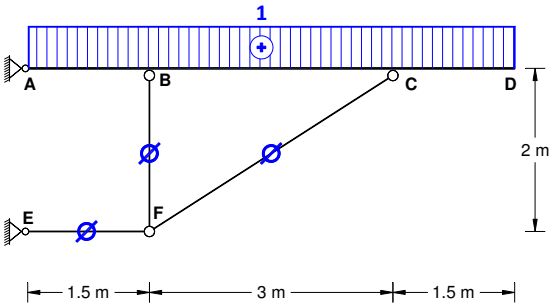
$$\delta_D^v = \int \frac{\bar{N}\times N}{E\,A}\,dz + \int \frac{\bar{M}\times M}{E\,I}\,dz + \sum \bar{N}\frac{N\,L}{E\,A}$$

$$\delta_D^v = 5{,}4698\times10^{-4} + 8{,}448\times10^{-3} + 8{,}292\times10^{-3} = 1{,}729\times10^{-2}\ \text{m} = 1{,}729\ \text{cm}\ \downarrow$$

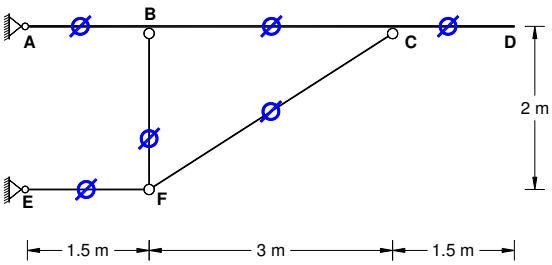
a_2) Deslocamento horizontal do ponto D



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

- **Aplicação do Teorema dos Trabalhos Virtuais (TTV)**

$$\bar{1}\times\delta_D^h = \underbrace{\int\frac{\bar{N}\times N}{E\,A}dz + \int\frac{\bar{M}\times M}{E\,I}\,dz}_{\text{barras contínuas}} + \underbrace{\sum\bar{N}\frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int\frac{\bar{N}\times N}{E\,A}dz = \frac{1}{29\times10^6\times0{,}12}\times1\times4{,}5\times141 = 1{,}823\times10^{-4}\ \text{m} = 0{,}18\ \text{mm}\ \rightarrow$$

$$\int\frac{\bar{M}\times M}{E\,I}dz = 0$$

$$\sum\bar{N}\frac{N\,L}{E\,A}=0$$

$$\delta_D^h = \int\frac{\bar{N}\times N}{E\,A}dz + \int\frac{\bar{M}\times M}{E\,I}\,dz + \sum\bar{N}\frac{N\,L}{E\,A} = 0{,}18\ \text{mm}\ \rightarrow$$

- **Deslocamento do ponto D**

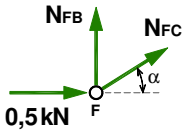
$$\delta_D = \sqrt{(\delta_D^v)^2+(\delta_D^h)^2} = \sqrt{1{,}729^2+0{,}018^2} = 1{,}729\ \text{cm}\ \searrow$$

a3) Rotação do ponto D

$$\begin{cases}\sum F_X=0 & \Rightarrow\ H_A+H_E=0\\ \sum F_Y=0 & \Rightarrow\ V_A=0\\ \sum M_A=0 & \Rightarrow\ H_E\times2-1=0\end{cases}\ \Rightarrow\ \begin{cases}H_A=-0{,}5\ \text{kN}\ \leftarrow\\ V_A=0\\ H_E=0{,}5\ \text{kN}\ \rightarrow\end{cases}$$

Nó E Barra EF $\Rightarrow$ N_{EF} = -0,5 kN (compressão)

