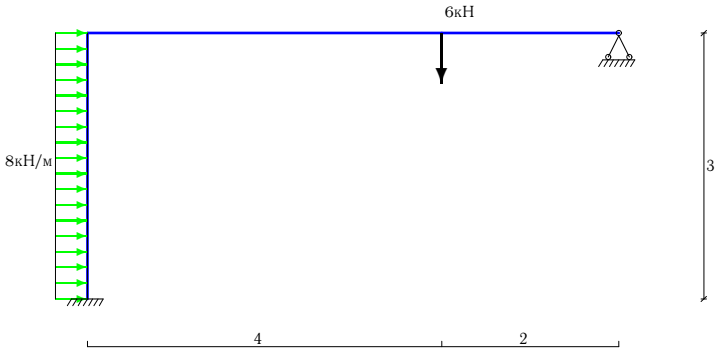
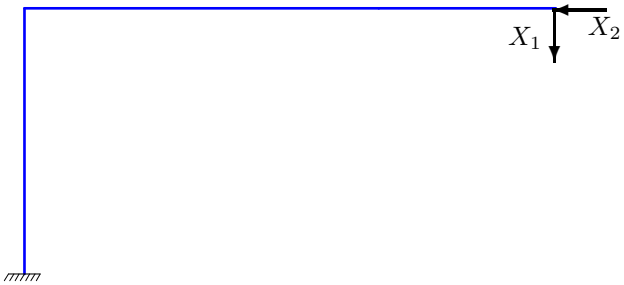
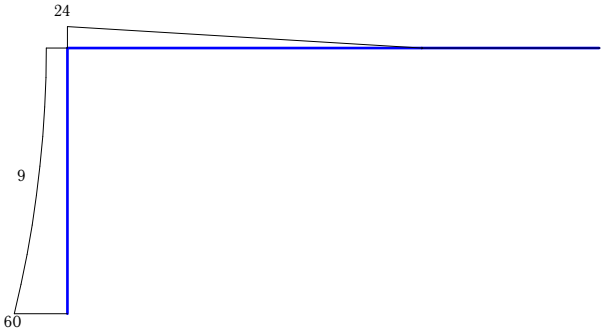
Расчет статически неопределимой рамы методом сил

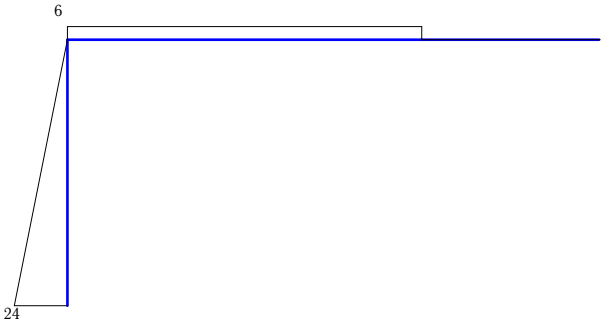


Основная система



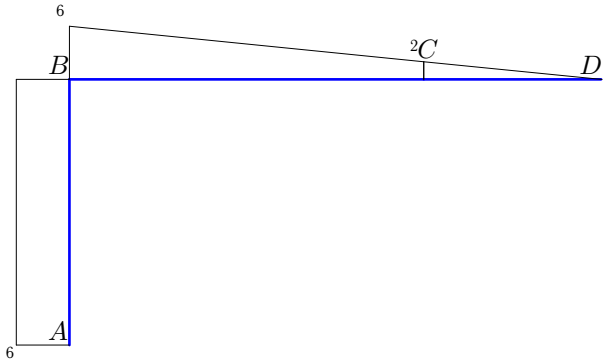


M_p



Q_p

N_p



m_1

m_2

Система канонических уравнений

$\delta_{11} \cdot X_1 + \delta_{12} \cdot X_2 + \Delta_{P1} = 0,$

$\delta_{21} \cdot X_1 + \delta_{22} \cdot X_2 + \Delta_{P2} = 0,$

или

$180 \cdot X_1 - 27 \cdot X_2 = -872;$

$-27 \cdot X_1 + 9 \cdot X_2 = 189;$

Коэффициенты системы находим по правилу Верещагина:

