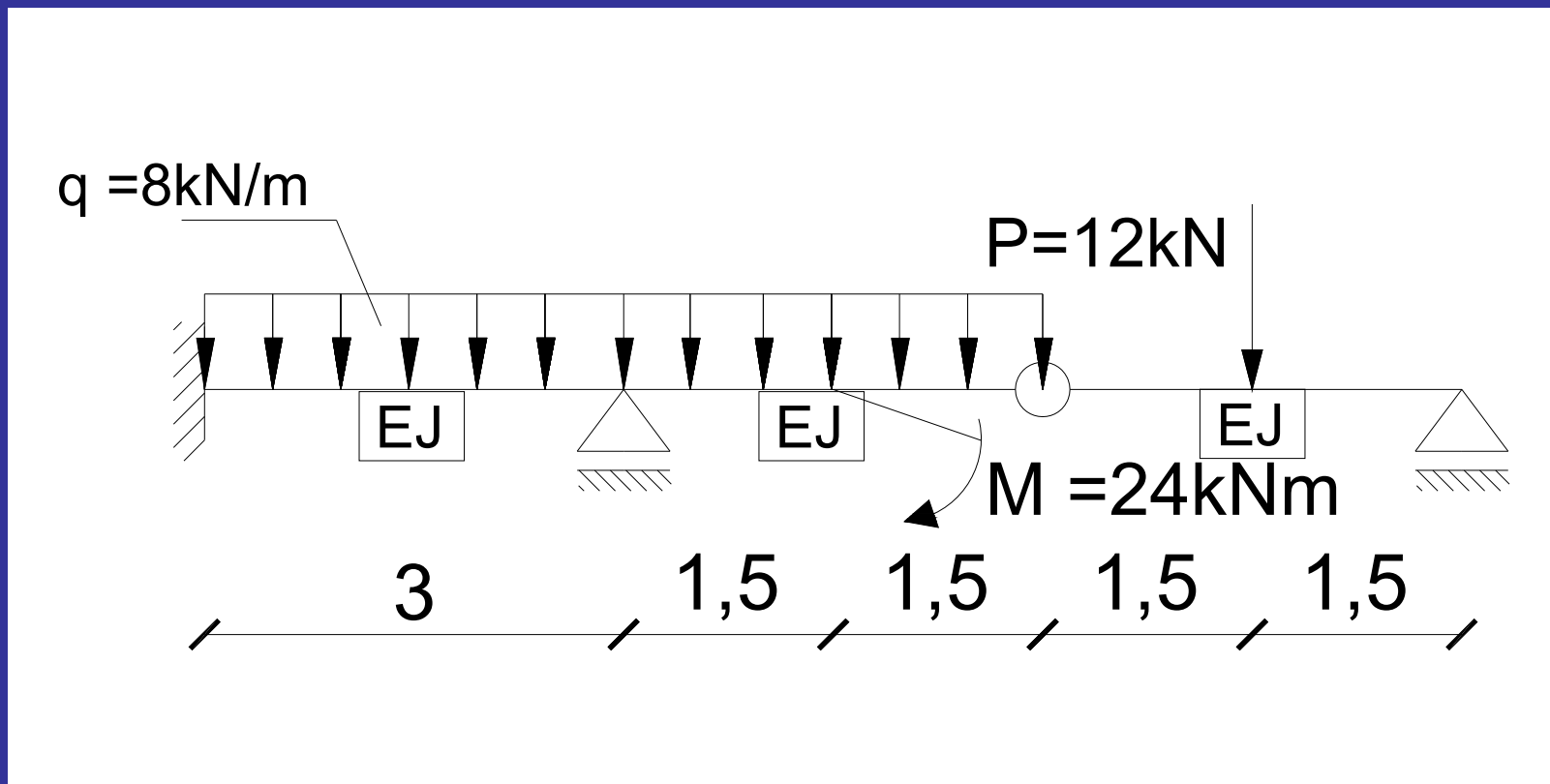


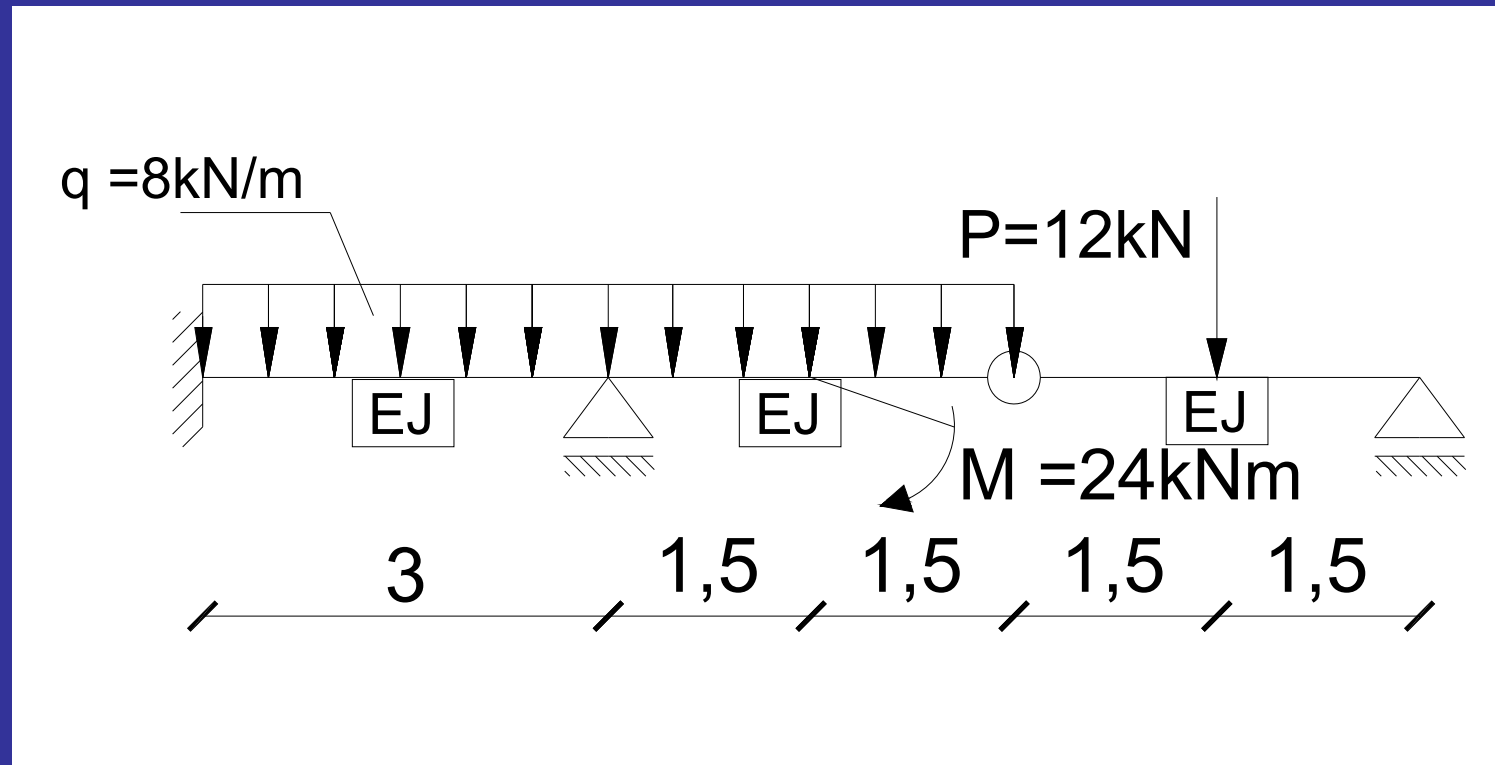
Metoda Sił

Rysowanie wykresów sił wewnętrznych
w belkach statycznie niewyznaczalnych

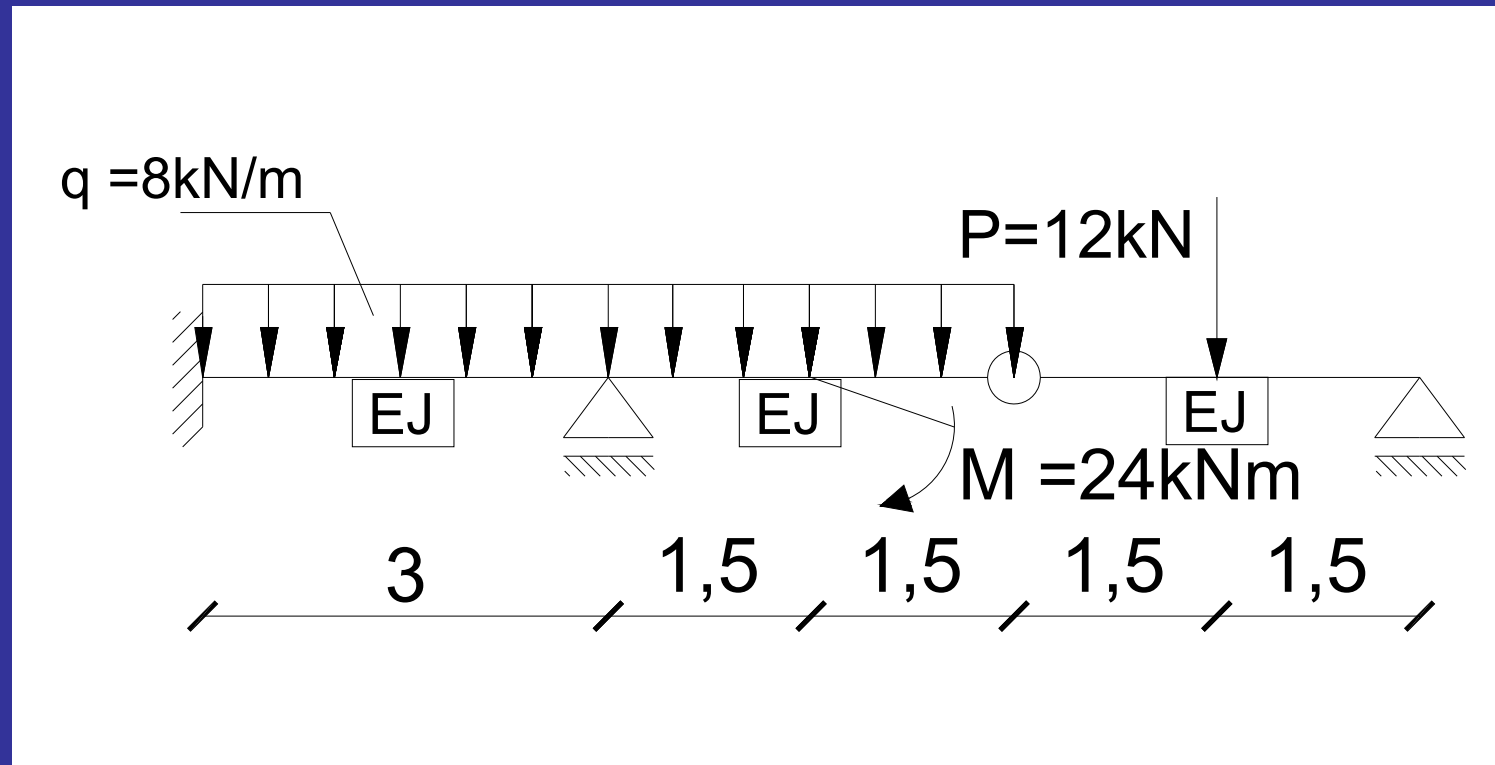
Zadanie: Narysuj wykresy sił N, T, M. Zadanie rozwiąż metodą sił. Wyznaczyć ugięcie przegubu z twierdzenia redukcyjnego.



Określenie stopnia statycznej niewyznaczalności :

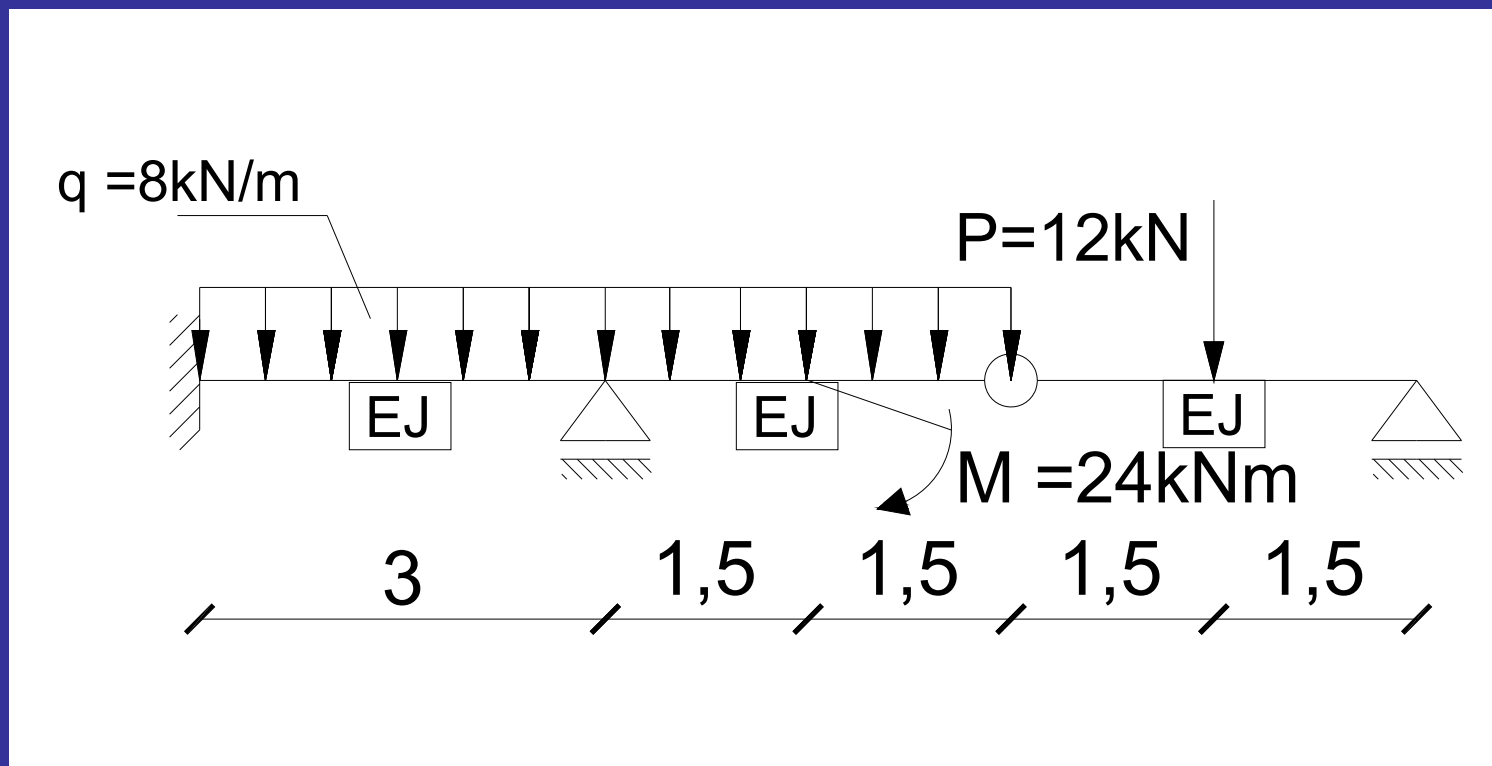


Określenie stopnia statycznej niewyznaczalności :



$$n_s = l_r - l_p - 3 = 5 - 1 - 3 = 1$$

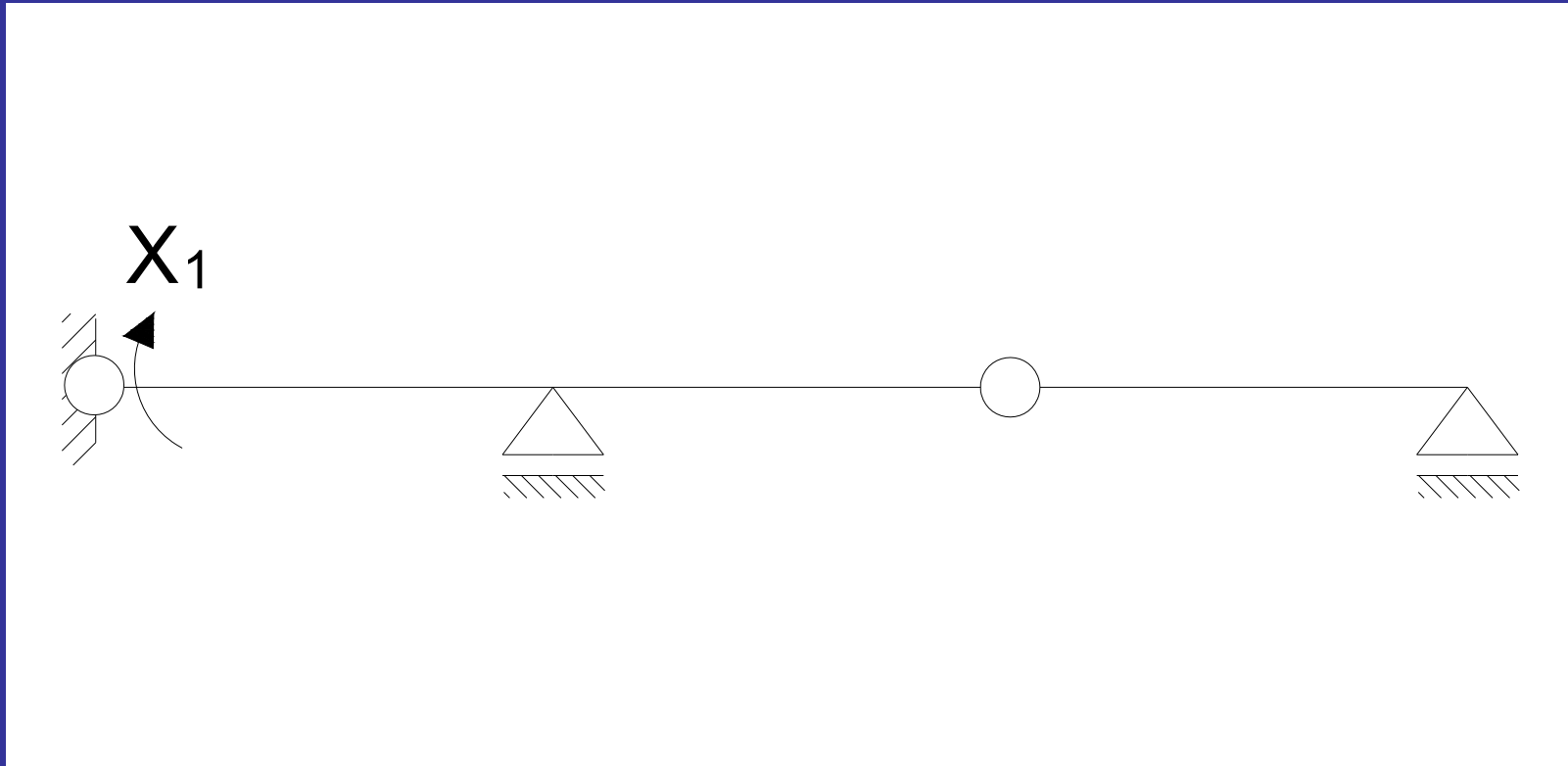
Określenie stopnia statycznej niewyznaczalności :