Nó F

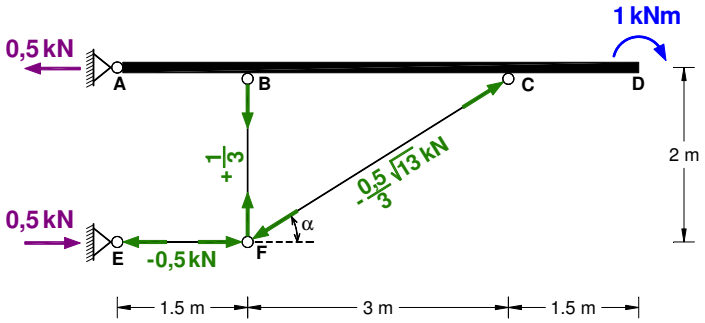


$$\text{tg}\,\alpha=\frac{2}{3}\ \Rightarrow\ \alpha=\text{arctg}\,\frac{2}{3}=33{,}69^\circ\ \Rightarrow\ \begin{cases}\cos\alpha=\frac{3}{\sqrt{13}}\\ \text{sen}\,\alpha=\frac{2}{\sqrt{13}}\end{cases}$$

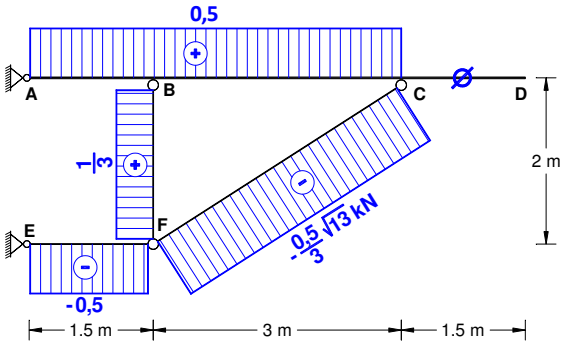
$$\begin{cases}\sum F_x=0\\ \sum F_y=0\end{cases}$$

$$\begin{cases}N_{FC}\cos\alpha+0{,}5=0\\ N_{FB}+N_{FC}\,\text{sen}\,\alpha=0\end{cases}$$

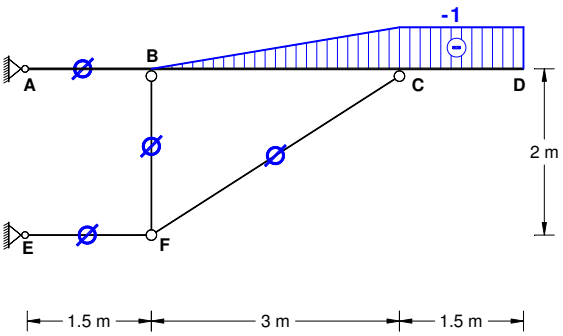
$$\begin{cases}N_{FC}=-\frac{0{,}5}{3}\sqrt{13}\ \text{kN}\ \text{(compressão)}\\ N_{FB}=\frac{1}{3}\ \text{kN}\ \text{(tracção)}\end{cases}$$



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

Barra BC $\Rightarrow \quad M(z) = -\frac{1}{3}z \ \text{kNm}$

- **Aplicação do Teorema dos Trabalhos Virtuais (TTV)**

$$\bar{1}\times\theta_D = \underbrace{\int \frac{\bar{N}\times N}{E\,A}\,dz + \int \frac{\bar{M}\times M}{E\,I}\,dz}_{\text{barras contínuas}} + \underbrace{\sum \bar{N}\frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int \frac{\bar{N}\times N}{E\,A}\,dz = \frac{1}{29\times10^{6}\times0{,}12}\times0{,}5\times4{,}5\times141 = 9{,}116\times10^{-5}\ \text{rad}$$

$$\int \frac{\bar{M}\times M}{E\,I}\,dz = \frac{1}{29\times10^{6}\times9\times10^{-4}}\left[\int_0^3\left[(-\frac{1}{3}z)\times(102-34.z-5z^2)\right]dz + \frac{-45\times1{,}5\times(-1)}{2}\right] =$$

$$= \frac{1}{26100}\left[\int_0^3(\frac{5}{3}z^3+\frac{34}{3}z^2-34.z)\,dz + 33{,}75\right] =$$

$$= \frac{1}{26100}\,(\frac{5}{12}3^4 + \frac{34}{9}3^3 - \frac{34}{2}\times3^2 - 33{,}75) = 6{,}284\times10^{-4}\ \text{rad}$$

