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**FAKULTETA ZA GRADBENIŠTVO IN GEODEZIJO**

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**ZBIRKA REŠENIH NALOG**

**Verzija 0.2b**

**LJUBLJANA oktober 2008**

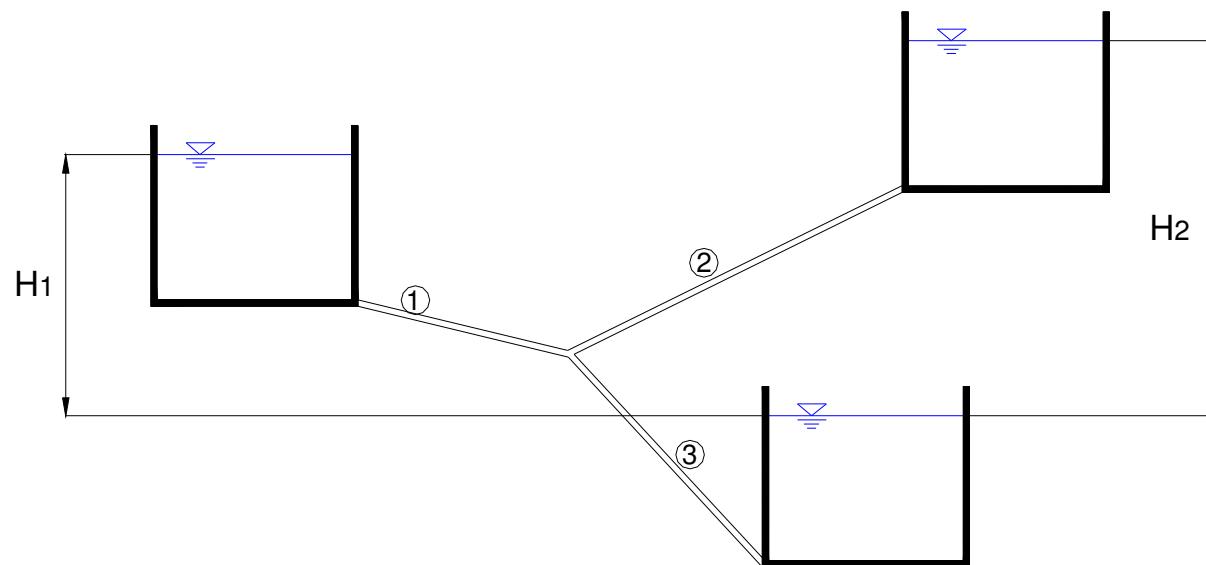


# **HIDRAVLIKA**

## **ZBIRKA REŠENIH NALOG**

1 del: TOK POD TLAKOM

**1.1 Določi hidravlični sistem in višinsko razliko  $H_2$ ! Dolgi cevovod!**



Podatki:

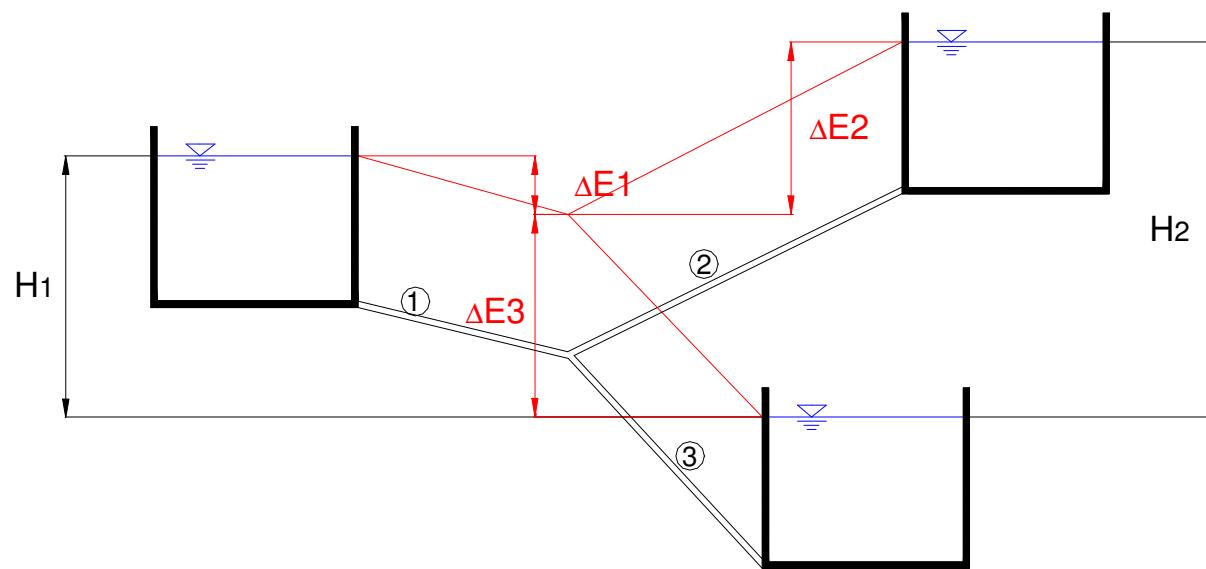
$$Q_1 = 12 \frac{\text{l}}{\text{s}}$$

$$H_1 = 11 \text{ m}$$

$$\lambda = 0,02$$

i	$L_i [\text{m}]$	$d_i [\text{cm}]$
1	150	10
2	200	15
3	250	15

Rešitev:



Enačbe:

- 1.)  $Q_1 + Q_2 = Q_3$
  - 2.)  $\Delta E_1 + \Delta E_3 = H_1$
  - 3.)  $\Delta E_2 + \Delta E_3 = H_2$
- 

$$\Delta E_1 = \frac{v_1^2}{2g} \cdot \frac{\lambda \cdot L_1}{d_1} = \frac{1,52^2}{19,62} \cdot \frac{0,02 \cdot 150}{0,1} = 3,53 \text{ m}$$

$$v_1 = \frac{Q_1 \cdot 4}{d_1^2 \cdot \pi} = \frac{12 \cdot 10^{-3} \cdot 4}{0,1^2 \cdot \pi} = 1,52 \frac{\text{m}}{\text{s}}$$

$$\Delta E_3 = H_1 - \Delta E_1 = 11,0 \text{ m} - 3,53 \text{ m} = 7,47 \text{ m}$$

$$\Delta E_3 = \frac{v_3^2}{2 \cdot g} \cdot \frac{\lambda \cdot L_3}{d_3}$$

$$v_3 = \sqrt{\left( \frac{\Delta E_3 \cdot 2 \cdot g \cdot d_3}{\lambda \cdot L_3} \right)} = \sqrt{\left( \frac{7,47 \cdot 2 \cdot 9,81 \cdot 0,15}{0,02 \cdot 250} \right)} = 2,10 \frac{\text{m}}{\text{s}}$$

$$Q_3 = \frac{v_3 \cdot d_3^2 \cdot \pi}{4} = 37,1 \frac{\text{l}}{\text{s}}$$

$$Q_2 = Q_3 - Q_1 = 37,1 \frac{\text{l}}{\text{s}} - 12,0 \frac{\text{l}}{\text{s}} = 25,1 \frac{\text{l}}{\text{s}}$$

$$v_2 = \frac{4 \cdot Q_2}{d_2^2 \cdot \pi} = \frac{4 \cdot 25,1 \cdot 10^{-3}}{0,15^2 \cdot \pi} = 1,42 \frac{\text{m}}{\text{s}}$$

$$\Delta E_2 = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{0,02 \cdot 200 \cdot 1,42^2}{0,15 \cdot 19,62} = 2,74 \text{ m}$$

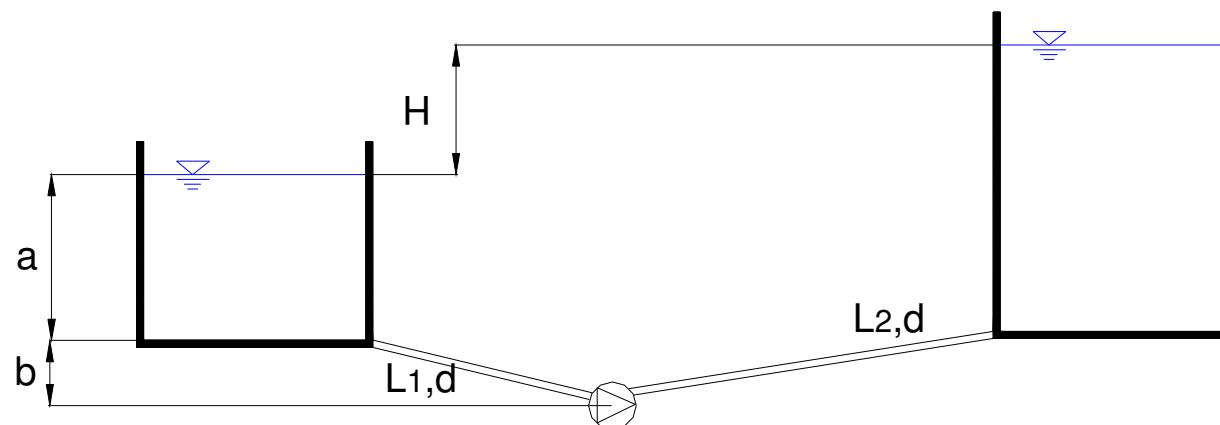
$$H_2 = \Delta E_2 + \Delta E_3 = 2,74 \text{ m} + 7,47 \text{ m} = 10,21 \text{ m}$$

Kontrola:

$$\Delta E_1 - \Delta E_2 + H_2 - H_1 = 0$$

$$3,53 \text{ m} - 2,74 \text{ m} + 10,21 \text{ m} - 11,0 \text{ m} = 0 \quad \underline{\underline{\text{OK}}}$$

**1.2 Določi  $Q_{\max}$  in  $N_c$  pod pogojem, da v črpalki ni niti podtlaka niti nadtlaka!**



Podatki:

$$H = 3 \text{ m}$$

$$a = 2 \text{ m}$$

$$b = 3,5 \text{ m}$$

$$\left| \frac{p}{\rho \cdot g} \right| = 0$$

$$\eta_c = 0,85$$

$$\xi_{vt} = 0,4$$

$$\xi_i = 1$$

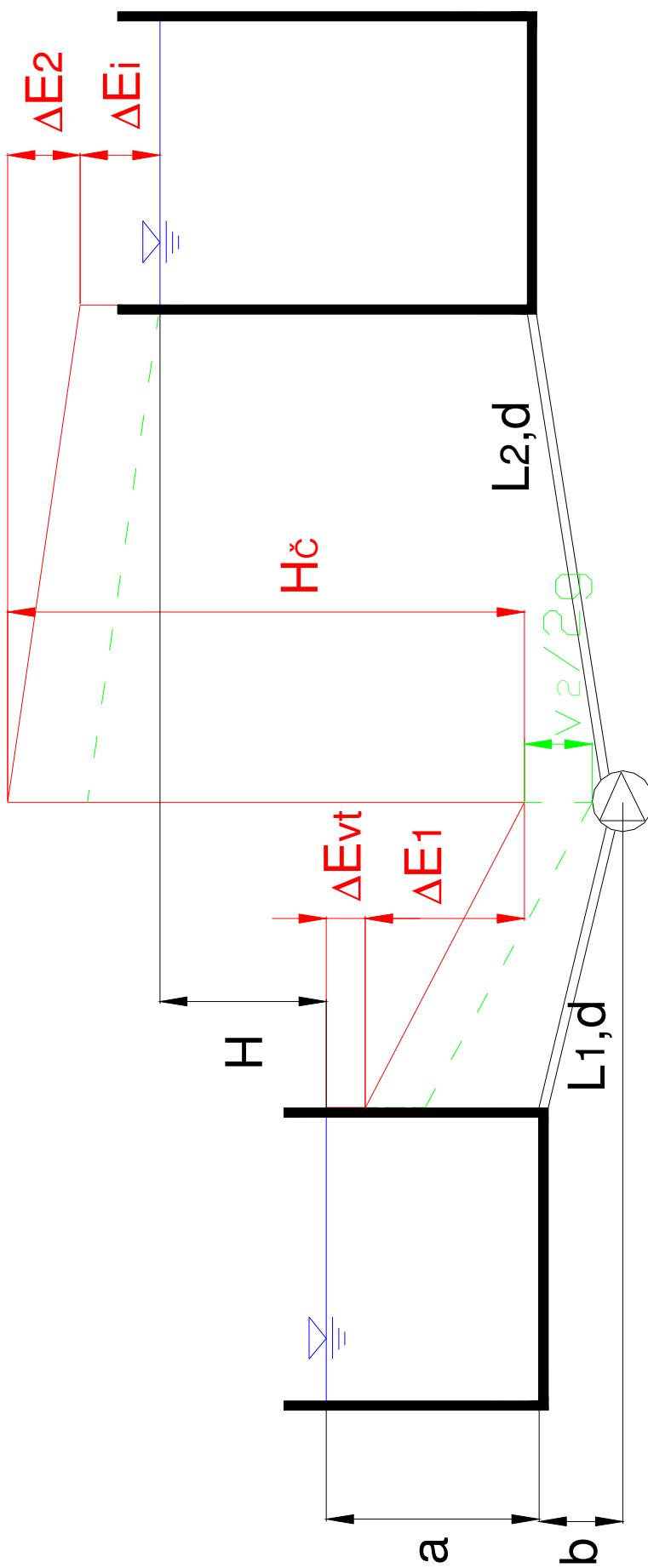
$$\lambda = 0,024$$

$$L_1 = 15 \text{ m}$$

$$L_2 = 20 \text{ m}$$

$$d = 5 \text{ cm}$$

Rešitev:



tlak = 0

$$\Delta E_{vt} + \Delta E_1 + \frac{v^2}{2 \cdot g} = a + b = 2 + 3,5 = 5,5 \text{ m}$$

$$\frac{v^2}{2 \cdot g} \cdot \left( \xi_{vt} + \frac{\lambda \cdot L_1}{d_1} + 1 \right) = 5,5 \text{ m}$$

$$v = \sqrt{\left( \frac{5,5 \cdot 19,62}{0,4 + \frac{0,024 \cdot 15}{0,05} + 1} \right)} = 3,54 \frac{\text{m}}{\text{s}}$$

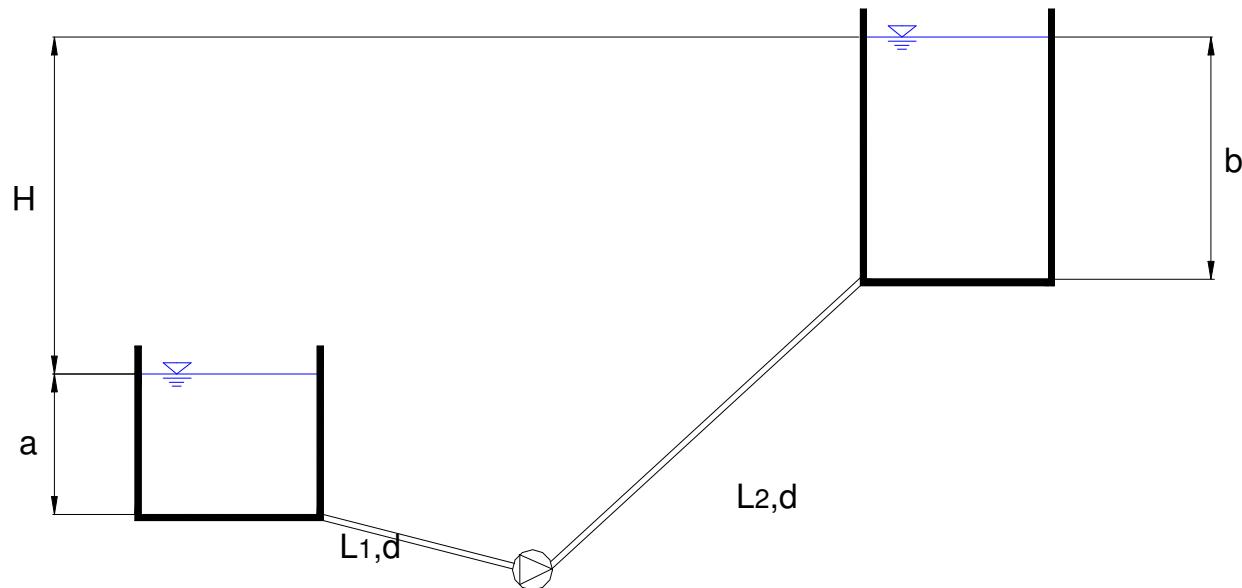
$$Q_{\max} = \frac{v \cdot d^2 \cdot \pi}{4} = 6,95 \frac{\text{l}}{\text{s}}$$

$$\Delta E_{vt} + \Delta E_1 - H_c + \Delta E_2 + \Delta E_i + H = 0$$

$$H_c = \frac{v^2}{2 \cdot g} \cdot \left( \xi_{vt} + \frac{\lambda \cdot L_1}{d_1} + \frac{\lambda \cdot L_2}{d_2} + 1 \right) + 3 = \frac{3,54^2}{19,62} \cdot \left( 0,4 + \frac{0,024 \cdot 35}{0,05} + 1 \right) + 3 = 14,62 \text{ m}$$

$$N_c = \frac{\rho \cdot g \cdot Q_c \cdot H_c}{\eta_c} = \frac{9,81 \cdot 6,96 \cdot 14,62}{0,85} = 1173 \text{ W}$$

**1.3 Določi pretok po sistemu, če je izmerjen podtlak na črpalki  $\left| \frac{p_c}{\rho \cdot g} \right|$ . Kolikšen je izkoristek črpalke  $\eta_c$ , če črpamo z močjo  $N_c$ ? Dolgi cevovod, lokalne izgube zanemarimo, upoštevamo le člen  $\frac{v^2}{2 \cdot g}$  pri podtlaku na črpalki!**



Podatki:

$$a = 5m$$

$$b = 4m$$

$$\lambda = 0,025$$

$$\left| \frac{p_c}{\rho \cdot g} \right| = 3m$$

$$L_1 = 250m$$

$$d_1 = 20cm$$

$$L_2 = 500m$$

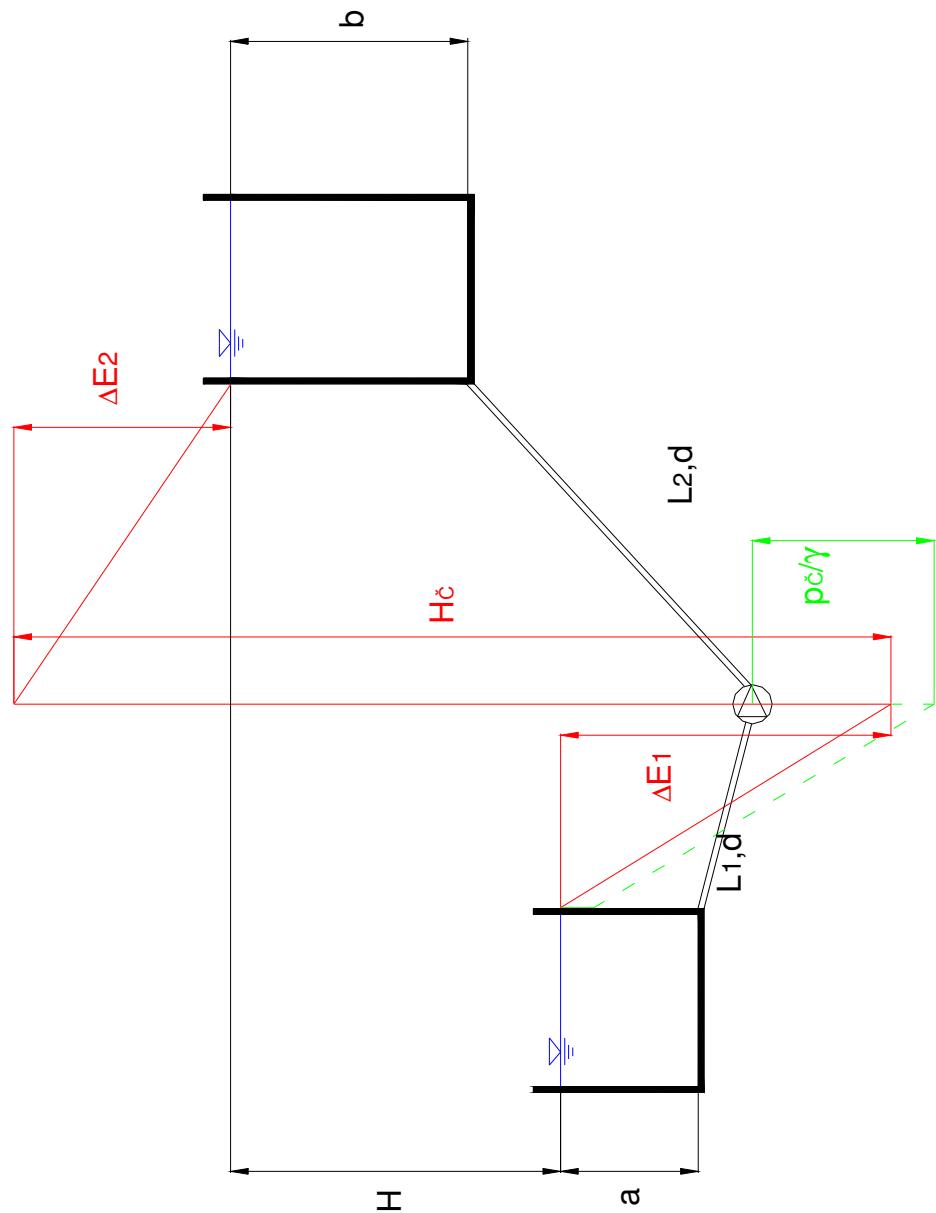
$$d_2 = 30cm$$

$$N_c = 13kW$$

$$\gamma = 0,025$$

$$H = 25m$$

Rešitev:



$$\Delta E_1 + \frac{v_1^2}{2 \cdot g} = a + \left| \frac{p_c}{\rho \cdot g} \right| = 5 + 3$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + 1 \right) = 8$$

$$\frac{v_1^2}{2 \cdot g} = \frac{8}{32,25}$$

$$v_1 = \sqrt{\left( \frac{19,62 \cdot 8}{32,25} \right)} = \underline{2,21 \frac{m}{s}}$$

$$Q = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 69,4 \frac{l}{s}$$

$$v_2 \cdot d_2^2 = v_1 \cdot d_1^2$$

$$v_2 = \frac{v_1 \cdot d_1^2}{d_2^2} = \frac{2,21 \cdot 0,2^2}{0,3^2} = 0,98 \frac{m}{s}$$

