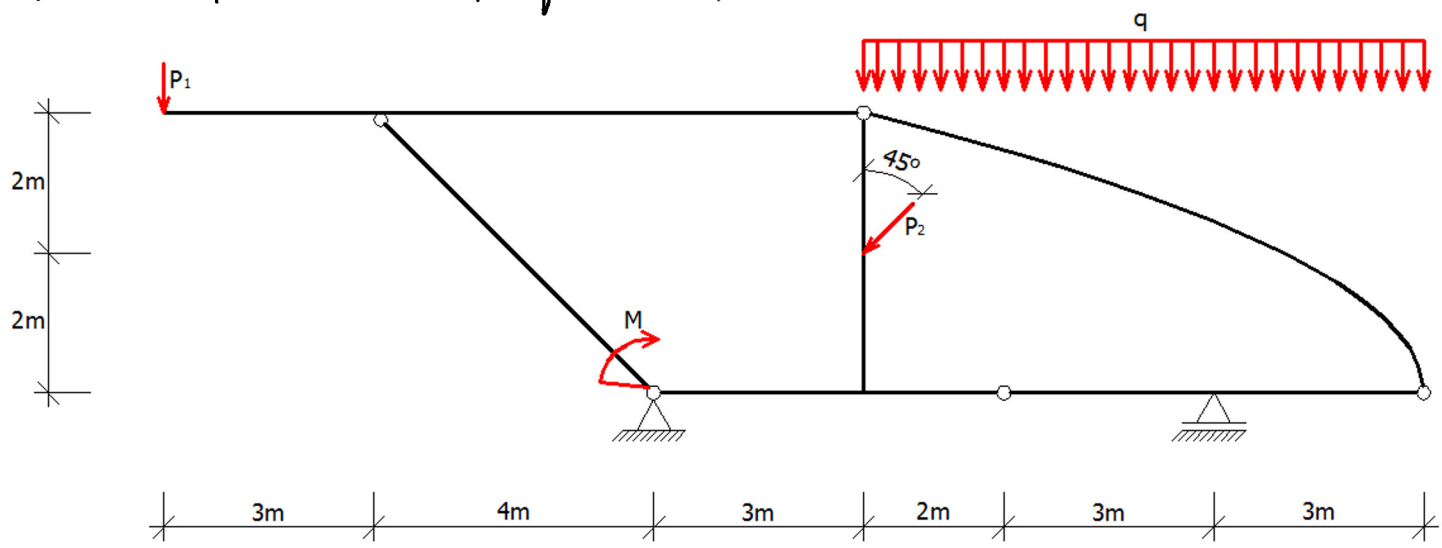
$P_1 = 10\,kN$, $P_2 = 20\,kN$, $q = 8\frac{kN}{m}$, $M = 45\,kNm$