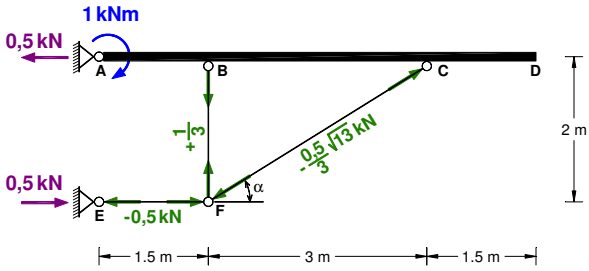
$$\sum \bar{N}\frac{N\,L}{E\,A} = \frac{1}{206\times10^{6}\times1{,}9\times10^{-3}}\left[-141\times(-0{,}5)\times1{,}5 + 102\times\frac{1}{3}\times2 - 47\sqrt{13}\times(-\frac{0{,}5}{3}\sqrt{13})\times\sqrt{13}\right] =$$

$$= 1{,}382\times10^{-3}\ \text{rad}$$

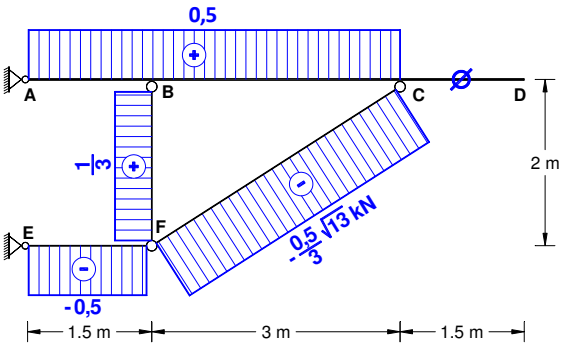
$$\theta_D = \int \frac{\bar{N}\times N}{E\,A}\,dz + \int \frac{\bar{M}\times M}{E\,I}\,dz + \sum \bar{N}\frac{N\,L}{E\,A}$$

$$\theta_D = 9{,}116\times10^{-5} + 6{,}284\times10^{-4} + 1{,}382\times10^{-3} = 2{,}102\times10^{-3}\ \text{rad}\ \circlearrowright$$

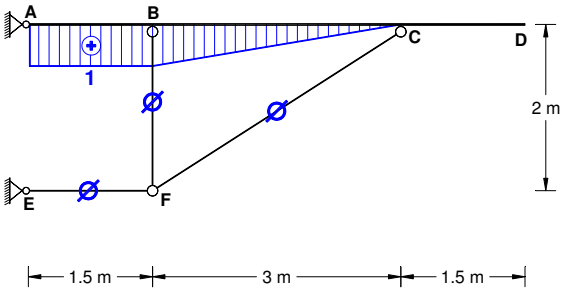
b) ROTAÇÃO DO PONTO A



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

Barra BC $\Rightarrow \quad M(z) = 1 - \frac{1}{3}z \quad \text{kNm}$

- **Aplicação do TTV**

$$\bar{1} \times \theta_A = \underbrace{\int \frac{\bar{N} \times N}{E\,A}\,dz + \int \frac{\bar{M} \times M}{E\,I}\,dz}_{\text{barras contínuas}} + \underbrace{\sum \bar{N} \frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int \frac{\bar{N} \times N}{E\,A}\,dz = \frac{1}{29 \times 10^6 \times 0{,}12} \times 0{,}5 \times 4{,}5 \times 141 = 9{,}116 \times 10^{-5} \text{ rad}$$