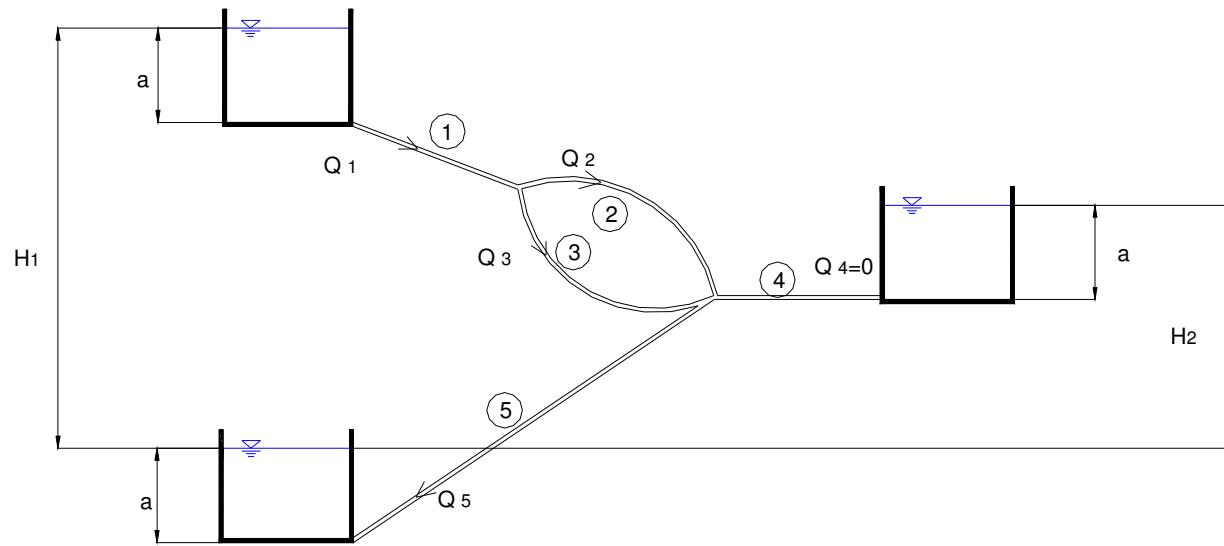
$$H + \Delta E_1 - H_c + \Delta E_2 = 0$$

$$H_c = H + \Delta E_1 + \Delta E_2 = 5 + \frac{v_1^2}{2 \cdot g} \cdot \frac{\lambda \cdot L_1}{d_1} + \frac{v_2^2}{2 \cdot g} \cdot \frac{\lambda \cdot L_2}{d_2}$$

$$H_c = 5 + \frac{2,21^2}{19,62} \cdot \frac{0,025 \cdot 250}{0,2} + \frac{0,98^2}{19,62} \cdot \frac{0,025 \cdot 500}{0,3} = 5 + 7,78 + 2,04 = \underline{14,82 m}$$

$$\eta_c = \frac{\rho \cdot g \cdot Q_c \cdot H_c}{N_c} = \frac{9,81 \cdot 69,4 \cdot 14,82}{13000} = \underline{0,776}$$

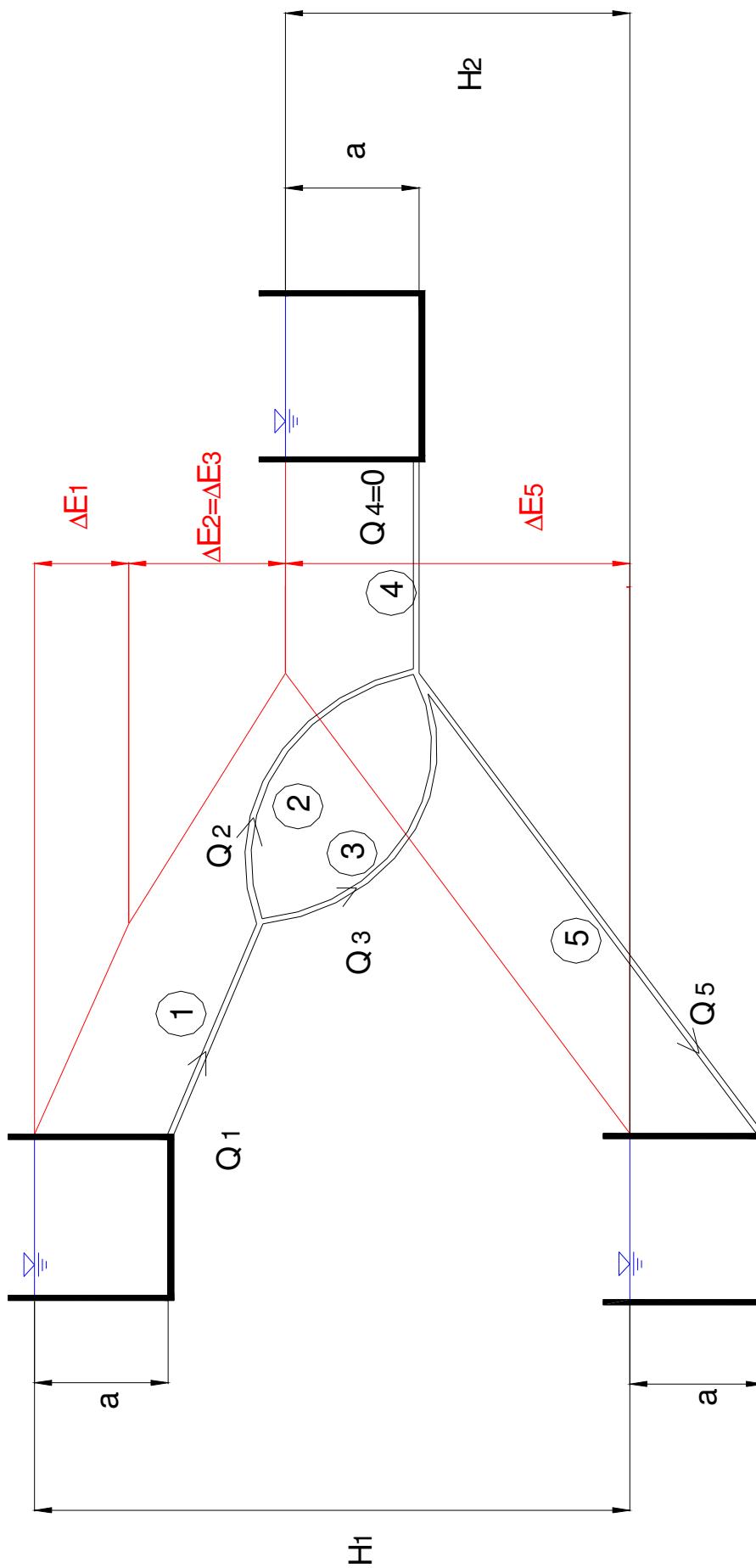
**1.4 Določi  $H_1$  in  $H_2$  tako, da v posodo B ne bo niti dotoka niti iztoka!**



Podatki:

i	$L_i[m]$	$d_i[cm]$	$\lambda = 0,03$
1	250	5	$a = 1cm$
2	200	5	
3	300	5	$Q_1 = 2 \frac{l}{s}$
4	400	5	
5	500	5	$H_1 = ? H_2 = ?$

Rešitev:



Neznane v<sub>2</sub>, v<sub>3</sub>, v<sub>4</sub>, v<sub>5</sub>, H<sub>1</sub>, H<sub>2</sub>.

Q<sub>4</sub> mora biti 0!

$$v_1 = \frac{Q_1}{S_1} = \frac{2 \cdot 10^{-3} \cdot 4}{0,05^2 \cdot \pi} = 1,02 \frac{m}{s}$$

$$\Delta E_1 = \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} = \frac{0,03 \cdot 250}{0,05} \cdot \frac{1,02^2}{19,62} = 7,95 m$$

$$Q_5 = Q_1 = 2 \frac{l}{s}$$

$$v_5 = v_1 = 1,02 \frac{m}{s}$$

$$Q_4 = 0 \frac{l}{s}$$

$$v_4 = 0 \frac{m}{s}$$

$$H_2 = \Delta E_5 = \frac{\lambda \cdot L_5}{d_5} \cdot \frac{v_5^2}{2 \cdot g} = \frac{0,03 \cdot 500}{0,05} \cdot \frac{1,02^2}{19,62} = 15,90 m$$

$$\Delta E_2 = \Delta E_3$$

$$\frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g}$$

$$v_2 = \sqrt{\left(\frac{L_3}{L_2}\right)} \cdot v_3 = 1,225 \cdot v_3$$

$$Q_2 + Q_3 = Q_1 = Q_5$$

$$\frac{1,225 \cdot v_3 \cdot d_2^2 \cdot \pi}{4} + \frac{v_3 \cdot d_3^2 \cdot \pi}{4} = \frac{v_1 \cdot d_1^2 \cdot \pi}{4}$$

$$v_3 \cdot (1,225 \cdot d_2^2 + d_3^2) = 1,02 \cdot d_1^2$$

$$v_3 \cdot 5,563 \cdot 10^{-3} = 2,55 \cdot 10^{-3}$$

$$v_3 = 0,46 \frac{m}{s}$$

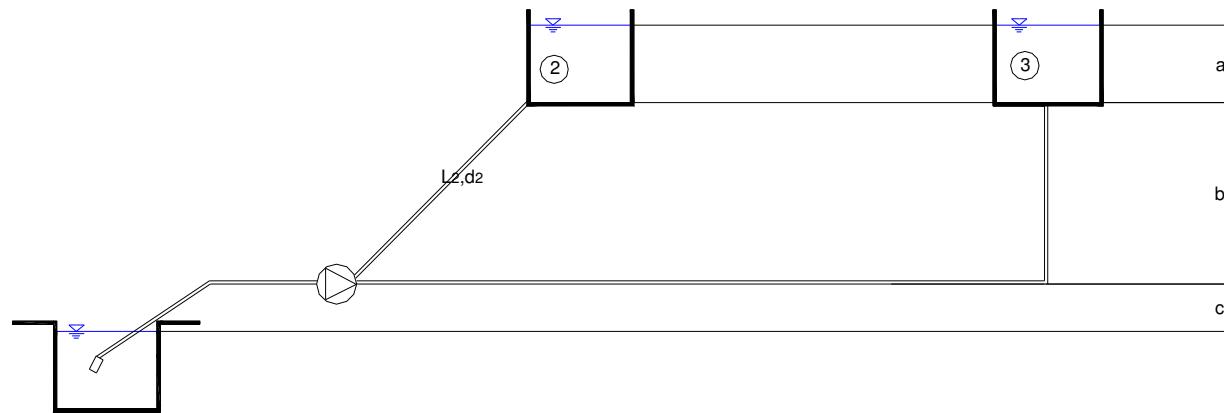
$$v_2 = 1,225 \cdot v_3 = 0,56 \frac{m}{s}$$

$$\Delta E_2 = \Delta E_3 = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{0,03 \cdot 200}{0,05} \cdot \frac{0,56^2}{19,62} = 1,92 m$$

$$\Delta E_3 = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} = \frac{0,03 \cdot 300}{0,05} \cdot \frac{0,46^2}{19,62} = 1,94 m$$

$$H_1 = H_2 + \Delta E_1 + \Delta E_2 = 15,91 + 7,93 + 1,94 = 25,79 m$$

**1.5 (\*)Določi max. pretok po sistemu, porazdelitev pretokov med posodama 2 in 3 in moč črpalke!**



Podatki:

$$a = 1 \text{ m}$$

$$b = 5 \text{ m}$$

$$c = 3 \text{ m}$$

$$d_1 = 10 \text{ cm}$$

$$d_2 = 2 \text{ cm}$$

$$d_3 = d_4 = 5 \text{ cm}$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{\min} = 6 \text{ m}$$

$$L_1 = 7 \text{ m}$$

$$L_2 = L_3 = 20 \text{ m}$$

$$\lambda = 0,02$$

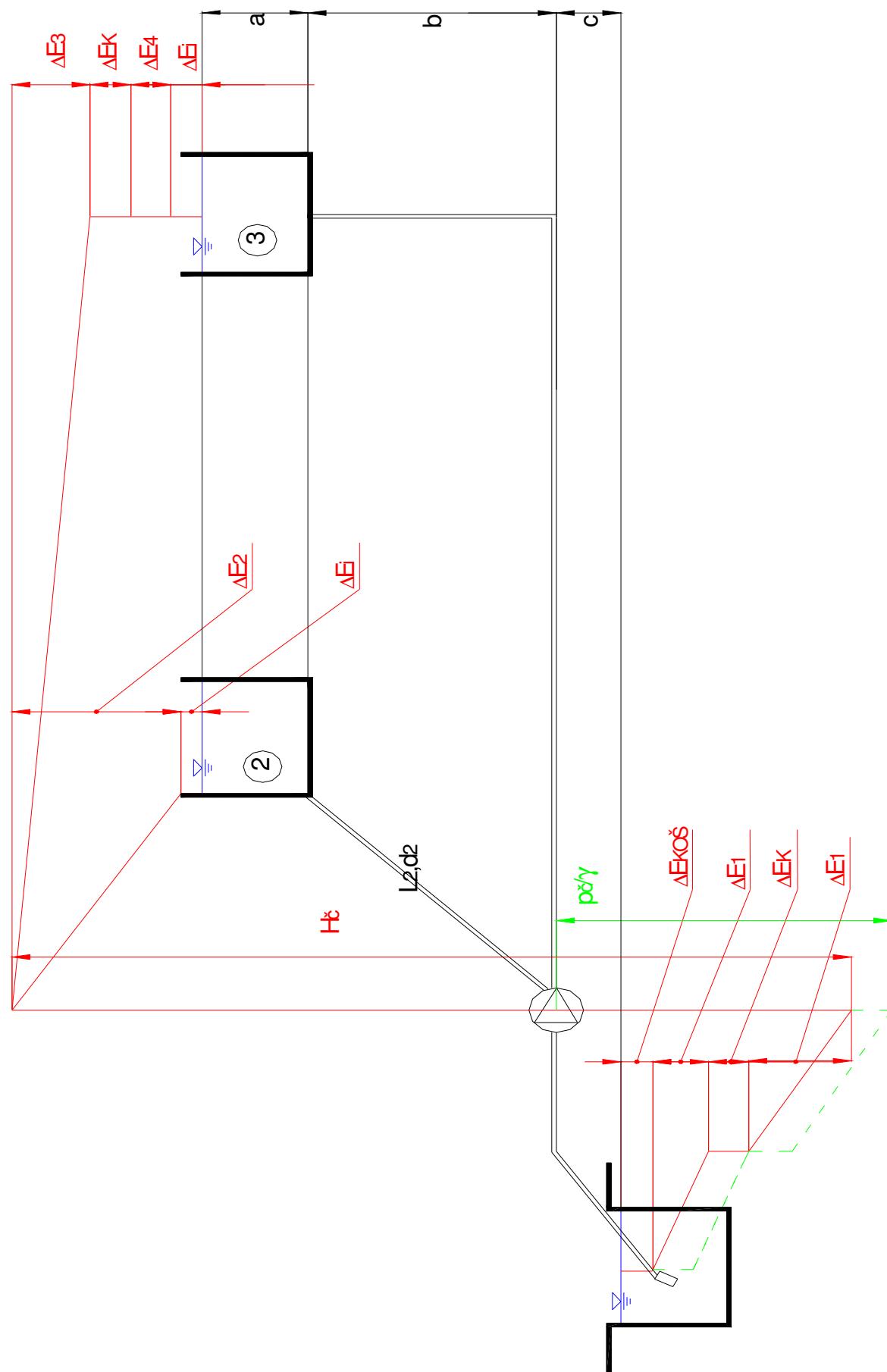
$$\xi_{KOŠ} = 8,0$$

$$\xi_{KOL} = 0,5$$

$$\eta_c = 0,8$$

$$Q_{\max} = ?, Q_1 = ?, Q_2 = ?, N_c = ?$$

Rešitev:



$$\Delta E_{KO\check{S}} + \Delta E_{L_1} + \Delta E_{KOL} + \frac{v_1^2}{2 \cdot g} - \left| \frac{p_{\check{c}}}{\rho \cdot g} \right|_{\min} + c = 0$$

$$\frac{v_1^2}{2 \cdot g} \left( \xi_{KO\check{S}} + \frac{\lambda \cdot L_1}{d_1} + \xi_{KOL} + 1 \right) = \left| \frac{p_{\check{c}}}{\rho \cdot g} \right|_{\min} - c = 3 \text{ m}$$

$$v_1 = \sqrt{\left[ \frac{3 \cdot 19,62}{8 + \frac{0,02 \cdot 7}{0,1} + 0,5 + 1} \right]} = 2,32 \frac{m}{s}$$

$$Q_{\max} = v_1 \cdot S_1 = \frac{2,32 \cdot 0,1^2 \cdot \pi}{4} = 18,22 \frac{l}{s}$$

$$\Delta E_{L_2} + \Delta E_{iA} = \Delta E_{L_3} + \Delta E_{KOL} + \Delta E_{L_4} + \Delta E_{iB}$$

$$\frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} + \frac{v_2^2}{2 \cdot g} = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} + \xi_{KOL} \cdot \frac{v_3^2}{2 \cdot g} + \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g} + \frac{v_3^2}{2 \cdot g}$$

$$\frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + 1 \right) = \frac{v_3^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_3}{d_3} + \xi_{KOL} + \frac{\lambda \cdot L_4}{d_4} + 1 \right)$$

$$v_2^2 = \frac{8 + 0,5 + 2 + 1}{21} \cdot v_3^2 = 0,54 \cdot v_3^2$$

$$v_2 = 0,74 \cdot v_3$$

$$Q_2 + Q_3 = Q_{\max}$$

$$0,74 \cdot v_3 \cdot d_2^2 + v_3 \cdot d_3^2 = v_1 \cdot d_1^2 = 2,32 \cdot 0,12 = 0,0232$$

$$v_3 \cdot 2,796 \cdot 10^{-3} = 0,0232$$

$$v_3 = 8,3 \frac{m}{s}$$

$$v_2 = 6,14 \frac{m}{s}$$

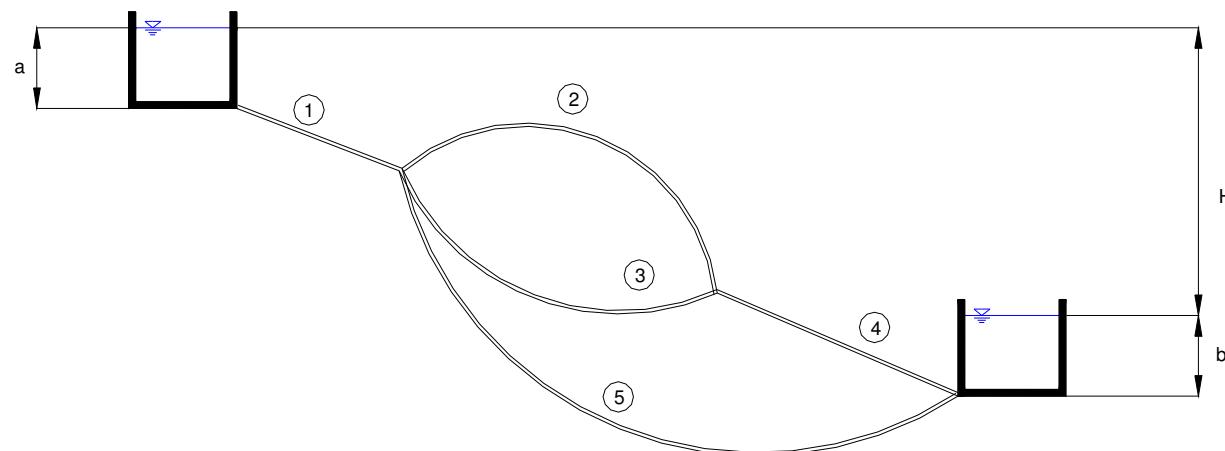
$$\Delta E_{\check{c}-2} = \Delta E_{L_2} + \Delta E_{iA} = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} + \frac{v_2^2}{2 \cdot g} = 40,35 \quad \underline{\underline{\text{OK}}}$$

$$\Delta E_{\check{c}-3} = \Delta E_{L_3} + \Delta E_{KOL} + \Delta E_{L_4} + \Delta E_{iB} = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} + \xi_{KOL} \cdot \frac{v_3^2}{2 \cdot g} + \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g} + \frac{v_3^2}{2 \cdot g} = 40,37 \quad \underline{\underline{\text{OK}}}$$

$$H_{\check{c}} = \Delta E_{\check{c}-2} + a + b + c + \Delta E_{KOL-\check{c}} = 40,35 + 1 + 5 + 3 + 2,71 = \underline{\underline{52,06 \text{ m}}}$$

$$N_{\check{c}} = \frac{Q_{\check{c}} \cdot H_{\check{c}} \cdot \rho \cdot g}{\eta_{\check{c}}} = \frac{18,25 \cdot 10^{-3} \cdot 52,06 \cdot 9810}{0,8} = \underline{\underline{11650 \text{ W}}}$$