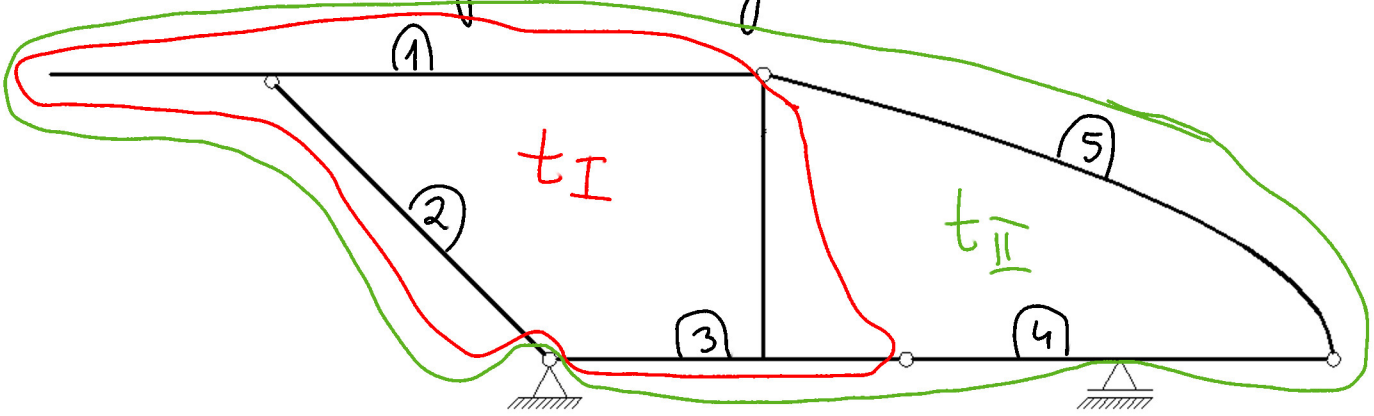
1. Sprawdzenie GN i SW

1.1. Warunek ilościowy

$n = e - 3t$, $e = 15$, $t = 5$

$n = 15 - 3 \cdot 5 = 0$ - war. spełniony

1.2. Warunek jakościowy

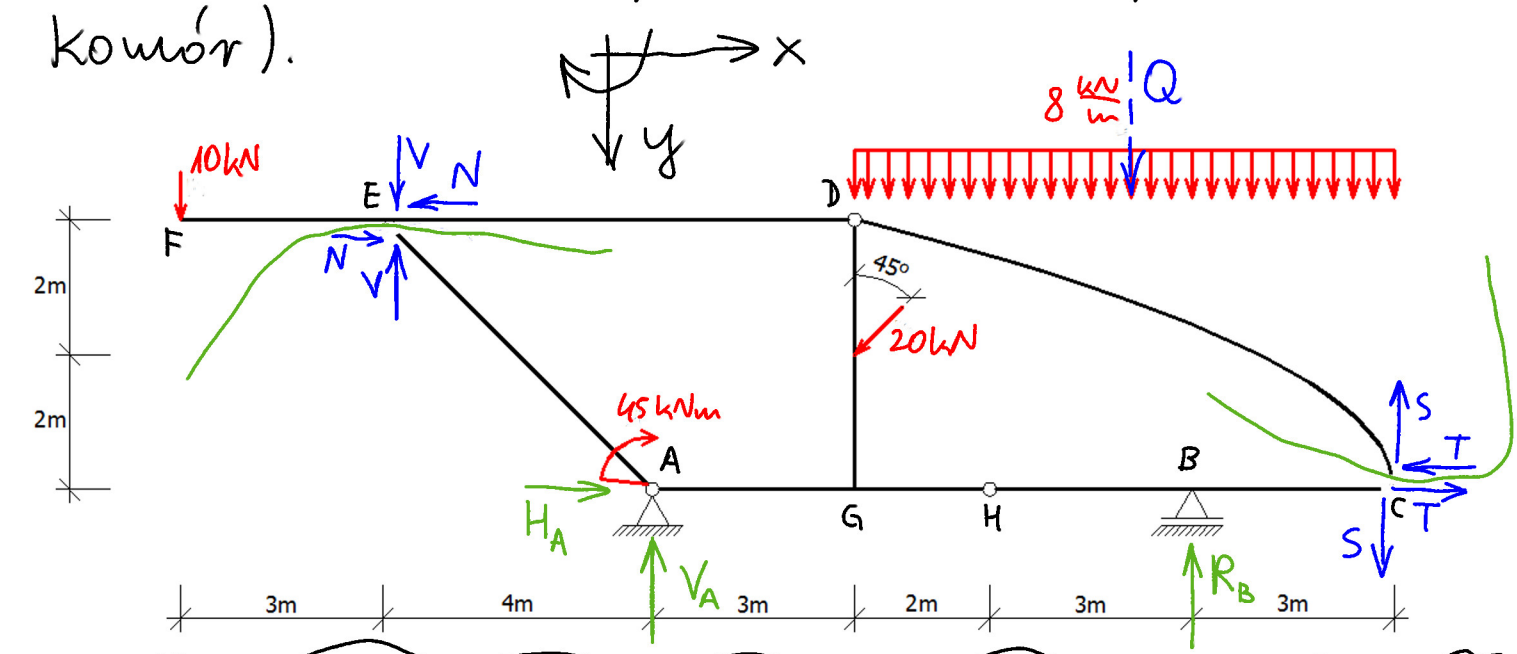


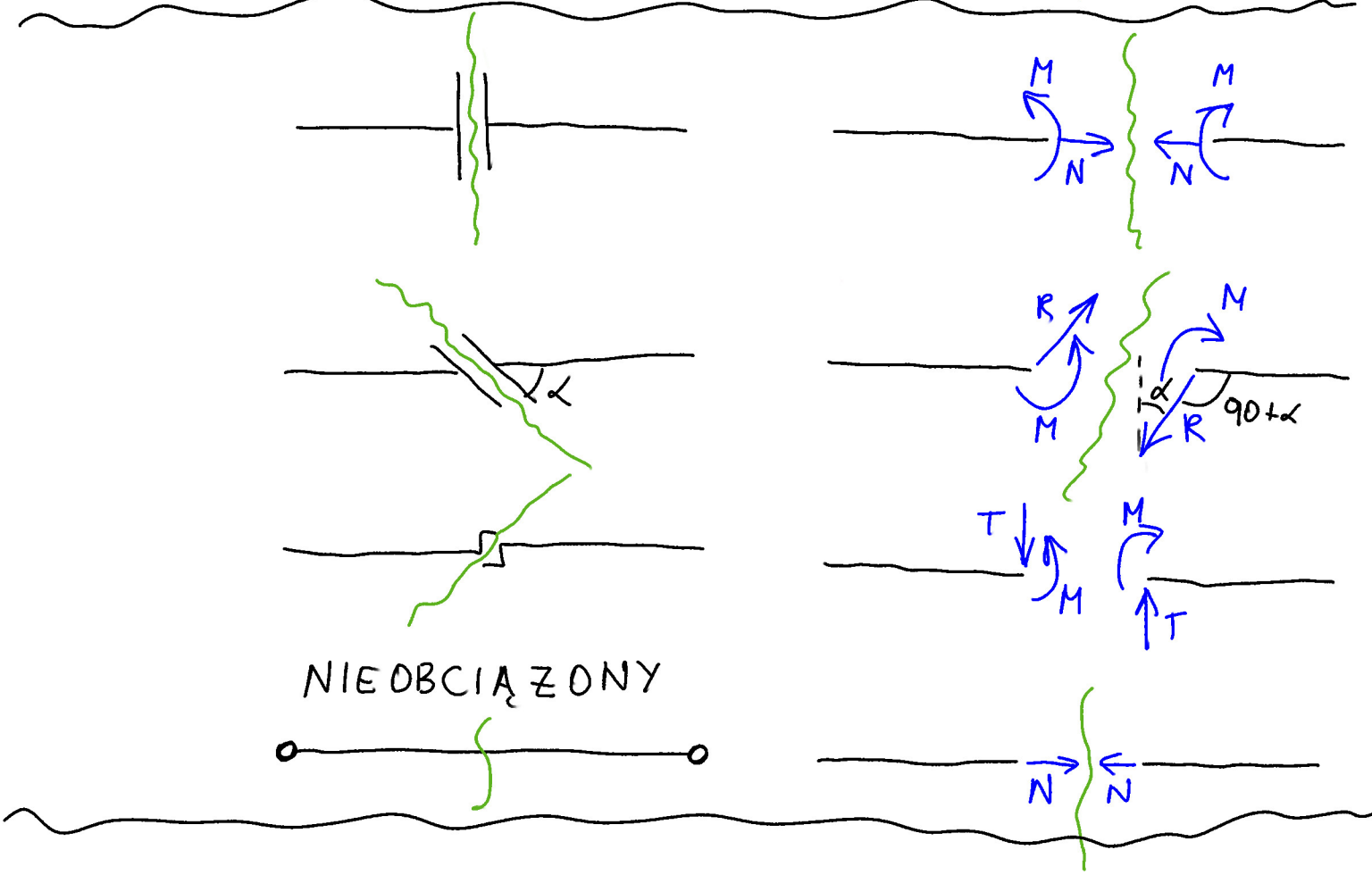
1) Na mocy tw. o 3. tarczach $t_1 - t_2 - t_3 \rightarrow t_I$
2) Na mocy tw. o 3. tarczach $t_I - t_4 - t_5 \rightarrow t_{II}$
3) Na mocy tw. o 2. tarczach $t_{II} - t_0 \rightarrow GN$

1.3. Podsumowanie

Wobec rozważanego kryterium ilościowego i jakościowego GN, analizowana rama jest GN i SW ($n=0$).

