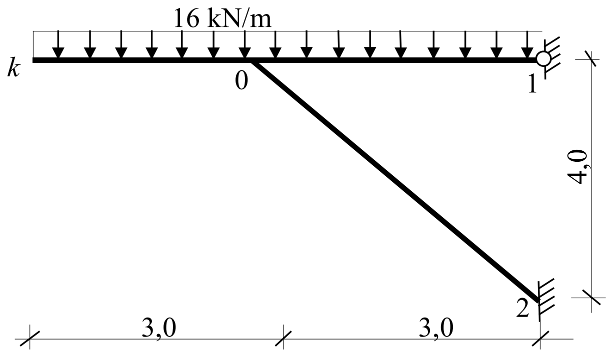
Zad.2. Wyznaczyć obrót przekroju *k* (uwzględnić wpływ M, N, T), korzystając z metody przemieszczeń:

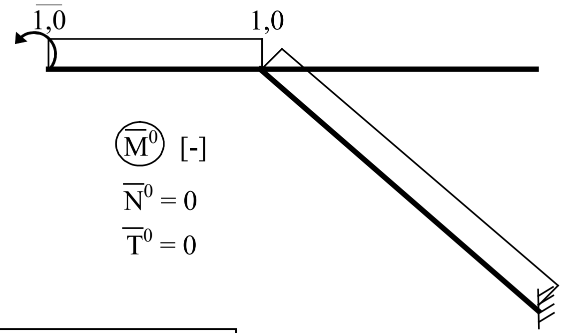
Schemat układu:



Obrót przekroju *k* (wykorzystujemy twierdzenie redukcyjne):

$$\varphi_k \cdot \overline{1} = \int_s \frac{\overline{M}^0 \cdot M_P^{(n)}}{EI} ds + \int_s \frac{\overline{N}^0 \cdot N_P^{(n)}}{EA} ds + \int_s \frac{\overline{T}^0 \cdot T_P^{(n)}}{GA} \kappa ds$$

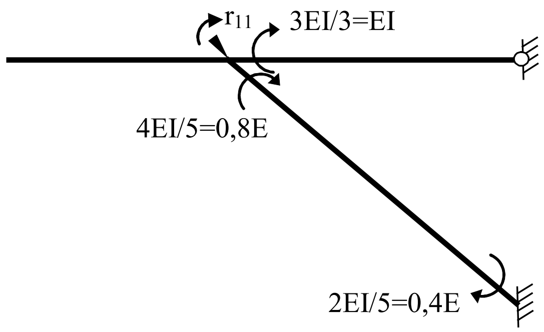
-układ podstawowy:



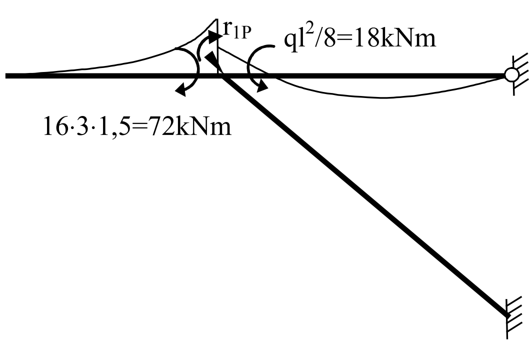
-stąd: $$\boxed{\varphi_k \cdot \overline{1} = \int_s \frac{\overline{M}^0 \cdot M_P^{(n)}}{EI} ds}$$

Wyznaczenie $M_P^{(n)}$; **SGN=1** (φ_1)

Stan φ_1=1



Stan „P”