**1.6 Določi hidravlični sistem, če sodelujejo cevi 1-4! Cevi 2, 3 in 4 zamenjamo s cevjo 5. Določi premer  $d_5$ , da se pretok po sistemu ne spremeni!**



Podatki:

$$d_1 = d_4 = 5\text{cm}$$

$$d_2 = d_3 = 3\text{cm}$$

$$L_1 = 100\text{m}$$

$$L_2 = L_3 = 200\text{m}$$

$$L_4 = 500\text{m}$$

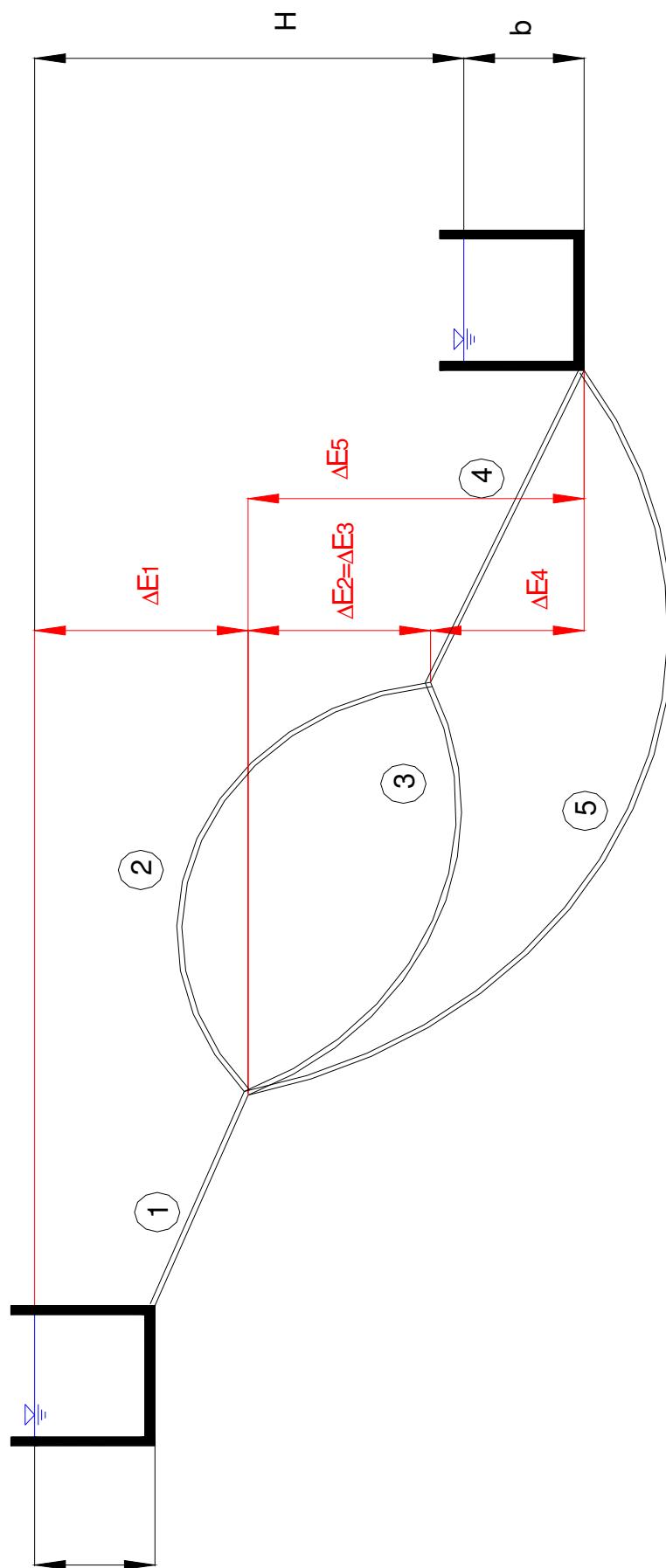
$$L_5 = 800\text{m}$$

$$a = 1\text{m}$$

$$b = 2\text{m}$$

$$H = 20\text{m}$$

Rešitev:



$$\underline{\Delta E_2 = \Delta E_3} \Rightarrow \underline{v_2 = v_3}$$

$$\underline{Q_1 = Q_4} \Rightarrow \underline{v_1 = v_4}$$

$$Q_1 = Q_2 + Q_3$$

$$\frac{v_1 \cdot d_1^2 \cdot \pi}{4} = \frac{2 \cdot v_2 \cdot d_2^2 \cdot \pi}{4}$$

$$v_1 = \frac{2 \cdot d_2^2}{d_1^2} \cdot v_2 = \frac{2 \cdot 0,03^2}{0,05^2} \cdot v_2 = \underline{0,72 \cdot v_2}$$

$$H = \Delta E_1 + \Delta E_2 + \Delta E_4$$

$$H = \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} + \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g}$$

$$H = \frac{\lambda \cdot L_1}{d_1} \cdot \frac{0,72 \cdot v_2^2}{2 \cdot g} + \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} + \frac{\lambda \cdot L_4}{d_4} \cdot \frac{0,72 \cdot v_2^2}{2 \cdot g}$$

0,

$$20 = \frac{0,018 \cdot 100}{0,05} \cdot \frac{0,72^2 \cdot v_2^2}{19,62} + \frac{0,018 \cdot 200}{0,03} \cdot \frac{v_2^2}{19,62} + \frac{0,018 \cdot 500}{0,05} \cdot \frac{0,72^2 \cdot v_2^2}{19,62}$$

$$v_2 = 1,3 \frac{m}{s} = v_3$$

$$v_1 = 0,936 \frac{m}{s} = v_4$$

$$Q_1 = 1,84 \frac{l}{s}$$

$$Q_2 = 0,92 \frac{l}{s}$$

$$H = 1,61 + 10,34 + 8,04 = \underline{19,99 m}$$

Ekvivalentna cev:

$$\Delta E_5 = \Delta E_2 + \Delta E_4 = H - \Delta E_1$$

$$Q_5 = Q_1 = Q_4 = Q_2 + Q_3$$

$$\frac{v_1 \cdot d_1^2 \cdot \pi}{4} = \frac{v_5 \cdot d_5^2 \cdot \pi}{4}$$

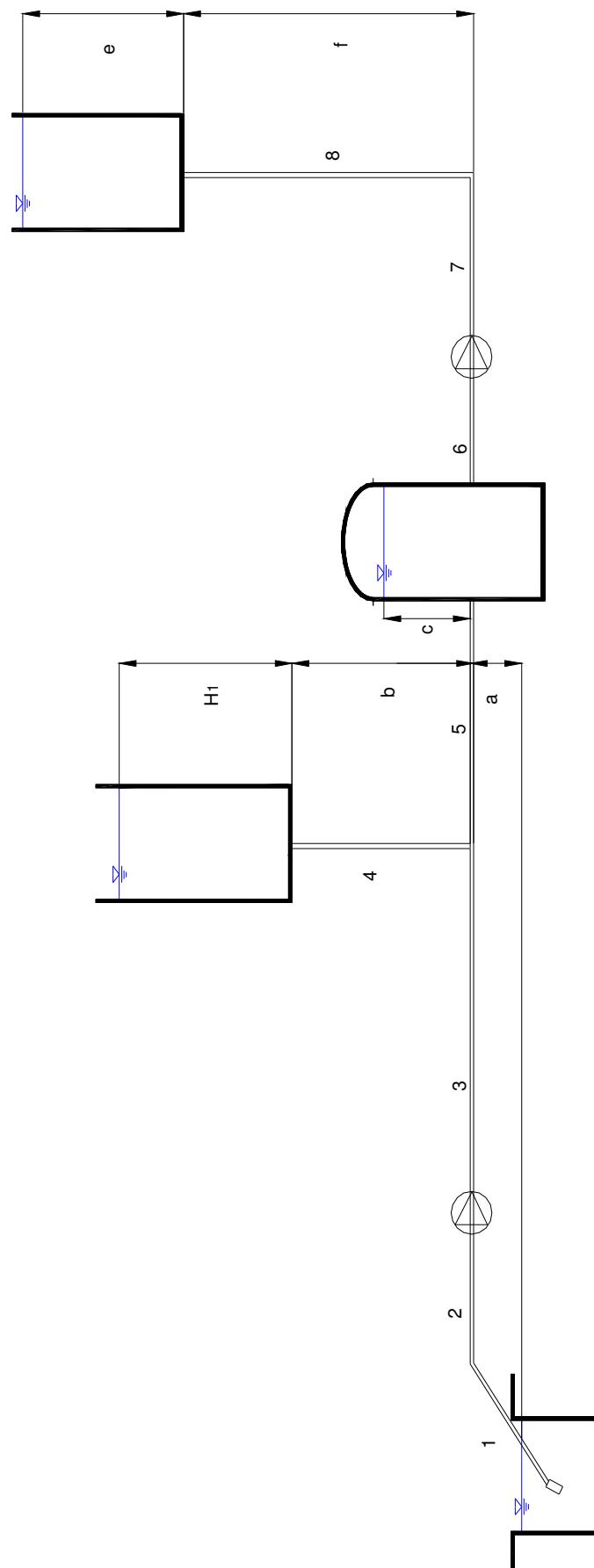
$$v_5 = v_1 \cdot \frac{d_1^2}{d_5^2} = 0,936 \cdot \frac{0,05^2}{d_2^5}$$

$$\Delta E_5 = \frac{\lambda \cdot L_5}{d_5} \cdot \frac{v_5^2}{19,62} = \frac{\lambda \cdot L_5}{d_5 \cdot 19,62} \cdot \left( v_1 \cdot \frac{d_1^2}{d_5^2} \right)^2$$

$$\lambda \cdot L_5 \cdot v_1^2 \cdot \frac{d_1^4}{d_5^4} = d_5 \cdot 19,62$$

$$d_5 = \sqrt[3]{\frac{\lambda \cdot L_5 \cdot v_1^2 \cdot d_1^4}{19,62}} = \sqrt[3]{\frac{0,018 \cdot 800 \cdot 0,936^2 \cdot 0,5^4}{19,62}} = 0,115m \cong 12cm$$

**1.7 (\*)Določi moči obeh črpalk  $N_{č1}$  in  $N_{č2}$  ter višino vode v posodi A!**



Podatki:

$$\lambda = 0,02$$

$$\eta_{\check{C}} = 0,85$$

$$d = 5 \text{ cm} (\text{ vse cevi })$$

$$L_1 = L_2 = 5m$$

$$L_3 = 4m$$

$$L_5 = L_6 = L_7 = 7m$$

$$a = 2m$$

$$b = 3m$$

$$c = 1m$$

$$e = 2m$$

$$f = 5m$$

$$p_p = 0,3bar$$

$$Q_{\check{C}1} = 1,25 \frac{l}{s}$$

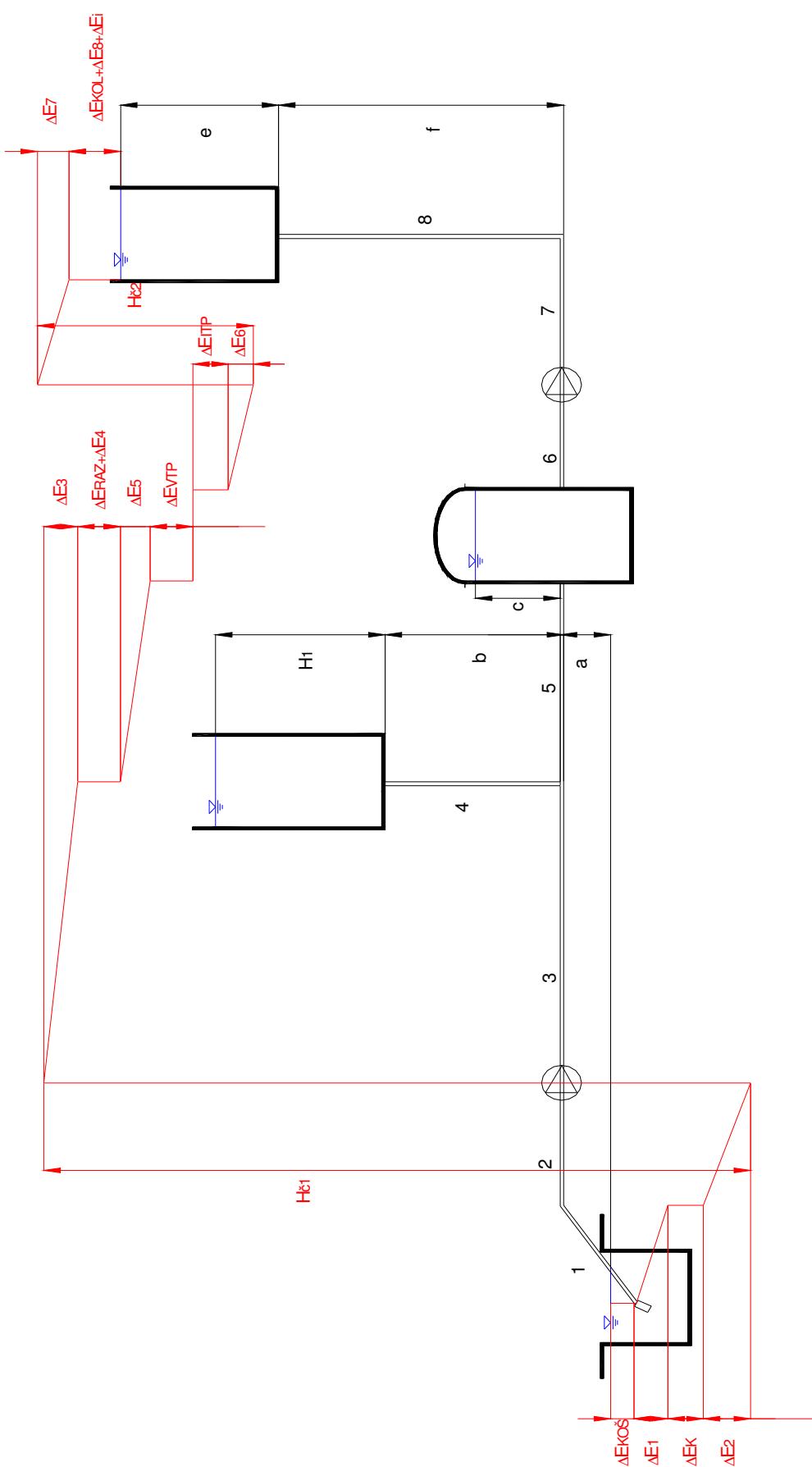
$$Q_{\check{C}2} = 1 \frac{l}{s}$$

$$\xi_{ITP} = \xi_{VTP} = 0,5$$

$$\xi_{RAZ} = \xi_{KOL} = 0,3$$

$$\xi_{KO\check{S}} = 8,0$$

Rešitev:



Desni del:

$$v_2 = \frac{Q_{\check{c}2} \cdot 4}{d^2 \cdot \pi} = \frac{4 \cdot 10^{-3}}{0,05^2 \cdot \pi} = 0,51 \frac{m}{s}$$

$$c + \frac{\rho_p}{\gamma} - \Delta E_{ITP} - \Delta E_6 + H_{\check{c}2} - \Delta E_7 - \Delta E_K - \Delta E_8 - \Delta E_i - e - f = 0$$

$$H_{\check{c}2} = 7 - 4 + \frac{v^2}{2 \cdot g} \cdot \left( \xi_{ITP} + \frac{\lambda \cdot L_6}{d} + \frac{\lambda \cdot L_7}{d} + \xi_K + \frac{\lambda \cdot L_8}{d} + 1 \right)$$

$$H_{\check{c}2} = 7 - 4 + \frac{0,51^2}{19,62} \cdot \left( 0,5 + \frac{0,02 \cdot 7}{0,05} + \frac{0,02 \cdot 7}{0,05} + 0,3 + \frac{0,02 \cdot 5}{0,05} + 1 \right) = 3,12 m$$

$$N_{\check{c}2} = \frac{Q_{\check{c}} \cdot H_{\check{c}} \cdot \rho \cdot g}{\eta_{\check{c}}} = \frac{1 \cdot 10^{-3} \cdot 3,12 \cdot 9810}{0,85} = 36,0 W$$

Levi del:

$$v_1 = \frac{Q_{\check{c}1} \cdot 4}{d^2 \cdot \pi} = 0,637 \frac{m}{s}$$

$$v_4 = \frac{(Q_{\check{c}1} - Q_{\check{c}2}) \cdot 4}{d^2 \cdot \pi} = 0,127 \frac{m}{s}$$

$$a + \Delta E_{KOS} + \Delta E_1 + \Delta E_k + \Delta E_2 - H_{\check{c}1} + \Delta E_3 + \Delta E_R + \Delta E_5 + \Delta E_{VTP} + \frac{\rho_p}{\gamma} + c = 0$$

$$H_{\check{c}} = 6 + \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KOS} + \frac{\lambda \cdot L_1}{d} + \xi_K + \frac{\lambda \cdot L_2}{d} + \frac{\lambda \cdot L_3}{d} + \xi_R \right) + \frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_5}{d} + \xi_{VTP} \right)$$

$$H_{\check{c}} = 6 + \frac{0,637^2}{19,62} \cdot \left( 8 + \frac{0,02 \cdot 14}{0,05} + 0,3 + 0,3 \right) + \frac{0,51^2}{19,62} \cdot \left( \frac{0,02 \cdot 7}{0,05} + 0,5 \right)$$