$EI \cdot \delta_{11} = \sum_n \int_0^s m_1 m_1 ds = 6 \cdot 6 \cdot 3 + (\frac{1}{2} \cdot 6 \cdot 4 \cdot \frac{2}{3} \cdot 6 + \frac{1}{2} \cdot 6 \cdot 4 \cdot \frac{1}{3} \cdot 2 + \frac{1}{2} \cdot \cdot 2 \cdot 4 \cdot \frac{2}{3} \cdot 2 + \frac{1}{2} \cdot 2 \cdot 4 \cdot \frac{1}{3} \cdot 6) + (\frac{1}{2} \cdot 2 \cdot 2 \cdot \frac{2}{3} \cdot 2) = +108 + 69.33 + 2.67 = 180;$

$EI \cdot \delta_{21} = \sum_n \int_0^s m_2 m_1 ds = (-\frac{1}{2} \cdot 3 \cdot 3 \cdot 6) = -27;$

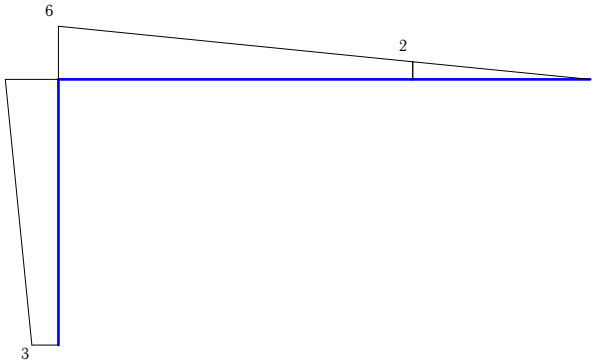
$EI \cdot \Delta_{P1} = \sum_n \int_0^s M_p m_1 ds = (\frac{1}{2} \cdot 60 \cdot 3 \cdot 6 + \frac{1}{2} \cdot 24 \cdot 3 \cdot 6) - 12 \cdot \cdot 9 + (\frac{1}{2} \cdot 24 \cdot 4 \cdot \frac{2}{3} \cdot 6 + \frac{1}{2} \cdot 24 \cdot 4 \cdot \frac{1}{3} \cdot 2) = +756 - 108 + 224 = 872;$

$EI \cdot \delta_{22} = \sum_n \int_0^s m_2 m_2 ds = (\frac{1}{2} \cdot 3 \cdot 3 \cdot \frac{2}{3} \cdot 3) = 9;$

$EI \cdot \Delta_{P2} = \sum_n \int_0^s M_p m_2 ds = (-\frac{1}{2} \cdot 60 \cdot 3 \cdot \frac{2}{3} \cdot 3 - \frac{1}{2} \cdot 24 \cdot 3 \cdot \cdot \frac{1}{3} \cdot 3) + 3 \cdot 9 = -216 + 27 = -189;$

Проверка коэффициентов системы канонических уравнений

$(m_s = m_1 + m_2.)$



$\boxed{m_s}$

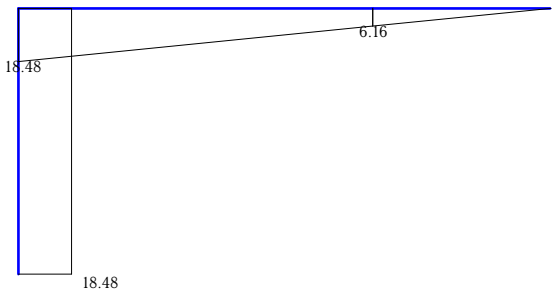
$EI(\delta_{11} + \delta_{21}) = \sum_n \int_0^s m_s m_1 ds = (\frac{1}{2} \cdot 3 \cdot 3 \cdot 6 + \frac{1}{2} \cdot 6 \cdot 3 \cdot 6) +$
$+ (\frac{1}{2} \cdot 6 \cdot 4 \cdot \frac{2}{3} \cdot 6 + \frac{1}{2} \cdot 6 \cdot 4 \cdot \frac{1}{3} \cdot 2 + \frac{1}{2} \cdot 2 \cdot 4 \cdot \frac{2}{3} \cdot 2 + \frac{1}{2} \cdot 2 \cdot 4 \cdot \frac{1}{3} \cdot$
$\cdot 6) + (\frac{1}{2} \cdot 2 \cdot 2 \cdot \frac{2}{3} \cdot 2) = 81 + 69.33 + 2.67 = 153;$

$EI(\delta_{12} + \delta_{22}) = \sum_n \int_0^s m_s m_2 ds = (-\frac{1}{2} \cdot 3 \cdot 3 \cdot \frac{2}{3} \cdot 3 - \frac{1}{2} \cdot 6 \cdot 3 \cdot$
$\cdot \frac{1}{3} \cdot 3) = -18;$