$$\int \frac{\bar{M} \times M}{E\,I}\,dz = \frac{1}{29 \times 10^6 \times 9 \times 10^{-4}} \left[\frac{102 \times 1{,}5 \times 1}{2} + \int_0^3 \left[(1 - \frac{1}{3}z) \times (102 - 34.z - 5z^2) \right] dz \right] =$$

$$= \frac{1}{26100} \left[76{,}5 + \int_0^3 (\frac{5}{3}z^3 + \frac{19}{3}z^2 - 68.z + 102)\,dz \right] =$$

$$= \frac{1}{26100} \left(76{,}5 + \frac{5}{12}3^4 + \frac{19}{9}3^3 - \frac{68}{2} \times 3^2 + 102 \times 3 \right) = 6{,}408 \times 10^{-3} \text{ rad}$$

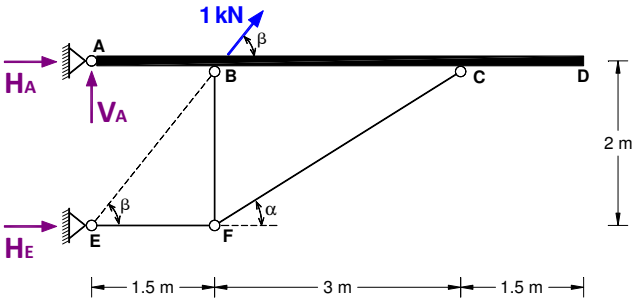
$$\sum \bar{N} \frac{N\,L}{E\,A} = \frac{1}{206 \times 10^6 \times 1{,}9 \times 10^{-3}} \left[-141 \times (-0{,}5) \times 1{,}5 + 102 \times \frac{1}{3} \times 2 - 47\sqrt{13} \times (-\frac{0{,}5}{3}\sqrt{13}) \times \sqrt{13} \right] =$$

$$= 1{,}382 \times 10^{-3} \text{ rad}$$

$$\theta_A = \int \frac{\bar{N} \times N}{E\,A}\,dz + \int \frac{\bar{M} \times M}{E\,I}\,dz + \sum \bar{N} \frac{N\,L}{E\,A} = 9{,}116 \times 10^{-5} + 6{,}408 \times 10^{-3} + 1{,}382 \times 10^{-3} = 7{,}881 \times 10^{-3} \text{ rad} \quad \circlearrowright$$

c) DESLOCAMENTO RELATIVO E-B

Como o ponto **E** está fixo (apoio sem assentamento), o deslocamento relativo dos pontos **E** e **B** ($\delta_{E\text{-}B}$) será igual ao deslocamento do ponto **B** na direcção **EB** ($\delta_{B\text{-}dir\,\overline{EB}}$).



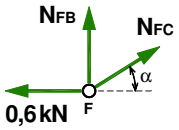
$$\text{tg}\,\beta = \frac{2}{1{,}5} \Rightarrow \beta = \text{arctg}\,\frac{2}{1{,}5} = 53{,}13^\circ$$

$$\beta \begin{cases} \cos\beta = 0{,}6 \\ \text{sen}\,\beta = 0{,}8 \end{cases}$$

$$\begin{cases} \sum F_X = 0 \Rightarrow H_A + H_E + 1\times\cos\beta = 0 \\ \sum F_Y = 0 \Rightarrow V_A + 1\times\text{sen}\,\beta = 0 \\ \sum M_A = 0 \Rightarrow H_E\times 2 + 1\times\text{sen}\,\beta\times 1{,}5 = 0 \end{cases} \Rightarrow \begin{cases} H_A = 0 \\ V_A = -0{,}8\ \text{kN}\ \downarrow \\ H_E = -0{,}6\ \text{kN}\ \leftarrow \end{cases}$$

Nó E Barra EF $\Rightarrow$ N_{EF} = 0,6 kN (tracção)