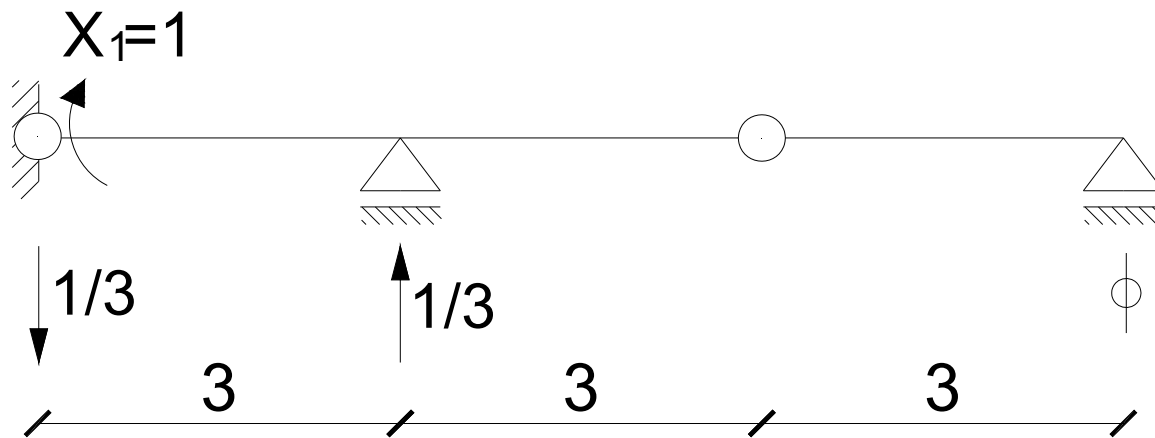
$$n_s = l_r - l_p - 3 = 5 - 1 - 3 = 1$$

Układ jednokrotnie
statycznie niewyznaczalny

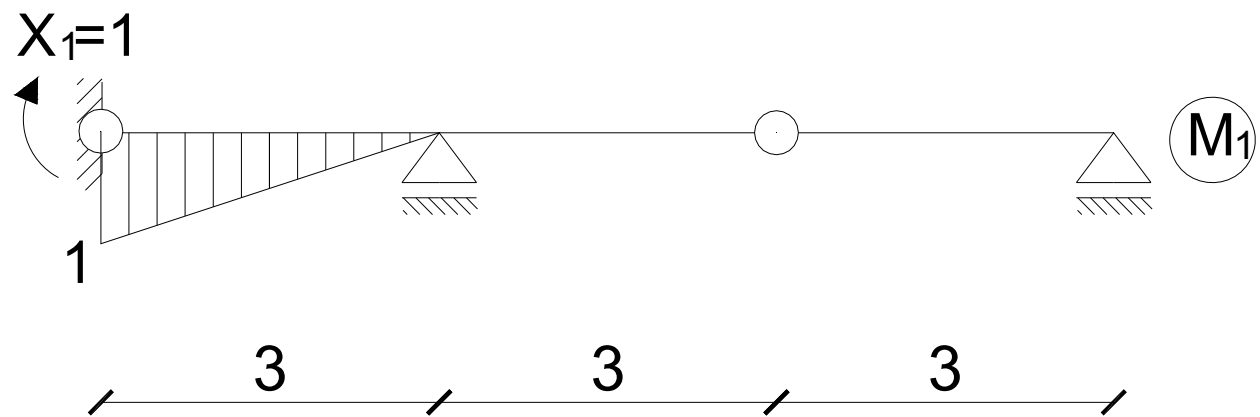
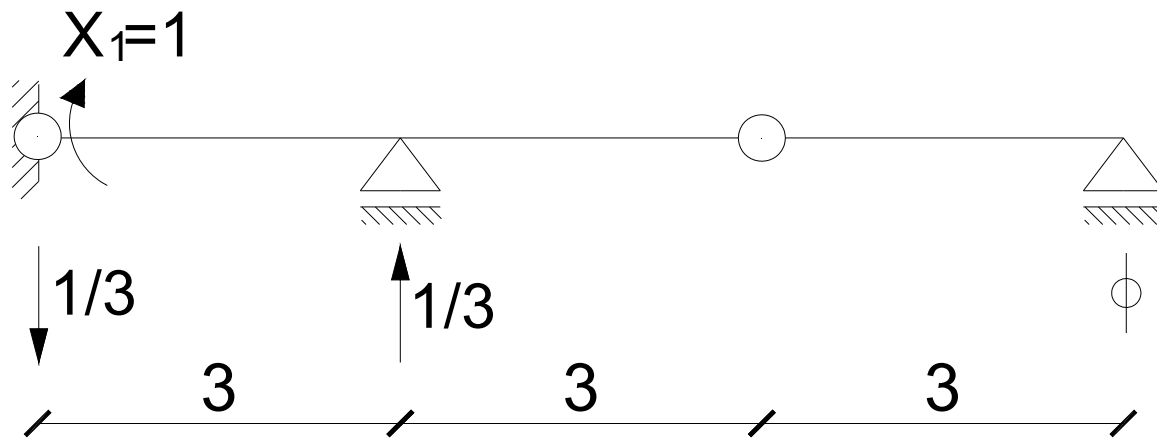
Schemat podstawowy statycznie wyznaczalny:



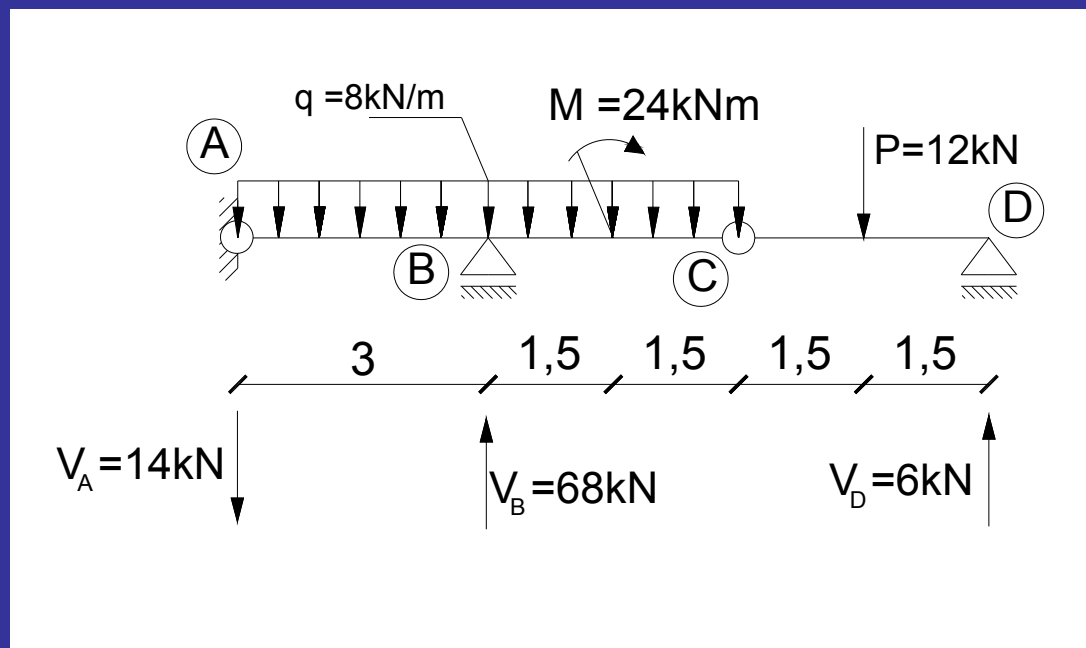
Wykres $X_1=1$



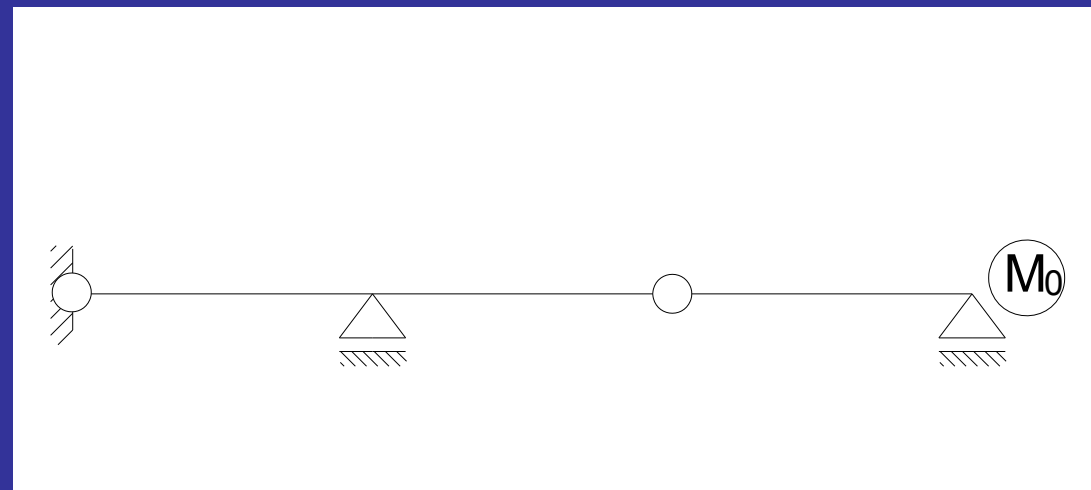
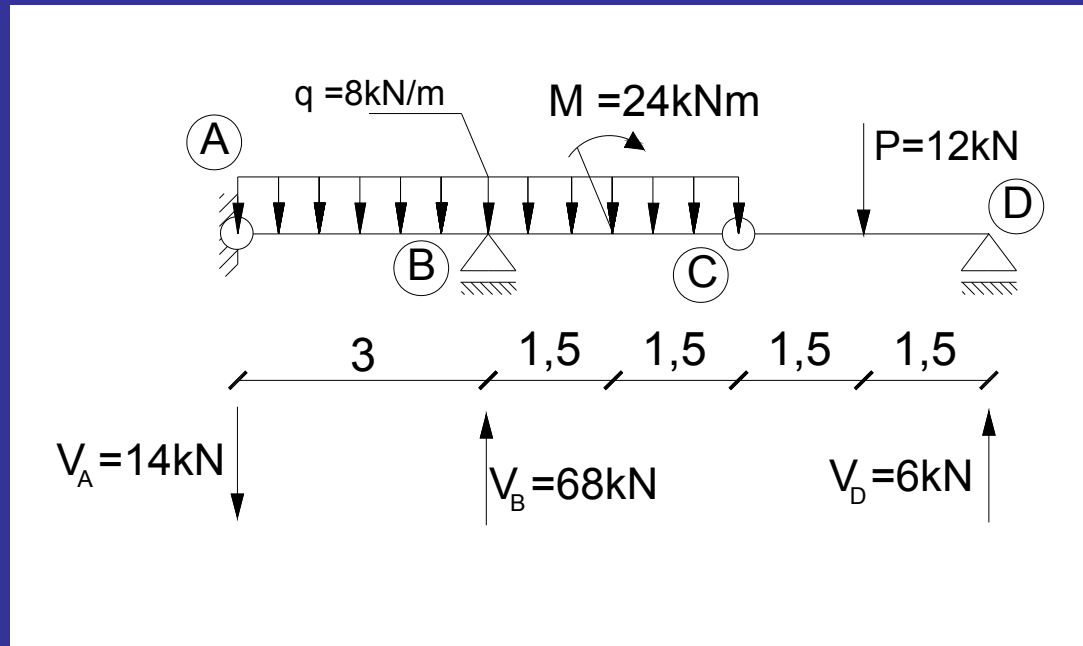
Wykres $X_1=1$



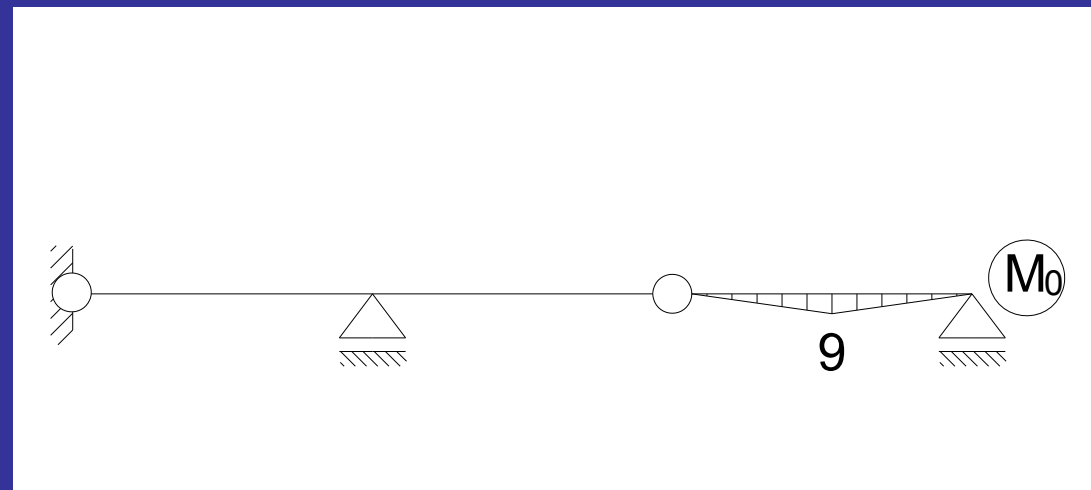
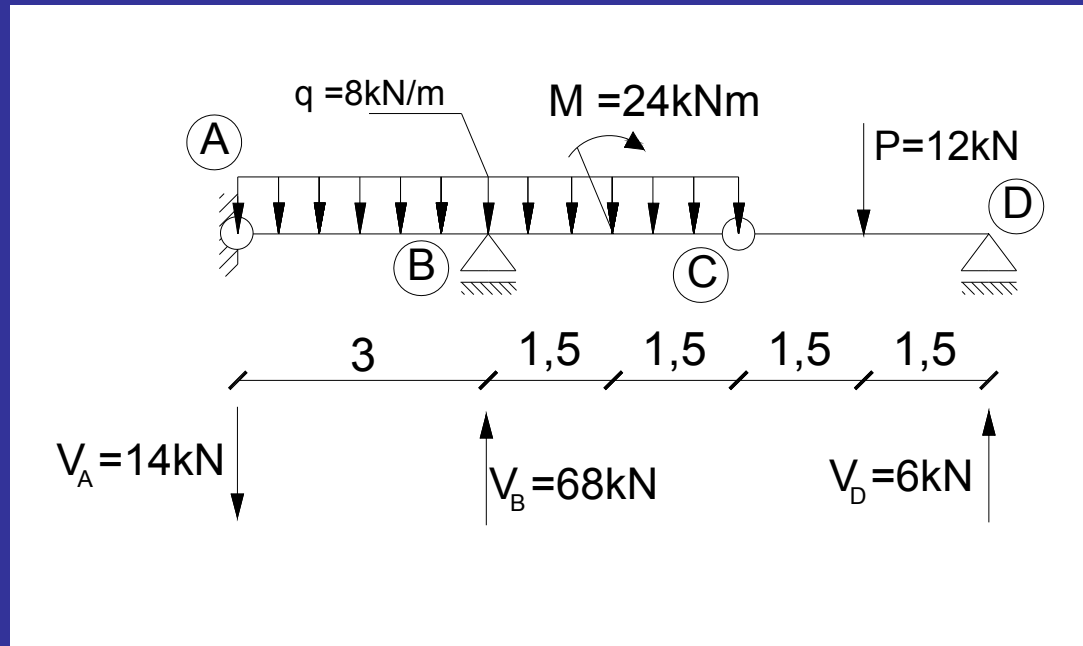
Wykres od obciążenia zewnętrznego:



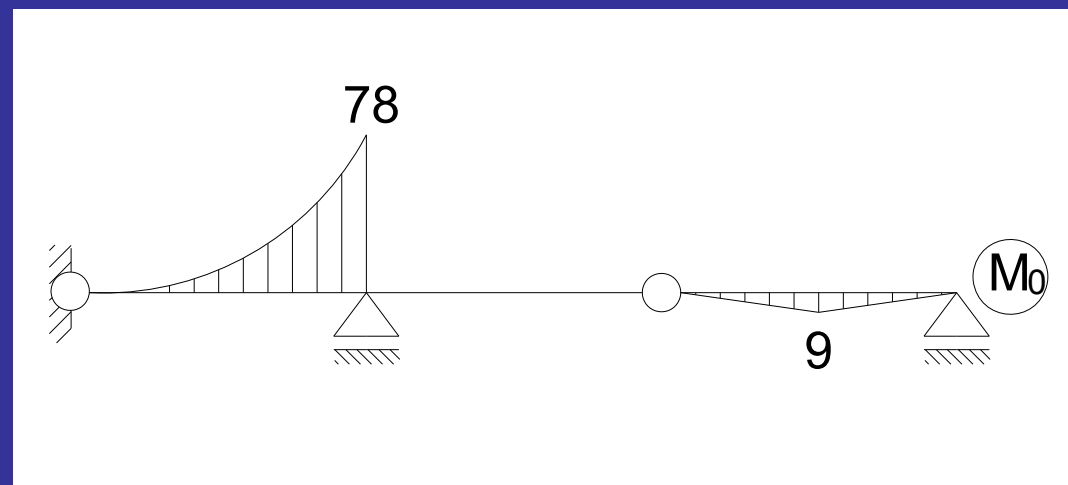
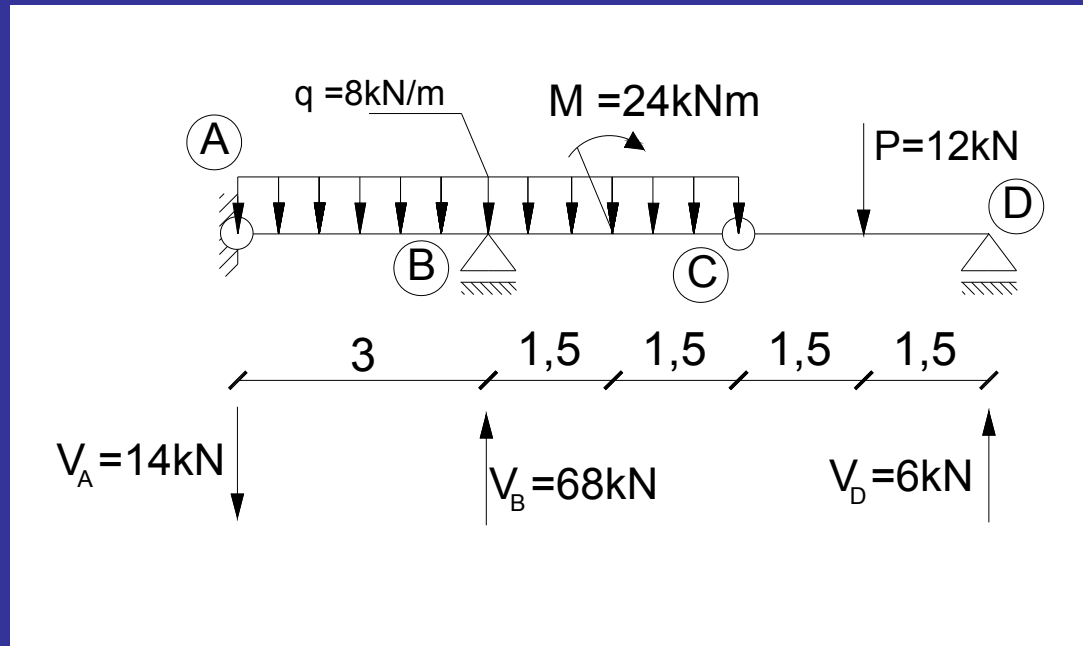
Wykres od obciążenia zewnętrznego:



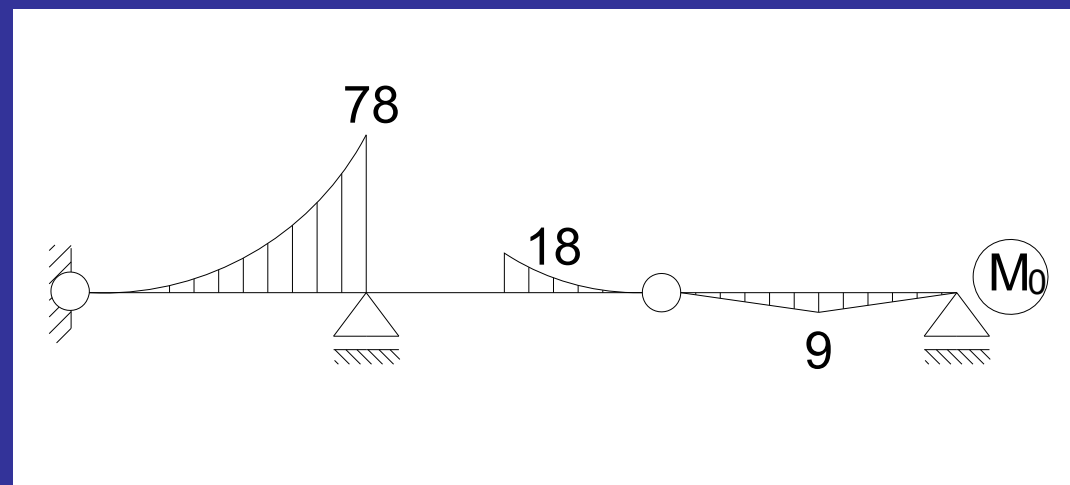
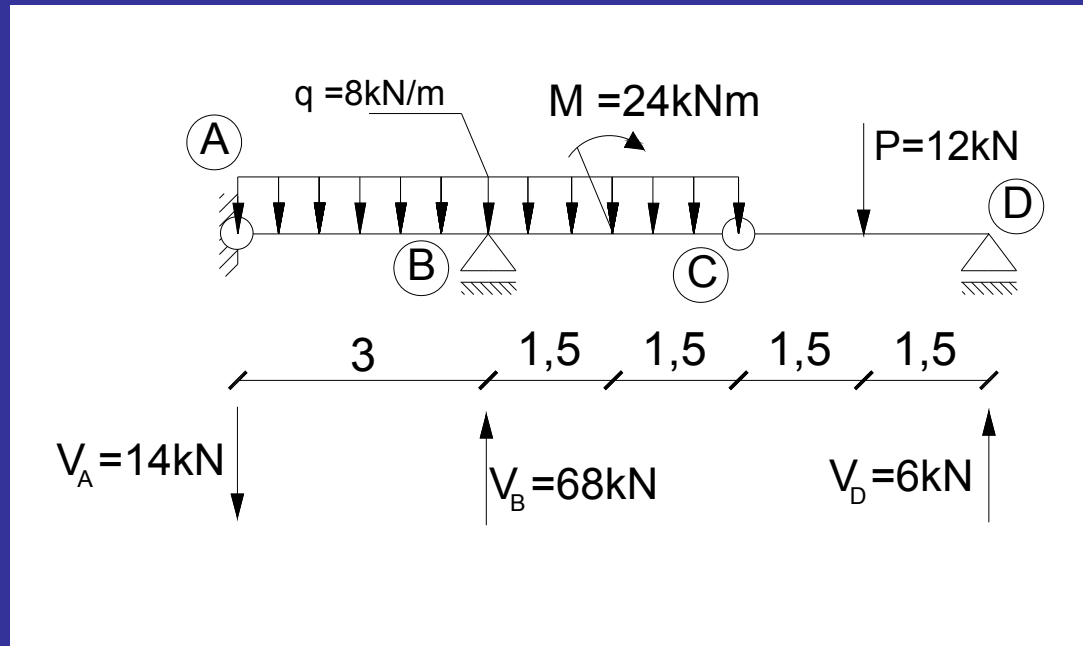
Wykres od obciążenia zewnętrznego:



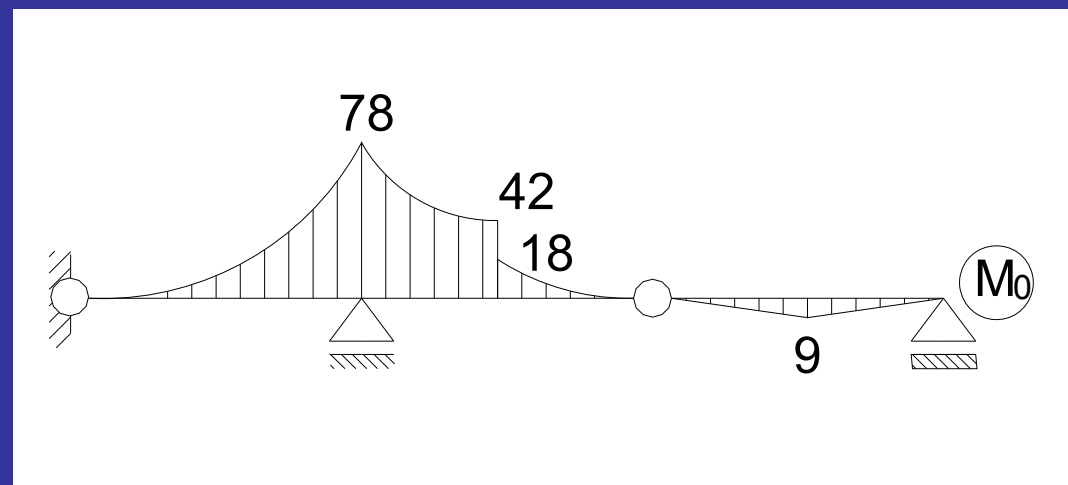
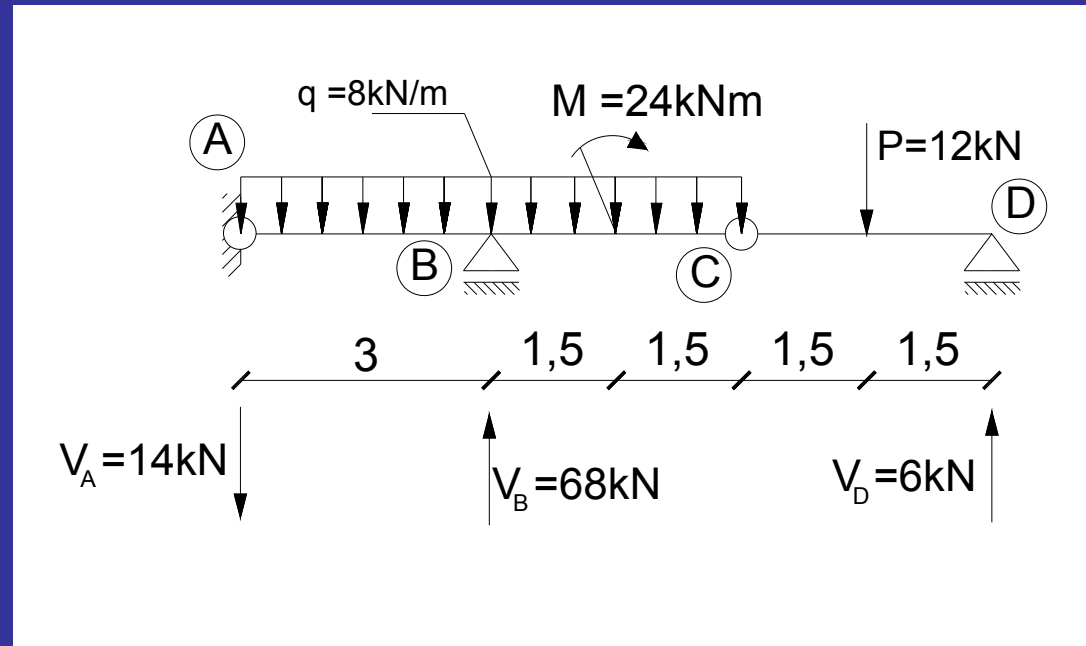
Wykres od obciążenia zewnętrznego:



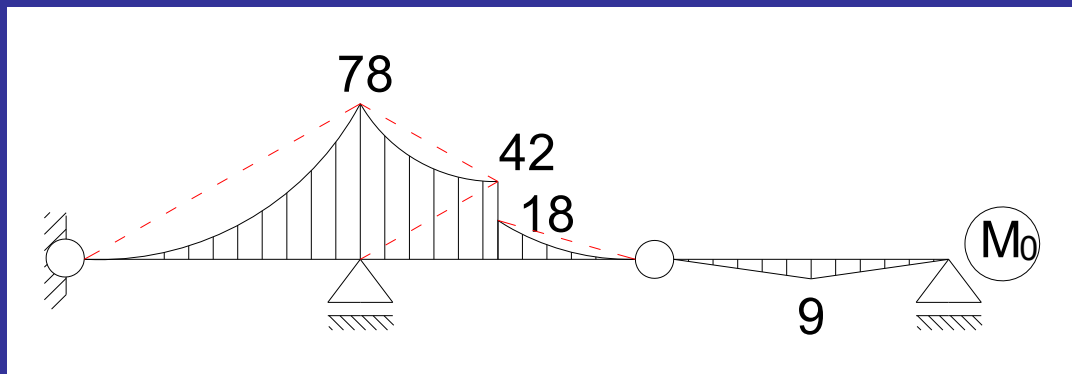
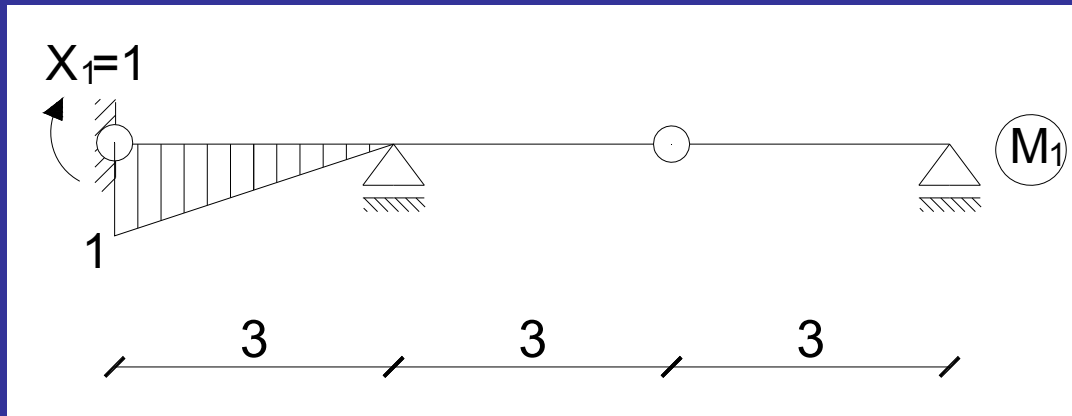
Wykres od obciążenia zewnętrznego:



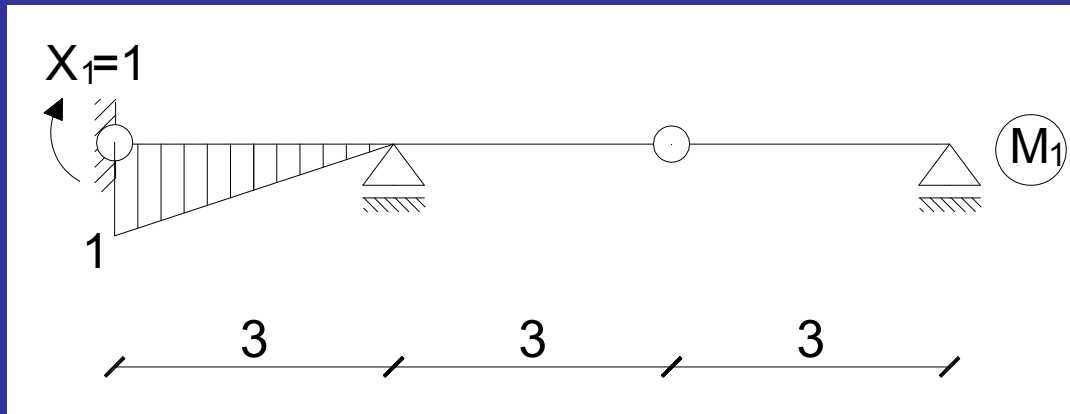
Wykres od obciążenia zewnętrznego:



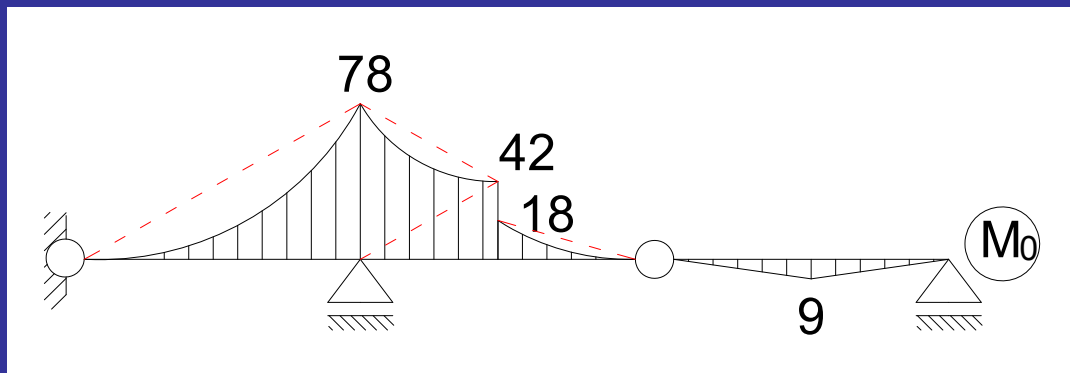
Całkowanie wykresów:



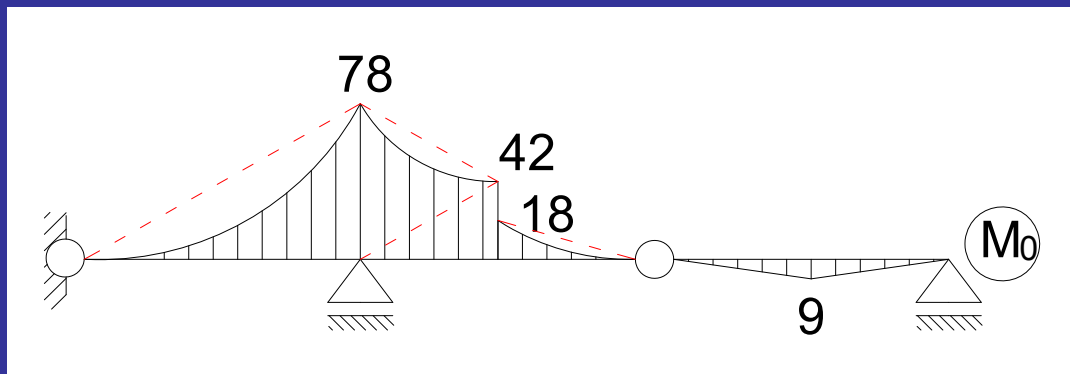
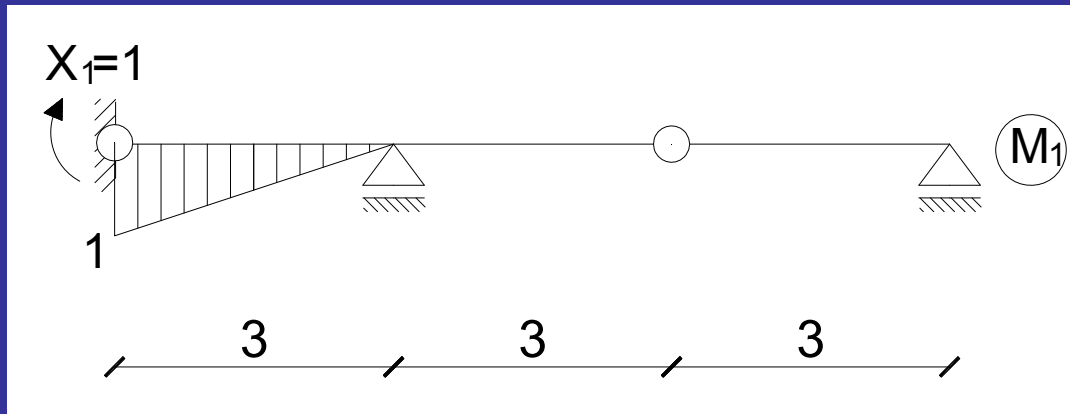
Całkowanie wykresów:



$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$



Całkowanie wykresów:

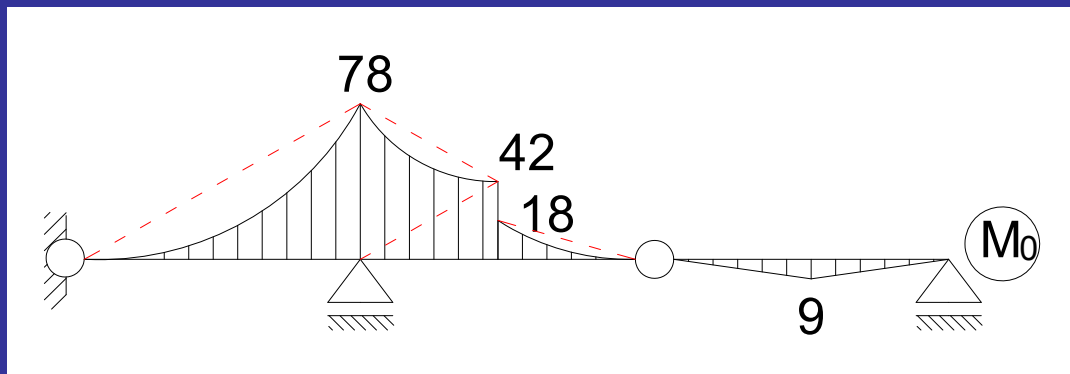
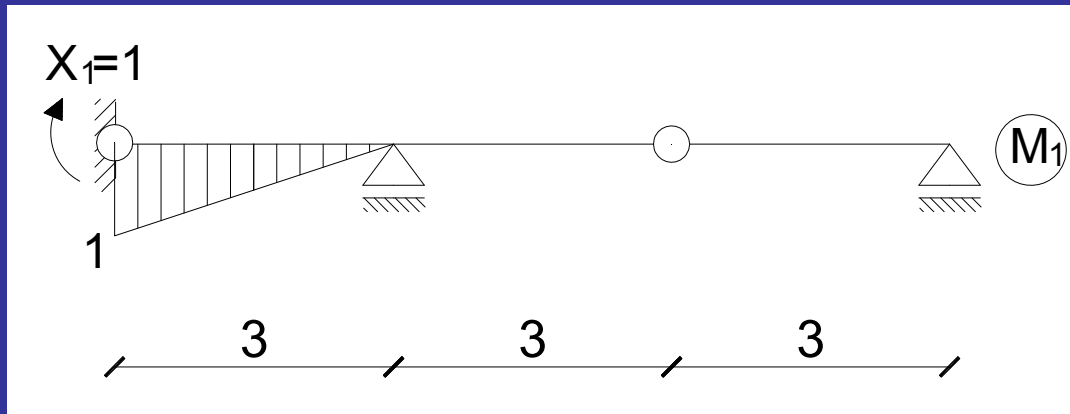


$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$

$$\delta_{10} = \frac{1}{EI} \left(-\frac{1}{2} \cdot 78 \cdot 3 \cdot \frac{1}{3} \cdot 1 \right)$$

$$+ \frac{1}{EI} \left(\frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 1 \right) = \frac{-30}{EI}$$

Całkowanie wykresów:



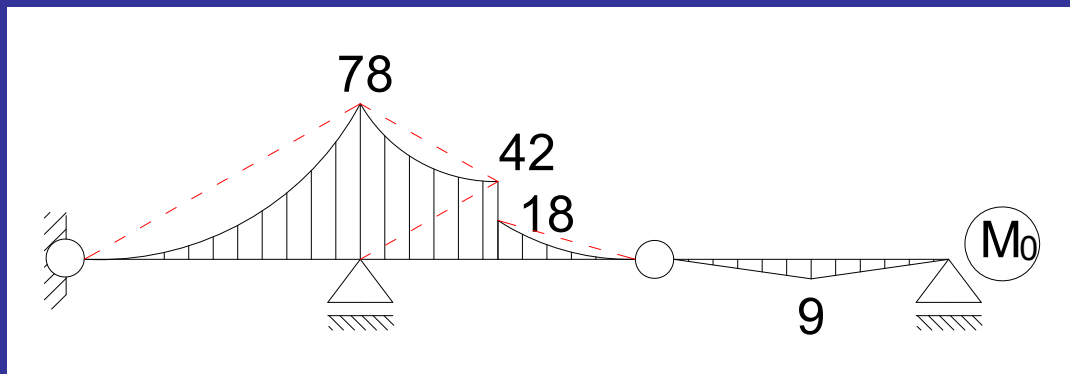
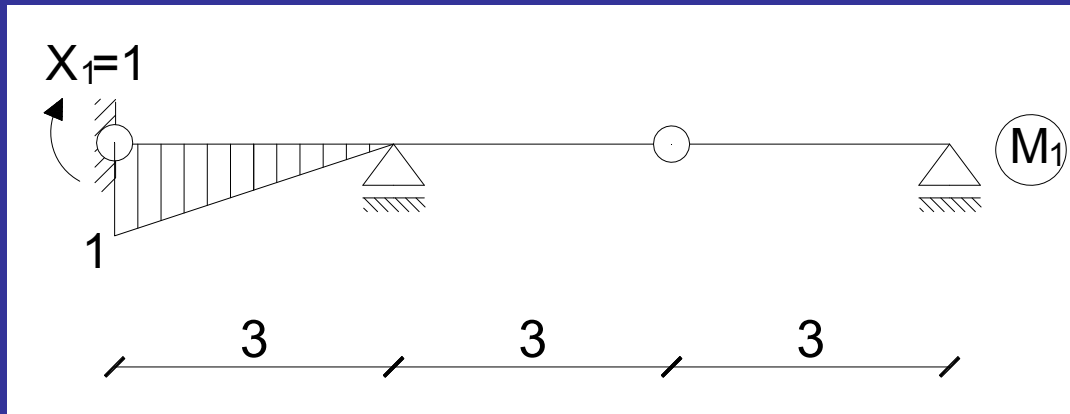
$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$

$$\delta_{10} = \frac{1}{EI} \left(-\frac{1}{2} \cdot 78 \cdot 3 \cdot \frac{1}{3} \cdot 1 \right)$$

$$+ \frac{1}{EI} \left(\frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 1 \right) = \frac{-30}{EI}$$

Równanie Metody Sił:

Całkowanie wykresów:



$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$

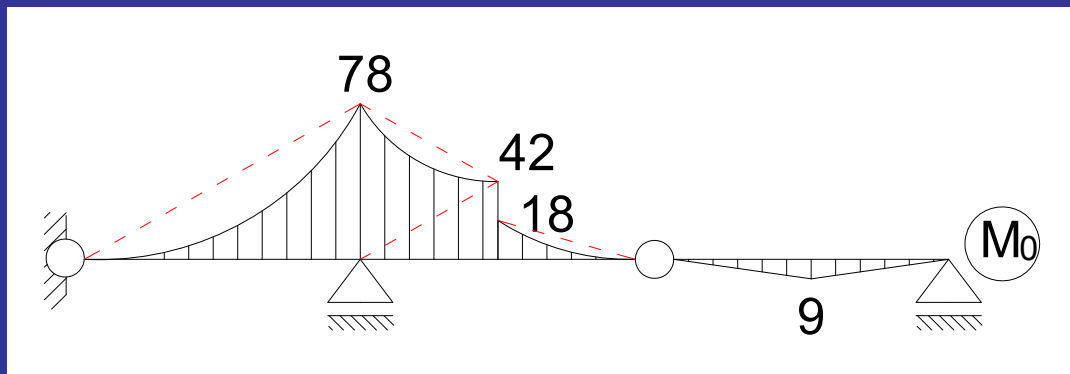
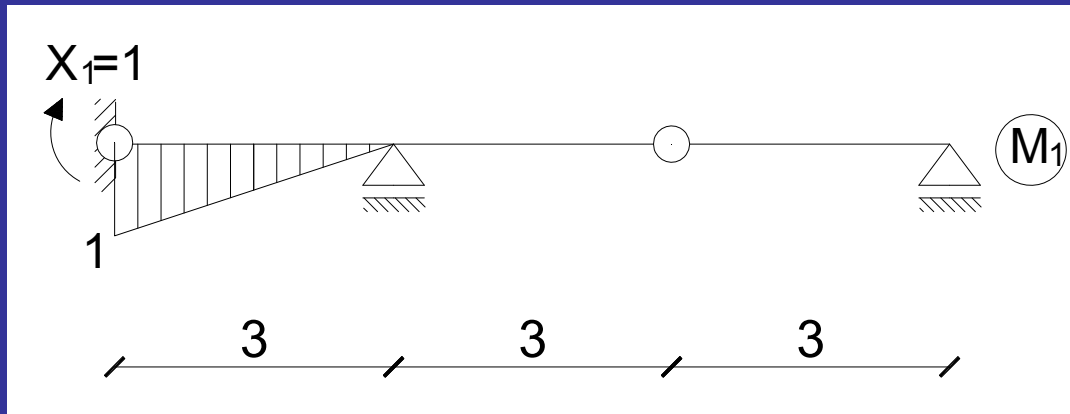
$$\delta_{10} = \frac{1}{EI} \left(-\frac{1}{2} \cdot 78 \cdot 3 \cdot \frac{1}{3} \cdot 1 \right)$$

$$+ \frac{1}{EI} \left(\frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 1 \right) = \frac{-30}{EI}$$

Równanie Metody Sił:

$$\delta_{11} \cdot X_1 + \delta_{10} = 0$$

Całkowanie wykresów:



$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$

$$\delta_{10} = \frac{1}{EI} \left(-\frac{1}{2} \cdot 78 \cdot 3 \cdot \frac{1}{3} \cdot 1 \right)$$

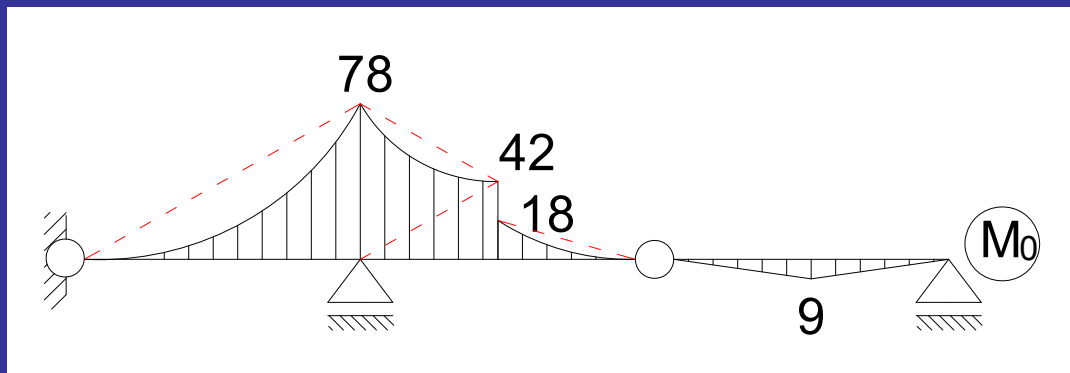
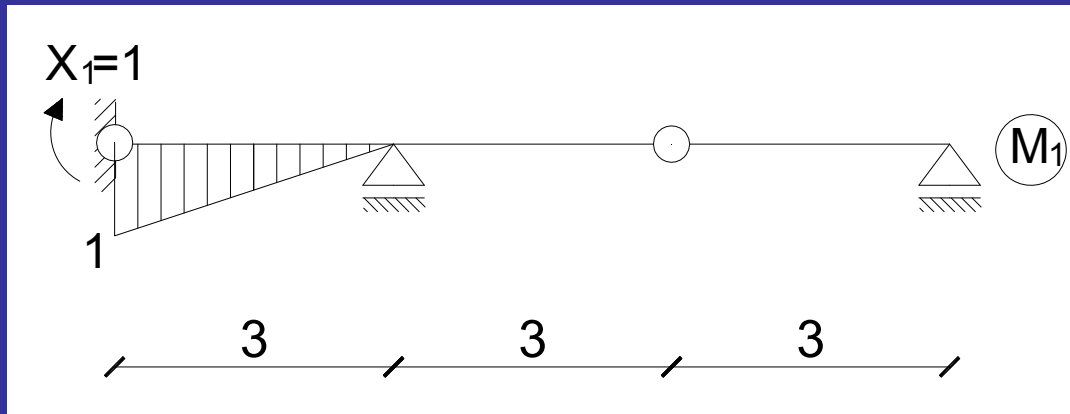
$$+ \frac{1}{EI} \left(\frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 1 \right) = \frac{-30}{EI}$$

Równanie Metody Sił:

$$\delta_{11} \cdot X_1 + \delta_{10} = 0$$

$$\frac{1}{EI} \cdot X_1 - \frac{30}{EI} = 0$$

Całkowanie wykresów:



$$\delta_{11} = \frac{1}{EI} \left(\frac{1}{2} \cdot 1 \cdot 3 \cdot \frac{2}{3} \cdot 1 \right) = \frac{1}{EI}$$

$$\delta_{10} = \frac{1}{EI} \left(-\frac{1}{2} \cdot 78 \cdot 3 \cdot \frac{1}{3} \cdot 1 \right)$$

$$+ \frac{1}{EI} \left(\frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 1 \right) = \frac{-30}{EI}$$

Równanie Metody Sił:

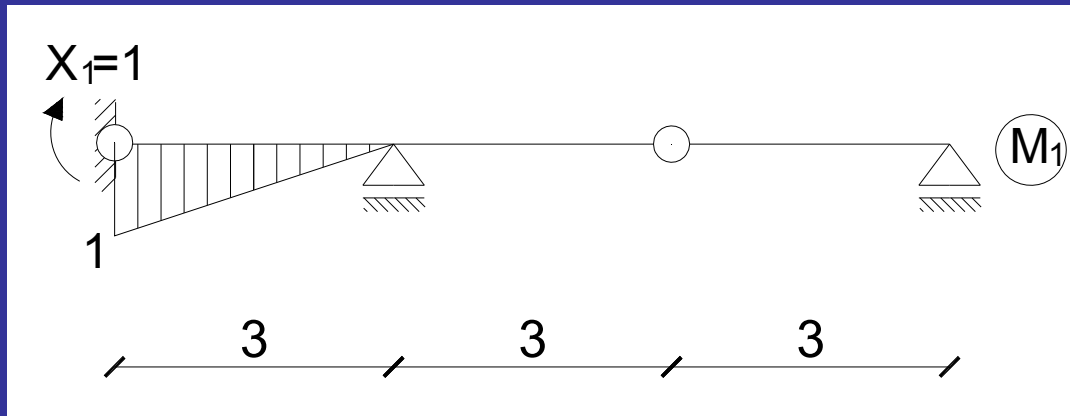
$$\delta_{11} \cdot X_1 + \delta_{10} = 0$$

$$\frac{1}{EI} \cdot X_1 - \frac{30}{EI} = 0$$

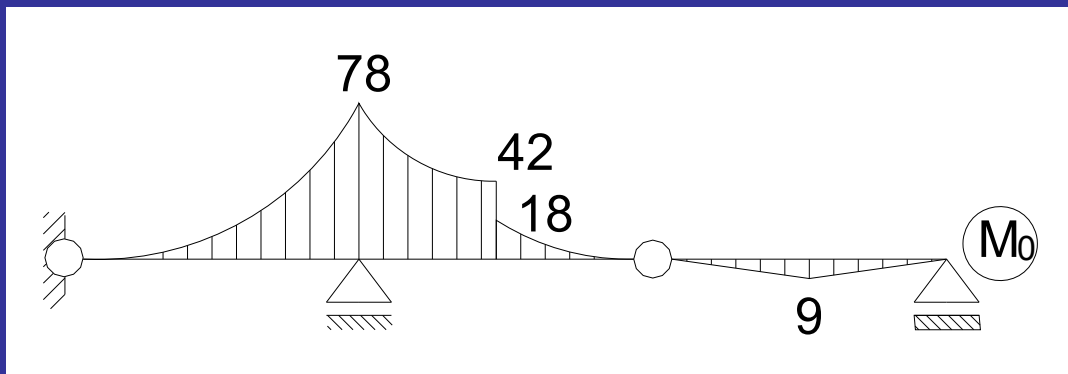
↓

$$X_1 = 30 \text{ kNm}$$

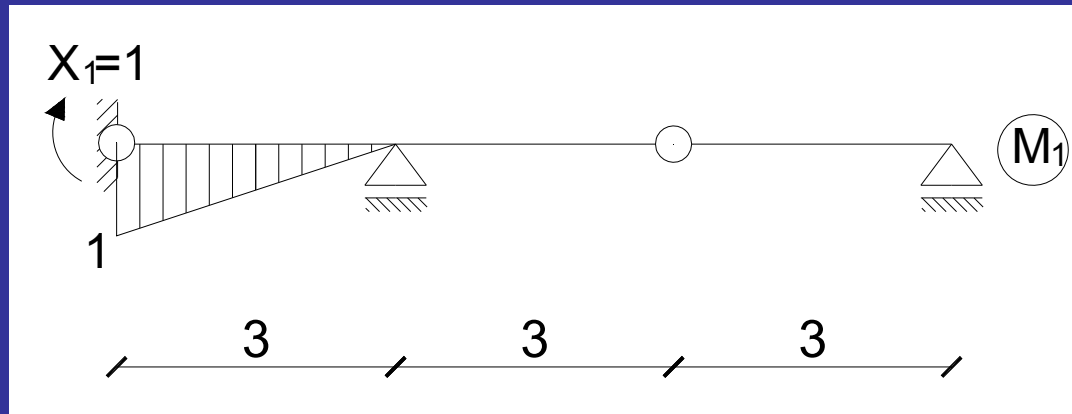
Ostateczny wykres momentów



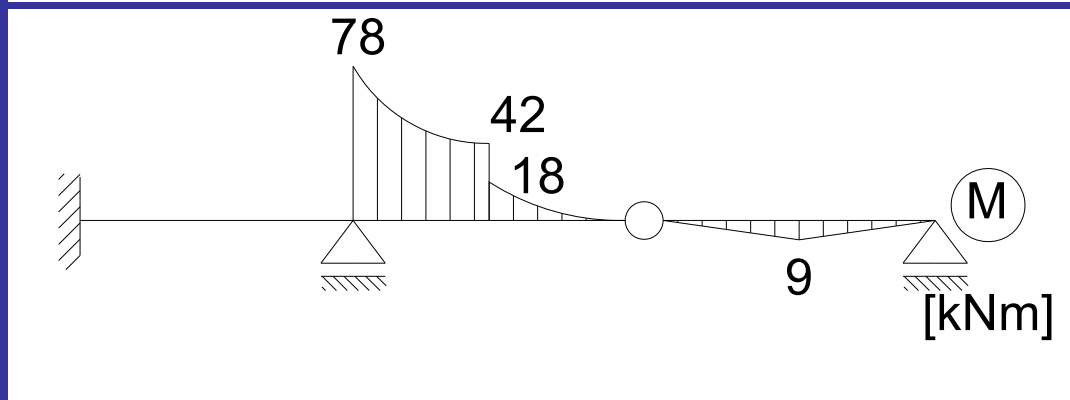
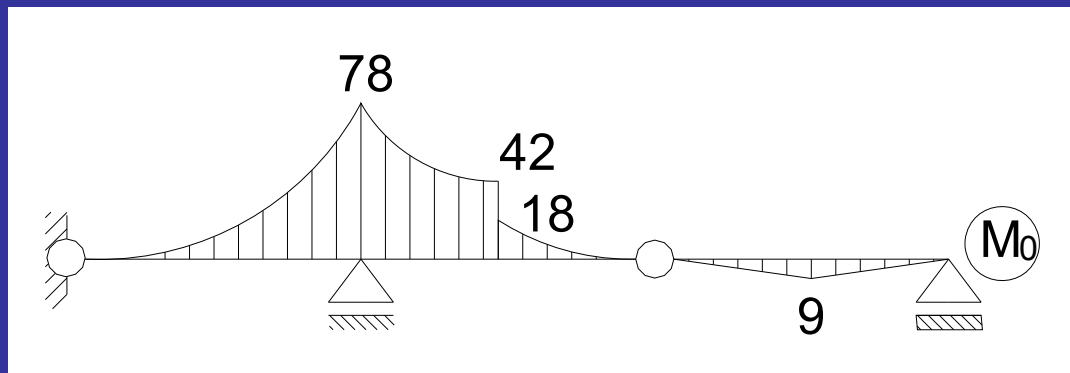
$$M_i = M_{i1} \cdot X_1 + M_{i0}$$



