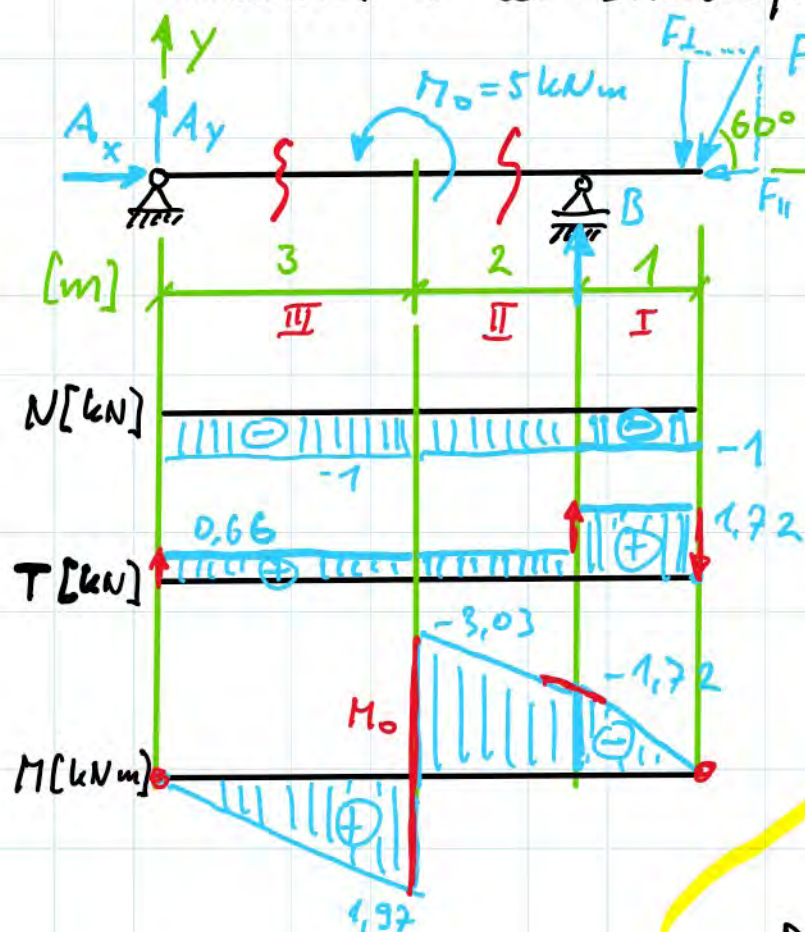


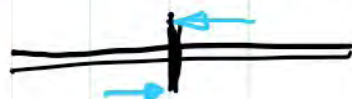
N, T, M - vaje

1) Izračunajte potek osne in prečne sile ter upogibnega momenta v levi strukturi! (N, T, M?)



$$F_H = F \cdot \cos 60^\circ = 1 \text{ kN}$$

$$F_V = F \cdot \sin 60^\circ = 1.732 \text{ kN}$$



Reakcije:

$$x: A_x - F_H = 0$$

$$A_x = F_H = 1 \text{ kN}$$

$$y: A_y + B - F_V = 0$$

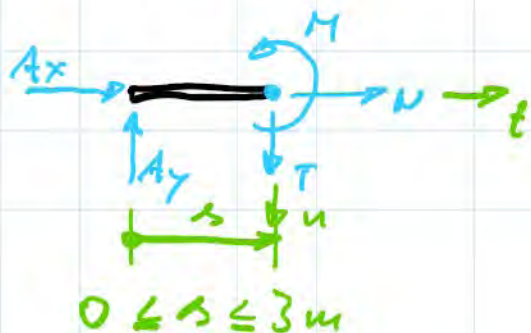
$$M_A: +B \cdot 5 + M_0 \cdot 3 - F_V \cdot 6 = 0$$

$$B = \frac{1}{5} (F_V \cdot 6 - M_0 \cdot 3) = \frac{1}{5} (1.732 \cdot 6 - 5)$$

$$B = 1.064 \text{ kN}$$

$$A_y = F_V - B = 0.668 \text{ kN}$$

III. polje



$$\sum F_{ix} = 0; \quad A_x + N = 0$$

$$N = -A_x = -1 \text{ kN}$$

$$\sum F_{iy} = 0; \quad A_y - T = 0;$$

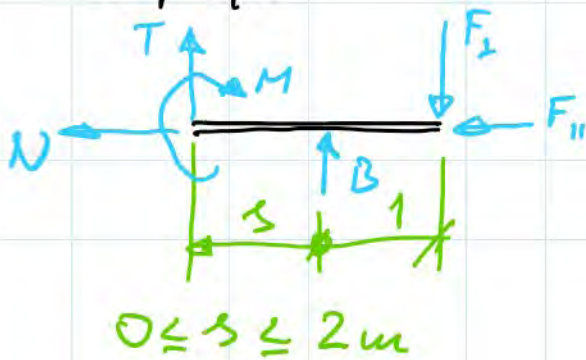
$$T = A_y = 0.668 \text{ kN}$$

$$\sum M_{j_b} = 0; \quad M - A_y \cdot s = 0$$

$$M(0) = 0$$

$$M(3) = 0.668 \cdot 3 = 1.968 \text{ kNm}$$

II. polje



$$t: N + F_{II} = 0$$

$$n: -F_I + T + B = 0$$

$$b: M - B \cdot s + F_I \cdot (s+1) = 0$$

$$M = -F_I \cdot s + B \cdot s - F_I \cdot 1$$

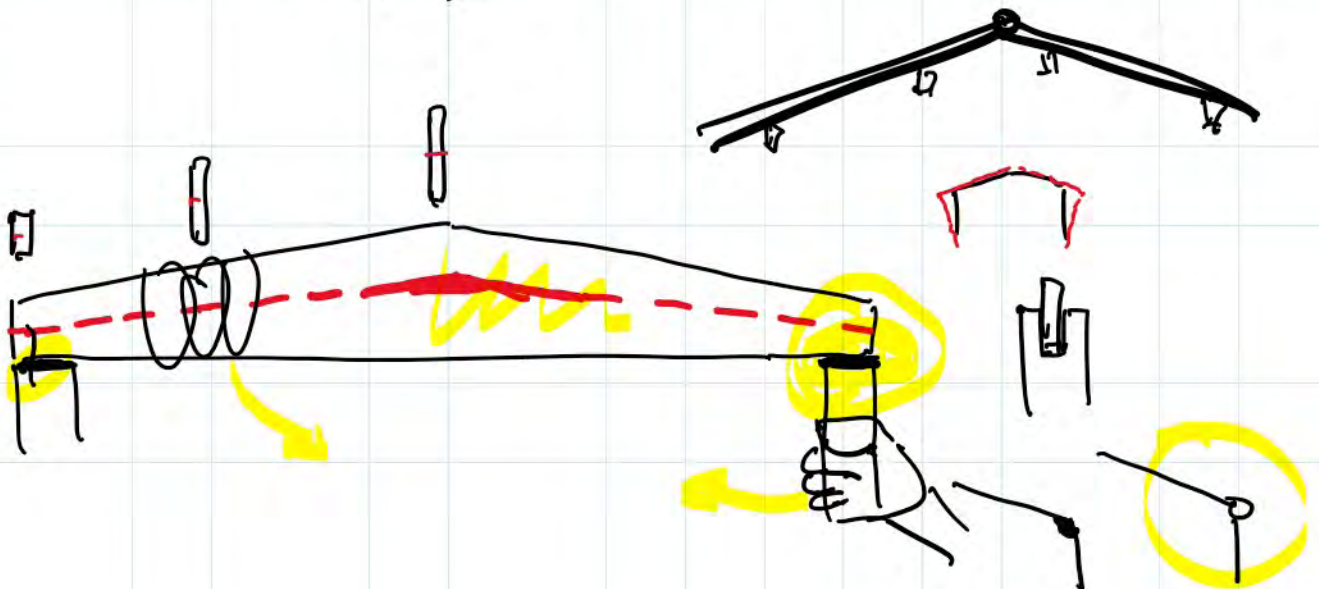
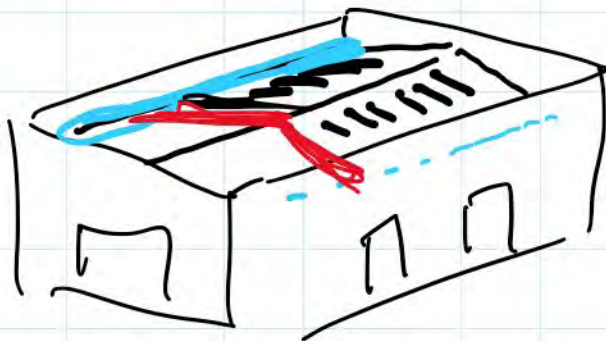
$$M = (B - F_I) \cdot s - F_I \cdot 1$$

