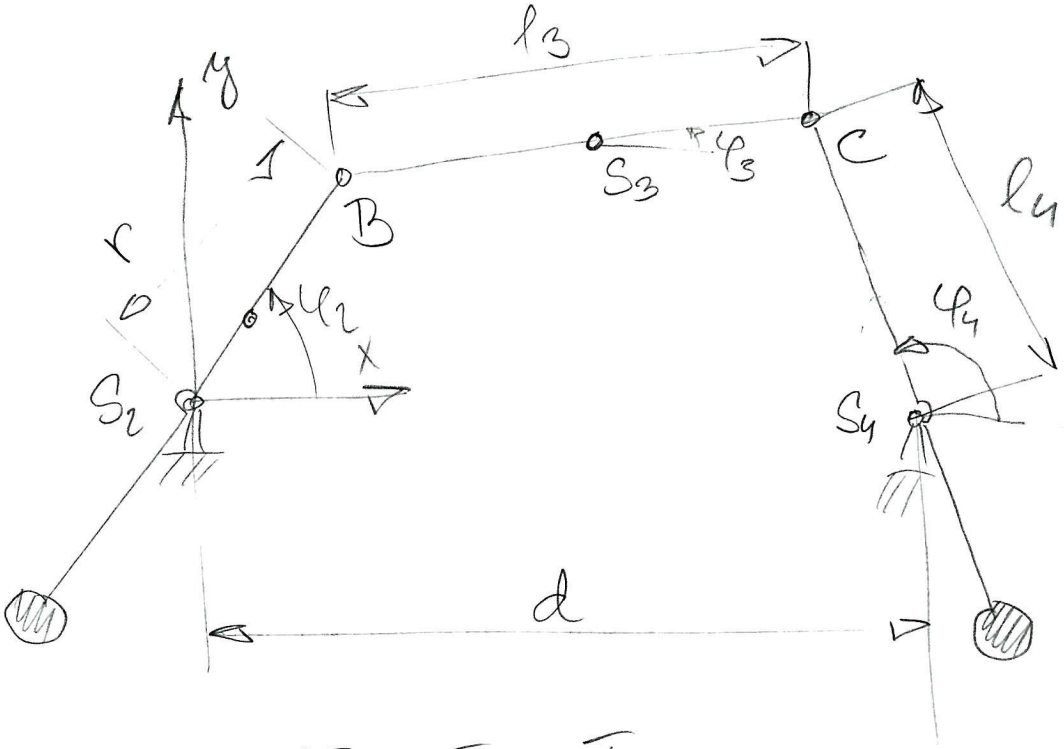


D: $m_2, m_3, m_4, I_{2S2}, I_{3S3}, I_{4S4}, r, l_3, l_4, d$

U: E_k

a) Zobecněné souřadnice

$$s = [\varphi_2, x_3, y_3, \varphi_3, \varphi_4] + x_2, y_2, x_4, y_4$$

$$E_k = \frac{1}{2} I_{2S2} \dot{\varphi}_2^2 + \frac{1}{2} m_3 (\dot{x}_3^2 + \dot{y}_3^2) + \frac{1}{2} I_{3S3} \dot{\varphi}_3^2 + \frac{1}{2} I_{4S4} \dot{\varphi}_4^2$$

b) Přirozené souřadnice

$$s = [x_B, y_B, x_C, y_C]$$

→ vyjádření E_k pro zvol. souřadnice

$$x_B = r\cos\varphi_2 \qquad \dot{x}_B = -r\sin\varphi_2\cdot\dot{\varphi}_2 \Big\}^{(2)}_{\varphi(2)} + \text{всем.}$$

$$y_B = r\sin\varphi_2 \qquad \dot{y}_B = r\cos\varphi_2\cdot\dot{\varphi}_2$$

$$\dot{\varphi}_2^2 =$$

$$\dot{x}_B^2 = r^2\sin^2\varphi_2\,\dot{\varphi}_2^2 \Big\} \quad \dot{x}_B^2 + \dot{y}_B^2 = r^2\dot{\varphi}_2^2(\underbrace{\sin^2\varphi_2 + \cos^2\varphi_2}_{\uparrow})$$

$$\dot{y}_B^2 = r^2\cos^2\varphi_2\,\dot{\varphi}_2^2$$

$$\Rightarrow \dot{\varphi}_2^2 = \frac{\dot{x}_B^2 + \dot{y}_B^2}{r^2}$$

$$x_3 = \frac{x_C + x_B}{2} \Rightarrow \dot{x}_3 = \frac{\dot{x}_C + \dot{x}_B}{2}$$