Ostateczny wykres momentów

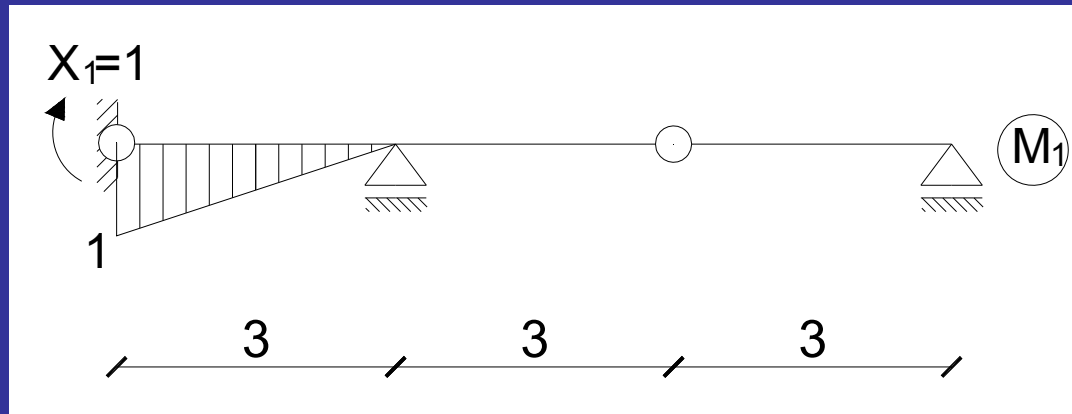


$$M_i = M_{i1} \cdot X_1 + M_{i0}$$

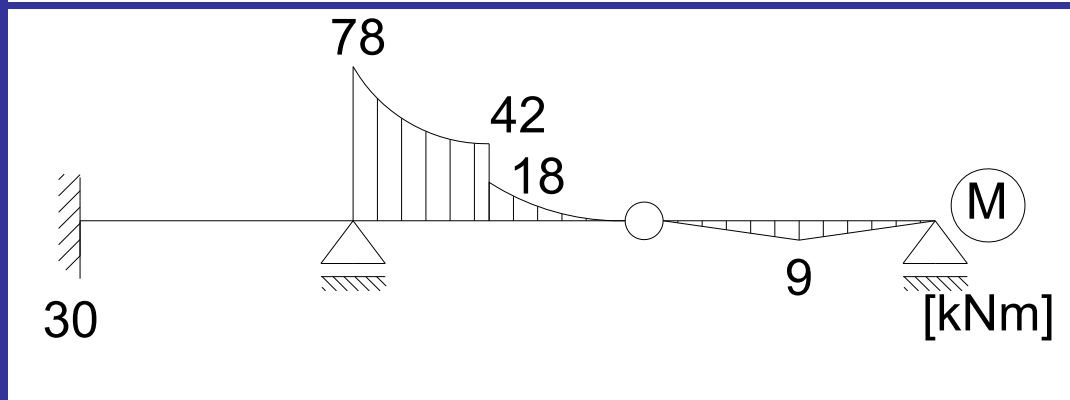
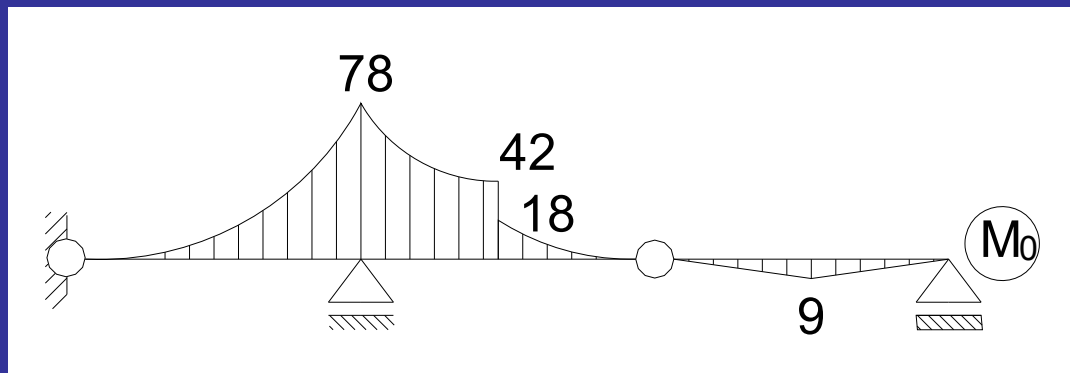


dr inż. Hanna Weber

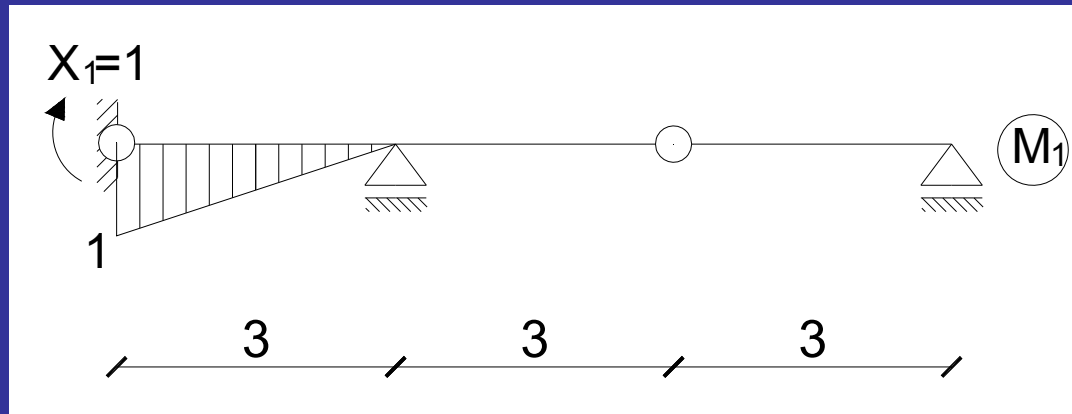
Ostateczny wykres momentów



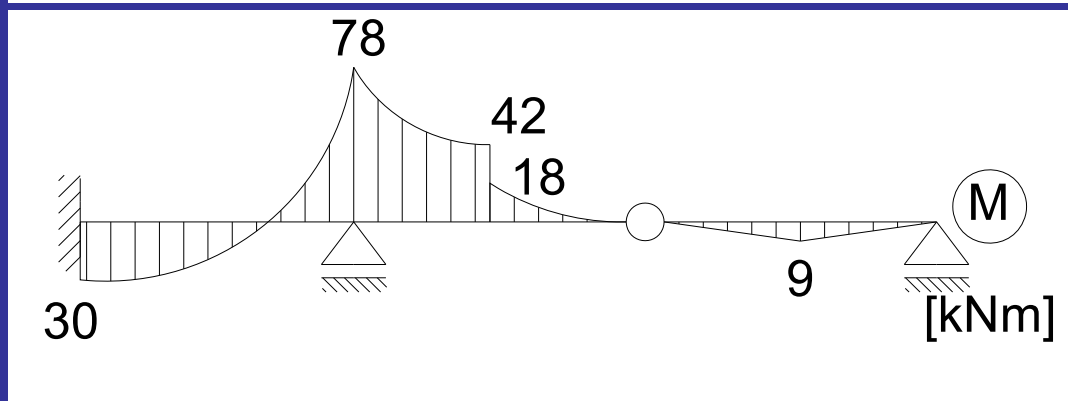
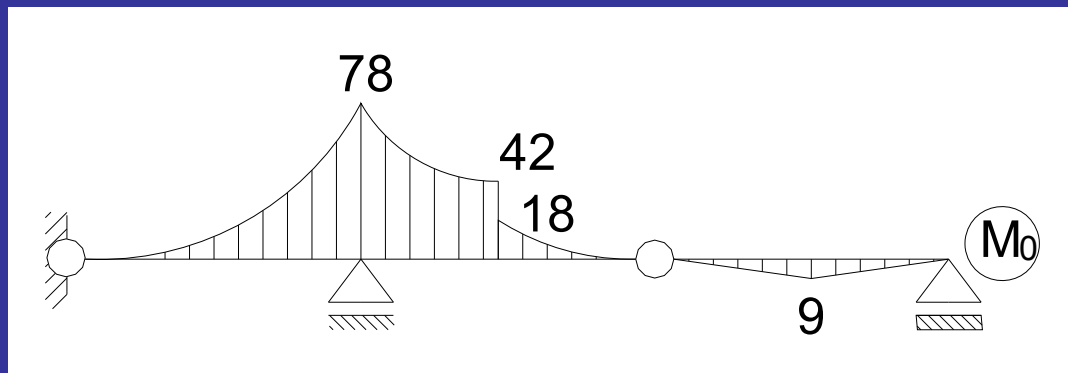
$$M_i = M_{i1} \cdot X_1 + M_{i0}$$



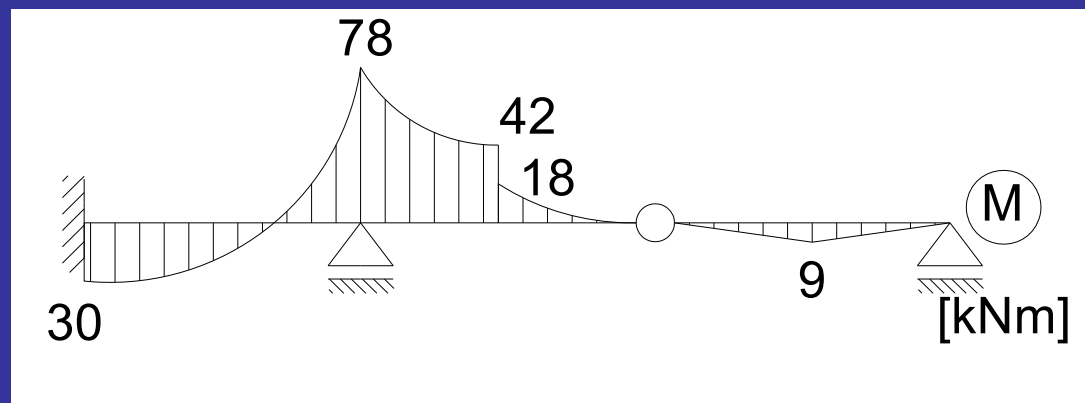
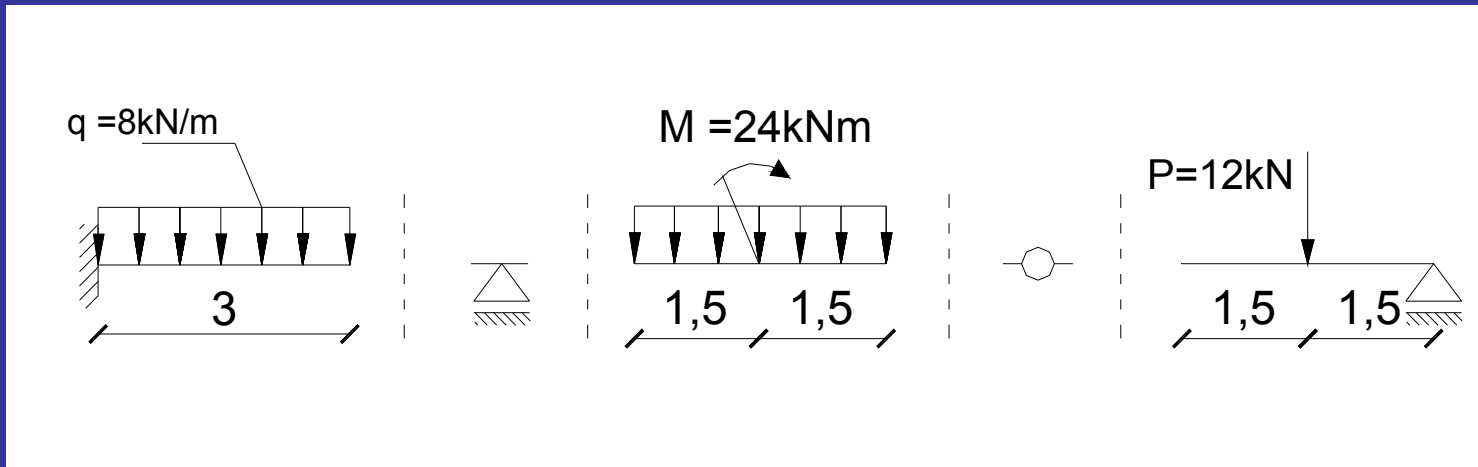
Ostateczny wykres momentów



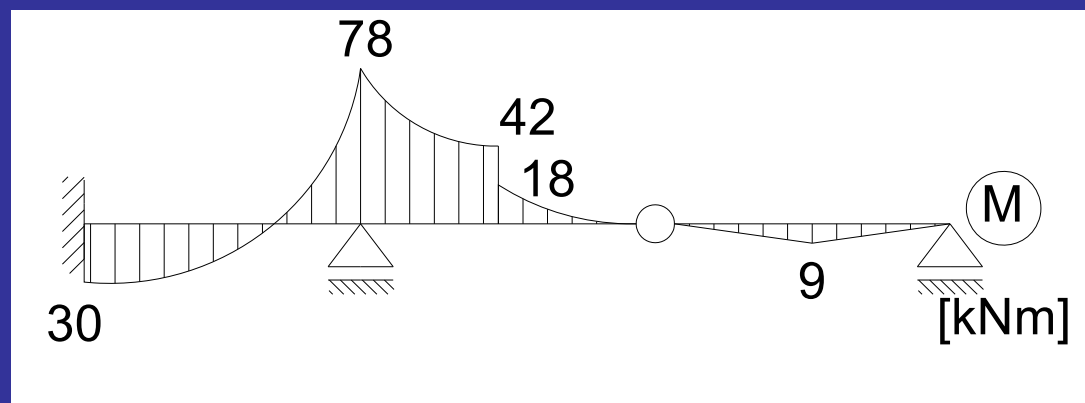
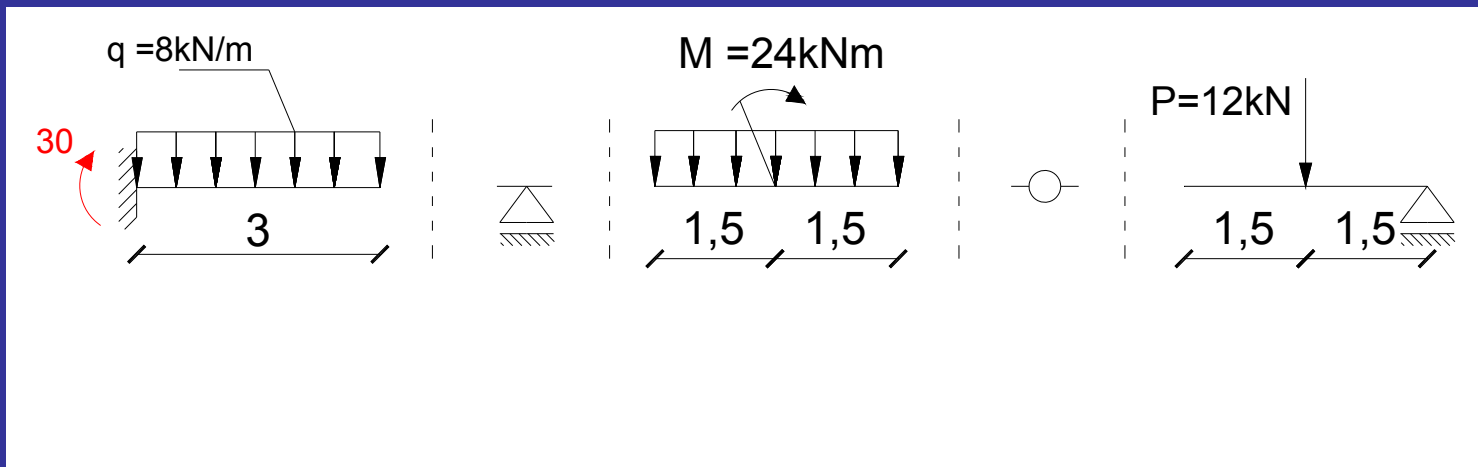
$$M_i = M_{i1} \cdot X_1 + M_{i0}$$



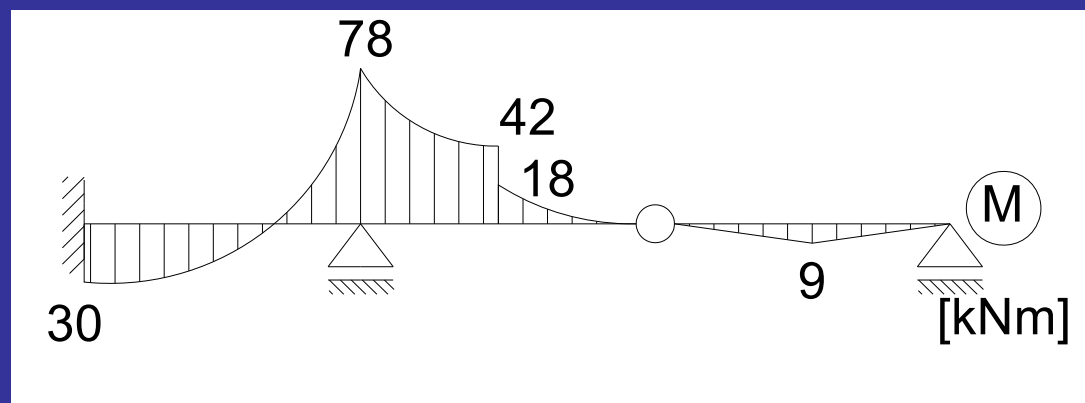
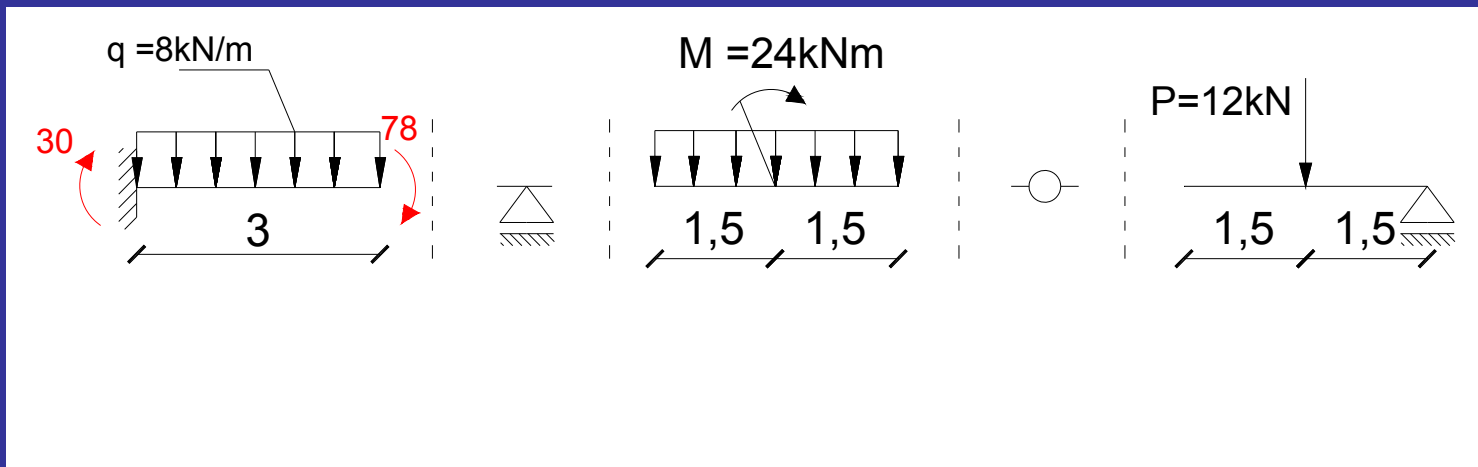
Wyznaczenie wartości sił tnących :