$$M = -0,686 \cdot s - 1,72 \cdot 1$$

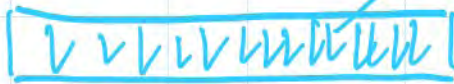
$$M(0) = -1,72 \text{ kNm}$$

$$M(2) = -3,032 \text{ kNm}$$

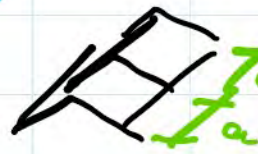
2) $N, T, M = ?$



$$q = 6 \text{ kN/m}$$



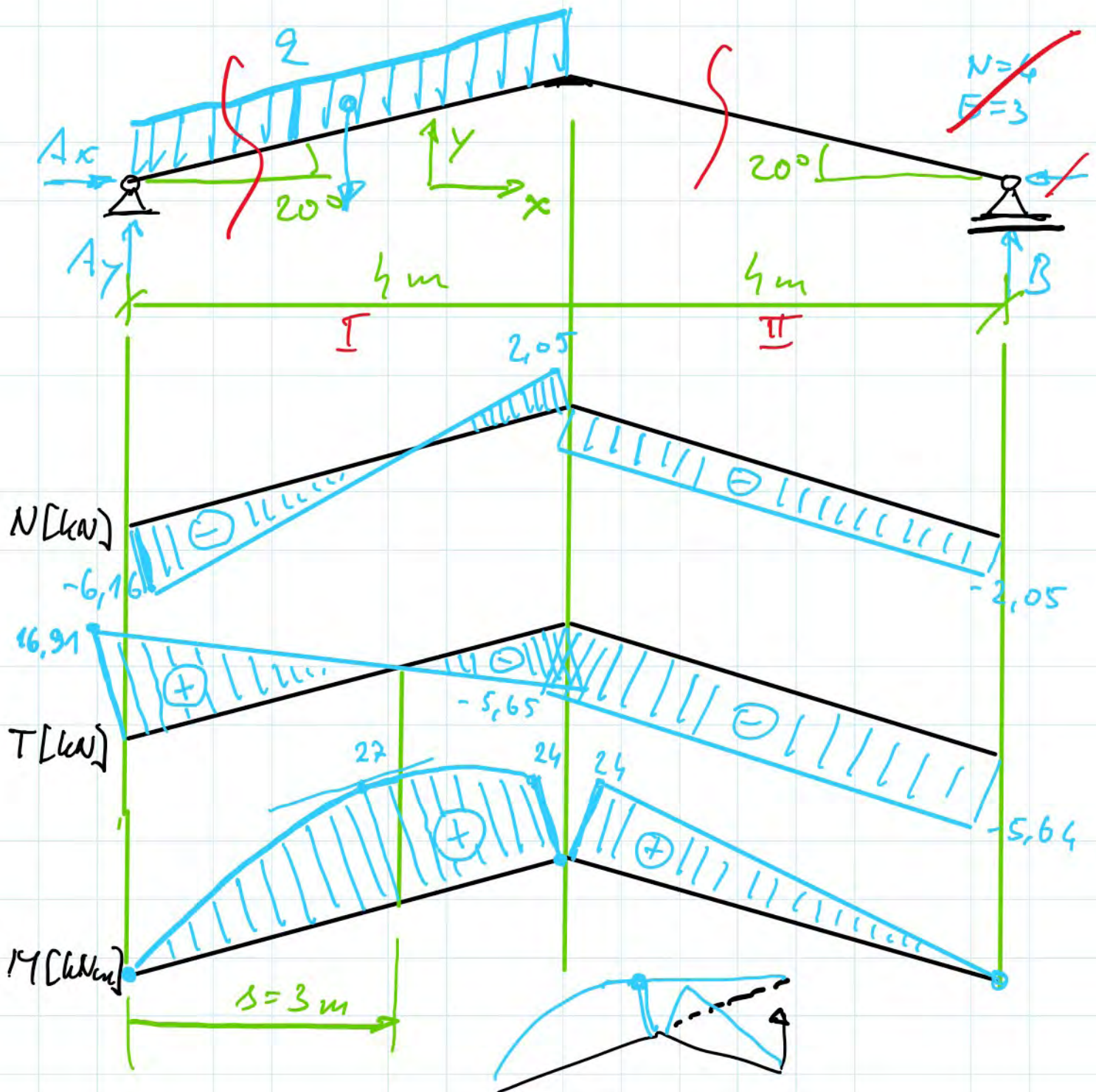
$$q_{\text{snow, lin}} = q_{\text{snow}} \cdot a$$



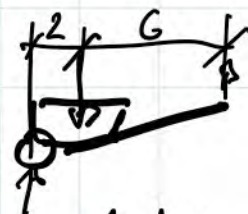
$$q_{\text{snow}} \approx 1700 \text{ N/m}^2$$

$$\rho_{\text{snow}} \approx 360 \text{ kg/m}^3$$

$$\approx 400 \text{ kg/m}^3$$



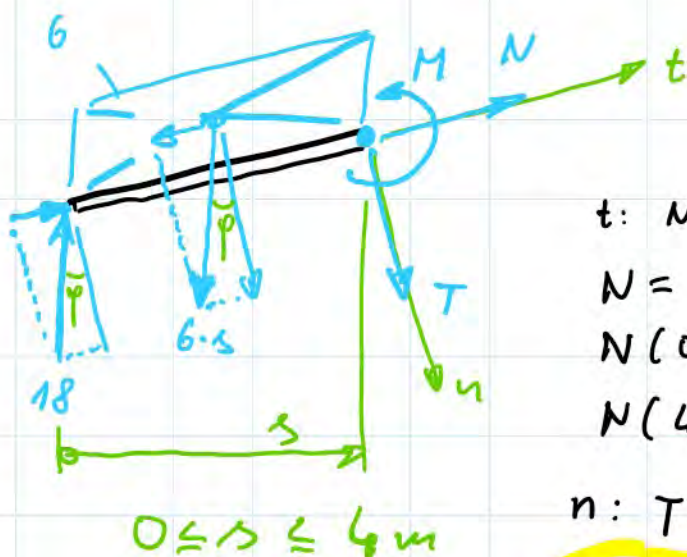
Reakcije: $A_x = 0$
 $A_y + B - q \cdot 4 = 0$
 $M_A: 2 \cdot 4 \cdot 2 - B \cdot 8 = 0$
 $B = 6 \text{ kN}$
 $A_y = 18 \text{ kN}$