Nó F

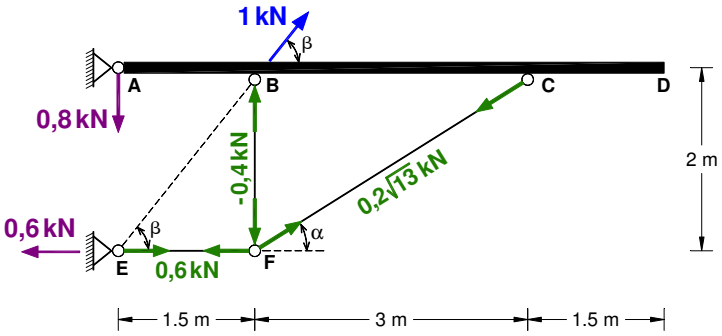


$$\text{tg}\,\alpha = \frac{2}{3} \Rightarrow \alpha = \text{arctg}\,\frac{2}{3} = 33{,}69^\circ \Rightarrow \begin{cases} \cos\alpha = \dfrac{3}{\sqrt{13}} \\ \text{sen}\,\alpha = \dfrac{2}{\sqrt{13}} \end{cases}$$

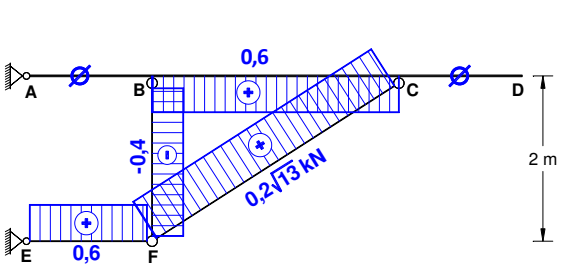
$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases}$$

$$\begin{cases} N_{FC}\cos\alpha - 0{,}6 = 0 \\ N_{FB} + N_{FC}\,\text{sen}\,\alpha = 0 \end{cases}$$

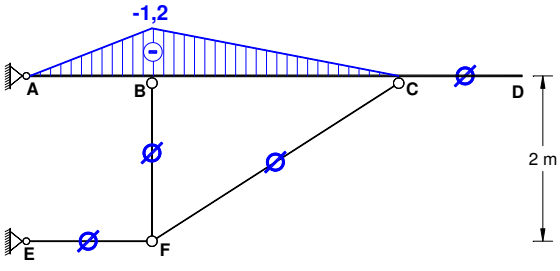
$$\begin{cases} N_{FC} = 0{,}2\sqrt{13}\ \text{kN}\ \text{(tracção)} \\ N_{FB} = -0{,}4\ \text{kN}\ \text{(compressão)} \end{cases}$$



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

Barra BC $\Rightarrow$ $M(z) = -1{,}2 + 0{,}4\,z$ kNm

- **Aplicação do Teorema dos Trabalhos Virtuais (TTV)**

$$\overline{1}\times\delta_{B\text{-dir}\,\overline{EB}} = \underbrace{\int\frac{\overline{N}\times N}{E\,A}dz + \int\frac{\overline{M}\times M}{E\,I}dz}_{\text{barras contínuas}} + \underbrace{\sum\overline{N}\frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int\frac{\overline{N}\times N}{E\,A}dz = \frac{1}{29\times10^{6}\times0{,}12}\times0{,}6\times3\times141 = 7{,}293\times10^{-5}\ \text{m}$$

$$\int\frac{\overline{M}\times M}{E\,I}dz = \frac{1}{29\times10^{6}\times9\times10^{-4}}\left[\frac{102\times(-1{,}2)\times1{,}5}{3} + \int_{0}^{3}\left[(-1{,}2+0{,}4\,z)\times(102-34\,.\,z-5z^{2})\right]dz\right] =$$

$$= \frac{1}{26100}\left[-61{,}2+\int_{0}^{3}(-2z^{3}-7{,}6\,z^{2}+81{,}6\,.\,z-122{,}4)\,dz\right] =$$