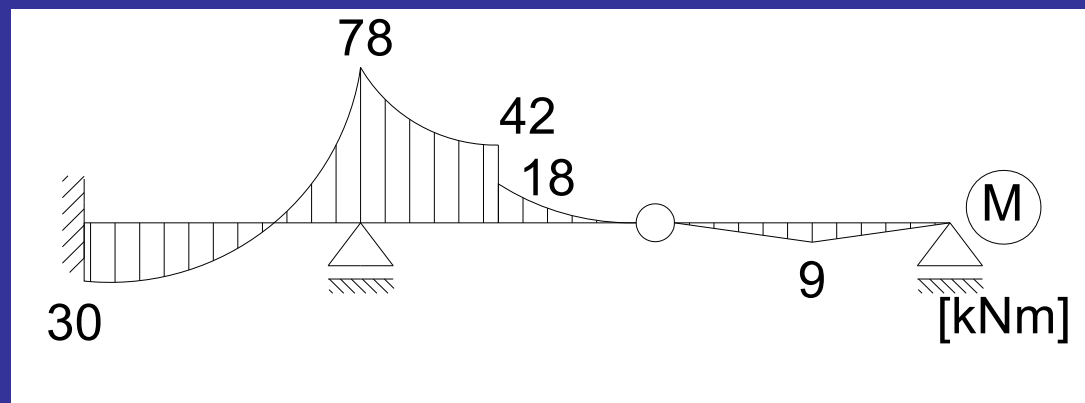
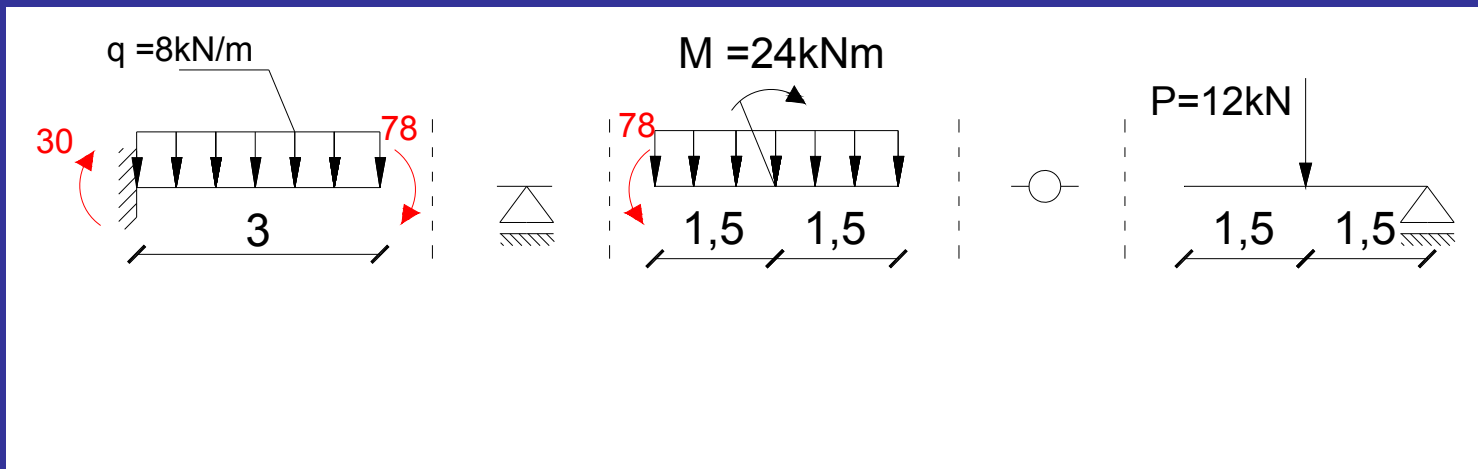
Wyznaczenie wartości sił tnących :



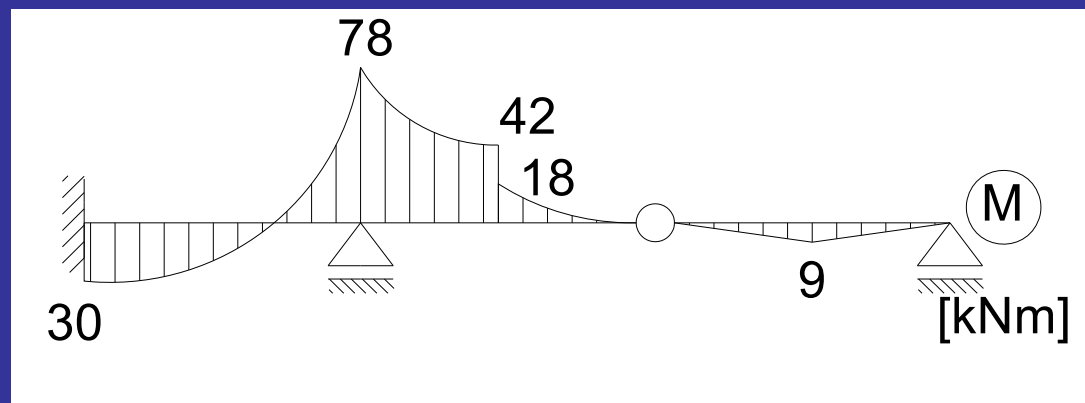
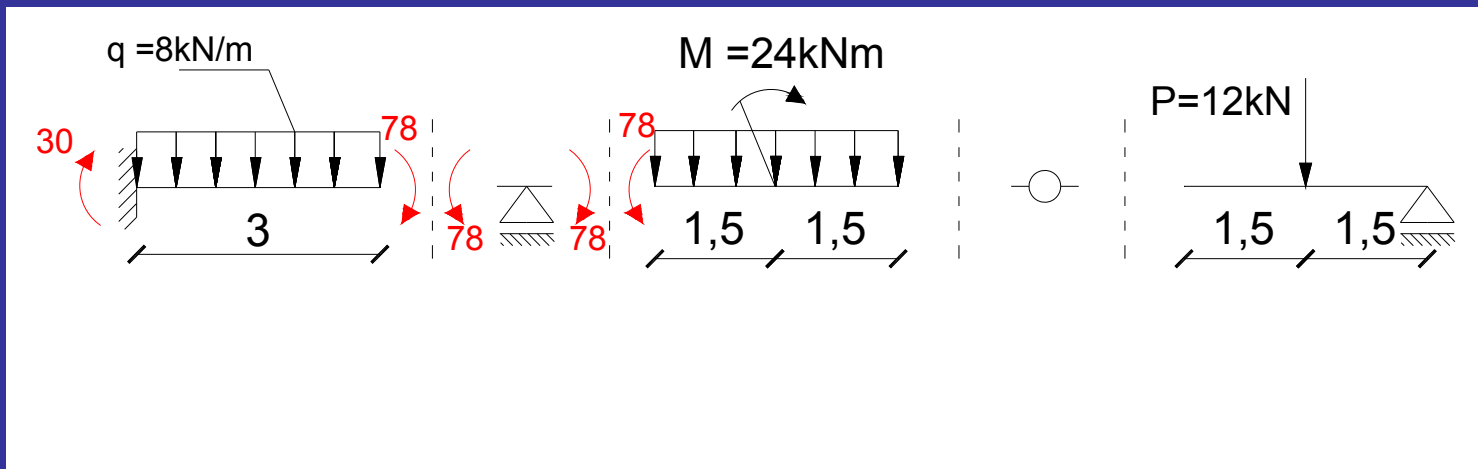
Wyznaczenie wartości sił tnących :



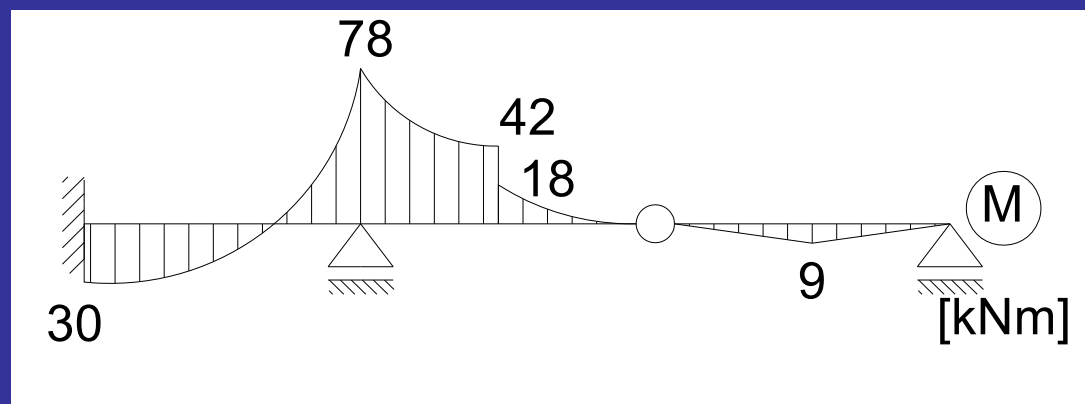
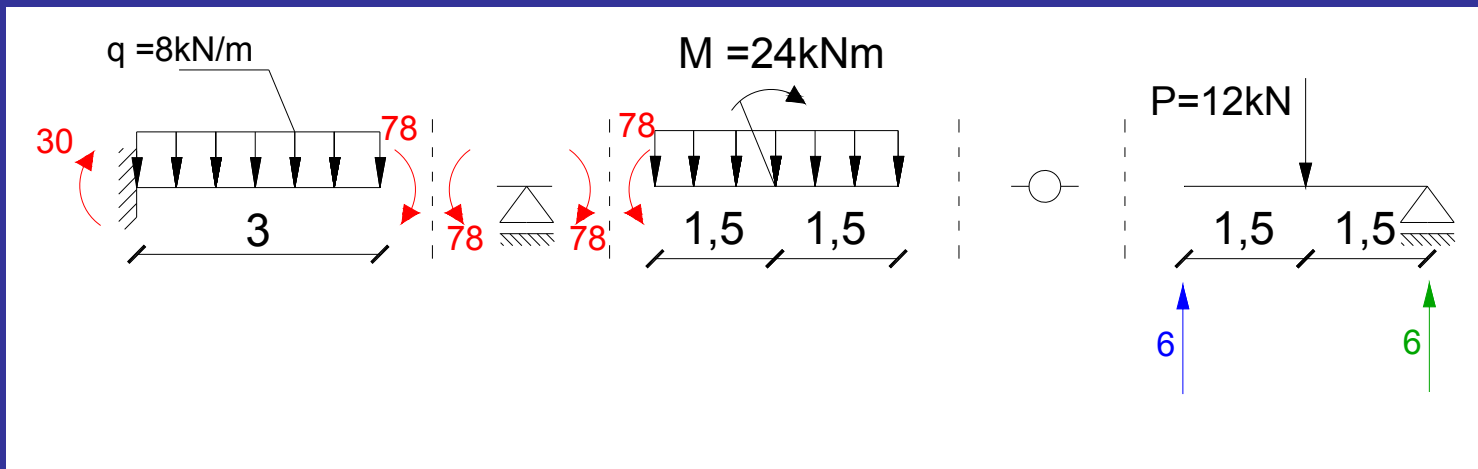
Wyznaczenie wartości sił tnących :



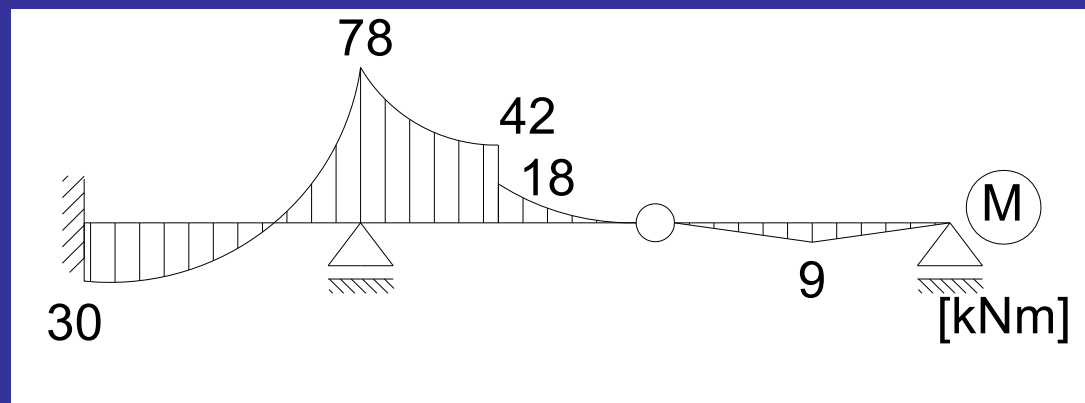
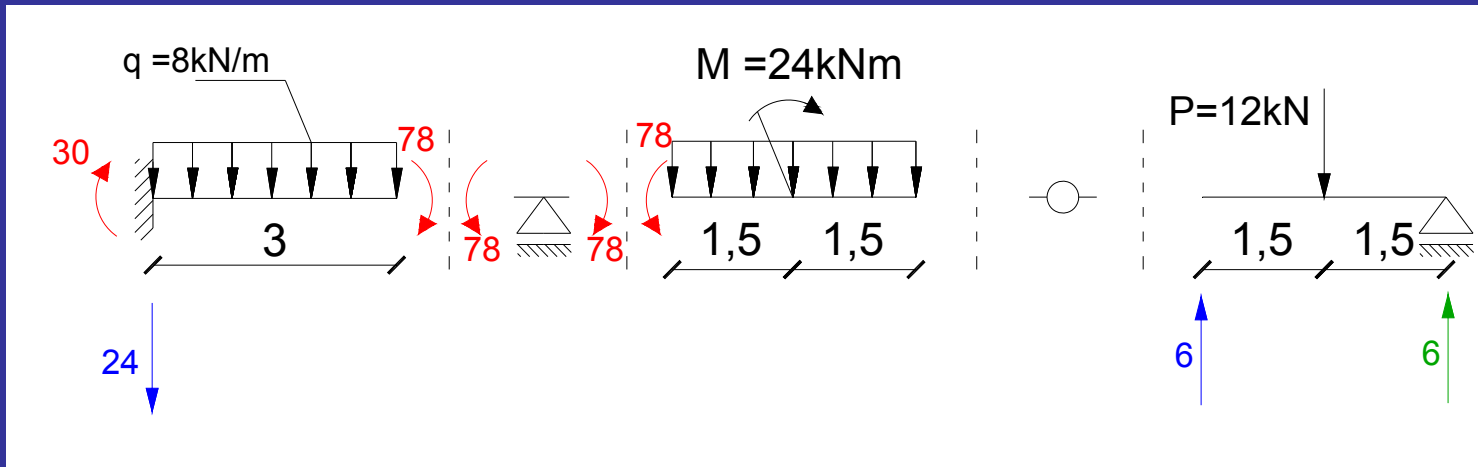
Wyznaczenie wartości sił tnących :



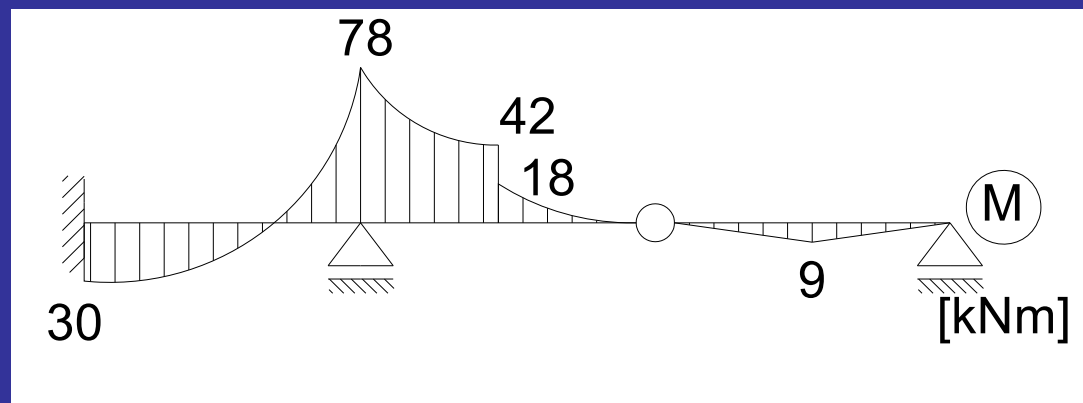
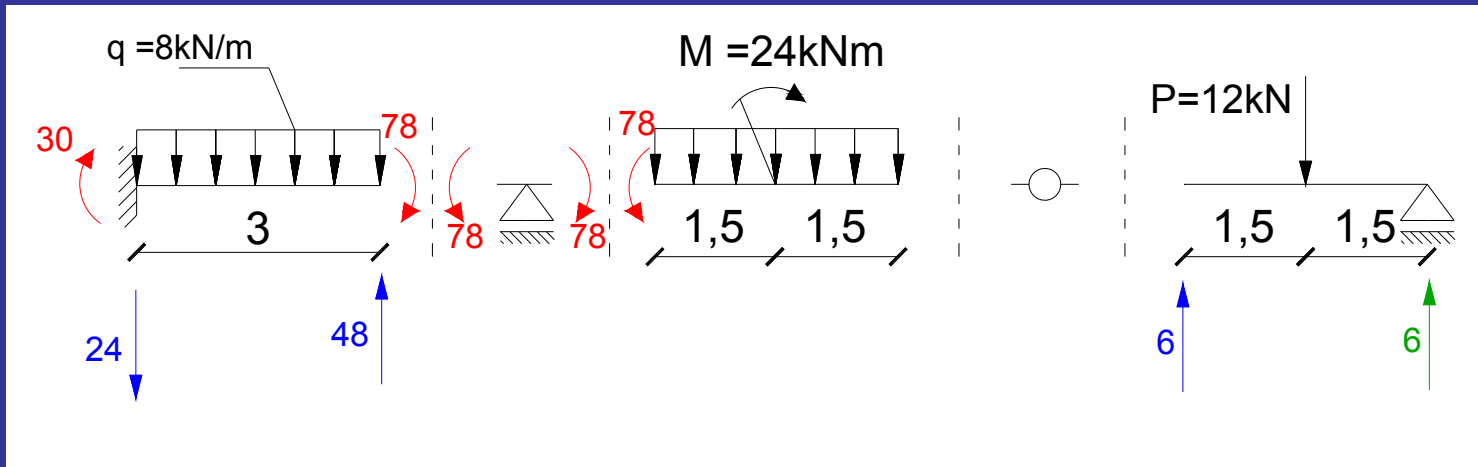
Wyznaczenie wartości sił tnących :