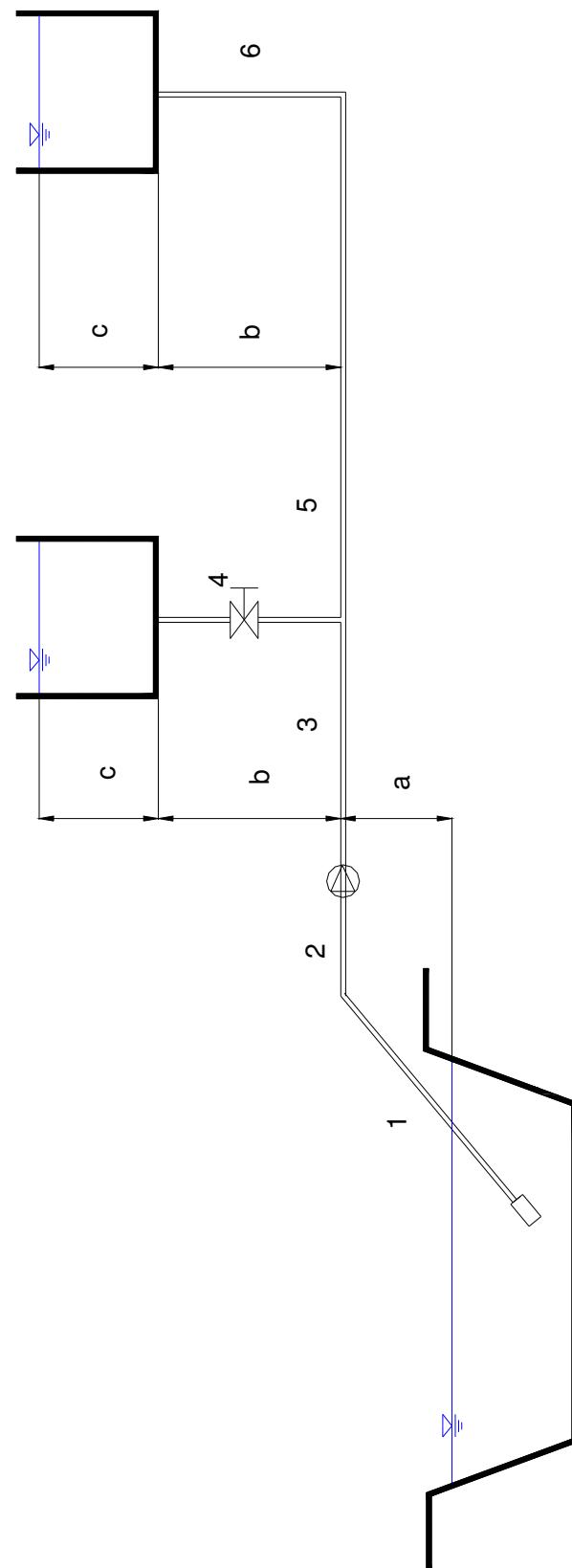
$$H_{\check{c}} = 6,34 m$$

$$N_{čl} = \frac{Q_č \cdot H_č \cdot \rho \cdot g}{\eta_č} = \frac{1,25 \cdot 10^{-3} \cdot 6,34 \cdot 9810}{0,85} = \underline{\underline{91,5W}}$$

Vmesna posoda :

$$\begin{aligned} a + \Delta E_{KOŠ} + \Delta E_1 + \Delta E_K + \Delta E_2 - H_{čl} + \Delta E_3 + \Delta E_R + \Delta E_4 + \Delta E_{IZT} + H_1 + b &= 0 \\ H_1 = 6,34 - 2 - \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KOŠ} + \frac{\lambda \cdot L_1}{d} + \xi_K + \frac{\lambda \cdot L_2}{d} + \frac{\lambda \cdot L_3}{d} + \xi_R \right) - \frac{v_4^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_4}{d} + 1 \right) - 3 \\ H_1 = 6,34 - \text{dokoncaj} \end{aligned}$$

**1.8 (\*) Izračunaj max. pretok, ki ga črpalka lahko črpa v posodi A in B. Določi moč črpalke in  $\xi_z$ , da bo dotok v obe posodi enak.**



Podatki:

$$a = 3m$$

$$b = 10m$$

$$c = 1m$$

$$d = 5cm$$

$$\lambda = 0,025$$

$$\xi_{KOŠ} = 8,0$$

$$\xi_K = \xi_R = 0,3$$

$$L_1 = 7m$$

$$L_2 = 3m$$

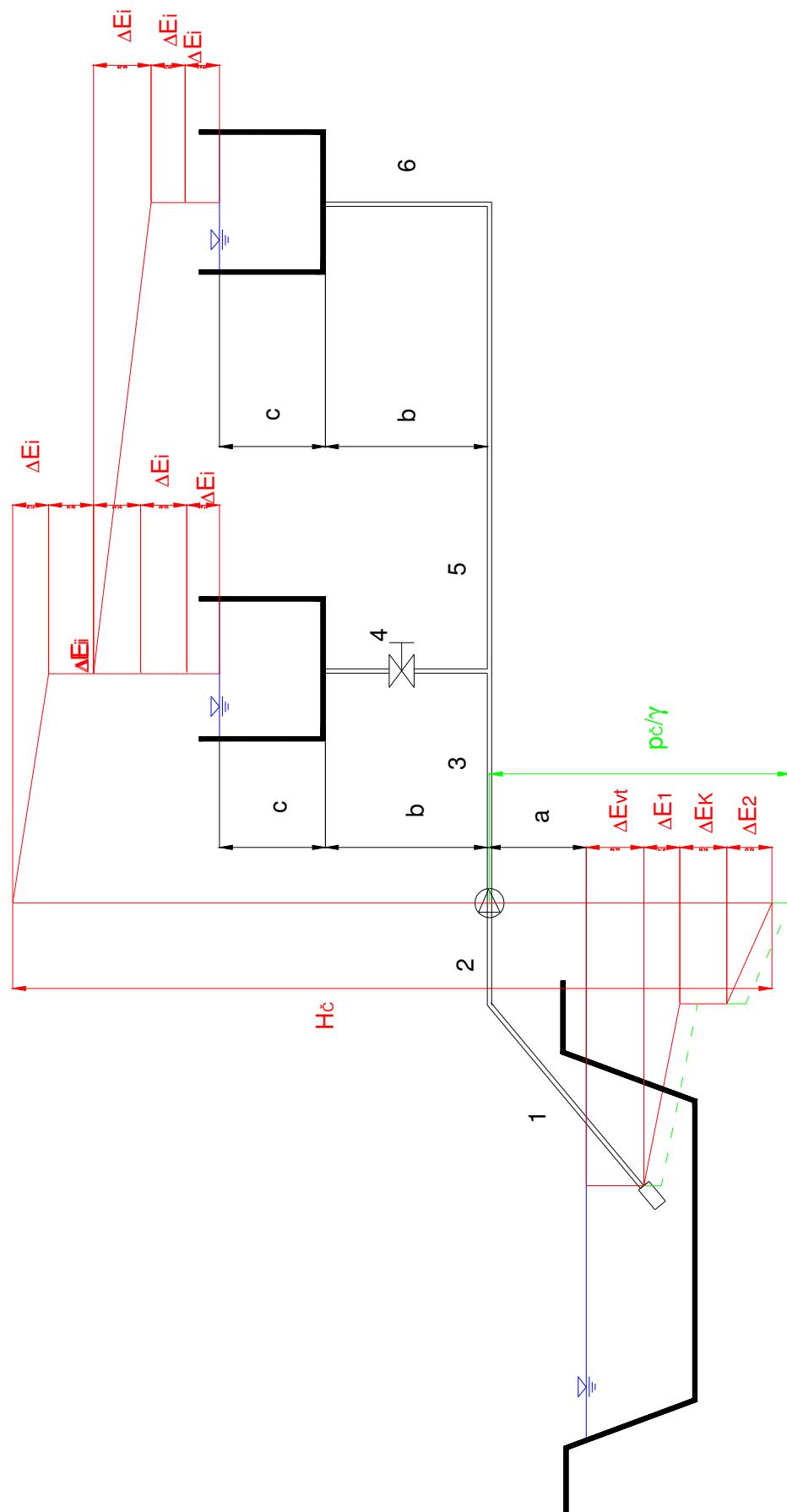
$$L_3 = L_5 = 50m$$

$$L_4 = L_6 = 10m$$

$$\eta_C = 0,8$$

$$\frac{p_{C_{\min}}}{\rho \cdot g} = -0,6bar$$

Rešitev:



1.) Izracunaj  $Q_{\max}$ :

$$\frac{p_c}{\rho \cdot g} = 6m = a + \Delta E_{KOŠ} + \Delta E_1 + \Delta E_K + \Delta E_2 + \frac{v_2^2}{2 \cdot g}$$

$$\frac{p_c}{\rho \cdot g} - a = \frac{v_2^2}{2 \cdot g} \cdot \left( \xi_{KOŠ} + \frac{\lambda \cdot (L_1 + L_2)}{d} + \xi_K + 1 \right)$$

$$6 - 3 = \frac{v_2^2}{2 \cdot g} \cdot \left( 8 + \frac{0,025 \cdot 10}{0,05} + 0,3 + 1 \right)$$

$$3 = \frac{v_2^2}{2 \cdot g} \cdot (14,3)$$

$$\frac{v_2^2}{2 \cdot g} = \frac{3}{14,3}$$

$$v_{\max} = \sqrt{\frac{3 \cdot 19,62}{14,3}} = 2,03 \frac{m}{s}$$

$$Q_{\max} = \frac{v \cdot d^2 \cdot \pi}{4} = \frac{2,03 \cdot 0,05^2 \cdot \pi}{4} \cong 4 \frac{l}{s}$$

$$Q_1 = Q_2 = Q_3 = 2 \cdot Q_4 = 2 \cdot Q_5 = 2 \cdot Q_6$$

$$Q_1 = Q_2 = Q_3 = v_1 \cdot S$$

$$2 \cdot Q_4 = 2 \cdot Q_5 = 2 \cdot Q_6 = v_4 \cdot S$$

$$H_c = a + b + c + \Delta E_{KOŠ} + \Delta E_1 + \Delta E_{KOL} + \Delta E_2 + \Delta E_3 + \Delta E_R + \Delta E_5 + \Delta E_6 + \Delta E_K + \frac{v_1^2}{2 \cdot g}$$

$$H_c - (a + b + c) = \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KOŠ} + \frac{\lambda \cdot L_1}{d} + \xi_K + \frac{\lambda \cdot L_2}{d} + \frac{\lambda \cdot L_3}{d} + \xi_R + \frac{\lambda \cdot L_5}{2 \cdot d} + \frac{\lambda \cdot L_6}{2 \cdot d} + \frac{\xi_K}{2} + \frac{1}{2} \right)$$

$$H_c - 14 = \frac{v_1^2}{2 \cdot g} \cdot 54,25$$

$$H_c = a + b + c + \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KOŠ} + \frac{\lambda \cdot (L_1 + L_2 + L_3)}{d} + \xi_R + \xi_K + \frac{\lambda \cdot L_4}{2 \cdot d} + \xi_Z + \frac{1}{2} \right)$$

$$H_c - 14 = \frac{v_1^2}{2 \cdot g} \cdot \left( 8 + \frac{0,025 \cdot 60}{0,05} + 0,3 + 0,3 + \frac{0,025 \cdot 10}{0,1} + \xi_Z + \frac{1}{2} \right)$$

$$\frac{v_4^2}{2 \cdot g} \cdot \left( 1 + \xi_K + \frac{\lambda \cdot L_6}{d} + \frac{\lambda \cdot L_5}{d} - \frac{\lambda \cdot L_4}{d} - \xi_Z - 1 \right)$$

$$\xi_Z = \xi_K + \frac{\lambda \cdot L_5}{d} = 0,3 + \frac{0,025 \cdot 50}{0,05} = 25,3$$

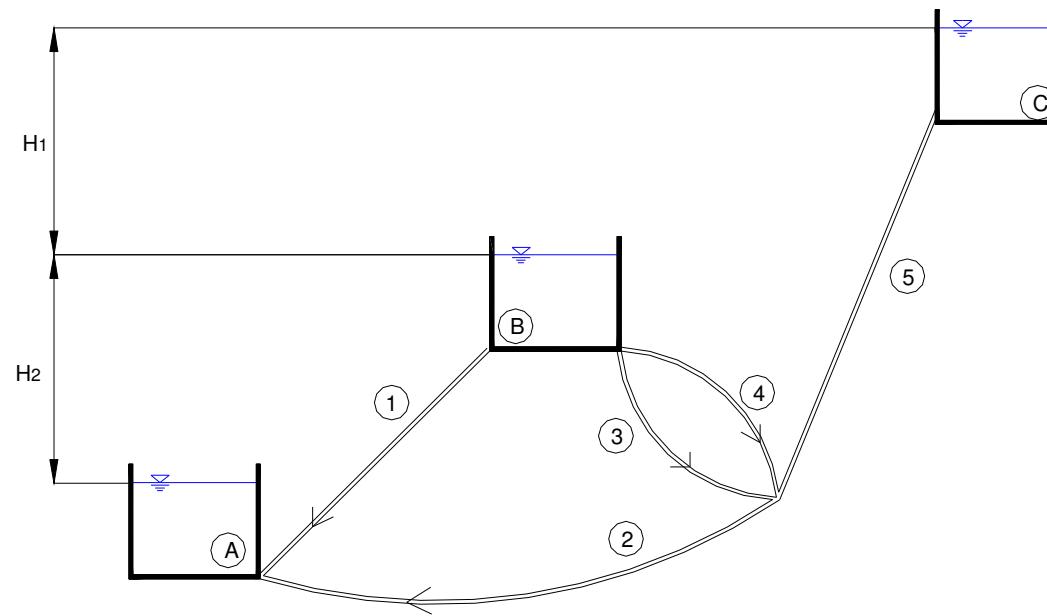
$$Q_3 = 4 \frac{l}{s} \Rightarrow v_3 = 2,03 \frac{m}{s}$$

$$Q_4 = 2 \frac{l}{s} \Rightarrow v_3 = v_5 = v_6 = 1,015 \frac{m}{s}$$

$$H_c = 14 + \frac{2,03^2 \cdot 54,25}{19,62} = \underline{\underline{25,4}} m$$

$$N_c = \frac{0,004 \cdot 25,4 \cdot 9810}{0,8} = \underline{\underline{1250}} W$$

**1.9 (\*) Gladine v posodah so konst. Določi višino  $H_2$  tako, da v posodo A doteka  $Q_A = 40 \text{ l/s}$ !**



Podatki:

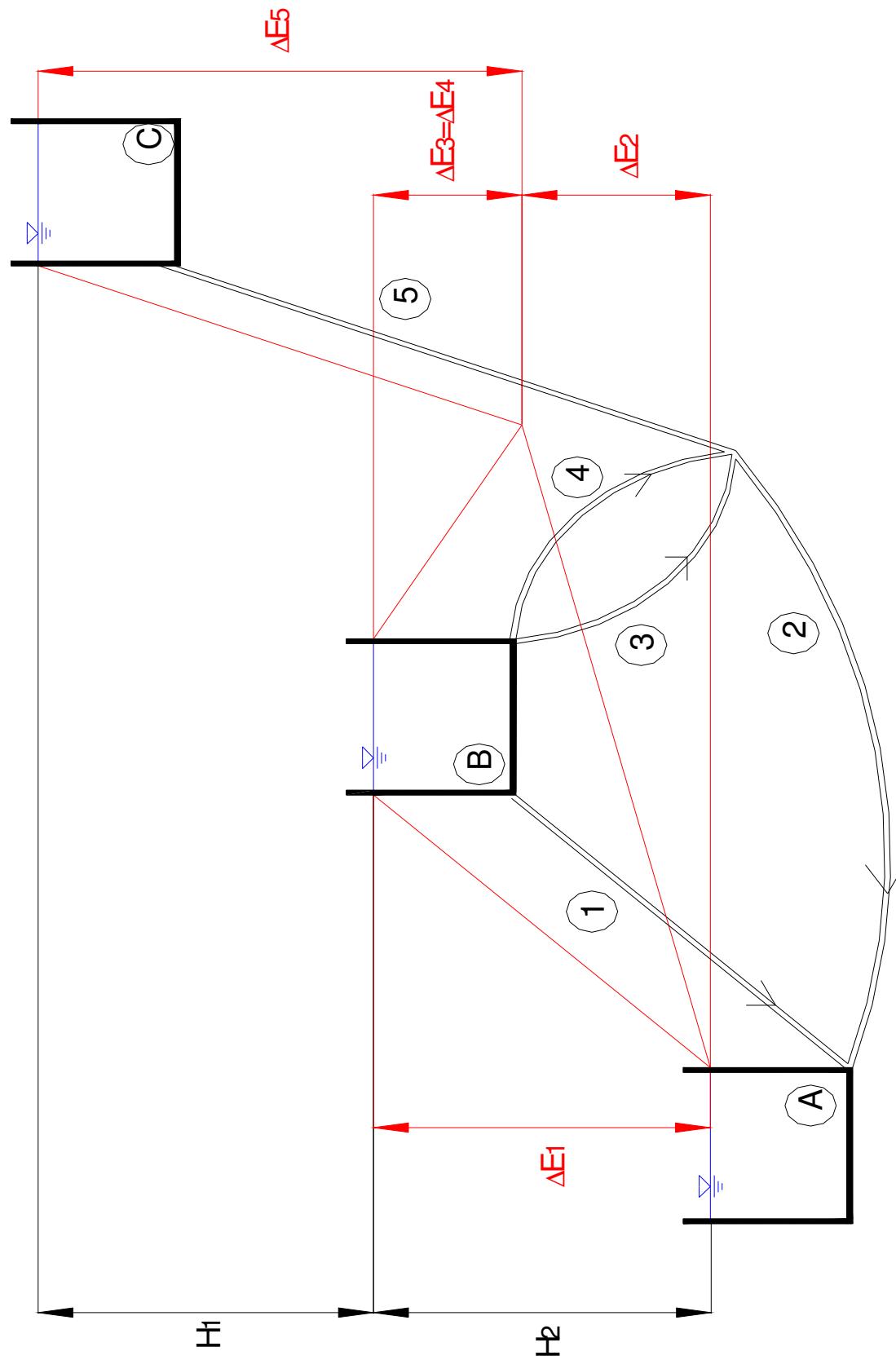
$$Q_A = 40 \frac{\text{l}}{\text{s}}$$

$$H_1 = 20 \text{ m}$$

$$\lambda = 0,03$$

i	$L_i [\text{m}]$	$d_i [\text{m}]$
1	300	0,10
2	600	0,20
3	300	0,20
4	200	0,15
5	800	0,20

Rešitev:



$$\Delta E_1 = H_1$$

$$\frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} = 20m \Rightarrow v_1 = \sqrt{\frac{20 \cdot 0,1 \cdot 19,62}{0,03 \cdot 300}}$$

$$v_1 = 2,09 \frac{m}{s}$$

$$Q_1 = 16,4 \frac{l}{s}$$

$$Q_2 = Q_A - Q_1 = 40 - 16,4 = 23,6 \frac{l}{s} \Rightarrow v_2 = \frac{Q \cdot 4}{d^2 \cdot \pi}$$

$$v_2 = \frac{0,0236 \cdot 4}{0,2^2 \cdot \pi} = 0,75 \frac{m}{s}$$

$$\frac{v_2^2}{2 \cdot g} = 0,029m$$

$$\Delta E_2 = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{0,03 \cdot 600}{0,2} \cdot 0,029 = 2,61m$$

$$\Delta E_3 = \Delta E_4 = H_1 - \Delta E_2 = 20 - 2,59 = 17,39m$$

$$\Delta E_3 = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g}$$

$$v_3 = \sqrt{\left( \frac{17,39 \cdot 19,62 \cdot 0,2}{0,03 \cdot 300} \right)} = 2,75 \frac{m}{s} \Rightarrow Q_3 = 86,4 \frac{l}{s}$$

$$v_4 = \sqrt{\left( \frac{17,41 \cdot 19,62 \cdot 0,15}{0,03 \cdot 200} \right)} = 2,92 \frac{m}{s} \Rightarrow Q_4 = 51,6 \frac{l}{s}$$

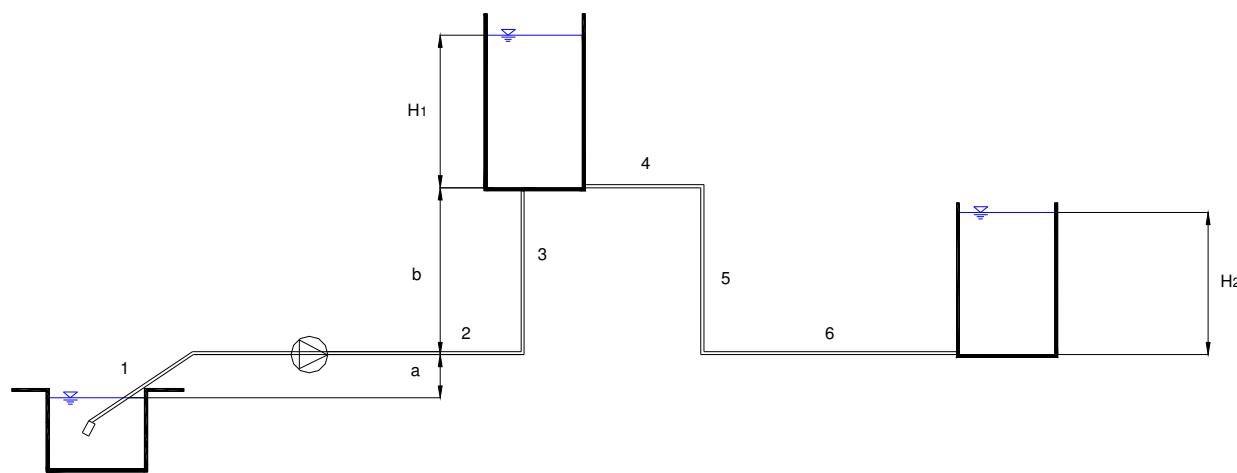
$$Q_5 = Q_3 + Q_4 - Q_2 = 86,4 + 51,6 - 23,6 = 114,4 \frac{l}{s}$$

$$v_5 = \frac{Q_5}{S_5} = \frac{0,1147 \cdot 4}{0,2^2 \cdot \pi} = 3,64 \frac{m}{s}$$

$$H_2 = \Delta E_3 + \Delta E_5 = 17,39 + \frac{\lambda \cdot L_5}{d_5} \cdot \frac{v_5^2}{2 \cdot g} = 98,42m (\text{ampak navzdol!!})$$

Posoda C mora biti dejansko zelo nizko, da se višek dotoka iz srednje posode zliva vanjo.

