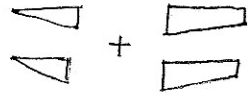
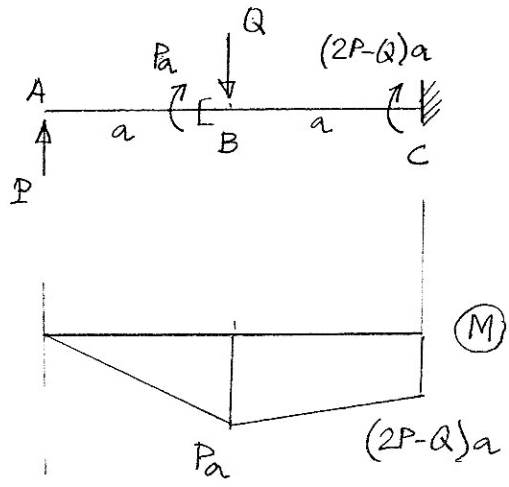
a) $U(P,Q) = \int_0^{l_b} \frac{M^2}{2EI}\,dx$ =  +

$$= \frac{a}{3(2EI)} P^2a^2 + \frac{a}{3(2EI)}\left[P^2a^2 + Pa(2P-Q)a + (2P-Q)^2a^2\right]$$

$$= \frac{P^2a^3}{3EI} + \frac{P(2P-Q)a^3}{6EI} + \frac{(2P-Q)^2a^3}{6EI}$$

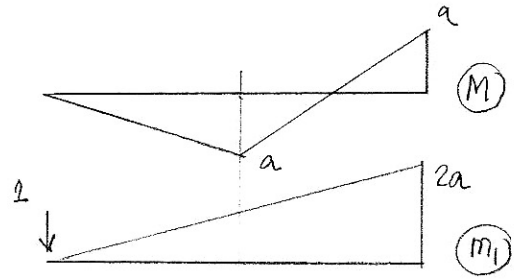


para $P = 1\,kN$ e $Q = 3\,kN$:

$$U = \frac{a^3}{EI}\left(\frac{1}{3} - \frac{1}{6} + \frac{1}{6}\right) = \boxed{\frac{a^3}{3EI}}$$

b) $$v_B = \left.\frac{\partial U}{\partial Q}\right|_{\substack{P=1\\Q=3}} = -\frac{Pa^3}{6EI} - \frac{2(2P-Q)a^3}{6EI} = \boxed{\frac{a^3}{6EI}}$$

c) Carga unitária:



$$v_A = \int_0^{l_b} \frac{Mm}{EI}\,dx$$

$$= -\frac{a}{3EI}a^2 + \frac{a}{6EI}\left(-2a^2 + 4a^2 - 2a^2 + a^2\right)$$

$$= \boxed{-\frac{a^3}{6EI}\ (\uparrow)}$$

$$\varphi_A = \frac{a}{2EI}(-a) + \frac{a}{6EI}\left(-2a + 2a + a - a\right) = \boxed{-\frac{a^2}{2EI}\ (\curvearrowleft)}$$