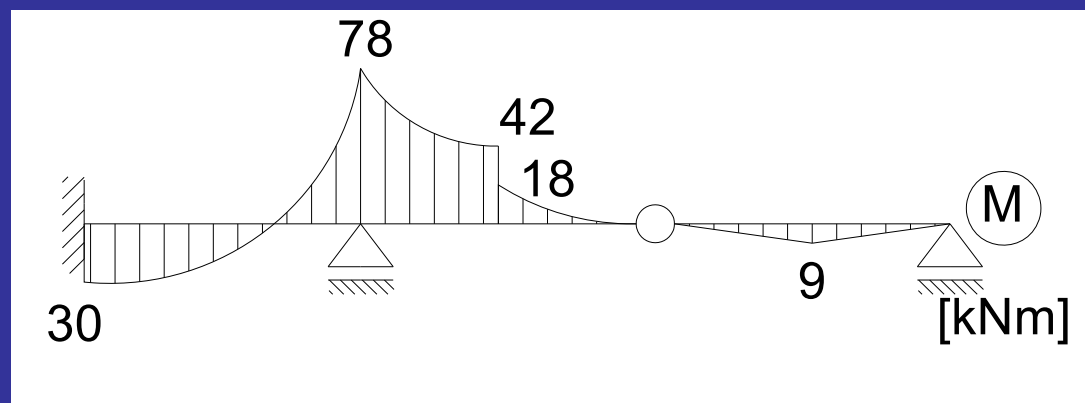
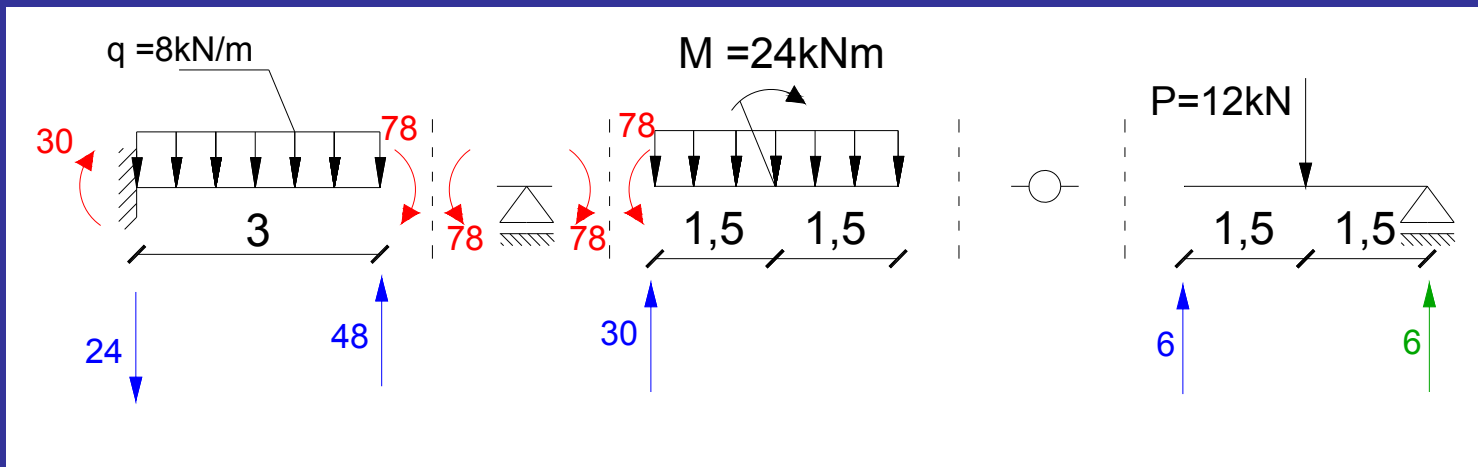
Wyznaczenie wartości sił tnących :



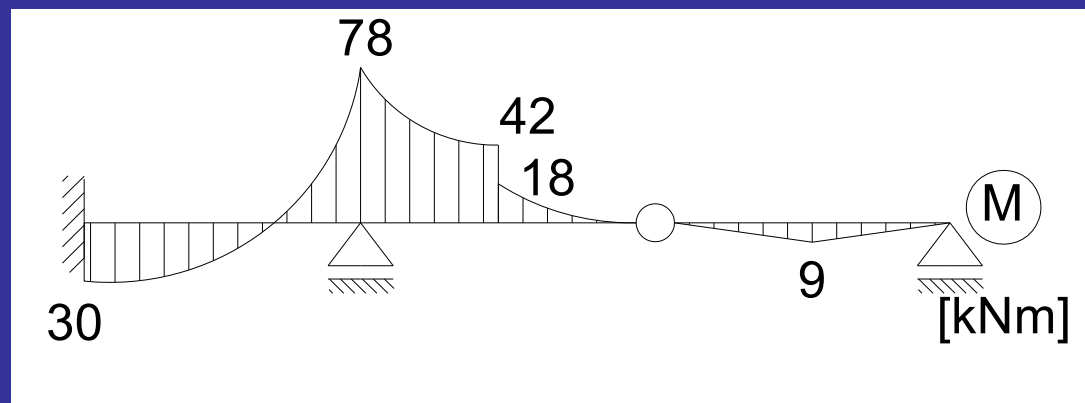
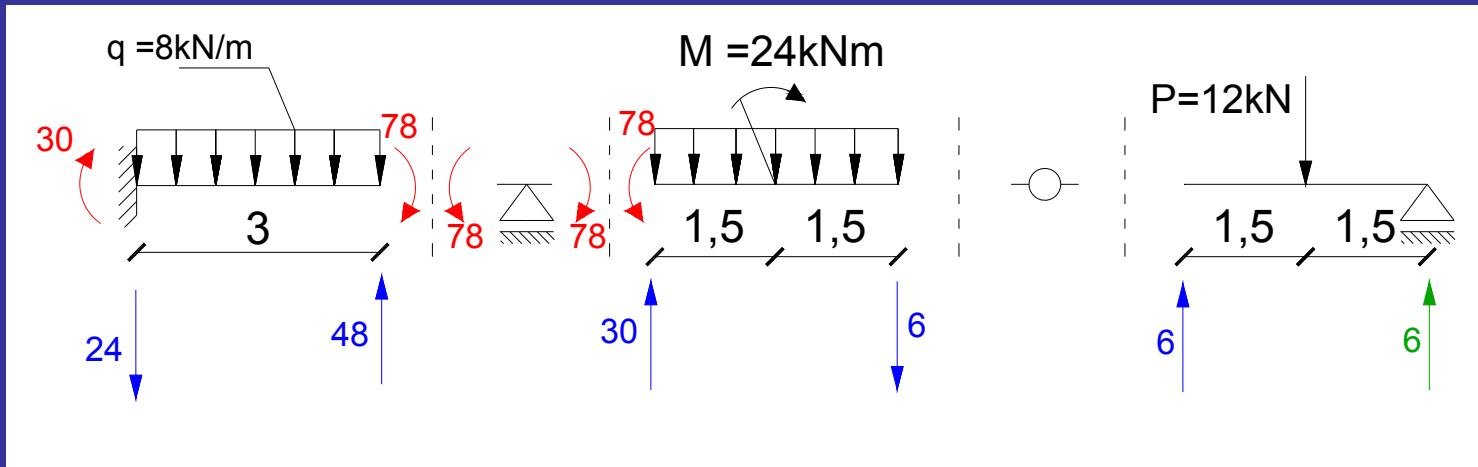
Wyznaczenie wartości sił tnących :



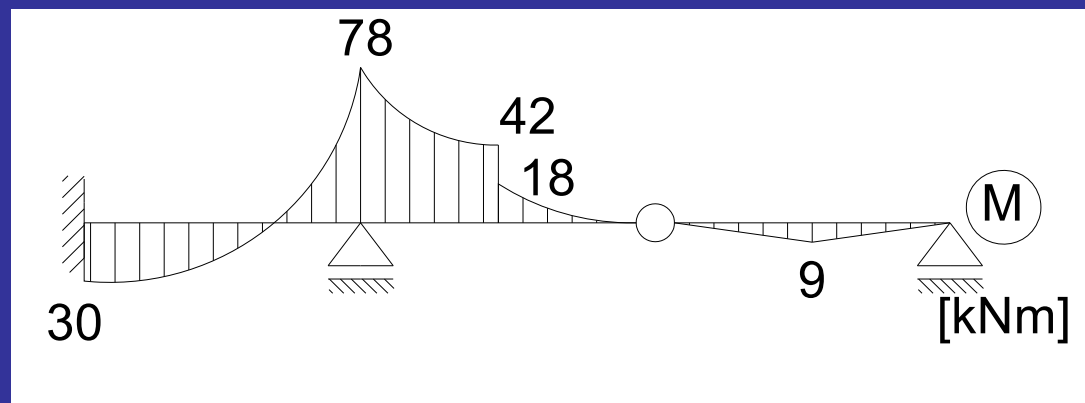
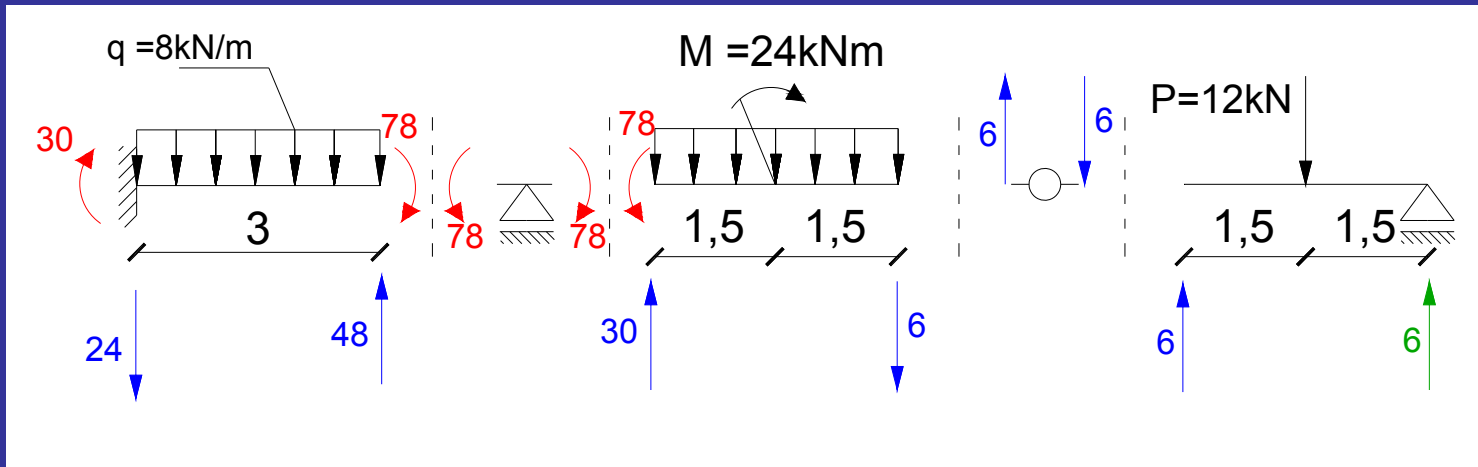
Wyznaczenie wartości sił tnących :



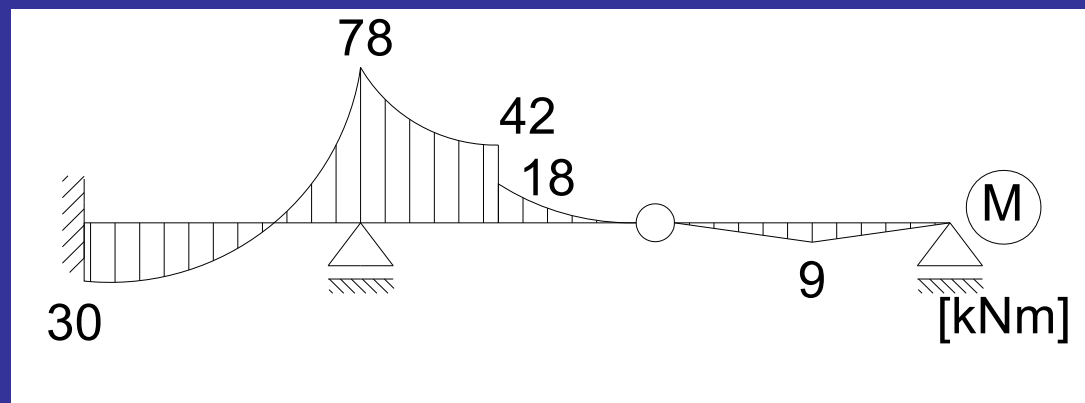
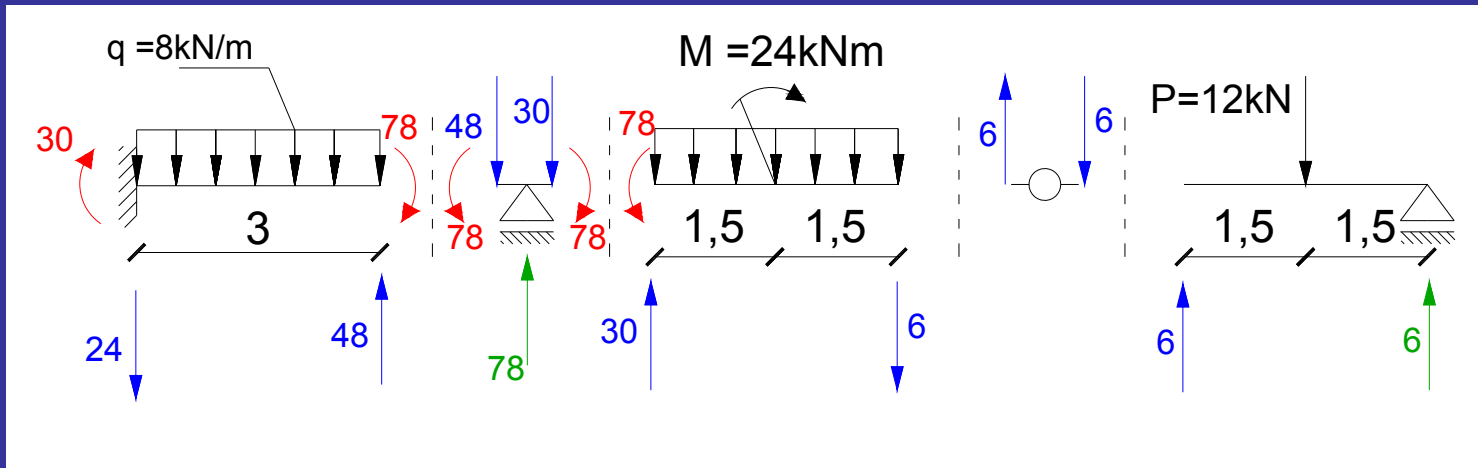
Wyznaczenie wartości sił tnących :



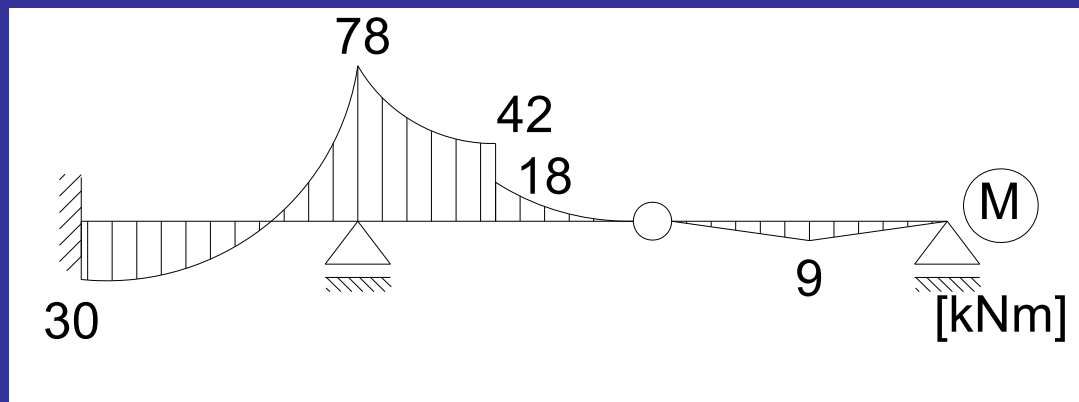
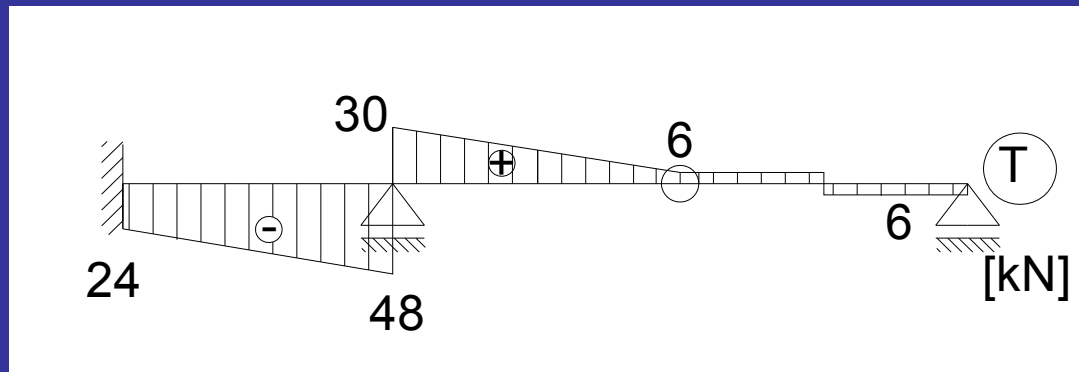
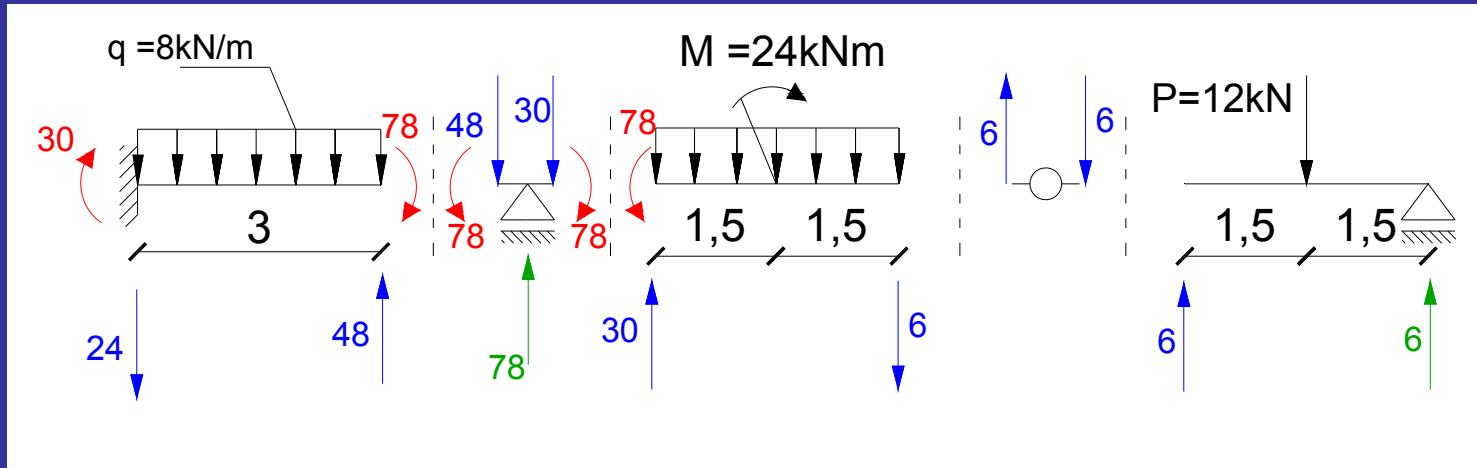
Wyznaczenie wartości sił tnących :