Arhimedovo
vzvodno pravilo

I. polje

$\varphi = 20^\circ$



$t: N + 18 \cdot \sin 20^\circ - 6 \cdot s \sin 20^\circ = 0$

$N = 2,052 \cdot s - 6,156$

$N(0) = -6,156 \text{ kN}$

$N(4) = 2,052 \text{ kN}$

$n: T - 18 \cdot \cos 20^\circ + 6 \cdot s \cdot \cos 20^\circ = 0$

$T = -5,638 s + 16,91$

$T(0) = 16,91 \text{ kN}$

$T(4) = -5,65 \text{ kN}$

$b: M - 18 \cdot s + 6 \cdot s \cdot \frac{s}{2} = 0 ; M = -3s^2 + 18s$

$\frac{dM}{ds} = -6s + 18 = 0$

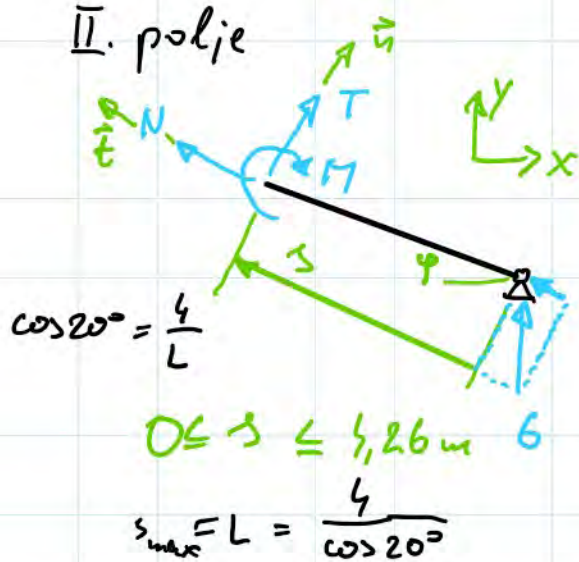
$s = \frac{18 \text{ m kN}}{6 \text{ kN}} = 3 \text{ m}$

$M(0) = 0$

$M(4) = -3 \cdot 4^2 + 18 \cdot 4 = 24 \text{ kNm}$

$M(3) = -3 \cdot 3^2 + 18 \cdot 3 = 27 \text{ kNm}$

II. polje



$$n: N + 6 \cdot \sin 20^\circ = 0 ; N = -2,05 \text{ kN}$$

$$t: T + 6 \cdot \cos 20^\circ = 0 ; T = -5,638 \text{ kN}$$

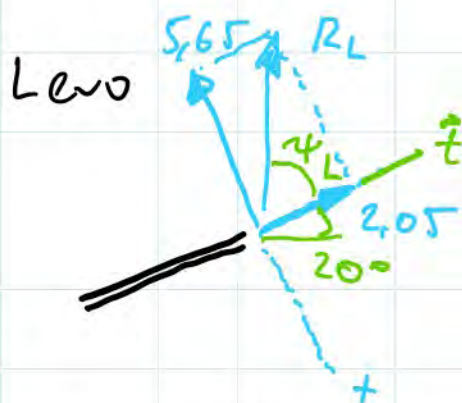
$$b: M - 6 \cdot \cos 20^\circ \cdot s = 0$$

$$M = 5,638 \cdot s$$

$$M(0) = 0$$

$$M(4,26) = 24,02 \text{ kNm}$$

Dodatek: dokažite ravnotežje sil v sklepu!



$$R_L = \sqrt{2,05^2 + 5,65^2}$$

$$R_L = 6,007 \text{ kN}$$

$$\tan \varphi_L = \frac{5,65}{2,05}$$

$$\varphi_L = 70^\circ$$



$$R_D = \sqrt{2,05^2 + 5,64^2} = 6,01 \text{ kN}$$

$$\tan \varphi_D = \frac{5,64}{2,05}$$

$$\varphi_D = 70^\circ$$

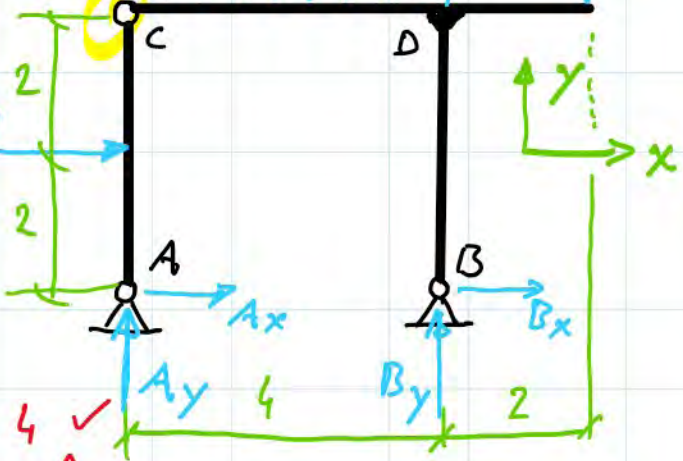
3) $N, T, M \dots$?

[m]

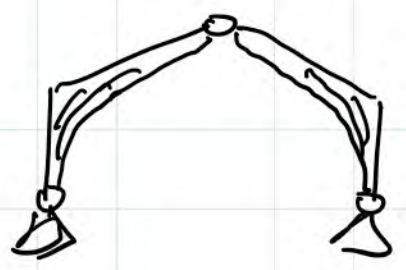
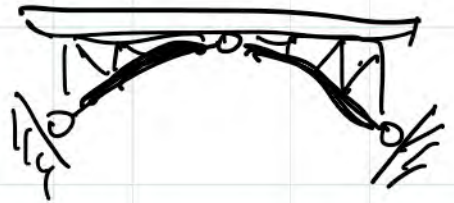
$$q = 0,125 \text{ kN/m}$$