**1.10 Določi maksimalni pretok po sistemu ter višini  $H_1$  in  $H_2$ ! Kontroliraj dopustne podtlake v cevovodu!**



Podatki:

$$a = 4\text{m}$$

$$b = 5\text{m}$$

$$d_1 = 10\text{cm}$$

$$d_2 = d_3 = 5\text{cm}$$

$$d_4 = d_5 = d_6 = 10\text{cm}$$

$$L_1 = L_2 = L_4 = L_6 = 8\text{m}$$

$$\xi_{KO\check{S}} = 8,0$$

$$\xi_{KOL} = 0,5$$

$$\xi_{VT} = 0,3$$

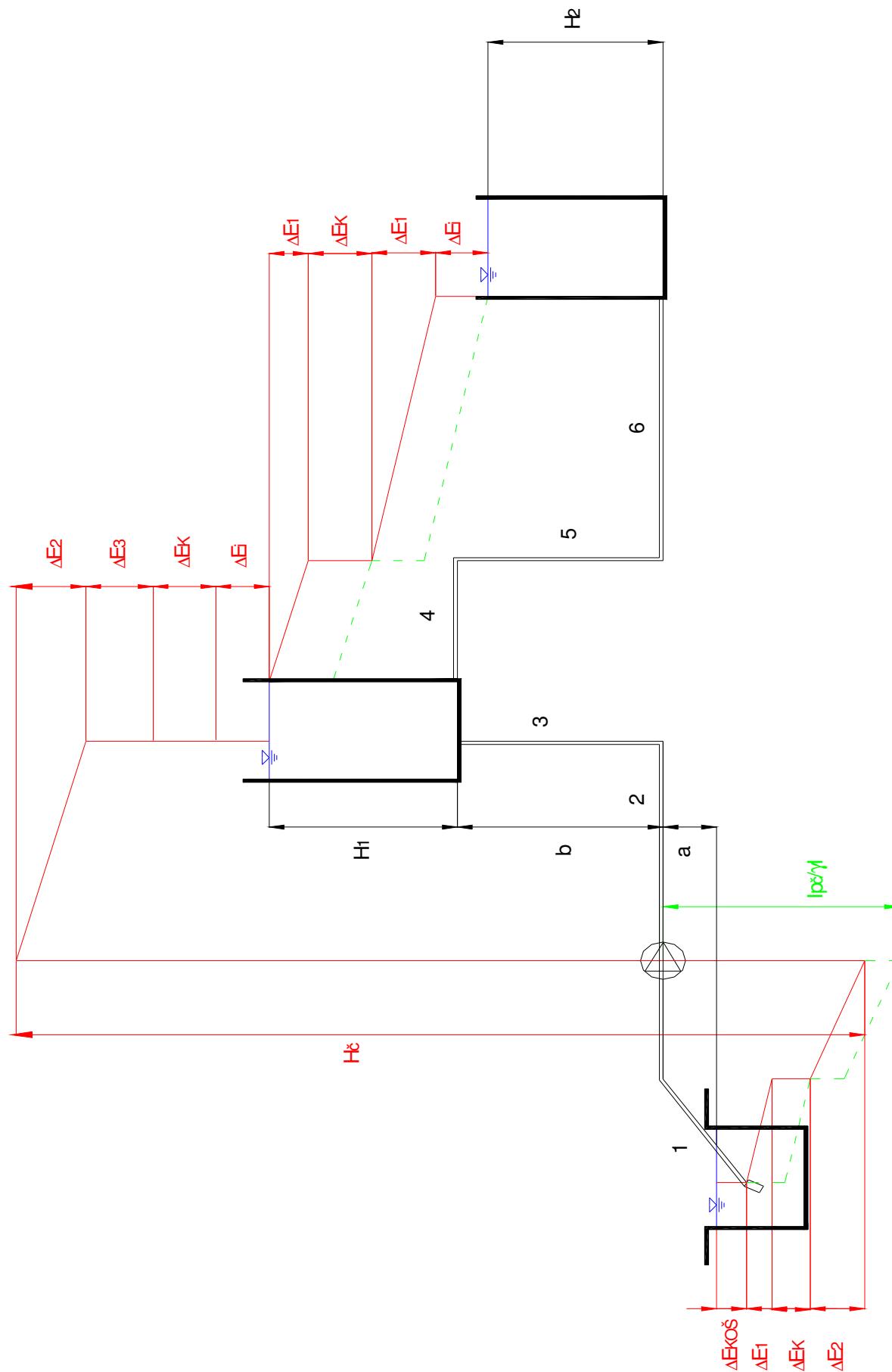
$$\lambda = 0,02$$

$$\eta_c = 0,8$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{\min} = 7\text{m}$$

$$N_c = 10\text{kW}$$

Rešitev:



$$Q_{\max} \Rightarrow \Delta E_{KO\check{S}} + \Delta E_1 + \Delta E_K + \frac{v^2}{2 \cdot g} + a = \left| \frac{p_c}{\gamma} \right|_{\min} = 7m$$

$$\frac{v^2}{2 \cdot g} \cdot \left( \xi_{KO\check{S}} + \frac{\lambda \cdot L_1}{d_1} + \xi_{KOL} + 1 \right) = 3m$$

$$\frac{v^2}{2 \cdot g} \cdot \left( 8 + \frac{0,02 \cdot 8}{0,1} + 0,5 + 1 \right) = 3m$$

$$\frac{v^2}{2 \cdot g} \cdot 11,1 = 3m$$

$$v_1 = 2,3 \frac{m}{s}$$

$$Q_{\max} = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 18,1 \frac{l}{s}$$

$$H_c \Rightarrow N_c = \frac{\rho \cdot g \cdot Q_c \cdot H_c}{\eta_c} \Rightarrow H_c = \frac{10000 \cdot 0,8}{9810 \cdot 18,1 \cdot 10^{-3}} = 45,05m$$

$$H_1 \Rightarrow \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KO\check{S}} + \frac{\lambda \cdot L_1}{d_1} + \xi_K \right) - H_c + \frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + \frac{\lambda \cdot L_3}{d_3} + \xi_K + 1 \right) + H_1 + b + a = 0$$

$$v_2 = \frac{4 \cdot Q_{\max}}{d_2^2 \cdot \pi} = \frac{4 \cdot 18,1 \cdot 10^{-3}}{0,05^2 \cdot \pi} = 9,22 \frac{m}{s}$$

$$\frac{2,3^2}{19,62} \cdot \left( 8 + \frac{0,02 \cdot 8}{0,1} + 0,5 \right) - 45,05 + \frac{9,22^2}{19,62} \cdot \left( \frac{0,02 \cdot 8}{0,05} + \frac{0,02 \cdot 5}{0,05} + 0,5 + 1 \right) + 9 = -H_1$$

$$41,96 - 45,05 = -H_1$$

$$H_1 = 3,09m$$

$$H_2 \Rightarrow b + H_1 - \frac{v_4^2}{2 \cdot g} \cdot \left( \xi_{VT} + \xi_{KOL} + \frac{\lambda \cdot L_4}{d_4} + \frac{\lambda \cdot L_5}{d_5} + \xi_{KOL} + \frac{\lambda \cdot L_6}{d_6} + 1,0 \right) - H_2 = 0$$

$$8,09 - \frac{2,3^2}{19,62} \cdot \left( 2,3 + \frac{0,02 \cdot 21}{0,1} \right) = H_2$$

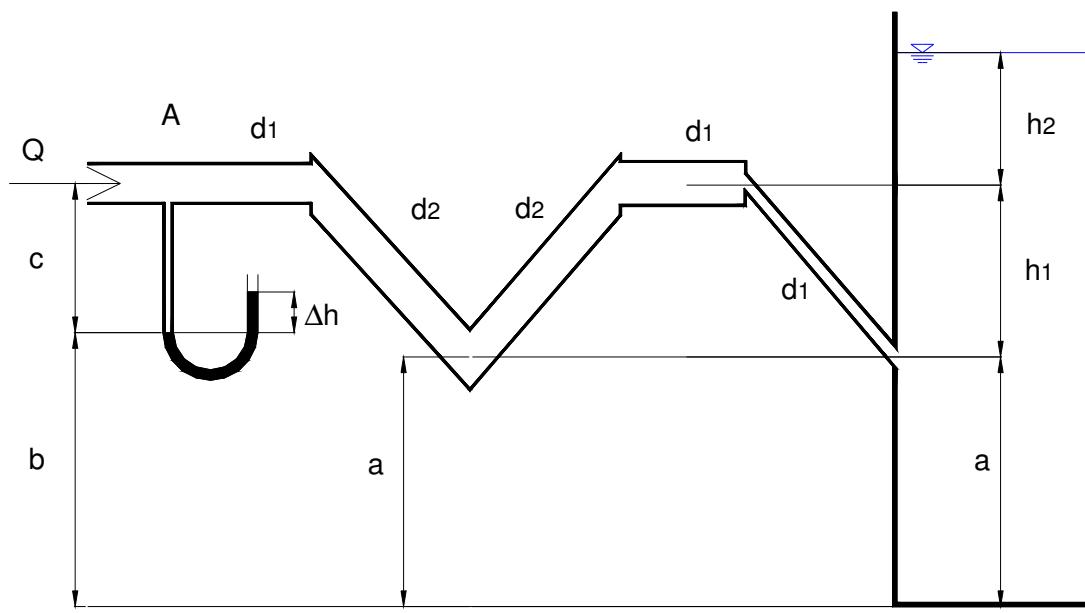
$$H_2 = 6,34m$$

Dejansko je kotrola podtlakov potrebna samo v kolenu med cevema 4 in 5. Vendar

pa pri višini vode v posodi 14,30 m in hitrosti v cevi 4  $2,3 \frac{m}{s}$  do podtlakov ne more priti.

**1.11 Z leve doteka Q vode, na desni je posoda z vodo.**

- a.) Iz višine  $\Delta h$  v namometru izračunaj višino vode v posodi ( $h_2$ ), če teče po sistemu  $Q = 22 \text{ l/s}$ .
- b.) V točki A imamo enako energijo, kot smo jo izračunali v točki a.) . Kolikšen je max. pretok po sistemu?
- c.) Kolikšen je  $\Delta h$  pri max. pretoku?



Podatki:

$$d_1 = 10 \text{ cm}$$

$$d_2 = 15 \text{ cm}$$

$$\lambda = 0,03$$

$$Q = 22 \frac{\text{l}}{\text{s}}$$

$$a = 1 \text{ m}$$

$$b = 3,5 \text{ m}$$

$$c = 0,5 \text{ m}$$

$$H_1 = 3 \text{ m}$$

$$L_1 = 3 \text{ m}$$

$$L_2 = L_3 = 6 \text{ m}$$

$$L_4 = L_5 = 8 \text{ m}$$

$$\Delta H = 30 \text{ cm}$$

$$\rho_{HG} = 13,6 \frac{\text{g}}{\text{cm}^3}$$

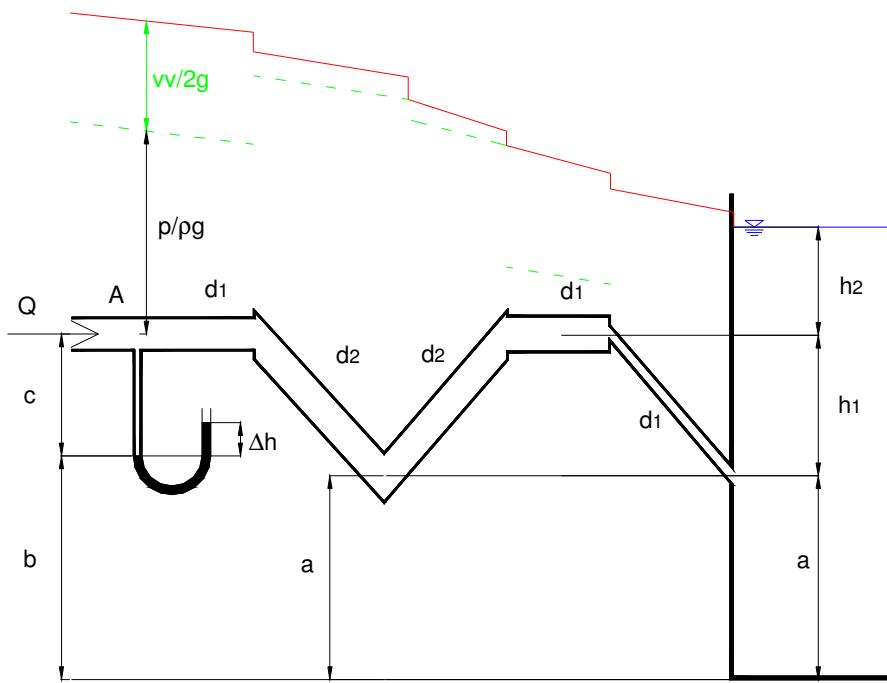
$$\xi_R = 0,3$$

$$\xi_K = 0,2$$

$$\xi_{VT} = 0,5$$

$$\xi_{ZOZ} = 0,5$$

Rešitev:



a)

$$p_1 = \Delta H \cdot \gamma_{HG} - b \cdot \gamma_V = 0,3 \cdot 136 - 0,5 \cdot 10 \equiv \frac{p_1}{\gamma} \cdot 3,58 m VS + 1 mm VS$$

$$v_1 = \frac{Q}{S_1} = \frac{0,022 \cdot 4}{0,1^2 \cdot \pi} = 2,8 \frac{m}{s}$$

$$\frac{v_1^2}{2 \cdot g} = 0,4 m$$

$$E_1 = 3,98 m$$

$$v_2 = \frac{Q}{S_2} = \frac{0,022 \cdot 4}{0,15^2 \cdot \pi} = 1,24 \frac{m}{s}$$

$$\frac{v_2^2}{2 \cdot g} = 0,08 m$$

$$c + b + \frac{p_1}{\gamma} + \frac{v_1^2}{2 \cdot g} = \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_R + \xi_K + \xi_K + \xi_{VR} + \frac{\lambda \cdot (L_1 + L_4 + L_5)}{d_1} \right) + \frac{v_2^2}{2 \cdot g} \cdot \left( \xi_K + \xi_Z + \xi_K + \frac{\lambda \cdot (L_1 + L_3)}{d_2} \right)$$

$$H_2 = 3,978 - \left[ 0,4 \cdot \left( 0,3 + 0,2 + 0,2 + 0,5 + \frac{0,03 \cdot 19}{0,1} \right) + 0,08 \cdot \left( 0,2 + 0,5 + 0,2 + \frac{0,03 \cdot 12}{0,15} \right) \right]$$

$$H_2 = 3,98 - (2,76 + 0,264) = 0,96 m$$

b)

$$Q_{\max} \Rightarrow \left| \frac{p_3}{\rho \cdot g} \right| = 7,5m$$

$$\frac{p_1}{\rho \cdot g} + \frac{v_1^2}{2 \cdot g} = \frac{v_1^2}{2 \cdot g} \cdot \left[ \frac{\lambda L_1}{d_1} + \xi_R \right] + \frac{v_1^2}{2 \cdot g} \cdot \left[ \lambda \cdot \frac{(L_2 + L_3)}{d_2} + \xi_k + \xi_z + \xi_k \right] + \frac{v_1^2}{2 \cdot g} \cdot \left[ \frac{\lambda L_4}{d_1} + \xi_k + 1 \right]$$

$$\frac{v_1}{v_2} = \frac{S_2}{S_1} = \frac{d_2^2}{d_1^2} = \frac{0,15^2}{0,1^2} = 2,25$$

$$v_1 = 2,25 \cdot v_2$$

$$\frac{v_1^2}{2 \cdot g} = 2,25^2 \cdot \frac{v_2^2}{2 \cdot g} = 5,06 \cdot \frac{v_2^2}{2 \cdot g}$$

$$3,98 + 7,5 = 5,06 \cdot \frac{v_2^2}{2 \cdot g} \cdot \left[ 0,03 \cdot \frac{3}{0,1} + 0,3 + 0,03 \cdot \frac{8}{0,1} + 0,2 + 1 \right] + \frac{v_2^2}{2 \cdot g} \cdot \left[ 0,03 \cdot \frac{12}{0,15} + 0,9 \right]$$

$$11,48 = 27,588 \cdot \frac{v_2^2}{2 \cdot g}$$

$$\frac{v_2^2}{2 \cdot g} = 0,416m$$

$$v_2 = 2,85 \frac{m}{s}$$

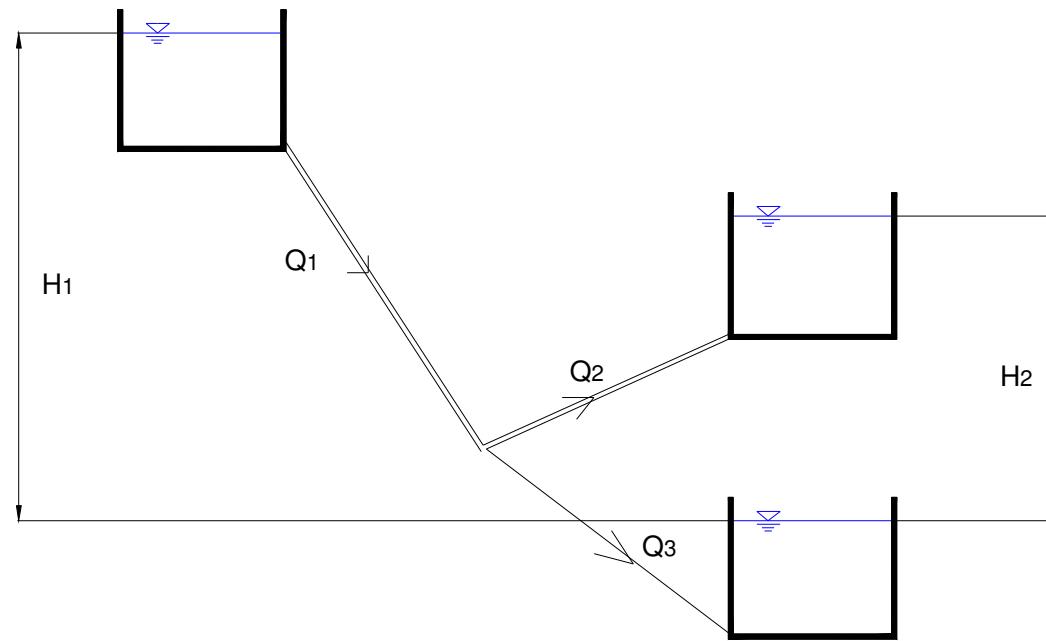
$$v_1 = 6,43 \frac{m}{s}$$

$$Q = 50,5 \frac{l}{s}$$

c.)