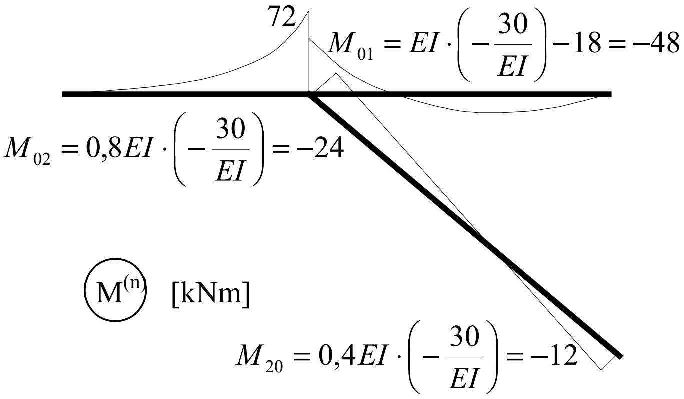


$$r_{11} = 1{,}8EI$$

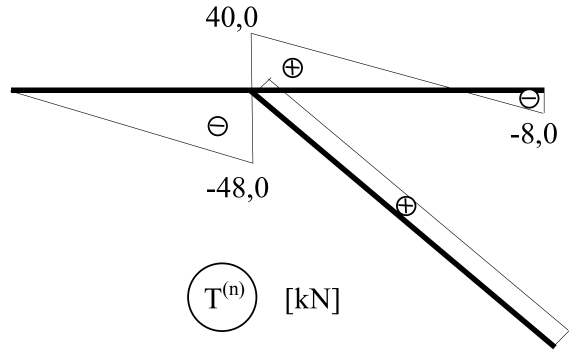
$$r_{1P} = 72 - 18 = 54kNm$$

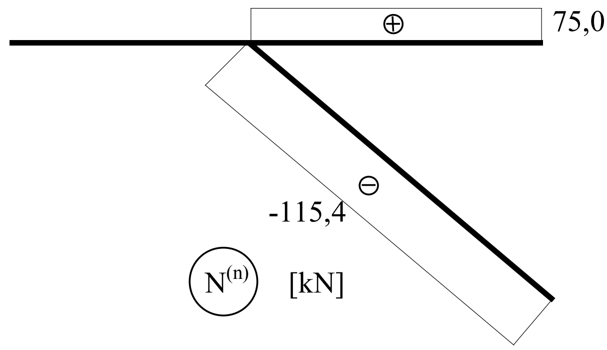
$$\varphi_1 = -\frac{r_{1P}}{r_{11}} = -\frac{30}{EI}$$

Ostateczny wykres $M^{(n)}$:

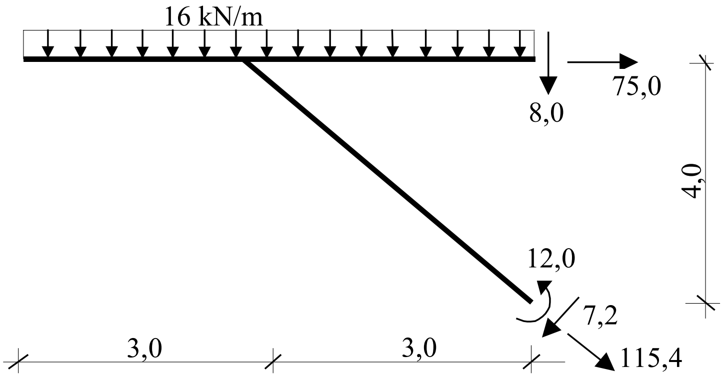


Wykresy $T^{(n)}$ i $N^{(n)}$ (nie są konieczne do rozwiązania zadania)



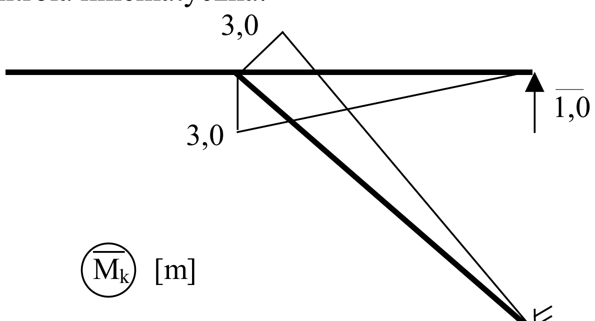


Kontrola statyczna:



$$\sum X = 0$$
$$\sum Y = 0$$
$$\sum M_2 = 0$$

Kontrola kinematyczna:



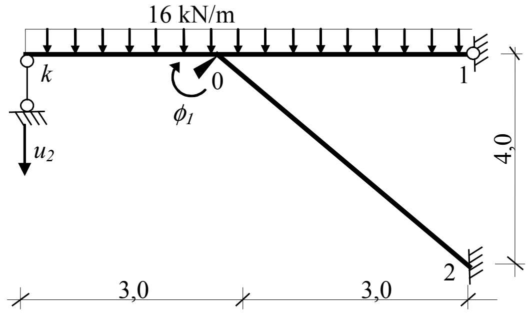
$$\nu_k \cdot 1{,}0 = \frac{1}{EI}\left[-\frac{1}{2}\cdot 3\cdot 3\cdot \frac{2}{3}\cdot 48 + \frac{2}{3}\cdot\frac{16\cdot 9}{8}\cdot 3\cdot 1{,}5 + \right.$$
$$\left. + \frac{1}{2}\cdot 3\cdot 5\cdot\left(\frac{2}{3}\cdot 24 - \frac{1}{3}\cdot 12\right)\right] = \frac{0{,}00}{EI}$$

Obrót przekroju *k* wynosi:

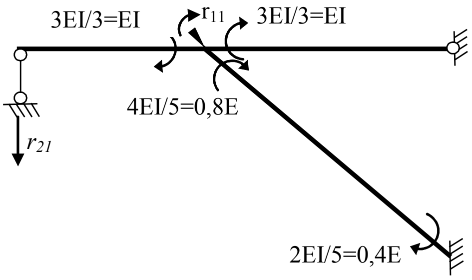
$$\varphi_k \cdot 1{,}0 = \int_s \frac{\overline{M}^0 \cdot M_P^{(n)}}{EI}\, ds = \frac{1}{EI}\left[3\cdot 1\cdot 36 - \frac{2}{3}\cdot\frac{16\cdot 9}{8}\cdot 3\cdot 1 + 1\cdot 5\cdot\frac{1}{2}\cdot(24-12)\right] = \frac{\mathbf{102{,}0}}{\mathbf{EI}}$$

Rozwiązanie alternatywne (specjalnie dla p.Damiana :-)

Wyznaczenie $M_P^{(n)}$;
SGN=2 (φ_1, u_2)



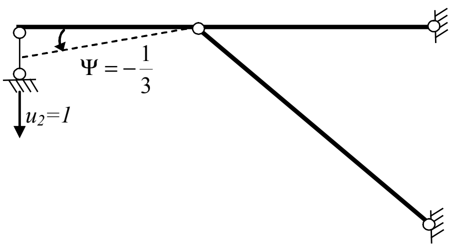
Stan φ_1=1

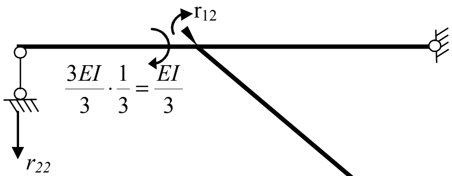


$$r_{11} = 2{,}8EI$$

$$r_{21} \cdot \overline{1} + EI \cdot \left(-\frac{1}{3}\right) = 0 \quad \Rightarrow \quad r_{21} = \frac{EI}{3}$$

Stan u_2=1

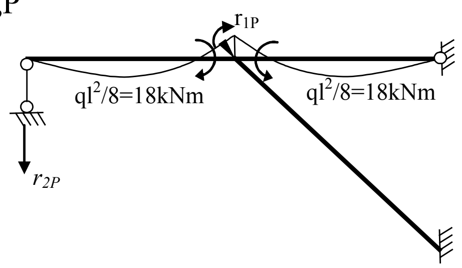




$$r_{12} = \frac{EI}{3}$$

$$r_{22} \cdot \overline{1} + \frac{EI}{3} \cdot \left(-\frac{1}{3}\right) = 0 \quad \Rightarrow \quad r_{22} = \frac{EI}{9}$$

Stan „P"



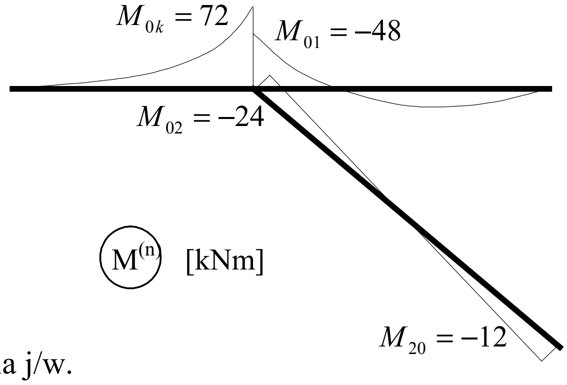
$$r_{1P} = 0$$

$$r_{2P} \cdot \overline{1} + 18 \cdot \left(-\frac{1}{3}\right) + 16 \cdot 3 \cdot 0{,}5 = 0 \quad \Rightarrow \quad r_{2P} = -18kNm$$

URK:

$$\begin{cases} 2{,}8EI\varphi_1 + \frac{EI}{3} u_2 = 0 \\ \frac{EI}{3}\varphi_1 + \frac{EI}{9} u_2 = 18 \end{cases} \qquad \begin{cases} \varphi_1 = -\frac{30}{EI} \\ u_2 = \frac{252}{EI} \end{cases}$$

Wykres $M_P^{(n)}$



$$M_{0k} = \frac{EI}{3} \cdot \frac{252}{EI} + EI \cdot \left(-\frac{30}{EI}\right) + 18 = 72$$

$$M_{01} = EI \cdot \left(-\frac{30}{EI}\right) - 18 = -48$$

$$M_{02} = 0{,}8EI \cdot \left(-\frac{30}{EI}\right) = -24$$

$$M_{20} = 0{,}4EI \cdot \left(-\frac{30}{EI}\right) = -12$$

Dalsze obliczenia j/w.