$$F_1 = 1 \text{ kN}$$

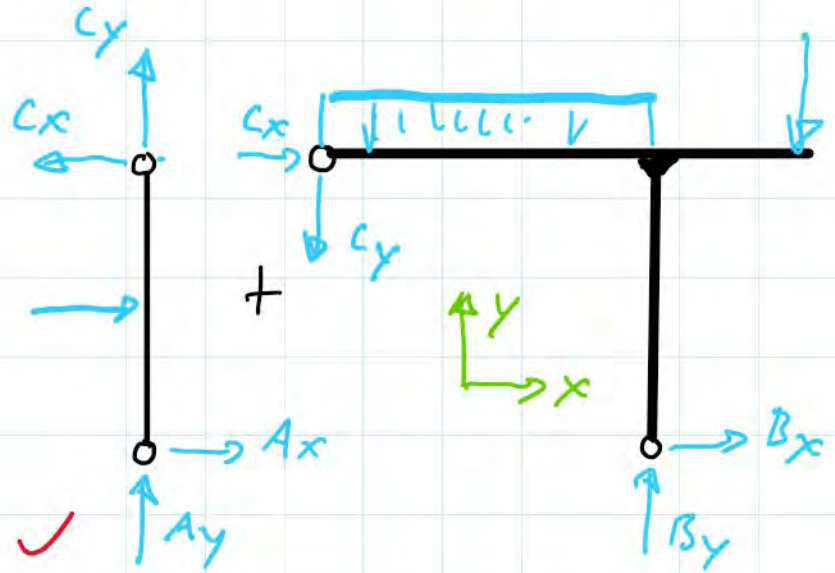
$$F_2 = 2 \text{ kN}$$



Nelzu: 4 ✓
Euaib: 3 ↑



⇒



Nelzu: 6
Euaib: 3 + 3 ✓

Levo:

$$A_x - C_x + F_2 = 0 \quad 2a$$

$$A_y + C_y = 0 \quad 3a$$

$$A: -F_2 \cdot 2 + C_x \cdot 4 = 0 \quad 1$$

$$\begin{aligned} A_x &= -1 \text{ kN} \\ B_x &= -1 \text{ kN} \\ C_x &= 1 \text{ kN} \end{aligned}$$

Deswo

$$B_x + C_x = 0 \quad 2b$$

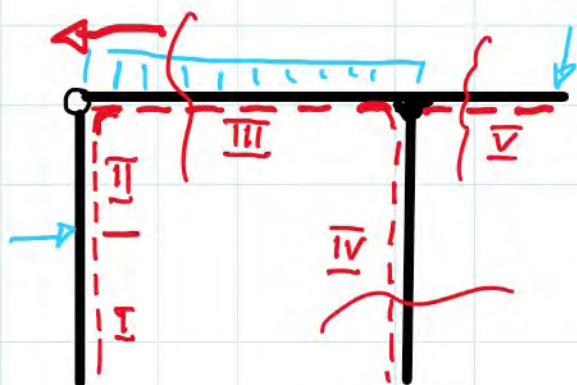
$$-C_y + B_y - F_1 - q \cdot 4 = 0 \quad 3b$$

$$B: -C_x \cdot 4 + q \cdot 4 \cdot 2 - F_1 \cdot 2 + C_y \cdot 4 = 0 \quad 2c$$

$$\begin{aligned} A_y &= -1,25 \text{ kN} \\ B_y &= 2,75 \text{ kN} \\ C_y &= +1,25 \text{ kN} \end{aligned}$$

Izračun N, T, M :

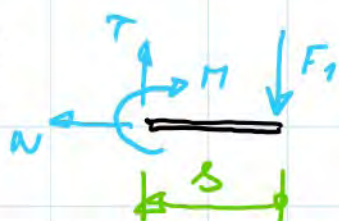
Razdelitev na polja



----- spodnja stran nosilca

V polje:

$$0 \leq s \leq 2m$$



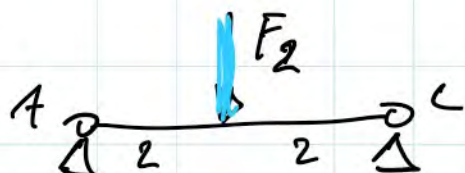
0/0/0/0/0

IV polje:

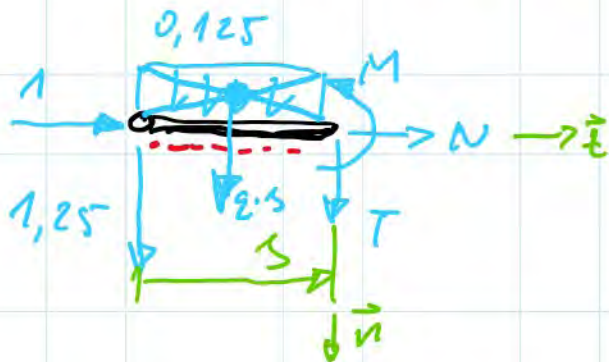
$$0 \leq s \leq 4m$$



I in II polje:



III polje $0 \leq s \leq 4\text{m}$



$$\text{c: } 1 + N = 0 ; N = -1\text{ kN}$$

$$\text{u: } 1,25 + T + 0,125 \cdot s = 0$$

$$T = -0,125s - 1,25$$

$$T(s=0) = -1,25\text{ kN}$$

$$T(s=4) = -1,75\text{ kN}$$

$$\text{b: } M + 1,25 \cdot s + 0,125 \cdot s \cdot \frac{s}{2} = 0$$

$$M = -\frac{0,125}{2} s^2 - 1,25s$$

$$M(0) = 0$$

$$M(4) = -1 - 5 = -6\text{ kNm}$$

$$\frac{dM}{ds} = -0,125 \cdot s - 1,25 = 0$$



$$\frac{dM}{ds} = T \dots \text{v ekstremum} = 0$$

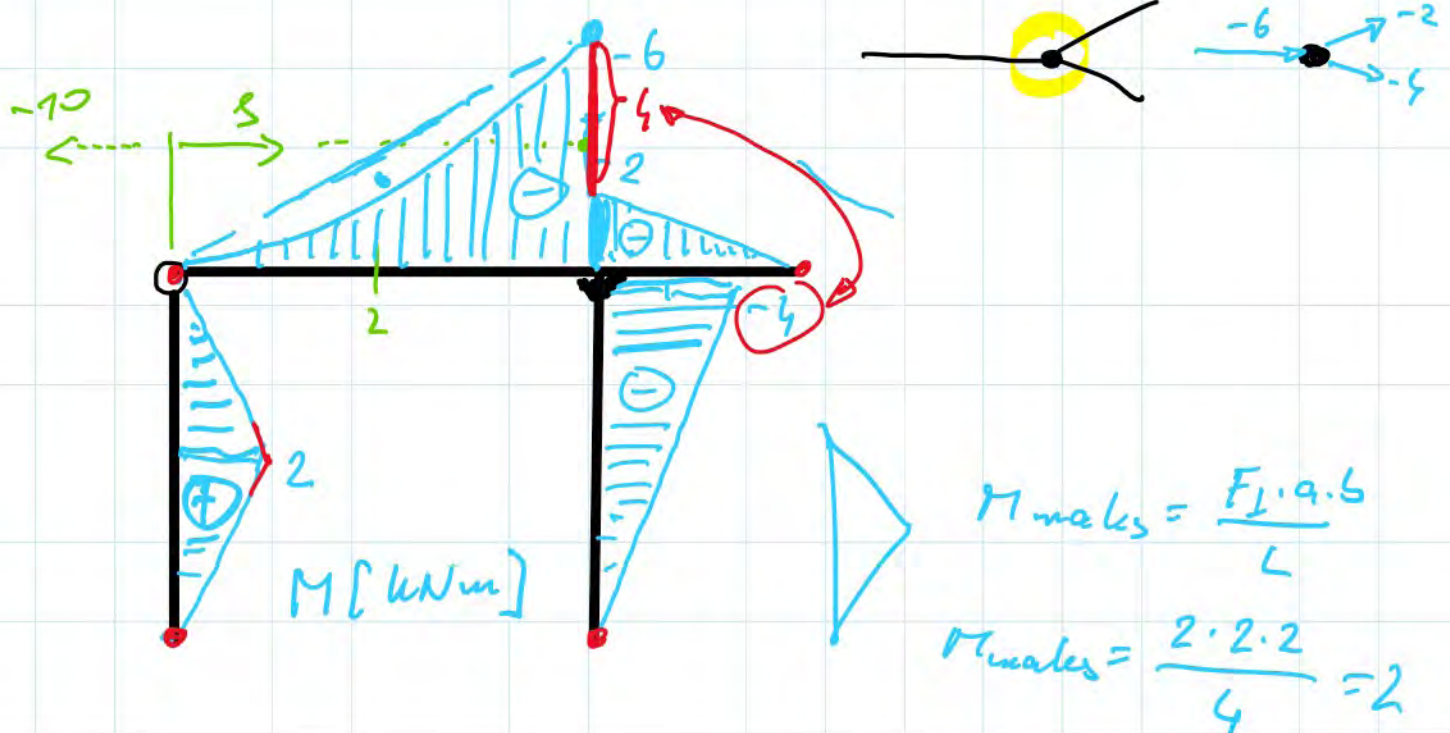
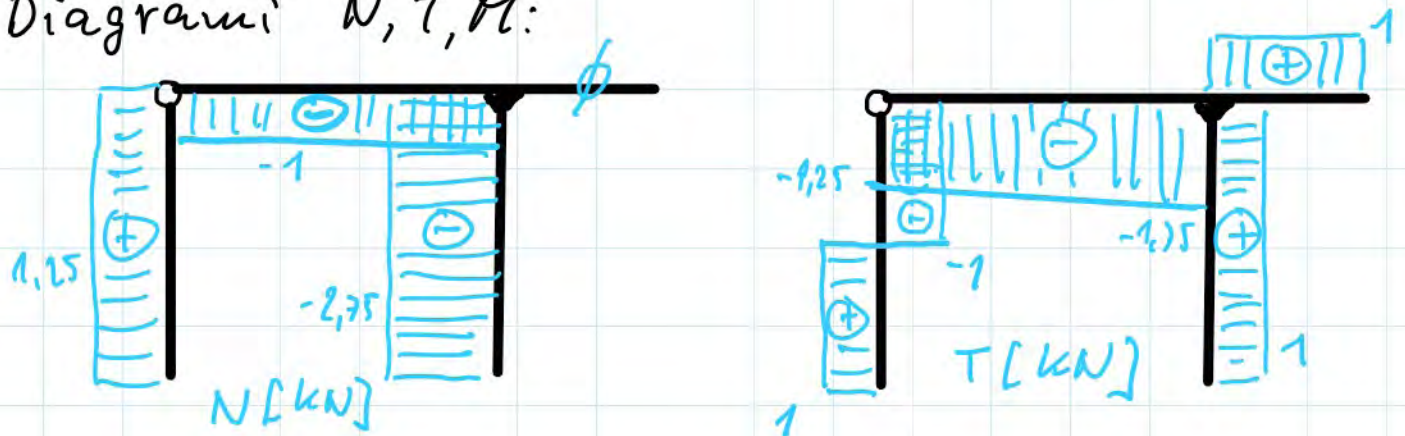
$$0,125 \cdot s = -1,25$$

$$s = -\frac{1,25}{0,125} = -10\text{ m}$$



$$M(2) = -\frac{1}{4} - 2,5 = -2,75\text{ kNm}$$

Diagrami N, T, M:



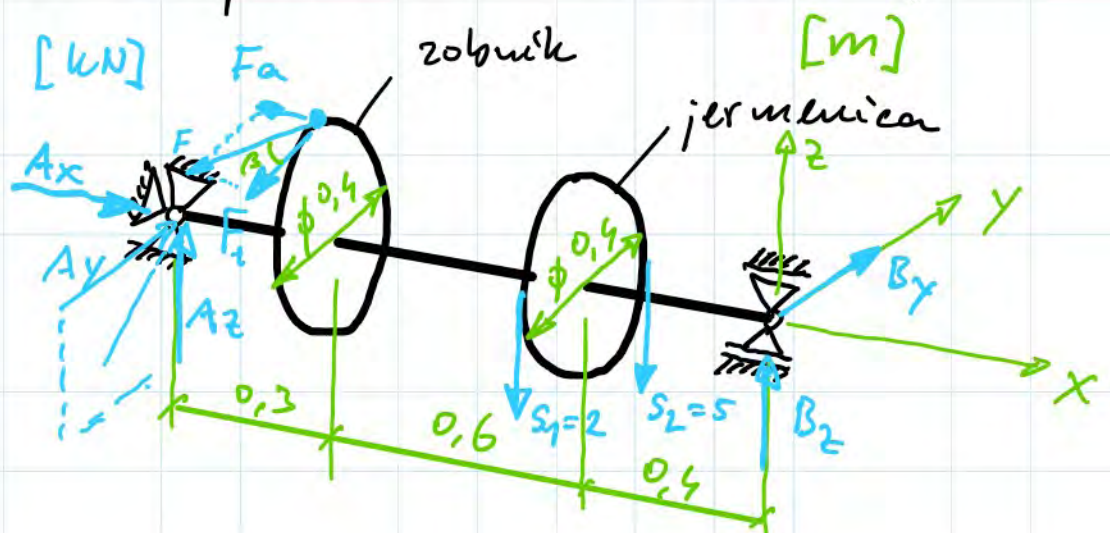
4) N, T, M ~ prostorski konstrukciji

$$\beta = 15^\circ$$

$$\frac{F_t}{F} = \cos \beta$$

$$\frac{F_a}{F} = \sin \beta$$

$$\tan \beta = \frac{F_a}{F_t}$$



$N = 5 + 1$
 $E = 6$

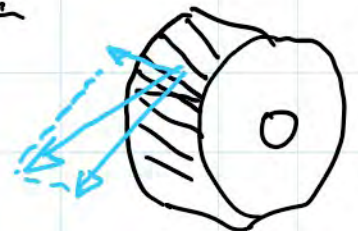
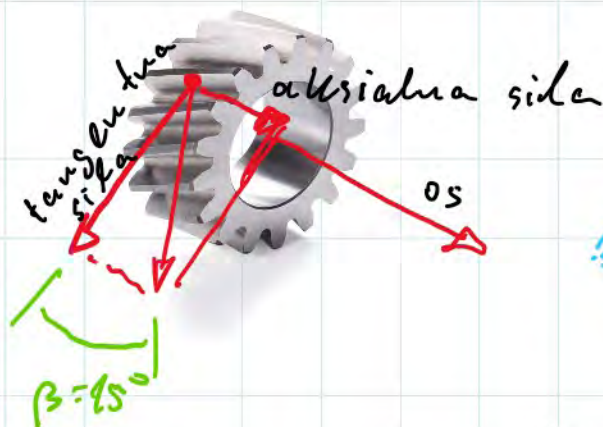
$N = E \dots$ statično določeni sistemi