$$= \frac{1}{26100}\left(-61{,}2 - \frac{2}{4}3^{4} - \frac{7{,}6}{3}3^{3} + \frac{81{,}6}{2}\times3^{2} - 122{,}4\times3\right) = -6{,}517\times10^{-3}\ \text{m}$$

$$\sum\overline{N}\frac{N\,L}{E\,A} = \frac{1}{206\times10^{6}\times1{,}9\times10^{-3}}\left[-141\times0{,}6\times1{,}5 + 102\times(-0{,}4)\times2 - 47\sqrt{13}\times0{,}2\sqrt{13}\times\sqrt{13}\right] =$$

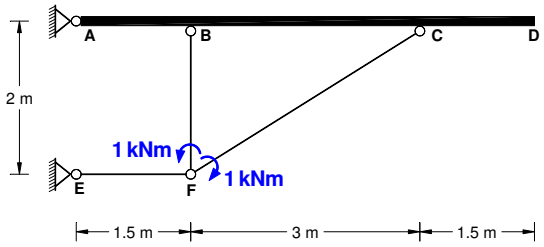
$$= -1{,}658\times10^{-3}\ \text{m}$$

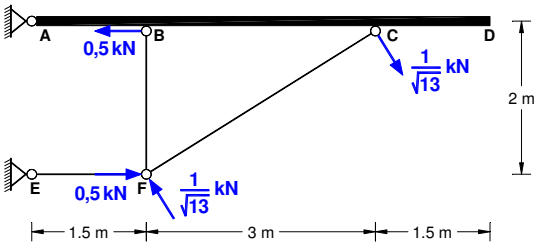
$$\delta_{B\text{-dir}\,\overline{EB}} = \int\frac{\overline{N}\times N}{E\,A}dz + \int\frac{\overline{M}\times M}{E\,I}dz + \sum\overline{N}\frac{N\,L}{E\,A}$$

$$\delta_{B\text{-dir}\,\overline{EB}} = 7{,}293\times10^{-5} - 6{,}517\times10^{-3} - 1{,}658\times10^{-3} = -8{,}102\times10^{-3}\ \text{m}$$

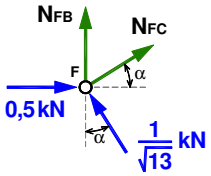
$\delta_{E\text{-}B} = \delta_{B\text{-dir}\,\overline{EB}} = -8{,}102$ mm (os pontos **E** e **B** aproximaram-se)

d) VARIAÇÃO DO ÂNGULO BFC





Nó F

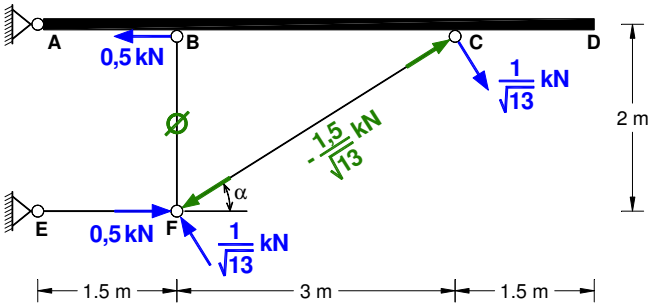


$$\text{tg}\,\alpha = \frac{2}{3} \Rightarrow \alpha = \text{arctg}\,\frac{2}{3} = 33{,}69^\circ \Rightarrow \begin{cases} \cos\alpha = \dfrac{3}{\sqrt{13}} \\ \text{sen}\,\alpha = \dfrac{2}{\sqrt{13}} \end{cases}$$