$$\frac{p_1}{\rho \cdot g} = E_1 - \frac{v_1^2}{2 \cdot g} = 3,98 - 2,11 = 1,87 mVS$$

**1.12 Določi pretoka  $Q_1$  in  $Q_2$  ter razliko višin med gladinama v posodi 2 in 3!**



Podatki:

$$Q_3 = 100 \frac{L}{s}$$

$$d_1 = 20cm$$

$$d_2 = 25cm$$

$$d_3 = 30cm$$

$$L_1 = 200m$$

$$L_2 = 300m$$

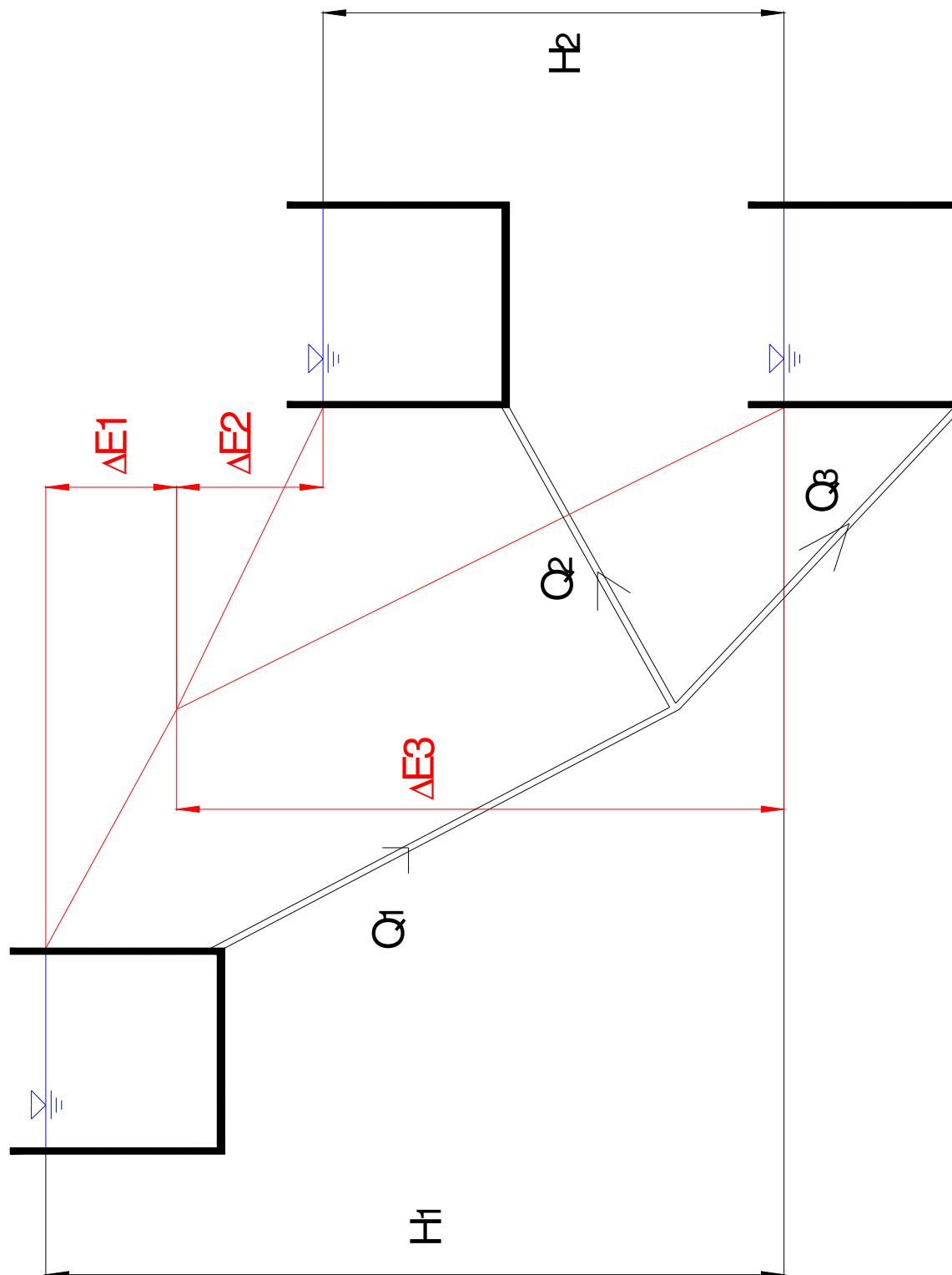
$$L_3 = 150m$$

$$\lambda = 0,02$$

$$H_1 = 30m$$

$$\overline{Q_1 = ?, Q_2 = ?, H_2 = ?}$$

Rešitev:



a.)  $Q_3 = Q_1 \pm Q_2$

b.)  $\Delta E_3 = \lambda \cdot \frac{L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g}$

c.)  $\Delta E_1 + \Delta E_3 = H_1$

d.)  $H_2 = \Delta E_3 \pm \Delta E_2$

$$v_3 = \frac{Q_3 \cdot 4}{d_3^2 \cdot \pi} = \frac{0,4}{0,3^2 \cdot \pi} = \sqrt{2} \frac{m}{s}$$

$$\frac{v_3^2}{2 \cdot g} = 0,102 m$$

b.)

$$\Delta E_3 = 0,02 \cdot \frac{150}{0,3} \cdot 0,102 = 1,02 m$$

c.)

$$\Delta E_1 = H_1 - \Delta E_3 = 30 - 1,02 = 28,98 m$$

$$\Delta E_1 = \lambda \cdot \frac{L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} \Rightarrow v_1 = \sqrt{\frac{\Delta E_1 \cdot d_1 \cdot 2 \cdot g}{\lambda \cdot L_1}}$$

$$v_1 = 5,33 \frac{m}{s}$$

d.)

$$Q_1 = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = \frac{5,33 \cdot 0,2^2 \cdot \pi}{4} = 0,167 \frac{m^3}{s} = 167 \frac{l}{s}$$

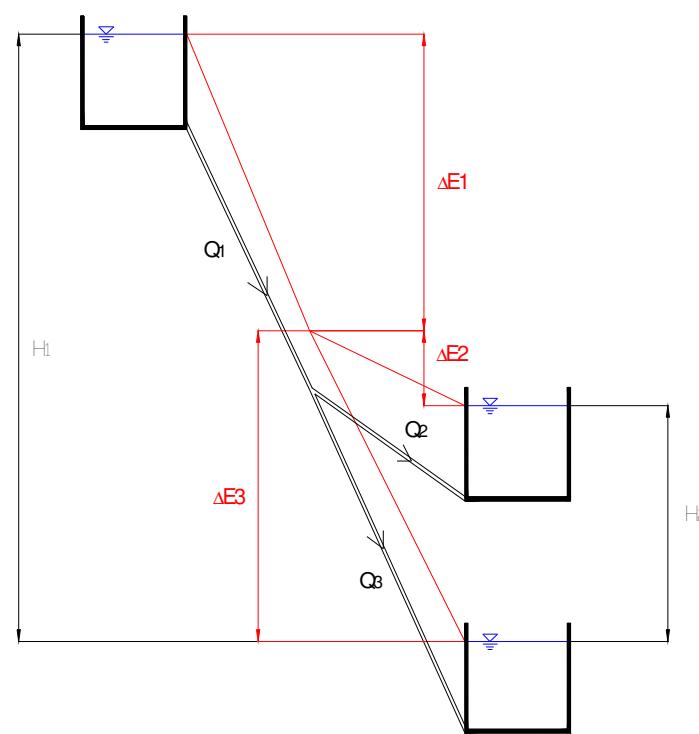
$$Q_2 = Q_1 - Q_3 = 67 \frac{l}{s}$$

$$v_2 = \frac{Q_2 \cdot 4}{d_2^2 \cdot \pi} = 1,38 \frac{m}{s}$$

$$\Delta E_2 = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{0,02 \cdot 300}{0,25} \cdot \frac{1,38^2}{2 \cdot 9,81} = 2,31 m$$

$$H_2 = 1,02 - 2,31 = -1,29 m$$

Dejansko stanje:

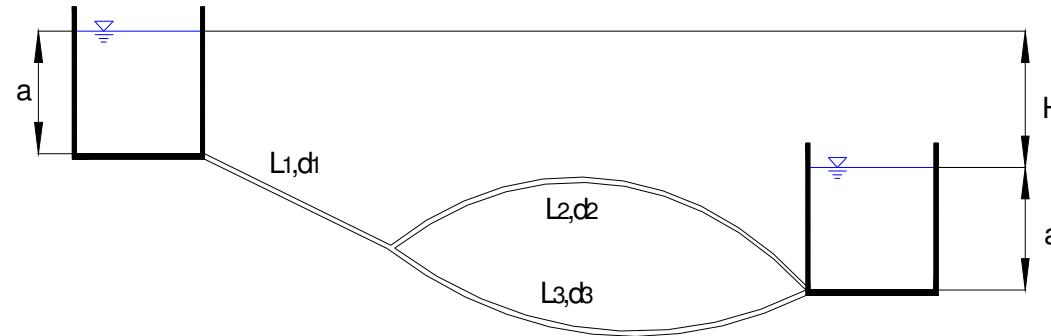


Kontrola:

$$H_1 + H_2 = \Delta E_1 + \Delta E_2$$

$$31,29 = 28,98 + 2,31 = 31,29 \quad \underline{\text{OK}}$$

**1.13 Za koliko se zmanjša pretok, če iz sistema odstranimo cev 3? Dolgi cevovod!**



Podatki:

$$a = 2m$$

$$b = 1m$$

$$H = 20m$$

$$L_1 = 100m$$

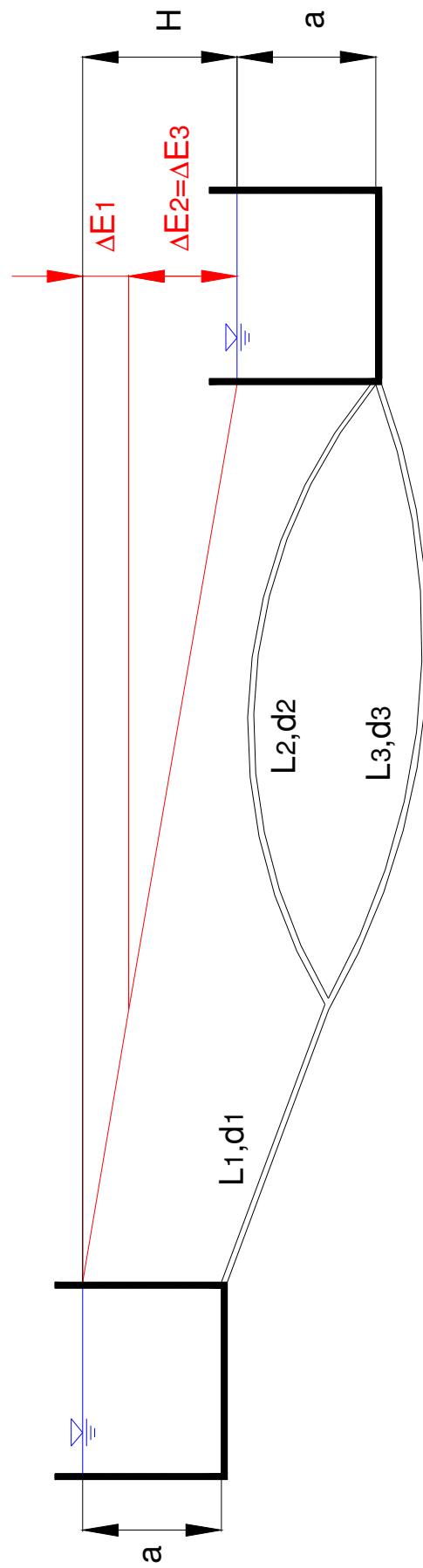
$$L_2 = L_3 = 150m$$

$$d_1 = 10cm$$

$$d_2 = d_3 = 5cm$$

$$\lambda = 0,02$$

Rešitev:



osnovni sistem, 3 cevi :

$$\Delta E_2 = \Delta E_3$$

$$v_2 = v_3 = 2 \cdot v_1$$

$$Q_2 = Q_3$$

$$Q_1 = Q_2 + Q_3 = 2 \cdot Q_2$$

$$v_1 \cdot d_1^2 = 2 \cdot v_2 \cdot d_2^2$$

$$v_1 = 2 \cdot v_2 \cdot \frac{d_2^2}{d_1^2} = 0,5 \cdot v_2 = \underline{0,5 \cdot v_3}$$

$$H = \lambda \cdot \left( \frac{L_1 \cdot v_1^2}{d_1 \cdot 2 \cdot g} + \frac{L_2 \cdot v_2^2}{d_2 \cdot 2 \cdot g} \right) = \lambda \cdot \left( \frac{L_1 \cdot v_1^2}{d_1 \cdot 2 \cdot g} + \frac{L_2 \cdot 4 \cdot v_1^2}{d_2 \cdot 2 \cdot g} \right) \Rightarrow \text{izrazimo } v_1^2$$

$$v_1^2 = \frac{2 \cdot H \cdot g}{\lambda \cdot \left( \frac{L_1}{d_1} + \frac{L_2 \cdot 4}{d_2} \right)}$$

$$v_1 = \sqrt{\frac{2 \cdot 20 \cdot 9,81}{0,02 \cdot \left( \frac{100}{0,1} + \frac{600}{0,05} \right)}} = 1,23 \frac{m}{s}$$

$$v_2 = v_3 = 2,46 \frac{m}{s}$$

$$Q_1 = \frac{1,23 \cdot 0,1^2 \cdot \pi}{4} = 9,66 \frac{l}{s}$$

$$Q_3 = Q_2 = \frac{Q_1}{2} = 4,83 \frac{l}{s}$$

Odstranimo cev L<sub>3</sub> :

$$Q_3 = Q_2$$

$$v_1 \cdot d_1^2 = v_2 \cdot d_2^2$$

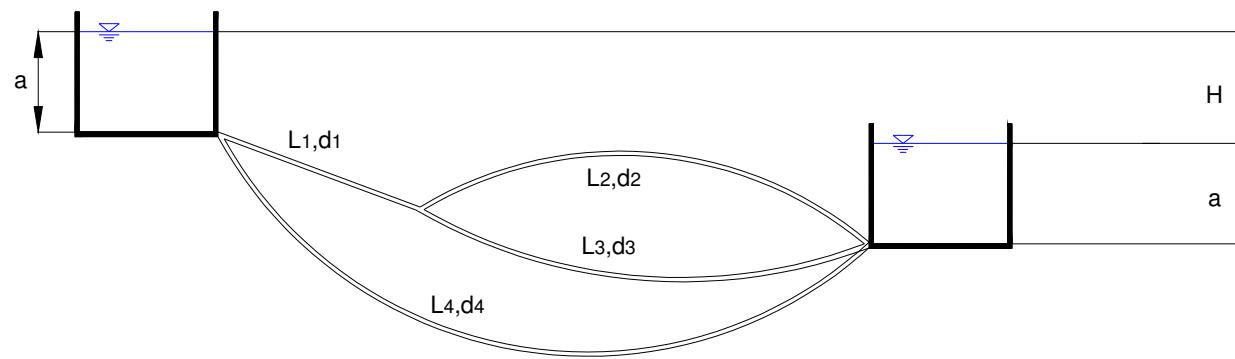
$$v_2 = v_1 \cdot \frac{d_1^2}{d_2^2} = v_1 \cdot \frac{(2 \cdot d_2)}{d_2^2} = 4 \cdot v_1$$

$$H = \frac{\lambda \cdot L_1 \cdot v_1^2}{d_1 \cdot 2 \cdot g} + \frac{\lambda \cdot L_2 \cdot (4 \cdot v_1)^2}{d_2 \cdot 2 \cdot g} = \frac{\lambda \cdot v_1^2}{2 \cdot g} \cdot \left( \frac{L_1}{d_1} + \frac{16 \cdot L_2}{d_2} \right)$$

$$v_1 = \sqrt{\frac{2 \cdot g \cdot H}{\lambda \cdot \left( \frac{L_1}{d_1} + \frac{16 \cdot L_2}{d_2} \right)}} = \sqrt{\frac{19,62 \cdot 20}{0,02 \cdot \left( \frac{100}{0,1} + \frac{16 \cdot 150}{0,05} \right)}} = \sqrt{\frac{392,4}{980}} = 0,63 \frac{m}{s}$$

$$\Delta Q[\%] = 100 - \left( \frac{0,63}{1,23} \right) \cdot 100 = \underline{49\%}$$

**1.14 Določi pretoke po sistemu! S kakšno cevjo ( $d_4$ ) dolžine  $L_4$  lahko zamenjamo cevi med obema bazenoma, da se pretok ne spremeni? Dolgi cevovod.**



Podatki:

$$a = 1m$$

$$H = 20m$$

$$L_1 = L_2 = L_3 = 200m$$

$$L_4 = 400m$$

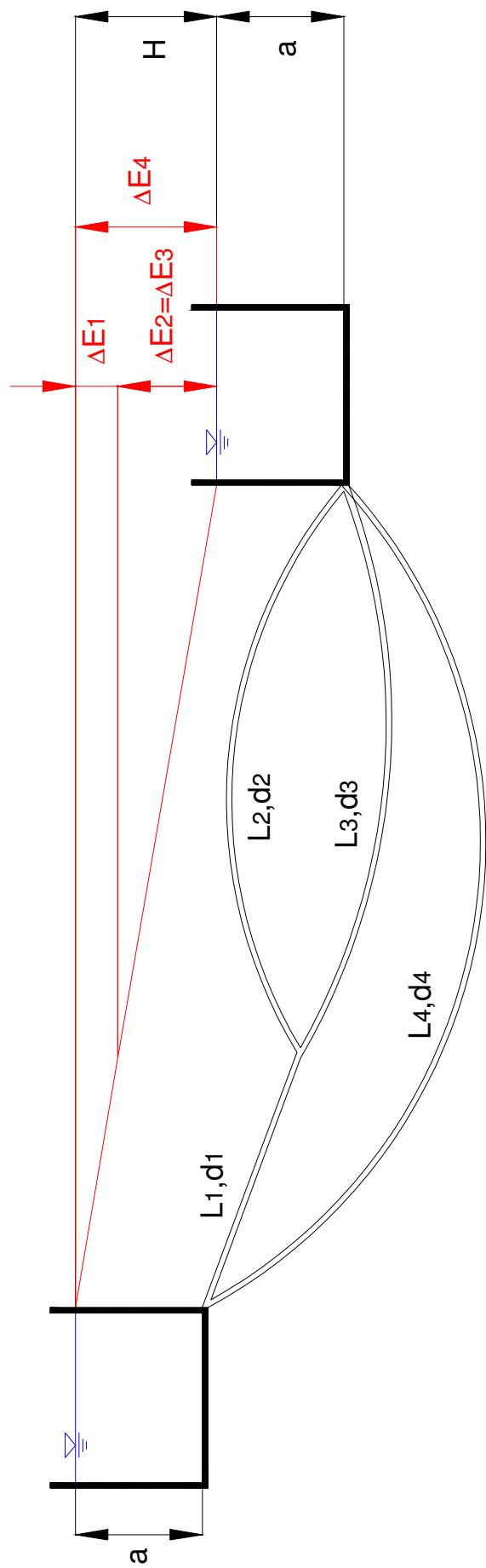
$$d_1 = 15cm$$

$$d_2 = d_3 = 10cm$$

$$\lambda = 0,02$$

$$\overline{Q_1 = ?, Q_2 = ?, Q_3 = ?, d_4 = ?}$$

Rešitev:



$$Q_4 = Q_1 = Q_2 + Q_3$$

$$\begin{aligned} v_1 \cdot d_1^2 &= v_2 \cdot d_2^2 + v_3 \cdot d_3^2 \\ v_1 \cdot d_1^2 &= 2 \cdot v_2 \cdot d_2^2 \\ v_1 &= 2 \cdot v_2 \cdot \frac{d_2^2}{d_1^2} = 2 \cdot v_2 \cdot \frac{0,1^2}{0,15^2} = \underline{0,889 \cdot v_2} \end{aligned}$$

$$\begin{aligned} \Delta E_2 + \Delta E_1 &= H \\ \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} &= H \end{aligned}$$