2. Wyznaczenie reakcji oraz interakcji (rozcięcie komór).



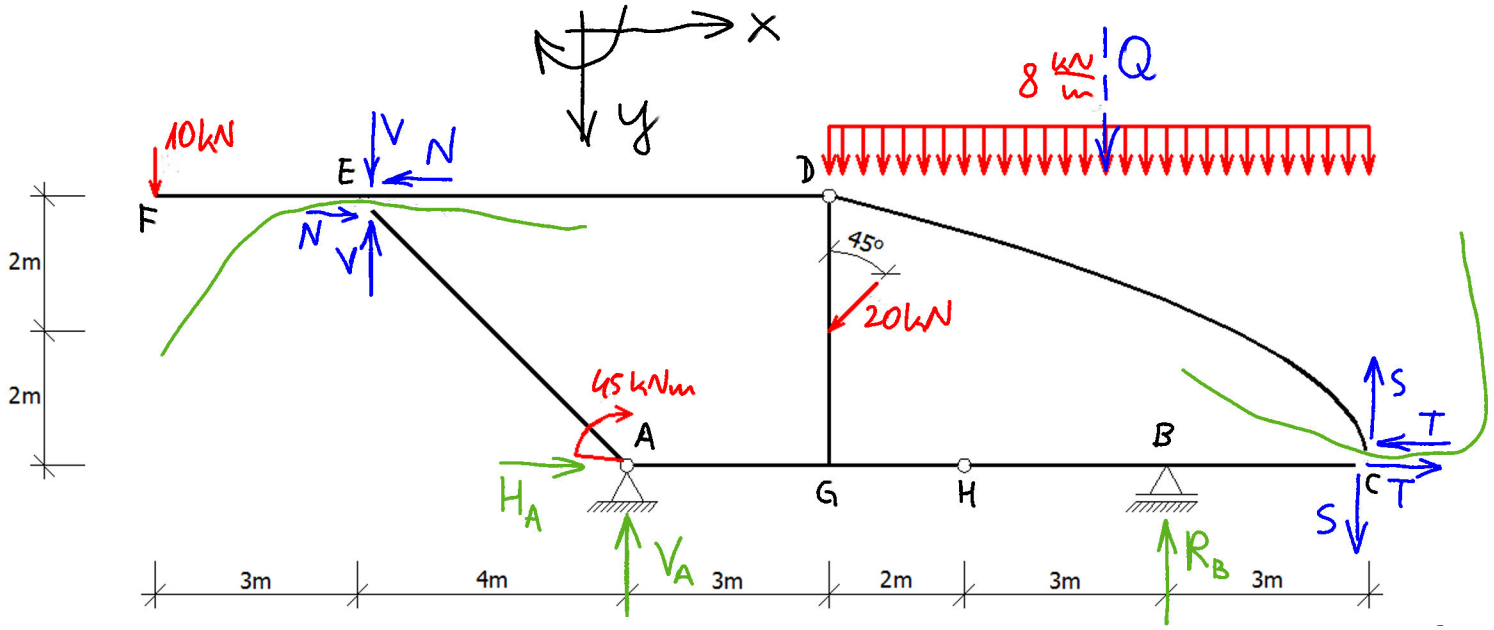


$$\sum x = 0 \;,\quad H_A - \frac{\sqrt{2}}{2}\cdot 20 = 0 \;,\quad \boxed{H_A = 14{,}142\ \text{kN}}$$

$$\sum M_A = 0 \;,\quad -8R_B + 45 - 7\cdot 10 - 2\cdot\frac{\sqrt{2}}{2}\cdot 20 + 3\cdot\frac{\sqrt{2}}{2}\cdot 20 + 8\cdot 8\cdot 7 = 0$$

$$\boxed{R_B = 54{,}643\ \text{kN}}$$

$$\sum Y = 0 \;,\quad -V_A - R_B + 8\cdot 8 + 10 + \frac{\sqrt{2}}{2}\cdot 20 = 0 \;,\quad \boxed{V_A = 33{,}5\ \text{kN}}$$



$$\Sigma M_H^P = 0 \;,\quad -3R_B + 6S = 0 \;,\quad S = 27{,}322\ \text{kN}$$

$$\Sigma M_D^L = 0 \;,\quad -10\cdot 10 - 7V = 0 \;,\quad V = -14{,}286\ \text{kN}$$

$$\Sigma M_A^G = 0 \;,\quad 45 + 4N + 4V = 0 \;,\quad N = 3{,}036\ \text{kN}$$

$$\Sigma M_D^P = 0 \;,\quad -8S + 4T + 8\cdot 8\cdot 4 = 0 \;,\quad T = -9{,}356\ \text{kN}$$

$S_{pr.}\quad \Sigma M_D = 0$

$$3V_A - 4H_A - 5R_B + 45 + 8\cdot 8\cdot 4 - 10\cdot 10 + 2\cdot \tfrac{\sqrt{2}}{2}\cdot 20 =$$

$$= 3\cdot 33{,}5 - 4\cdot 10\sqrt{2} - 5\cdot 54{,}643 + 45 + 256 - 100 + 20\sqrt{2} =$$