$N > E \dots$ statično nedoločeni
 rešitev: frohwst

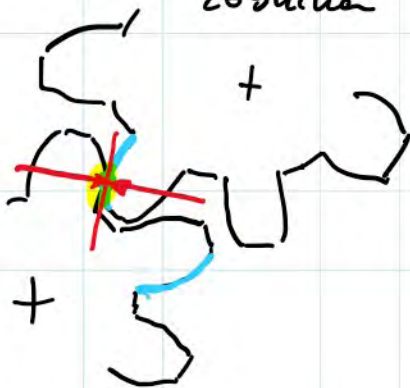
$N < E \dots$ statično predloženi
 rešitev: dinamika
 $F = m \cdot a$



zobnik s poševnim ozobljenjem



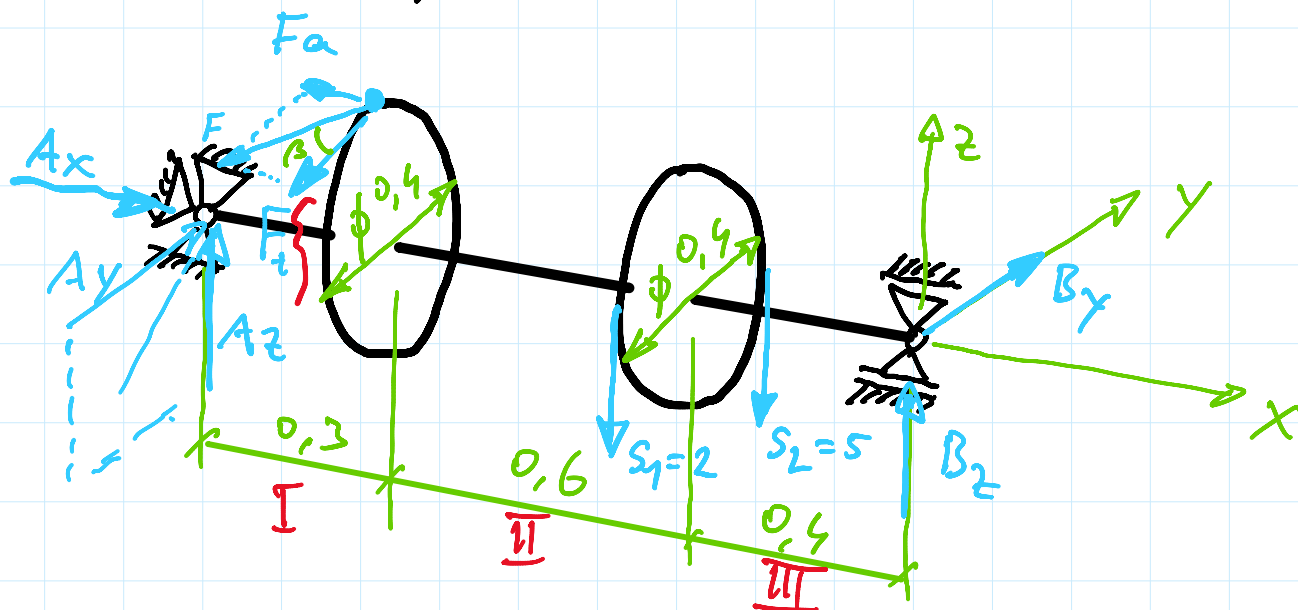
čelna zobnika



jernenica



Izračun reakcij:



$$\sum F_{ix} = 0; \quad A_x - F_a = 0$$

$$\sum F_{iy} = 0; \quad A_y - F_t + B_y = 0 \quad (3)$$

$$\sum F_{iz} = 0; \quad A_z - S_1 - S_2 + B_z = 0$$

$$\sum M_{ix} = 0; \quad F_t \cdot 0.2 + S_1 \cdot 0.2 - S_2 \cdot 0.2 = 0 \quad (1)$$

$$\sum M_{iy} = 0; \quad A_z \cdot 1.3 - S_1 \cdot 0.4 - S_2 \cdot 0.4 - F_a \cdot 0.2 = 0$$

$$\sum M_{iz} = 0; \quad -A_y \cdot 1.3 + F_t \cdot 1 = 0 \quad (2)$$

$$A_x = 0.803 \text{ kN} = F_a \quad F_t = 3 \text{ kN}$$

$$A_y = 2.307 \text{ kN}$$

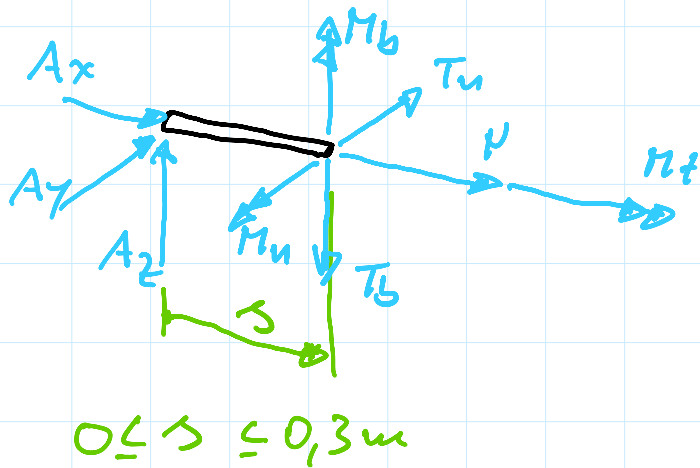
$$B_y = 0.692 \text{ kN}$$

$$A_z = 2.277 \text{ kN}$$

$$B_z = 4.723 \text{ kN}$$

Izračun N, T, M po posameznih poljih:

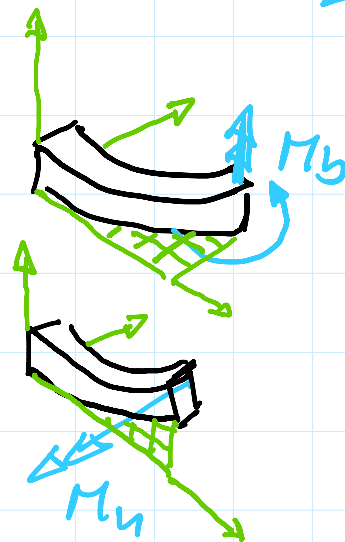
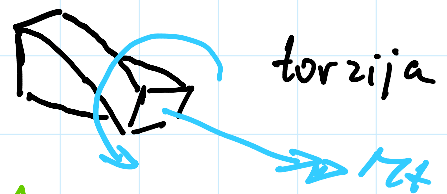
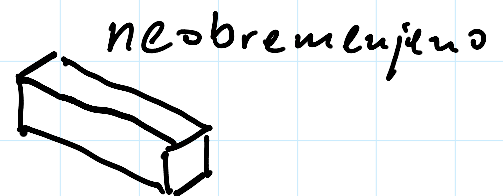
I. polje



upogib v horizontalni ravnini

upogib v vertikalni ravnini

Delovanje navorov:



Ravnotežne enačbe:

$$N + A_x = 0 ; N = -0,803 \text{ kN}$$

$$T_n + A_y = 0 ; T_n = -2,307 \text{ kN}$$

$$T_b - A_z = 0 ; T_b = 2,277 \text{ kN}$$

$$M_t = 0$$

$$M_n - A_z \cdot s = 0 ; M_n = 2,277 \cdot s$$

$$M_n(0) = 0$$

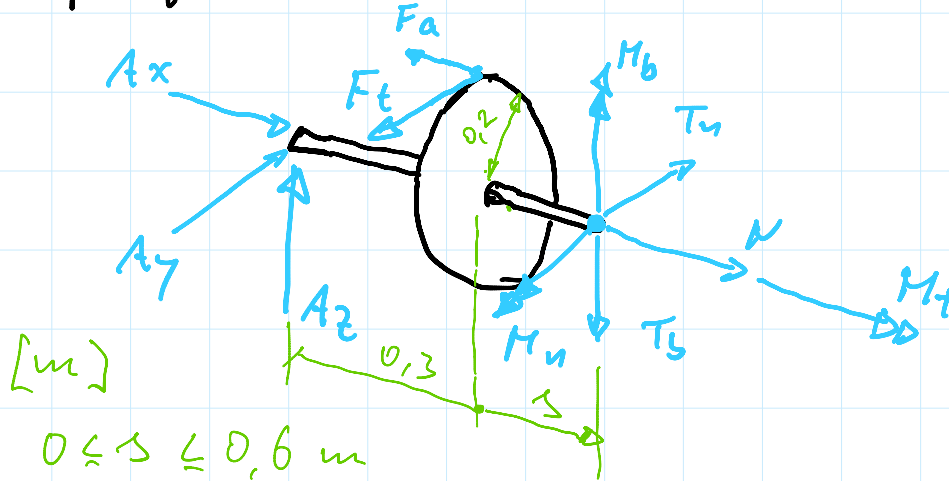
$$M_n(0,3) = 0,683 \text{ kNm}$$

$$M_b - A_y \cdot s = 0 ; \quad M_b = 2,307 \cdot s$$

$$M_b(0) = 0$$

$$M_b(0,3) = 0,692 \text{ kNm}$$

II polje



$$A_x - F_a + N = 0 ; \quad N = 0$$

$$T_n + A_y - F_t = 0 ; \quad T_n = -2,307 + 3 = 0,693 \text{ kN}$$

$$T_b - A_z = 0 ; \quad T_b = 2,277 \text{ kN}$$

$$M_t + F_t \cdot 0,2 = 0 ; \quad M_t = -3 \cdot 0,2 = -0,6 \text{ kNm}$$

$$M_n + F_a \cdot 0,2 - A_z(0,3 + s) = 0$$

$$M_n = A_z \cdot s + A_z \cdot 0,3 - F_a \cdot 0,2$$

$$M_n = 2,277 \cdot s + 2,307 \cdot 0,3 - 0,803 \cdot 0,2$$

$$M_n = 2,277 \cdot s + 0,5315 ; \quad M_n(0) = 0,531 \text{ kNm}$$

$$M_n(0,6) = 1,888 \text{ kNm}$$

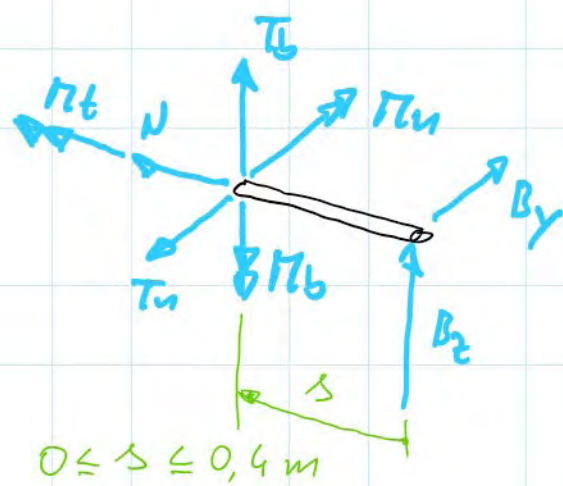
$$M_b + F_t \cdot s - A_y \cdot (0,3 + s) = 0$$

$$M_b = A_y \cdot s - F_t \cdot s + A_y \cdot 0,3$$

$$M_b = -0,693 \cdot s + 0,692 ; \quad M_b(0) = 0,692 \text{ kNm}$$

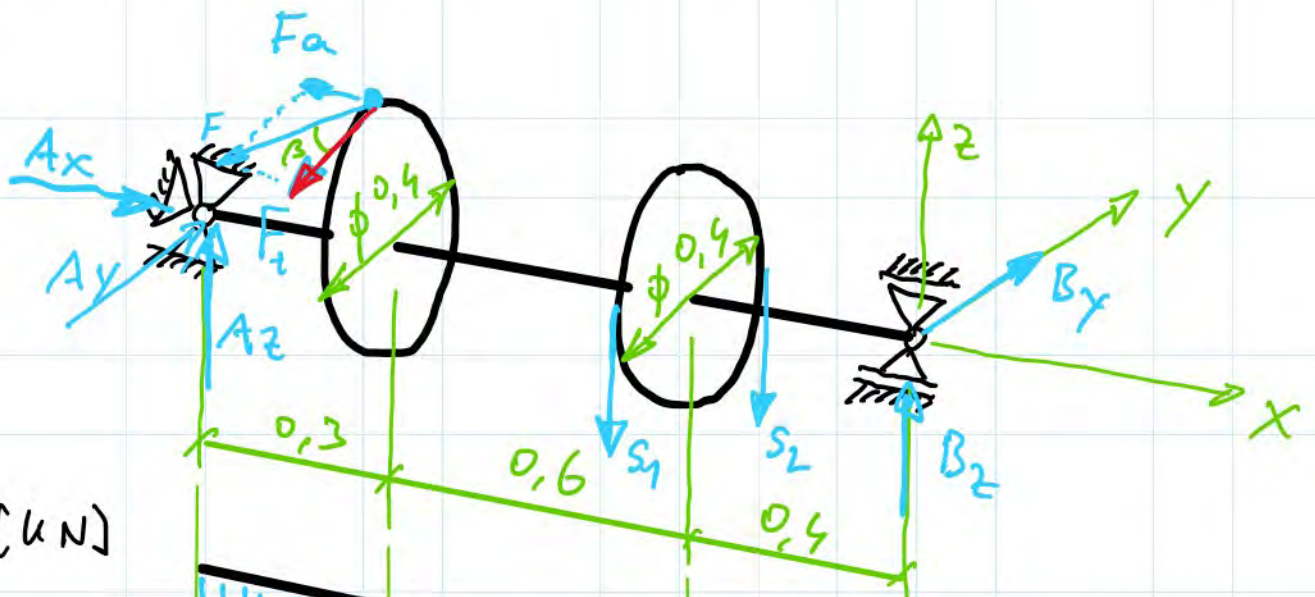
$$M_b(0,6) = 0,226 \text{ kNm}$$

III. polje



doma

Diagrami N, T, M :