$$y_3 = \frac{y_C + y_B}{2} \Rightarrow \dot{y}_3 = \frac{\dot{y}_C + \dot{y}_B}{2}$$

$$l_3\cos\varphi_3 = x_C - x_B \qquad \dot{x}_C - \dot{x}_B = -l_3\sin\varphi_3\dot{\varphi}_3 \Big\}^{(2)} + \text{всем}$$

$$l_3\sin\varphi_3 = y_C - y_B \qquad \dot{y}_C - \dot{y}_B = l_3\cdot\cos\varphi_3\dot{\varphi}_3 \Big\}$$

$$\Rightarrow \dot{\varphi}_3^2 = \frac{(\dot{x}_C - \dot{x}_B)^2 + (\dot{y}_C - \dot{y}_B)^2}{l_3^2}$$

$$d + l_4\cos\varphi_4 = x_C \qquad \dot{x}_C = -l_4\sin\varphi_4\dot{\varphi}_4 \Big\}^{(2)}$$

$$l_4\cdot\sin\varphi_4 = y_C \qquad \dot{y}_C = l_4\cos\varphi_4\dot{\varphi}_4 \Big\}$$

$$\Rightarrow \dot{\varphi}_4^2 = \frac{\dot{x}_C^2 + \dot{y}_C^2}{l_4^2}$$

Kin. energie

$$E_k = \frac{1}{2} I_{2S2} \frac{\dot{x}_B^2 + \dot{y}_B^2}{r^2} + \frac{1}{2} m_3 \left[\left(\frac{\dot{x}_C + \dot{x}_B}{2} \right)^2 + \left(\frac{\dot{y}_C + \dot{y}_B}{2} \right)^2 \right] +$$

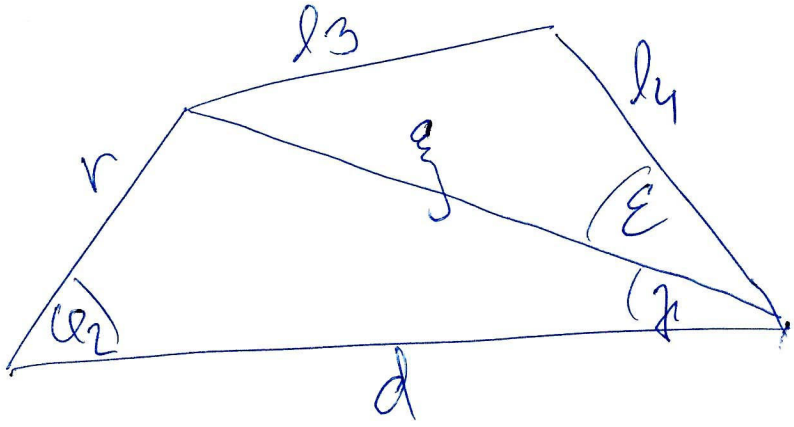
$$+ \frac{1}{2} I_{3S3} \frac{(\dot{x}_C - \dot{x}_B)^2 + (\dot{y}_C - \dot{y}_B)^2}{l_3^2} + \frac{1}{2} I_{4S4} \frac{\dot{x}_C^2 + \dot{y}_C^2}{l_4^2}$$

c) Nezávislé souřadnice

$q = \varphi_2 \Rightarrow$ vyjádřit $x_3(\varphi_2), y_3(\varphi_3), \varphi_3(\varphi_2), \varphi_4(\varphi_2)$

$$x_3 = r\cos\varphi_2 + \frac{l_3}{2}\cos\varphi_3 \qquad \dot{x}_3 = -r\dot{\varphi}_2 \sin\varphi_2 - \frac{l_3}{2}\dot{\varphi}_3 \sin\varphi_3$$

$$y_3 = r\sin\varphi_2 + \frac{l_3}{2}\sin\varphi_3 \qquad \dot{y}_3 = r\dot{\varphi}_2 \cos\varphi_2 + \frac{l_3}{2}\cdot\dot{\varphi}_3 \cos\varphi_3$$



$$\xi^2 = r^2 + d^2 - 2rd\cos\varphi_2$$

$$\gamma = \arcsin\left(\frac{r}{\xi}\sin\varphi_2\right)$$

$$\varepsilon = \arccos\left[\frac{\xi^2 + l_4^2 - l_3^2}{2\xi l_4}\right]$$

$$\varphi_4 = \pi - \gamma - \varepsilon$$

$$l_4 \sin\varphi_4 = r\sin\varphi_2 + l_3\sin\varphi_3 \Rightarrow \varphi_3 =$$

$\Rightarrow$ KOMPLIKOVANÉ

pož. soud
vs. X
vazb. ree