$$= 429{,}784 - 429{,}784 = 0 \quad \checkmark$$

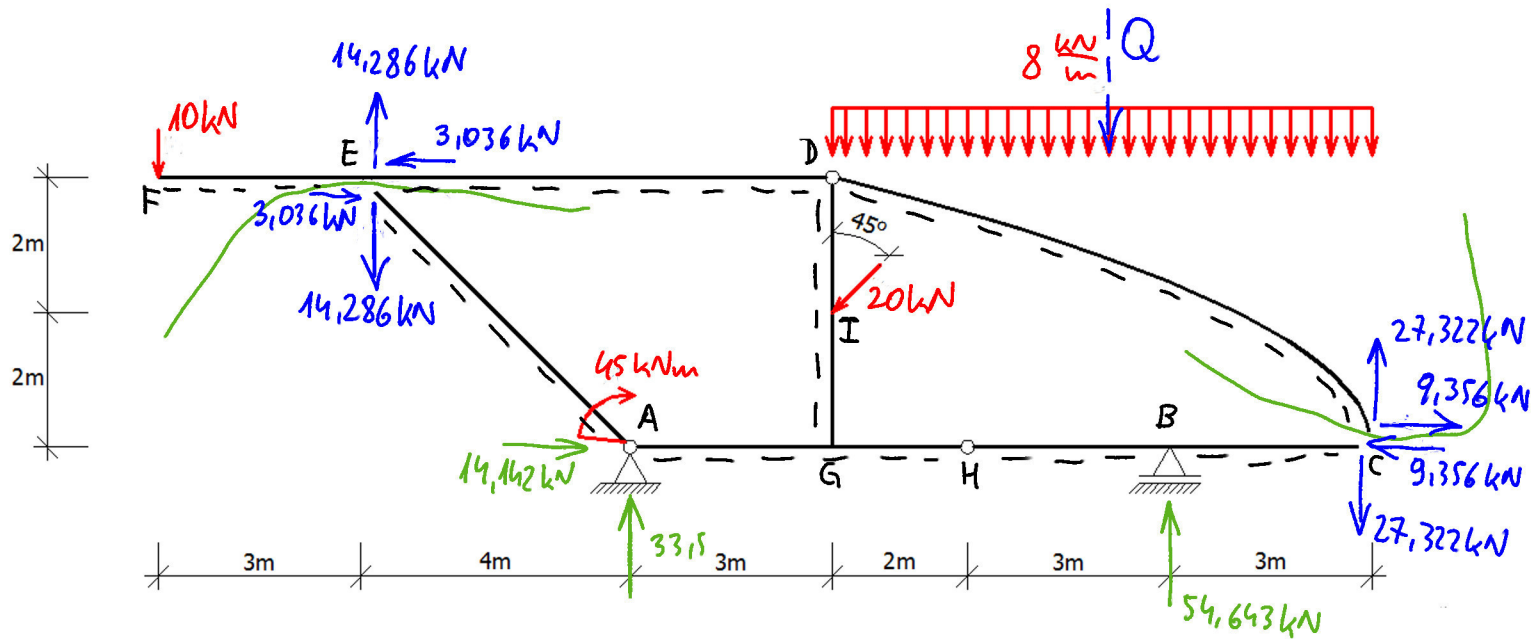
$$\Sigma M_D^P = 0$$

$$\tfrac{\sqrt{2}}{2}\cdot 20\cdot 2 - 5R_B + 8S - 4T + 3V_A - 4H_A + 45 + 7V = 0$$

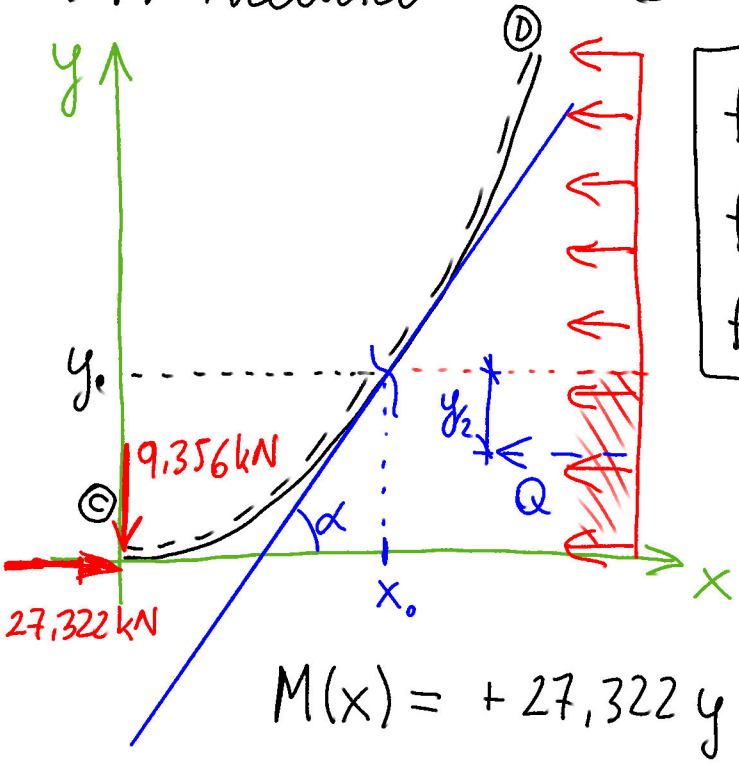
$$20\sqrt{2} - 5\cdot 54{,}643 + 8\cdot 27{,}322 - 4\cdot(-9{,}356) + 3\cdot 33{,}5 +$$

$$- 4\cdot 14{,}142 + 45 + 7\cdot(-14{,}286) = 429{,}784 - 429{,}785 = -0{,}001\text{kNm} \approx 0$$