$EI(\Delta_1 + \Delta_2) = \sum_n \int_0^s m_s M_p ds = +(\frac{1}{2} \cdot 60 \cdot 3 \cdot \frac{2}{3} \cdot 3 + \frac{1}{2} \cdot 60 \cdot$
$\cdot 3 \cdot \frac{1}{3} \cdot 6 + \frac{1}{2} \cdot 24 \cdot 3 \cdot \frac{2}{3} \cdot 6 + \frac{1}{2} \cdot 24 \cdot 3 \cdot \frac{1}{3} \cdot 3) - 9 \cdot 9 + (\frac{1}{2} \cdot 24 \cdot 4 \cdot \frac{2}{3} \cdot$
$\cdot 6 + \frac{1}{2} \cdot 24 \cdot 4 \cdot \frac{1}{3} \cdot 2) = 540 - 81 + 224 = 683;$

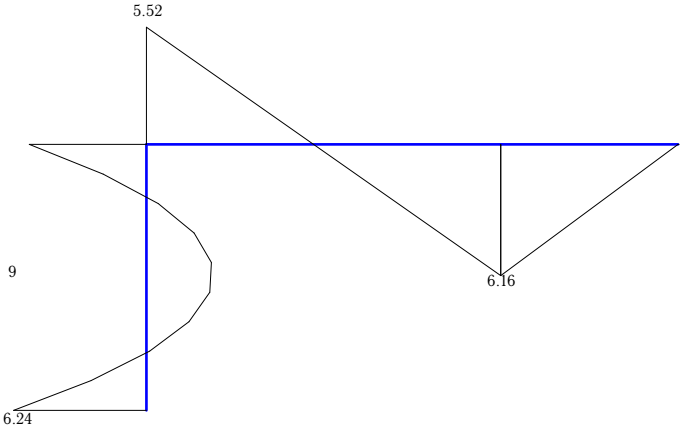
Решение системы:

$X_1 = -3.08; \quad X_2 = 11.76;$

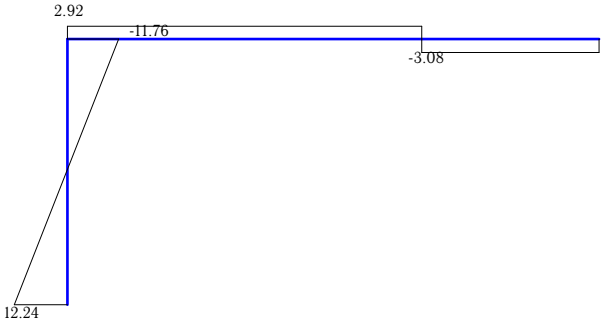


$\boxed{m_1 \cdot x_1}$

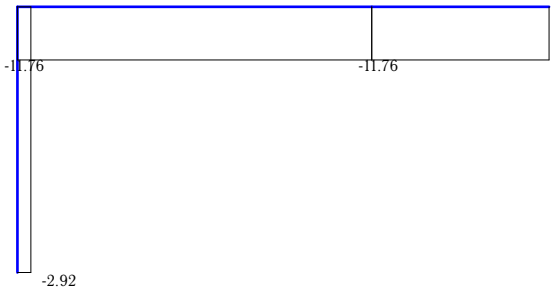
$\boxed{m_2 \cdot x_2}$



M



Q



N

Кинематическая проверка

$\sum_n \int_0^s Mm_1 ds = +(\frac{1}{2} \cdot 6.24 \cdot 3 \cdot 6 + \frac{1}{2} \cdot 5.52 \cdot 3 \cdot 6) - 12 \cdot 9 +$
$+ (\frac{1}{2} \cdot 5.52 \cdot 4 \cdot \frac{2}{3} \cdot 6 + \frac{1}{2} \cdot 5.52 \cdot 4 \cdot \frac{1}{3} \cdot 2 - \frac{1}{2} \cdot 6.16 \cdot 4 \cdot \frac{2}{3} \cdot 2 - \frac{1}{2} \cdot 6.16 \cdot 4 \cdot$
$\cdot \frac{1}{3} \cdot 6) + (-\frac{1}{2} \cdot 6.16 \cdot 2 \cdot \frac{2}{3} \cdot 2) = +105.82 - 108 + 10.4 - 8.22 = 0;$

$\sum_n \int_0^s Mm_2 ds = +(-\frac{1}{2} \cdot 6.24 \cdot 3 \cdot \frac{2}{3} \cdot 3 - \frac{1}{2} \cdot 5.52 \cdot 3 \cdot \frac{1}{3} \cdot 3) +$
$+ 3 \cdot 9 = -27 + 27 = 0;$