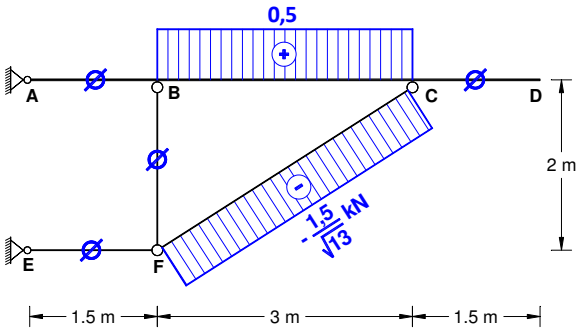
$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases}$$

$$\begin{cases} N_{FC}\cos\alpha + 0{,}5 - \dfrac{1}{\sqrt{13}}\,\text{sen}\,\alpha = 0 \\ N_{FB} + N_{FC}\,\text{sen}\,\alpha + \dfrac{1}{\sqrt{13}}\cos\alpha = 0 \end{cases}$$

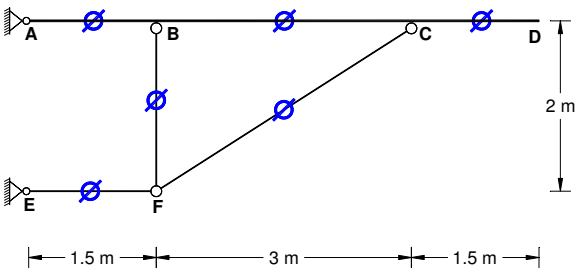
$$\begin{cases} N_{FC} = -\dfrac{1{,}5}{\sqrt{13}}\ \text{kN} \quad \text{(compressão)} \\ N_{FB} = 0 \end{cases}$$



- **Diagramas de Esforços – sistema virtual**



ESFORÇO AXIAL (kN)



MOMENTO FLECTOR (kNm)

- **Aplicação do Teorema dos Trabalhos Virtuais (TTV)**

$$\bar{1}\times\Delta\varphi_{BFC} = \underbrace{\int\frac{\bar{N}\times N}{E\,A}dz + \int\frac{\bar{M}\times M}{E\,I}dz}_{\text{barras contínuas}} + \underbrace{\sum\bar{N}\frac{N\,L}{E\,A}}_{\text{barras bi-articuladas}}$$

$$\int\frac{\bar{N}\times N}{E\,A}dz = \frac{1}{29\times10^{6}\times0{,}12}\times0{,}5\times3\times141 = 6{,}078\times10^{-5}\ \text{rad}$$