3. Wyznaczenie sił przekrojowych



3.1. Przedział C-D (z prawej) $0 \leq x \leq 4m$



$$f(x) = ax^2 + bx + c$$

$$f(x) = ax^2$$

$$f(4m) = 8$$

$$16a = 8$$

$$a = \frac{1}{2}$$

$$f(x) = \frac{1}{2}x^2$$

$$f'(x) = x$$

$$\alpha = \operatorname{arctg}(x)$$

$$M(x) = +27{,}322\,y + 9{,}356\,x - 8 \cdot y\,\frac{y}{2} =$$

$$= 27{,}322 \cdot \frac{1}{2}x^2 + 9{,}356\,x - 8 \cdot \frac{1}{2}x^2 \cdot \frac{1}{2} \cdot \frac{1}{2}x^2 =$$

$$= -x^4 + 13{,}661\,x^2 + 9{,}356\,x$$

$$T(x) = -27{,}322 \cdot \sin\alpha - 9{,}356 \cdot \cos\alpha + 8 \cdot y \sin\alpha =$$

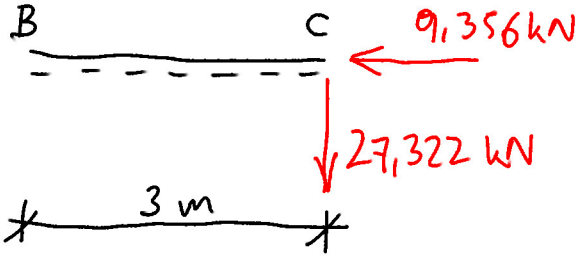
$$= 4x^2 \sin\alpha - 27{,}322 \sin\alpha - 9{,}356 \cos\alpha$$

$$N(x) = -27{,}322 \cos\alpha + 9{,}356 \sin\alpha + 8 \cdot y \cos\alpha =$$

$$= 4x^2 \cos\alpha - 27{,}322 \cos\alpha + 9{,}356 \sin\alpha$$

x [m]	alfa [deg]	M(x) [kNm]	T(x) [kN]	N(x) [kN]
0	0,00	**0,000**	**-9,356**	**-27,322**
0,5	26,57	**8,031**	**-20,140**	**-19,359**
1	45,00	**22,017**	**-23,107**	**-9,875**
1,5	56,31	**39,709**	**-20,435**	**-2,379**
2	63,43	**57,356**	**-14,311**	**3,305**
2,5	68,20	**69,709**	**-5,631**	**7,824**
3	71,57	**70,017**	**5,274**	**11,620**
3,5	74,05	**50,031**	**18,274**	**14,951**
4	75,96	**0,000**	**33,314**	**17,972**