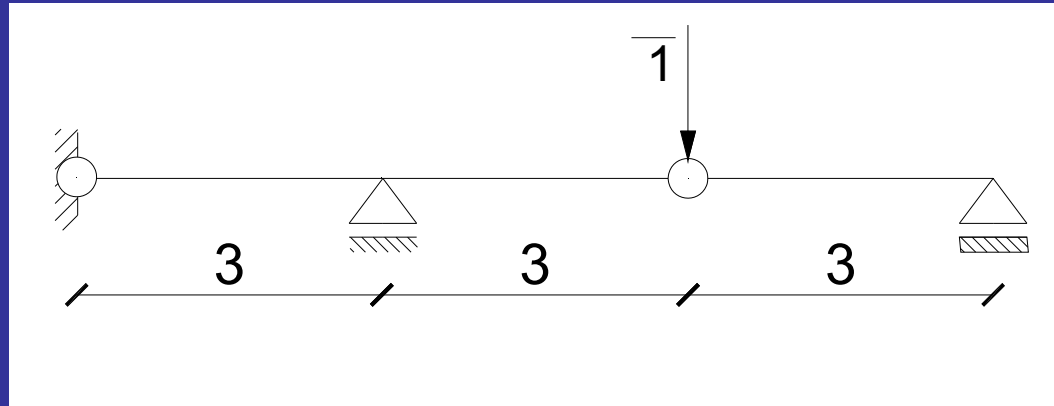
Wyznaczenie wartości sił tnących :



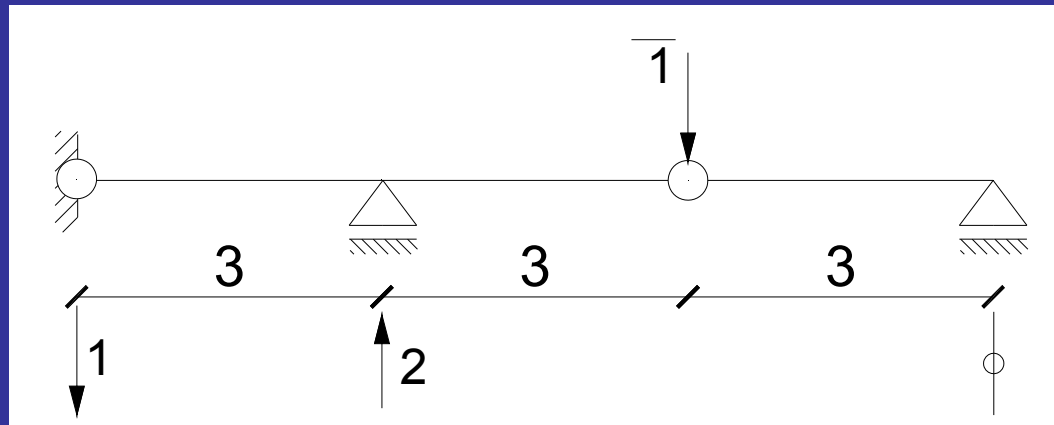
Wyznaczenie wartości sił tnących :



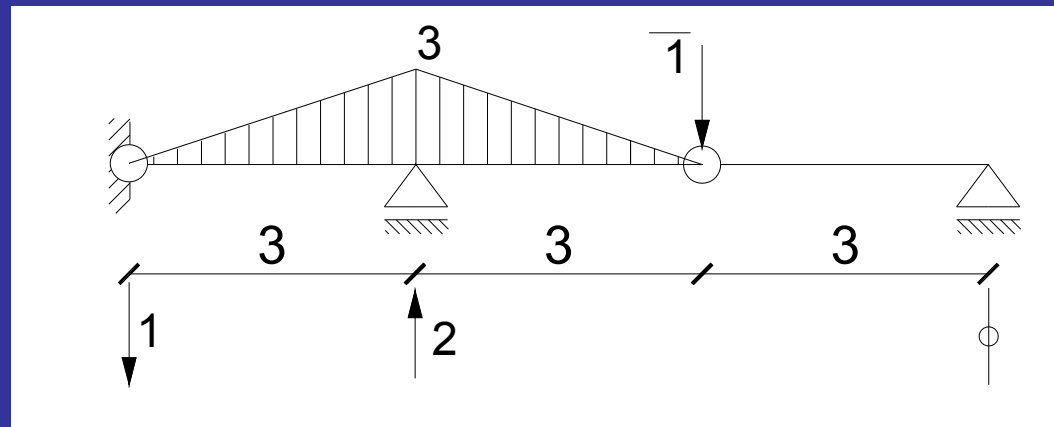
Ugięcie przegubu:



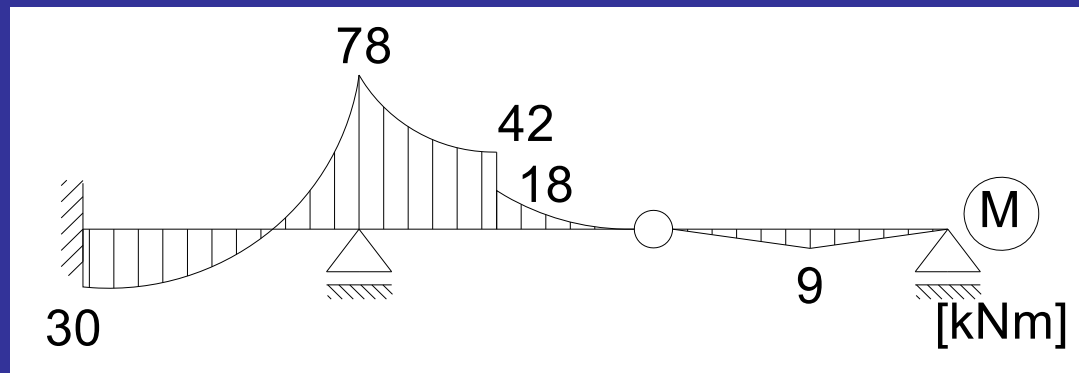
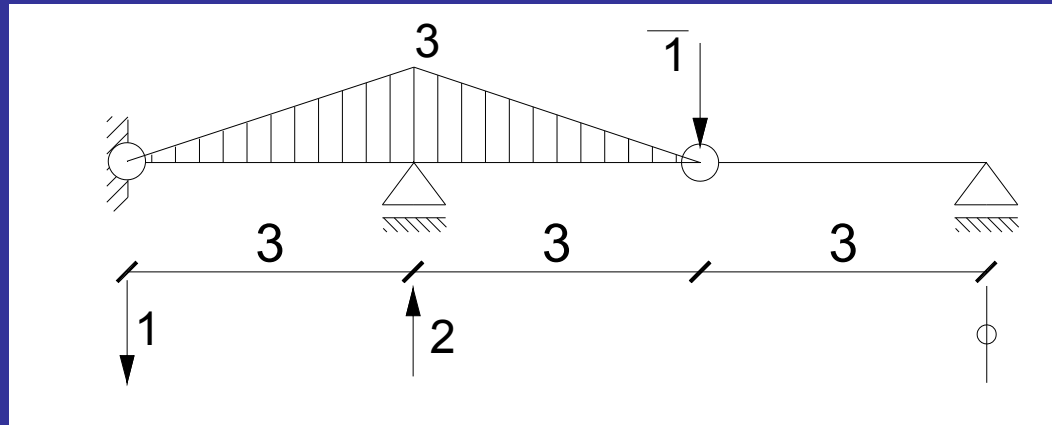
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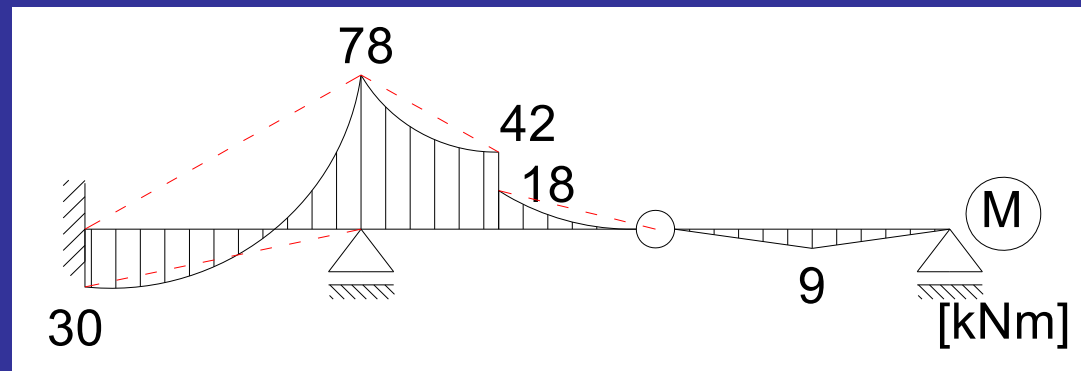
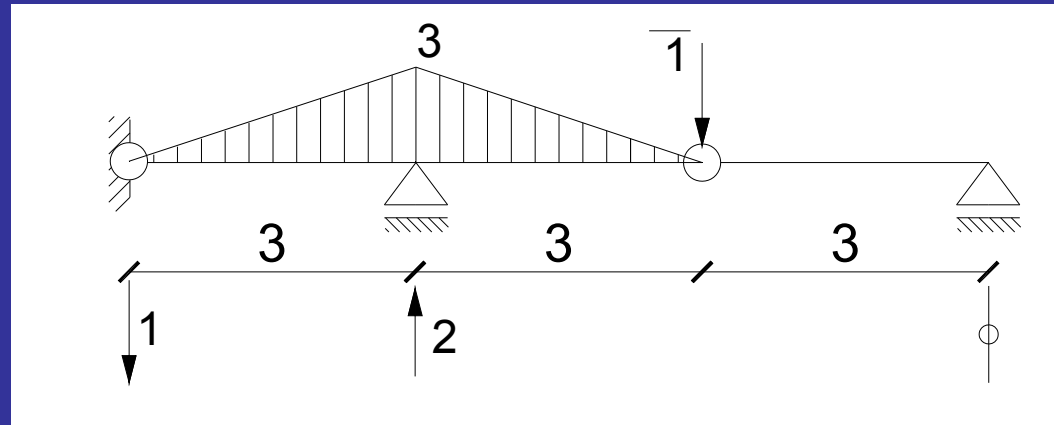
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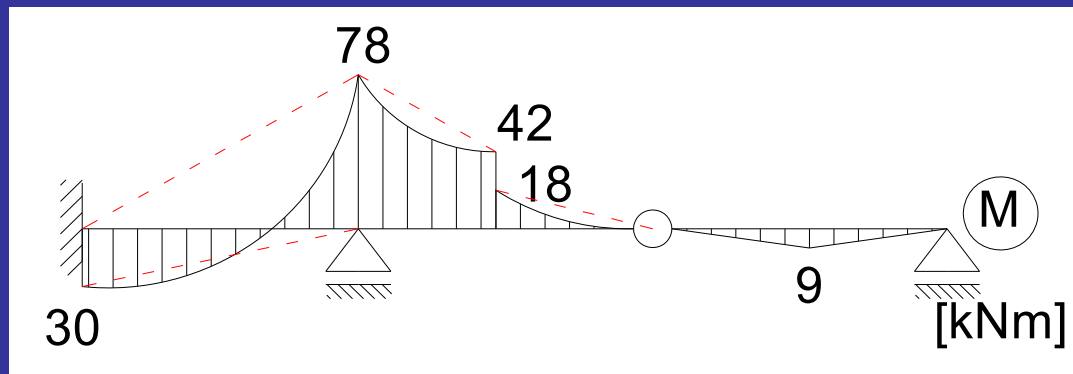
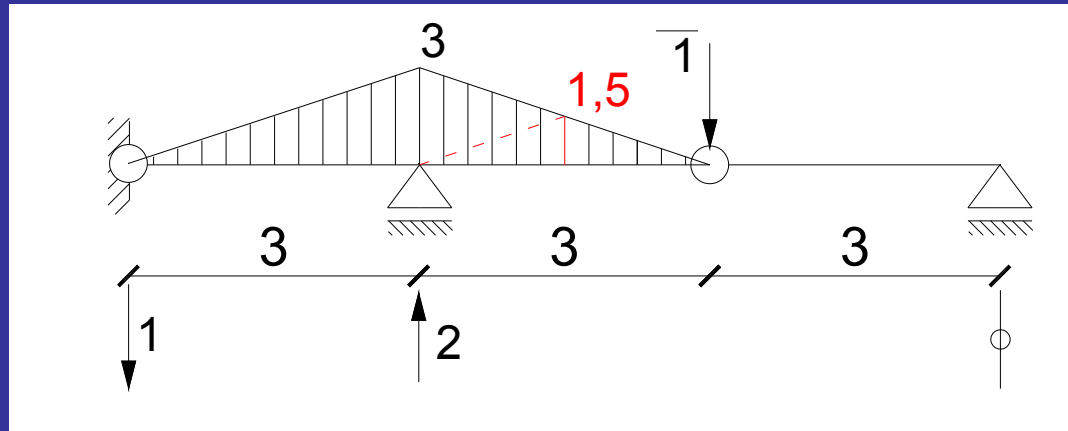
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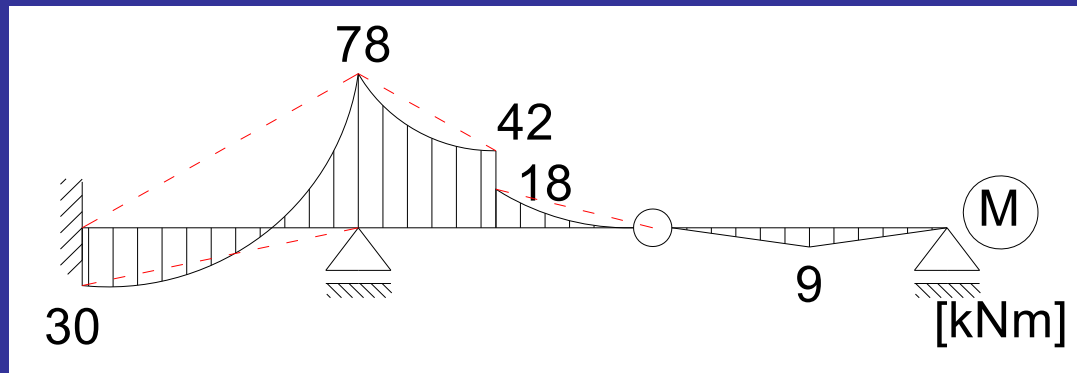
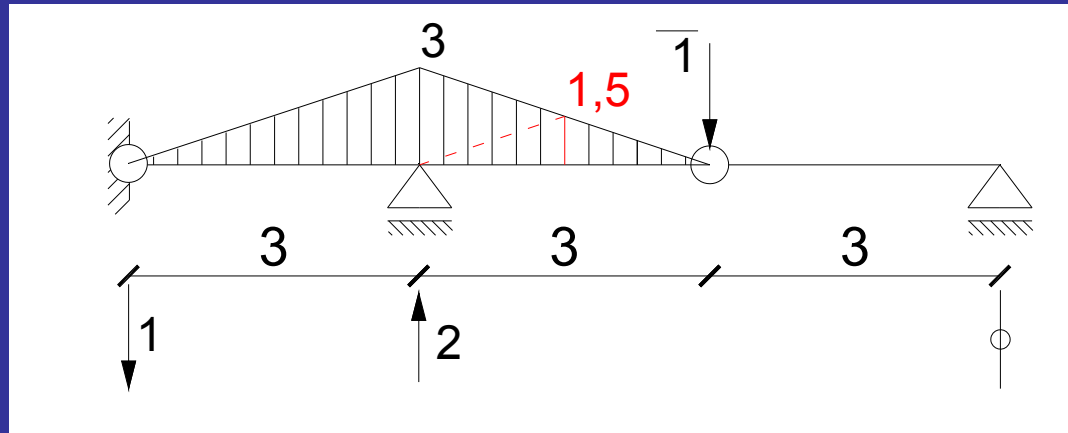
Ugięcie przegubu:



Ugięcie przegubu:



Ugięcie przegubu:



$$V_c = \frac{1}{EI} \left[\frac{1}{2} \cdot 3 \cdot 3 \cdot \left(\frac{2}{3} \cdot 78 - \frac{1}{3} \cdot 30 \right) - \frac{2}{3} \cdot \frac{8 \cdot 3^2}{8} \cdot 3 \cdot \frac{1}{2} \cdot 3 + \frac{1}{2} \cdot 3 \cdot 1,5 \cdot \left(\frac{2}{3} \cdot 78 + \frac{1}{3} \cdot 42 \right) + \frac{1}{2} \cdot 1,5 \cdot 1,5 \cdot \left(\frac{1}{3} \cdot 78 + \frac{2}{3} \cdot 42 \right) \right]$$

$$+ \frac{1}{EI} \left[\frac{1}{2} \cdot 1,5 \cdot 1,5 \cdot \left(\frac{2}{3} \cdot 18 \right) - \frac{2}{3} \cdot \frac{8 \cdot 1,5^2}{8} \cdot 1,5 \cdot \left(\frac{1}{2} \cdot 1,5 + \frac{1}{2} \cdot 3 \right) - \frac{2}{3} \cdot \frac{8 \cdot 1,5^2}{8} \cdot 1,5 \cdot \left(\frac{1}{2} \cdot 1,5 \right) \right]$$