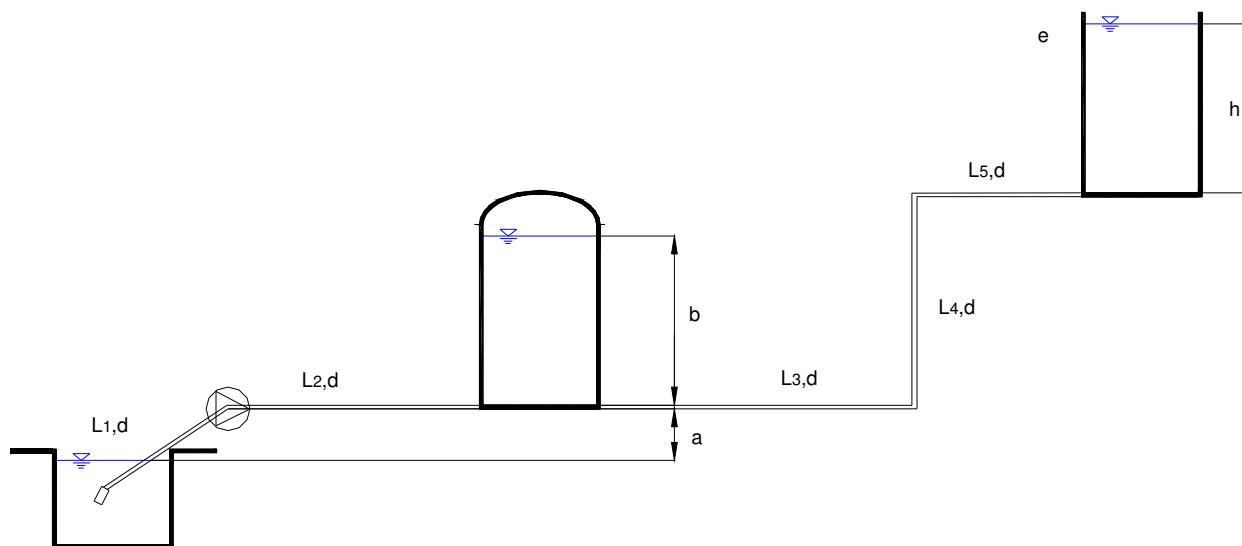
$$\begin{aligned} \Delta E_2 &= \Delta E_1 \\ \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} &= \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} \\ v_2 &= v_3 \\ Q_2 = Q_3 &= \underline{\frac{Q_1}{2}} \end{aligned}$$

$$\begin{aligned} \frac{0,02 \cdot 200}{0,15} \cdot \frac{0,889^2 \cdot v_2^2}{2 \cdot 9,81} + \frac{0,02 \cdot 200}{0,1} \cdot \frac{v_2^2}{2 \cdot 9,81} &= 20 \\ 1,074 \cdot v_2^2 + 2,039 \cdot v_2^2 &= 20 \\ 3,113 \cdot v_2^2 &= 20 \end{aligned}$$

$$\begin{aligned} v_2 &= 2,53 \frac{m}{s} \\ v_1 &= 2,25 \frac{m}{s} \\ Q_4 = Q_1 &= \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 39,7 \frac{l}{s} \end{aligned}$$

$$\begin{aligned} v_4 &= \frac{4 \cdot Q}{d_4^2 \cdot \pi} \\ \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g} &= H \\ \frac{\lambda \cdot L_4}{d_4} \cdot \frac{16 \cdot Q^2}{d_4^4 \cdot \pi^2 \cdot 2 \cdot g} &= H \\ d_4^5 &= \frac{16 \cdot \lambda \cdot L_4 \cdot Q_4^2}{\pi^2 \cdot 2 \cdot g \cdot H} \Rightarrow d_4 = \sqrt[5]{\frac{16 \cdot 0,02 \cdot 400 \cdot (39,7 \cdot 10^{-3})^2}{\pi^2 \cdot 2 \cdot 9,81 \cdot 20}} = \underline{0,139 m} \end{aligned}$$

**1.15 Določi max. pretok, gladino v desni posodi  $h$  in tlak v hidroforu  $p!$**



Podatki:

$$L_1 = L_2 = 5m$$

$$L_3 = 8m$$

$$L_4 = 3m$$

$$L_5 = 4m$$

$$N_c = 1kW$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{min} = 6m$$

$$d = 5cm$$

$$a = b = 2m$$

$$\xi_{KO\check{S}} = 8,0$$

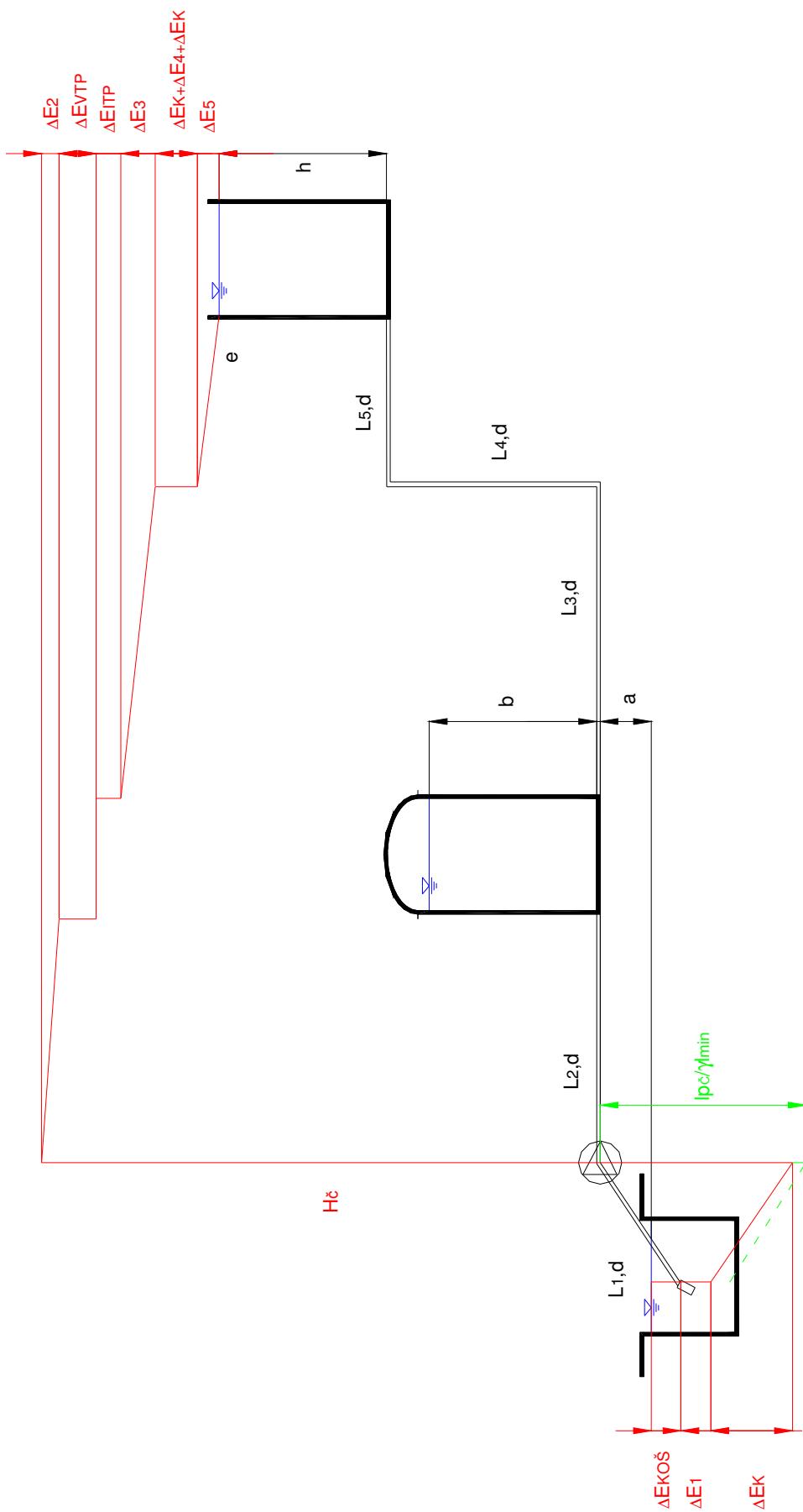
$$\xi_{KOL} = 0,5$$

$$\xi_{vtTP} = 0,5$$

$$\xi_{itTP} = 0,5$$

$$\lambda = 0,018$$

Rešitev:





Izracun  $Q_{\max}$ :

$$\frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \xi_{KOS} \cdot \frac{v_1^2}{2 \cdot g} + \frac{v_1^2}{2 \cdot g} - \left| \frac{p_C}{\rho \cdot g} \right|_{\min} + a = 0$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + \xi_{KOS} + 1 \right) = \left| \frac{p_C}{\rho \cdot g} \right|_{\min} - a = 4$$

$$v_1 = \sqrt{\frac{8 \cdot 9,81}{8,0 + \frac{0,018 \cdot 5}{0,05} + 1}} = 2,696 \frac{m}{s}$$

$$Q_{\max} = \frac{2,696 \cdot 0,05^2 \cdot \pi}{4} = 5,29 \frac{l}{s}$$

$$N_c = \frac{Q_{\max} \cdot H_c \cdot \rho \cdot g}{\eta_c} \Rightarrow H_c = \frac{N_c \cdot \eta_c}{Q_{\max} \cdot \rho \cdot g} = \frac{1000 \cdot 0,8}{5,29 \cdot 9,81} = 15,41 m$$

Izracun tlaka v hidroforu:

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + \xi_{KOS} \right) - H_c + \frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + \xi_{vTP} \right) + \frac{p}{\gamma} + b + a = 0$$

$$\frac{p}{\rho \cdot g} = H_c - a - b - \frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + \xi_{KOS} + \frac{\lambda \cdot L_2}{d_2} + \xi_{vTP} \right)$$

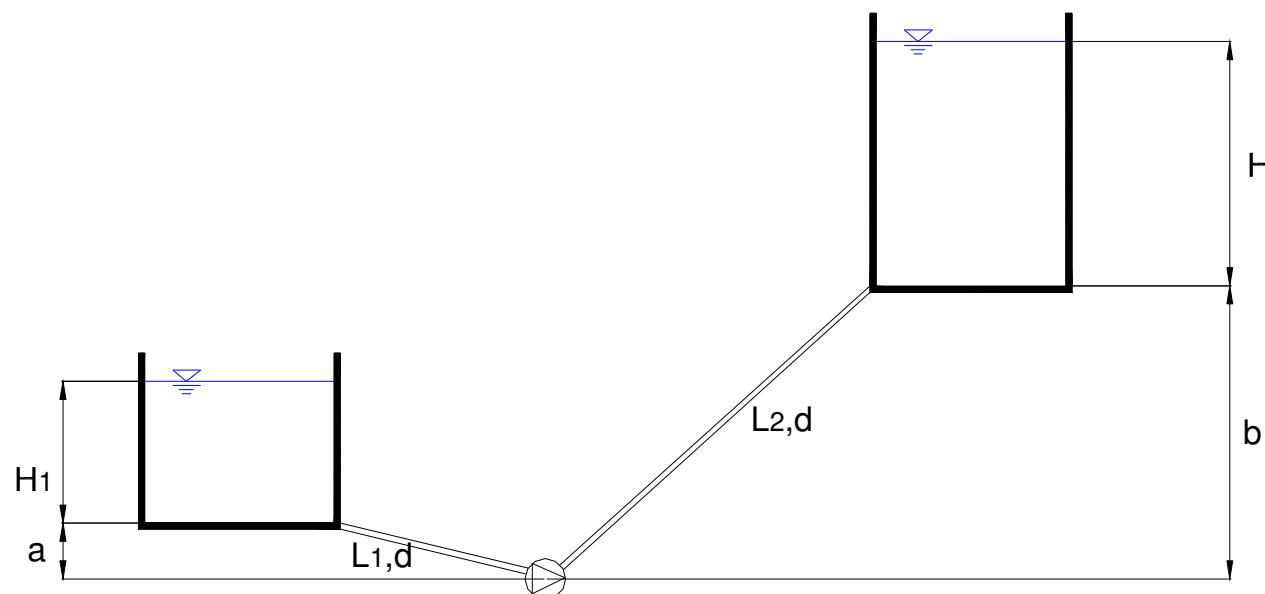
$$\frac{p}{\rho \cdot g} = 15,41 - 4 - 2 - \frac{2,696^2}{2 \cdot 9,81} \cdot \left( 8,0 + \frac{0,018 \cdot 10}{0,05} + 0,5 \right) = 6,51 m ?$$

$$p = 0,651 bar$$

$$b + \frac{p}{\rho \cdot g} - \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{vTP} + \frac{\lambda \cdot L_3}{d_3} + 2 \cdot \xi_K + \frac{\lambda \cdot L_4}{d_4} + \frac{\lambda \cdot L_5}{d_5} + \xi_i \right) - h - L_4 = 0$$

$$h = 2 + 6,51 - \frac{2,696^2}{16,82} \cdot \left( 0,5 + \frac{0,018 \cdot 15}{0,05} + 1,0 + 1,0 \right) - 3 = 5,51 - 2,92 = 2,58 m$$

**1.16 Določi  $Q_{\max}$  in  $N_c$  pod pogojem, da je v črpalki NADTLAK 4 m!**



Podatki:

$$a = 9 \text{ m}$$

$$b = 15 \text{ m}$$

$$H_1 = 1 \text{ m}$$

$$H_2 = 5 \text{ m}$$

$$\lambda = 0,028$$

$$\xi_{VT} = 0,4$$

$$L_1 = 15 \text{ m}$$

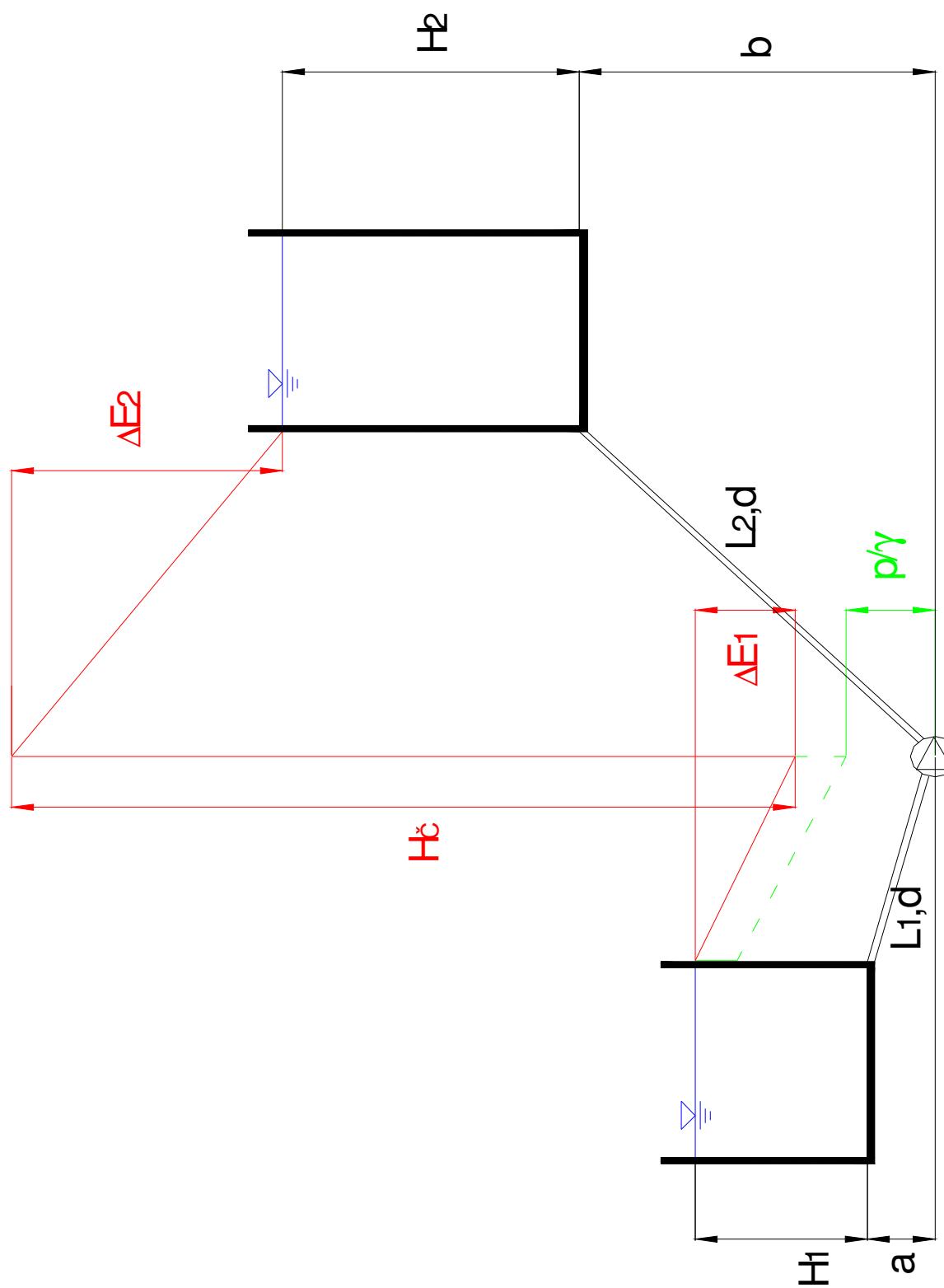
$$L_2 = 20 \text{ m}$$

$$d = 5 \text{ cm}$$

$$\left( \frac{p}{\rho \cdot g} \right)_{\min} = +4 \text{ m}$$

$$\eta_c = 0,8$$

Rešitev:



$$a + H_1 - \Delta E_{VT} - \Delta E_1 - \frac{v_1^2}{2 \cdot g} - \frac{p}{\rho \cdot g} = 0$$

$$a + H_1 - \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d} + 1 \right) - \frac{p}{\rho \cdot g} = 0 \Rightarrow \text{izrazimo } v_1$$

$$\frac{v_1^2}{2 \cdot g} = \frac{a + H_1 - \frac{p}{\rho \cdot g}}{\xi_{VT} + \frac{\lambda \cdot L_1}{d} + 1}$$

$$v_1 = \sqrt{\frac{19,62 \cdot 6}{0,4 + \frac{0,028 \cdot 15}{0,05} + 1}} = 3,47 \frac{m}{s}$$

$$Q_{\max} = \frac{v_1 \cdot d^2 \cdot \pi}{4} = \frac{3,47 \cdot 0,05^2 \cdot \pi}{4} = 6,81 \frac{l}{s}$$

$$a + H_1 - \Delta E_{VT} - \Delta E_1 + H_c - \Delta E_2 - \Delta E_i - H_2 - b = 0$$

$$a + H_1 = 10m$$

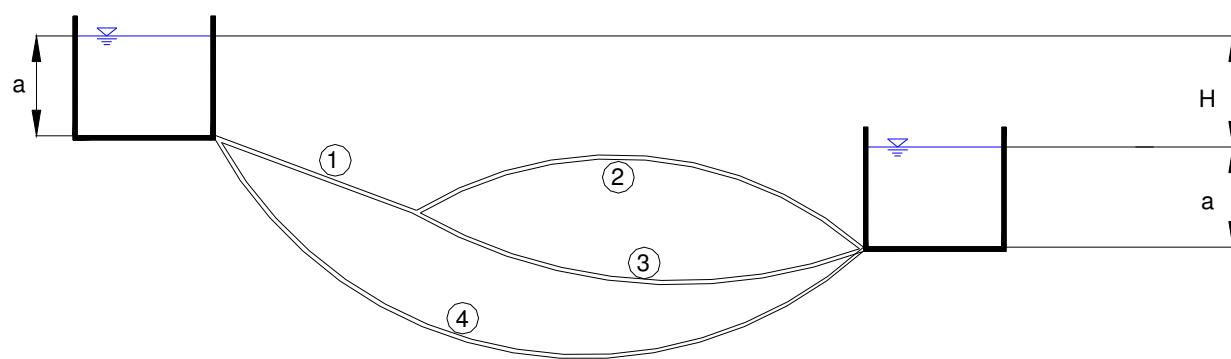
$$H_2 + b = 20m$$

$$H_c = -10 + 20 + \frac{v^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d} + \frac{\lambda \cdot L_2}{d} + \xi_i \right)$$

$$H_c = 10 + \frac{3,47^2}{2 \cdot 9,81} \cdot \left( 0,4 + \frac{0,028 \cdot 35}{0,05} + 1,0 \right) = 22,88m$$

$$N_c = \frac{\rho \cdot g \cdot H_c \cdot Q_c}{\eta_c} = \frac{9810 \cdot 22,88 \cdot 6,81 \cdot 10^{-3}}{0,8} = 1911W \cong 2kW$$