3.2. Przedział C-B (z prawej)

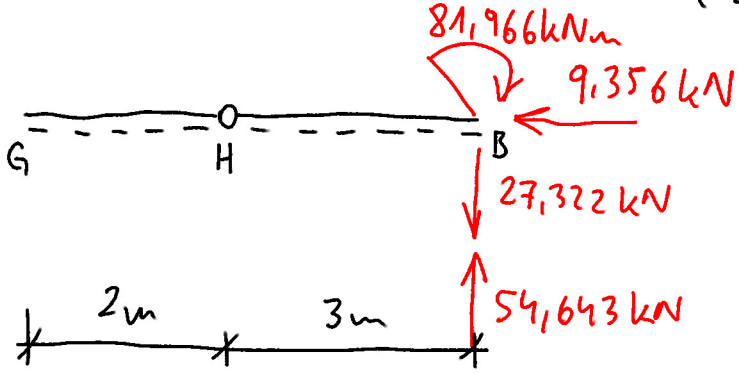


$M_{CB} = 0$, $M_{BC} = -27,322 \cdot 3 = -81,966$ kNm

$T_{CB} = T_{BC} = 27,322$ kN

$N_{CB} = N_{BC} = -9,356$ kN

3.3. Przedział B-H-G (z prawej)



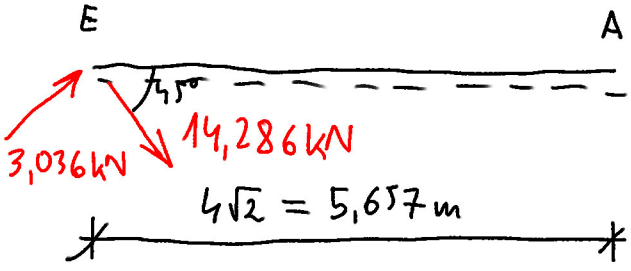
$M_{BG} = -81,966$ kNm

$M_{GB} = -81,966 - 27,322 \cdot 5 + 54,643 \cdot 5 = 54,639$ kNm

$T_{BG} = T_{GB} = 27,322 - 54,643 = -27,321$ kN

$N_{BG} = N_{GB} = -9,356$ kN

3.4. Przedział E-A (z lewej)



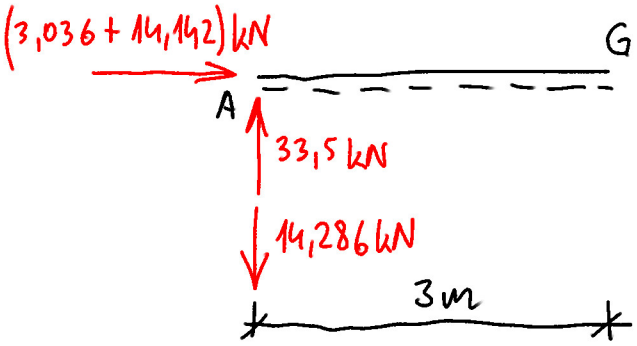
$M_{EA} = 0$

$M_{AE} = \frac{\sqrt{2}}{2} \cdot 3,036 \cdot 5,657 - \frac{\sqrt{2}}{2} \cdot 14,286 \cdot 5,657 = -45$ kNm (moment skupiony nieskończenie blisko przegubu)

$T_{EA} = T_{AE} = \frac{\sqrt{2}}{2} \cdot 3,036 - \frac{\sqrt{2}}{2} \cdot 14,286 = -7,955$ kN

$N_{EA} = N_{AE} = -\frac{\sqrt{2}}{2} \cdot 3,036 - \frac{\sqrt{2}}{2} \cdot 14,286 = -12,249$ kN

3.5. Predriet A-G (z lewej)



$M_{AG} = 0$

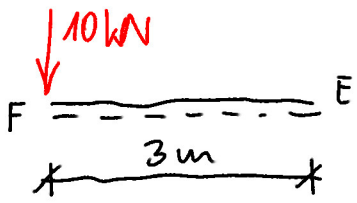
$M_{GA} = 33,5 \cdot 3 - 14,286 \cdot 3 = 57,642\ kNm$

$T_{AG} = T_{GA} = 33,5 - 14,286 = 19,214\ kN$

$N_{AG} = N_{GA} = -3,036 - 14,142 =$

$= -17,178\ kN$

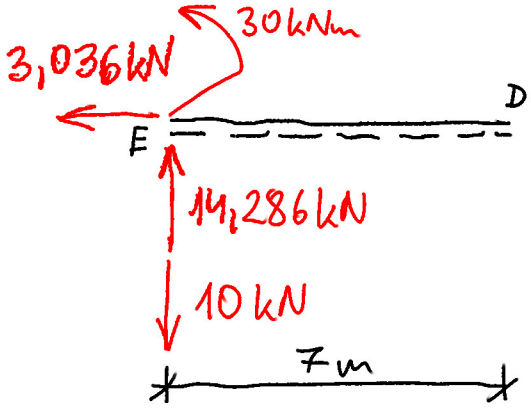
3.6. Predriet F-E (z lewej)