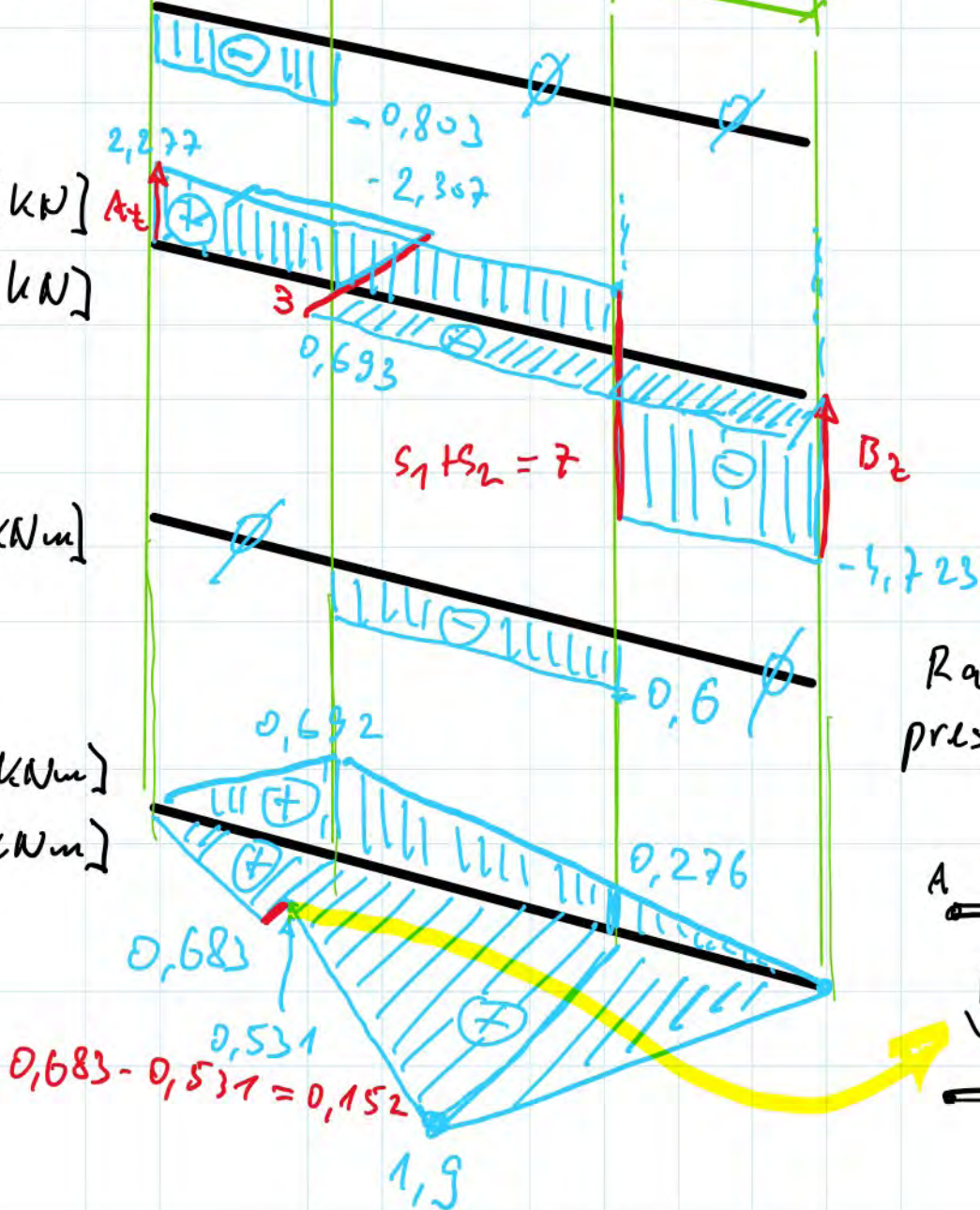


$N [kN]$

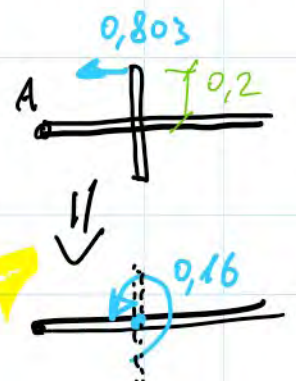
$T_n [kN]$
 $T_b [kN]$

$M_t [kNm]$

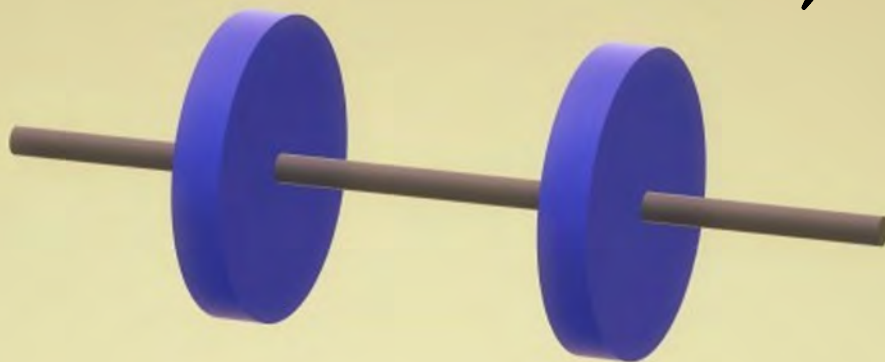
$M_n [kNm]$
 $M_b [kNm]$



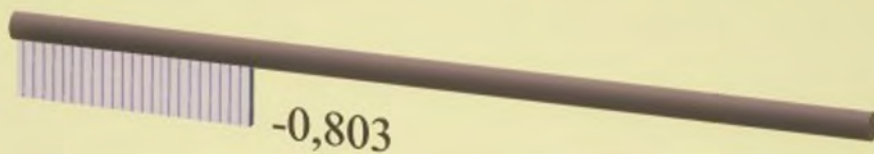
Razlog preskoka M_n :



Isti diagrami, narisani s pomočjo
Office 365 3D Viewer-ja

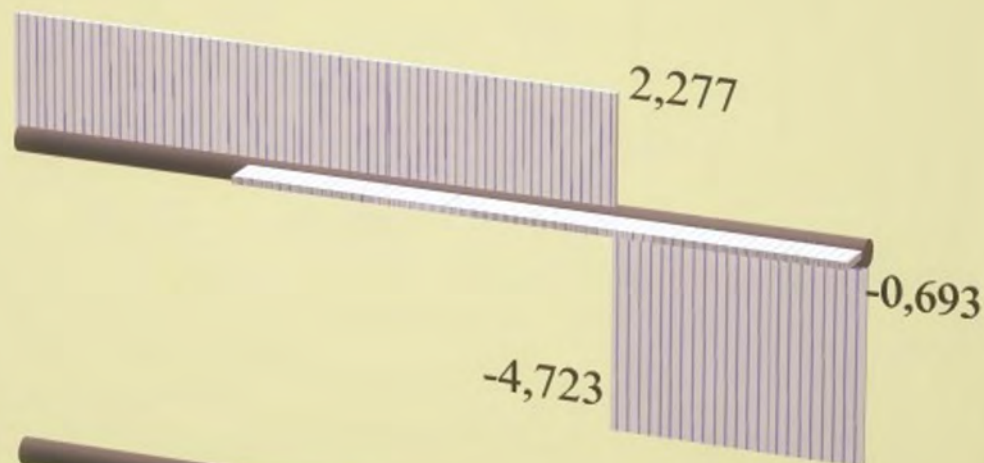


N [kN]

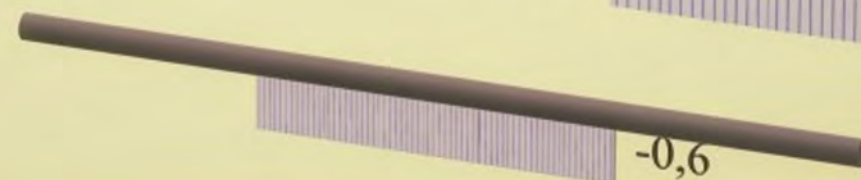


Tn [kN]

Tb [kN]



Mt [kNm]



Mn [kNm]

Mb [kNm]