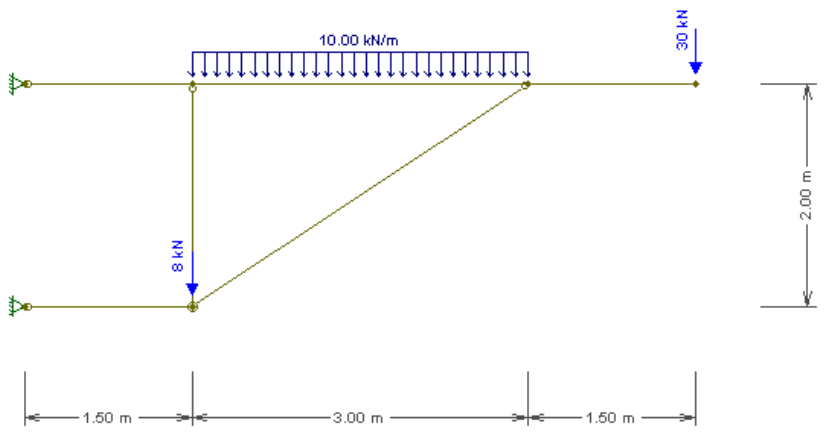
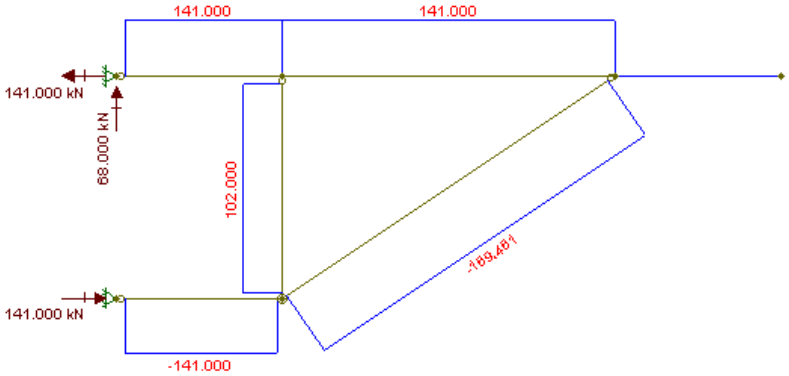
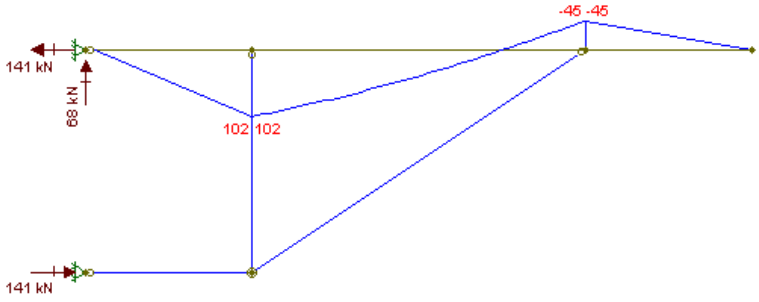
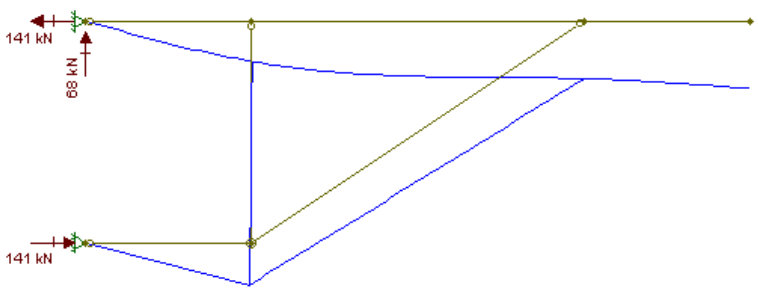
$$\int\frac{\bar{M}\times M}{E\,I}dz = 0$$

$$\sum\bar{N}\frac{N\,L}{E\,A} = \frac{-47\sqrt{13}\times(-\frac{1{,}5}{\sqrt{13}})\times\sqrt{13}}{206\times10^{6}\times1{,}9\times10^{-3}} = 6{,}494\times10^{-4}\ \text{rad}$$

$$\Delta\varphi_{BFC} = \int\frac{\bar{N}\times N}{E\,A}dz + \int\frac{\bar{M}\times M}{E\,I}dz + \sum\bar{N}\frac{N\,L}{E\,A}$$

$\Delta\varphi_{BFC} = 6{,}078\times10^{-5} + 6{,}494\times10^{-4} = 7{,}102\times10^{-4}$ rad (o ângulo **BFC** aumentou)

e) PROGRAMA FTOOL

GEOMETRIA	
ESFORÇO TRANSVERSO (kN)	
MOMENTO FLECTOR (kNm)	
DEFORMADA	

Deslocamentos e rotações obtidos com o programa FTOOL

Deslocamento e rotação do ponto **D** Sentidos positivos: 	Node Results Nodal Displacements: Dx = 1.823e-002 cm Dy = -1.729e+000 cm Rz = -2.105e-003 rad
Rotação do ponto **A** Sentidos positivos: 	Member Displacements and Rotations **Init:** Dx: 0.000e+000 cm Dy: 0.000e+000 cm **Rz: -7.881e-003 rad** End: Dx: 6.078e-003 cm Dy: -1.036e+000 cm Rz: -4.950e-003 rad