$M_{FE} = 0$, $M_{EF} = -10 \cdot 3 = -30\ kNm$

$T_{FE} = T_{EF} = -10\ kN$, $N_{FE} = N_{EF} = 0$

3.7. Predriet E-D (z lewej)



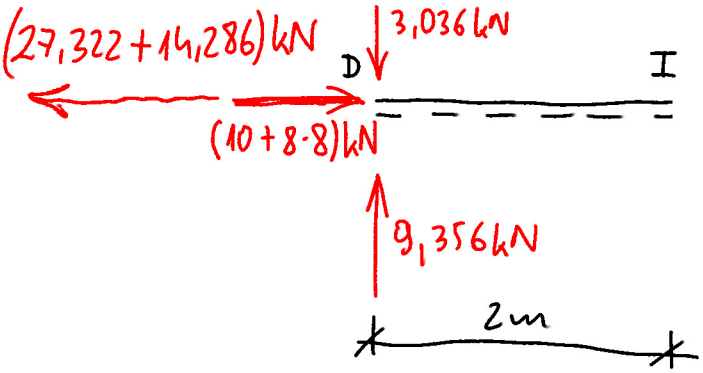
$M_{ED} = -30\ kNm$

$M_{DE} = -30 + 14,286 \cdot 7 - 10 \cdot 7 = 0$

$T_{ED} = T_{DE} = 14,286 - 10 = 4,286\ kN$

$N_{ED} = N_{DE} = 3,036\ kN$

3.8. Predriet D-I (z lewej)



$M_{DI} = 0$

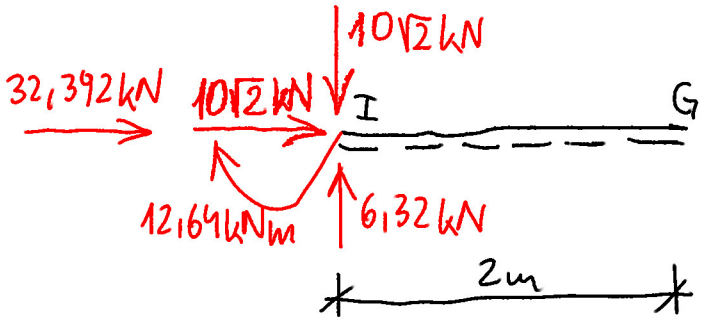
$M_{ID} = 9,356 \cdot 2 - 3,036 \cdot 2 = 12,64\ kNm$

$T_{DI} = T_{ID} = 9,356 - 3,036 = 6,32\ kN$

$N_{DI} = N_{ID} = 27,322 + 14,286 - 10 +$

$- 8 \cdot 8 = -32,392\ kN$

3.9. Przedział I - G (z lewej)



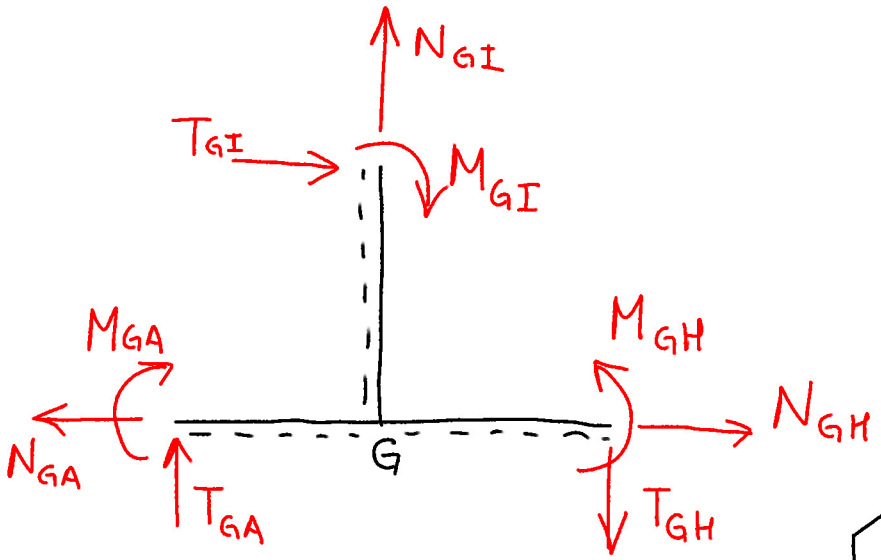
$$M_{IG} = 12,164 \text{ kNm}$$

$$M_{GI} = 12,164 - 10\sqrt{2} \cdot 2 + 6,32 \cdot 2 =$$
$$= -3,004 \text{ kNm}$$

$$T_{IG} = T_{GI} = 6,32 - 10\sqrt{2} =$$
$$= -7,822 \text{ kN}$$

$$N_{IG} = N_{GI} = -32,392 - 10\sqrt{2} =$$
$$= -46,534 \text{ kN}$$

3.10. Równowaga węzła G



$$M_{GI} = -3,004 \text{ kNm}$$
$$T_{GI} = -7,822 \text{ kN}$$
$$N_{GI} = -46,534 \text{ kN}$$
$$M_{GA} = 57,642 \text{ kNm}$$
$$T_{GA} = 19,214 \text{ kN}$$
$$N_{GA} = -17,178 \text{ kN}$$
$$M_{GH} = 54,639 \text{ kNm}$$
$$T_{GH} = -27,321 \text{ kN}$$
$$N_{GH} = -9,356 \text{ kN}$$

$$\Sigma M_G = 0$$

$$M_{GA} + M_{GI} - M_{GH} = 57,642 + (-3,004) + -54,639 \cong 0$$

$$\Sigma Y = 0, \quad -T_{GA} - N_{GI} + T_{GH} = -19,214 - (-46,534) + (-27,321) =$$
$$= 46,534 - 46,535 \cong 0$$

$$\Sigma X = 0, \quad -N_{GA} + T_{GI} + N_{GH} = -(-17,178) - 7,822 + (-9,356) =$$
$$= 17,178 - 17,178 = 0$$

3.11. Wykresy sił przekrojowych