**1.17 Določi preteke po sistemu 1-2-3! V sistemu želimo podvojiti pretok, zato dodamo cev 4. Izračunaj premer cevi  $d_4$  pri podani dolžini  $L_4$ . Dolgi cevovod!**



Podatki:

$$a = 1m$$

$$H = 20m$$

$$L_1 = L_2 = L_3 = 200m$$

$$L_4 = 400m$$

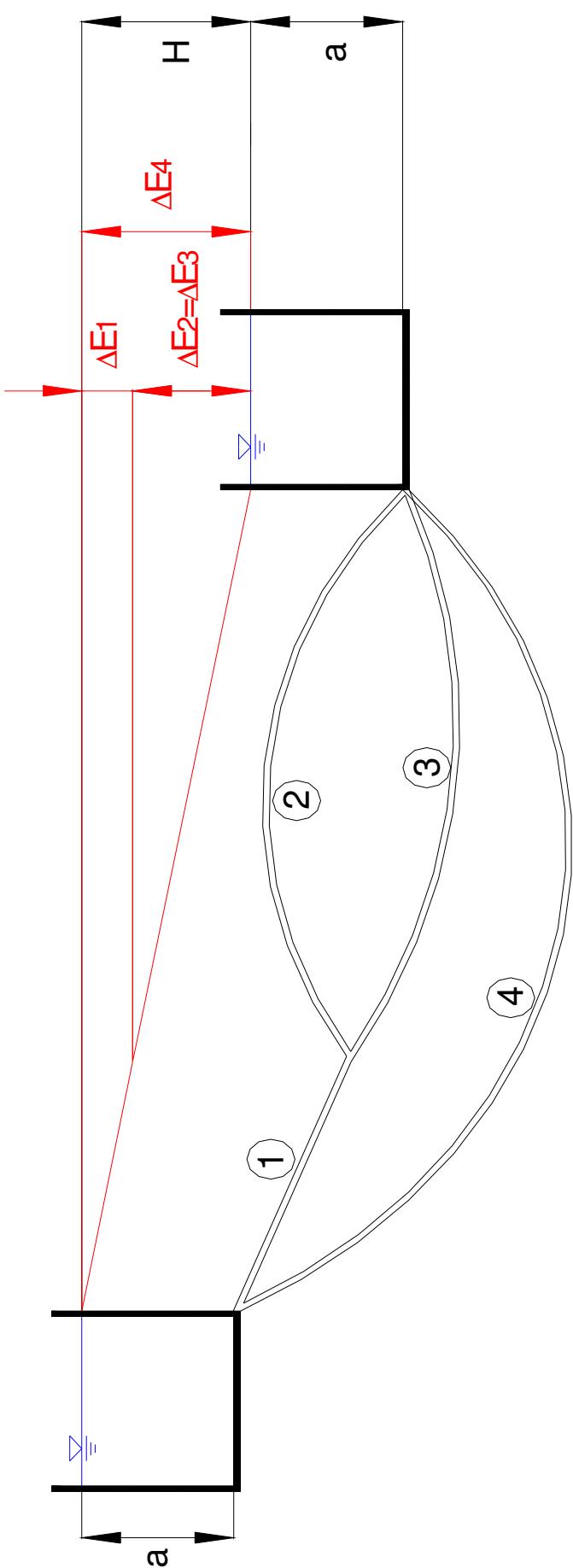
$$d_1 = 15cm$$

$$d_2 = d_3 = 10cm$$

$$\lambda = 0,02$$

$$\overline{Q_1 = ?, Q_2 = ?, Q_3 = ?, Q_4 = ?, d_4 = ?}$$

Rešitev:

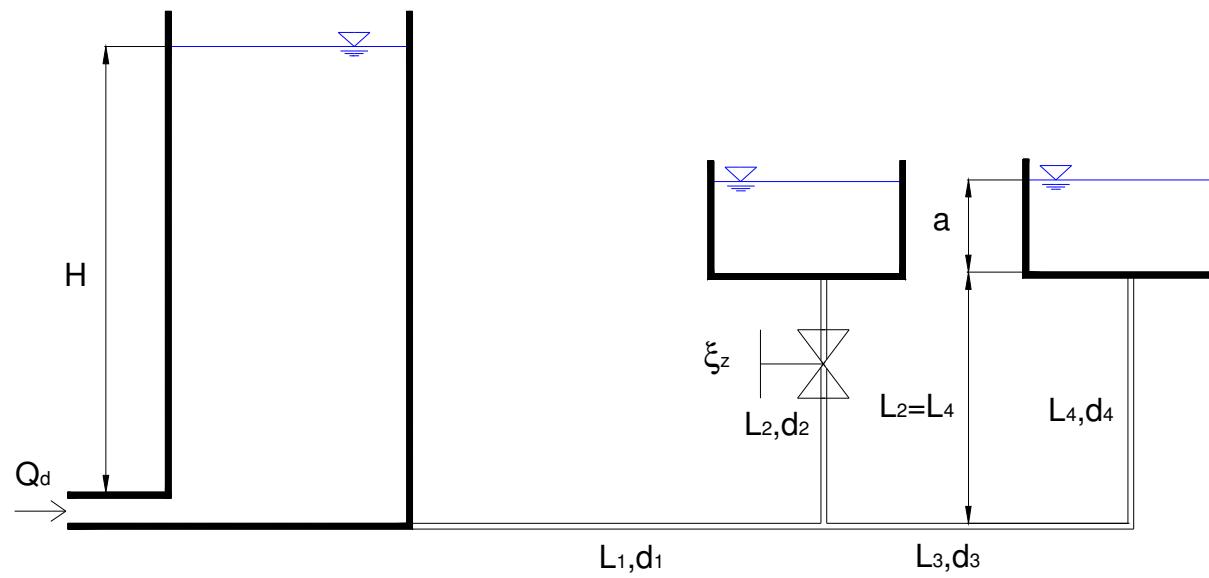


$$\begin{aligned}
 Q_1 &= Q_2 + Q_3 \\
 v_1 \cdot d_1^2 &= v_2 \cdot d_2^2 + v_3 \cdot d_3^2 = 2 \cdot v_2 \cdot d_2^2 \\
 L_2 &= L_3 \text{ in } d_2 = d_3 \Rightarrow v_2 = v_3 \\
 v_1 &= 2 \cdot v_2 \cdot \frac{d_2^2}{d_1^2} = 2 \cdot v_2 \cdot \frac{0,1^2}{0,15^2} = \underline{0,8889 \cdot v_2}
 \end{aligned}$$

$$\begin{aligned}
 \Delta E_1 + \Delta E_2 &= H \\
 \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} &= H \\
 \frac{0,02 \cdot 200}{0,15} \cdot \frac{0,8889 \cdot v_2^2}{2 \cdot 9,81} + \frac{0,02 \cdot 200}{0,1} \cdot \frac{v_2^2}{2 \cdot 9,81} &= 20m \\
 1,074 \cdot v_2^2 + 2,039 \cdot v_2^2 &= 20m \\
 v_2 &= 2,53 \frac{m}{s} \\
 v_1 &= 2,25 \frac{m}{s} \\
 Q_1 &= 39,7 \frac{l}{s}
 \end{aligned}$$

$$\begin{aligned}
 \Delta E_2 &= \Delta E_3 \\
 \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} &= \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} \\
 v_2 &= v_3 \\
 Q_2 = Q_3 &= \frac{Q_1}{2} = 0,01985 \frac{m^3}{s} = 19,85 \frac{l}{s} \\
 \text{Dodatna cev mora prevajati } Q &= 39,7 \frac{l}{s} \text{ in } \Delta E_4 = H: \\
 Q &= \frac{v_4 \cdot d_4^2 \cdot \pi}{4} \\
 v_4 &= \frac{4 \cdot Q}{d_4^2 \cdot \pi} \\
 \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g} &= H \\
 d_4^5 &= \frac{\lambda \cdot L_4 \cdot Q^2}{H \cdot \pi^2 \cdot g} \\
 d_4 &= \underline{13,91 cm?}
 \end{aligned}$$

**1.18 (\*)Določi višino vode H v levi posodi, če v obe desni posodi doteka po 3 l/s!**  
**Določi koeficient zasuna  $\xi_z$ !**



Podatki:

$$\xi_{RAZ} = 0,35$$

$$\xi_{KOL} = 0,3$$

$$\xi_{vt} = 0,5$$

$$L_1 = L_3 = 10m$$

$$L_2 = L_4 = 6m$$

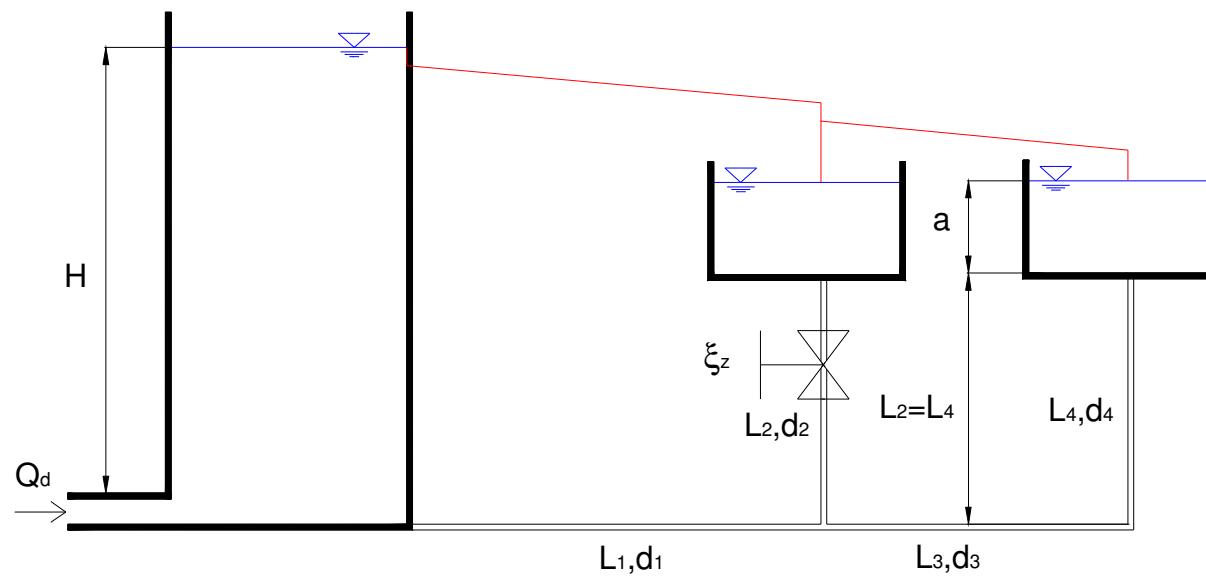
$$a = 1m$$

$$Q_d = 6 \frac{l}{s}$$

$$d = 5cm$$

$$\xi_z = ?$$

Rešitev:



$$Q_1 = Q_d$$

$$Q_2 = Q_3 = Q_4 = \frac{Q_d}{2}$$

$$v_1 = 2 \cdot v_2 = 3,06 \frac{m}{s}$$

$$v_2 = v_3 = v_4 = \frac{Q_d \cdot 4}{2 \cdot d^2 \cdot \pi} = \frac{0,006 \cdot 4}{2 \cdot 0,05^2 \cdot \pi} = 1,53 \frac{m}{s}$$

$$H = L_4 + a + \frac{v_2^2}{2 \cdot g} \left( \xi_i + \frac{\lambda \cdot L_4}{d} + \xi_{KOL} + \frac{\lambda \cdot L_3}{d} \right) + \frac{v_1^2}{2 \cdot g} \left( \xi_R + \frac{\lambda \cdot L_1}{d} + \xi_{VT} \right)$$

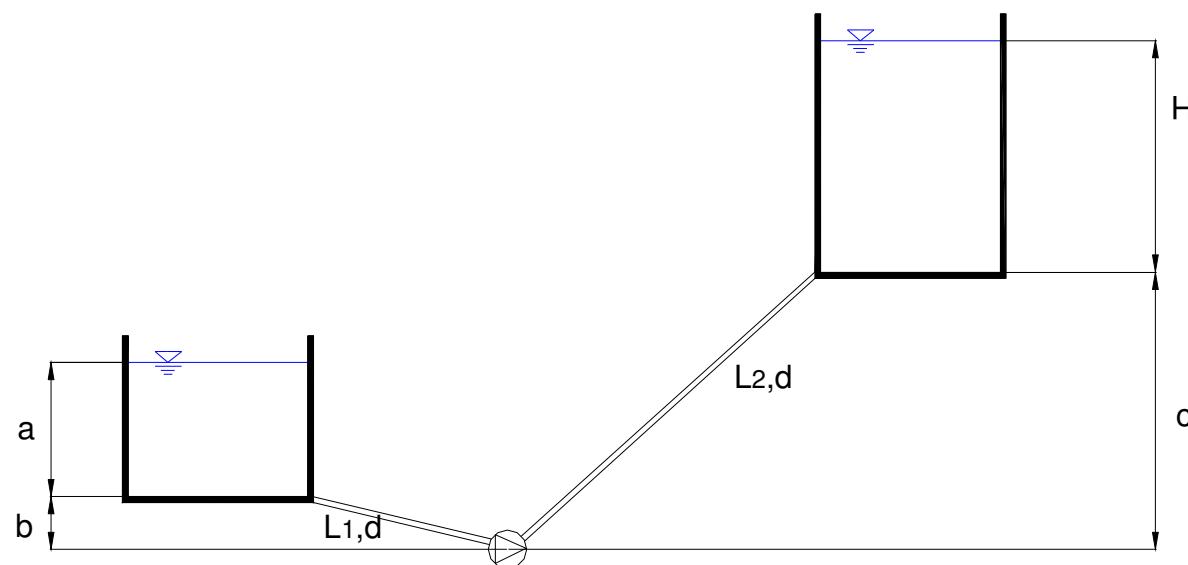
$$H = 6 + 1 + \frac{1,53^2}{2 \cdot 9,81} \left( 1,0 + \frac{0,03 \cdot 16}{0,05} + 0,3 \right) + \frac{3,06^2}{2 \cdot 9,81} \left( 0,35 + \frac{0,03 \cdot 10}{0,05} + 0,5 \right)$$

$$H = 7 + 10,9 \cdot 0,1193 + 6,85 \cdot 0,4772 = 11,56 m$$

$$\Delta E_z = \Delta E_3 + \Delta E_K = \frac{v_3^2}{2 \cdot g} \cdot \left( \xi_K + \frac{\lambda \cdot L_3}{d} \right) = \frac{1,53^2}{2 \cdot 9,81} \cdot \left( 0,03 + \frac{0,03 \cdot 10}{0,05} \right) = 0,75 m$$

$$\xi_z = \frac{\lambda \cdot L_3}{d} + \xi_K = \frac{0,03 \cdot 10}{0,05} + 0,3 = 6,3$$

**1.19 Določi max. pretok po sistemu in globino vode v desni posodi, če zahtevamo, da je na črpalki vedno NADTLAK vsaj 2m!**



Podatki:

$$a = 8\text{ m}$$

$$b = 1\text{ m}$$

$$c = 15\text{ m}$$

$$L_1 = 15\text{ m}$$

$$L_2 = 20\text{ m}$$

$$d_1 = d_2 = 5\text{ cm}$$

$$\xi_{VT} = 0,5$$

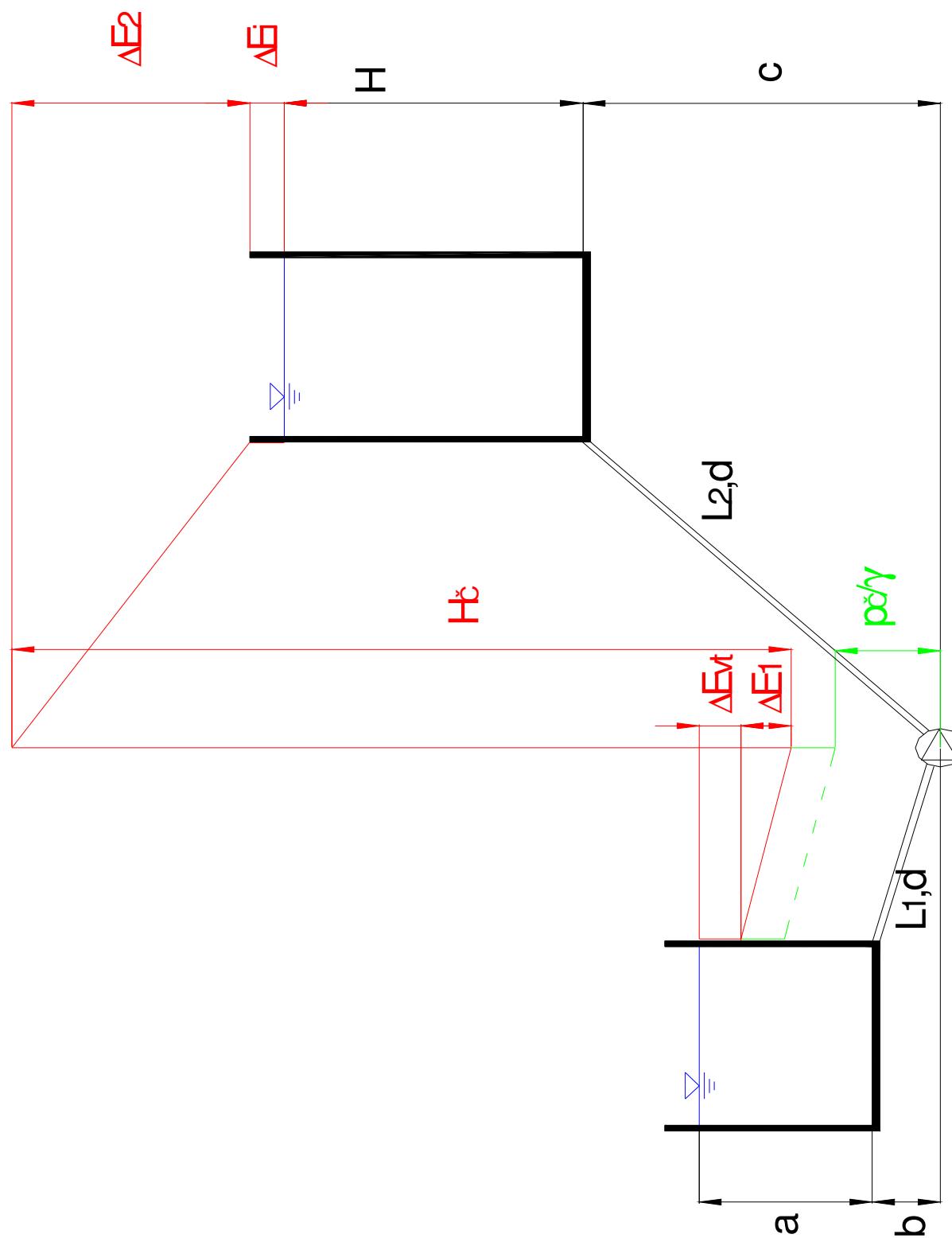
$$\lambda = 0,025$$

$$\eta_c = 2500\text{ W}$$

$$\left( \frac{p}{\rho \cdot g} \right)_{\min} = 2\text{ m}$$

$$Q_{\max} = ?, H_2 = ?$$

Rešitev:



$$a + b - \Delta E_{VT} - \Delta E_1 - \frac{v_1^2}{2 \cdot g} - \frac{p}{\rho \cdot g} = 0$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + 1 \right) = a + b - \frac{p}{\rho \cdot g} \Rightarrow \text{izrazimo } v_1$$

$$v_1 = \sqrt{\frac{2 \cdot 9,81 \cdot 7}{0,5 + \frac{0,025 \cdot 15}{0,05} + 1}} = 3,91 \frac{m}{s}$$

$$Q_{\max} = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 7,67 \frac{l}{s}$$

$$N_c = \frac{\rho \cdot g \cdot Q_{\max} \cdot H_c}{\eta_c} \Rightarrow H_c = \frac{\eta_c \cdot N_c}{\rho \cdot g \cdot Q_{\max}} = \frac{2500 \cdot 0,8}{9810 \cdot 7,67 \cdot 10^{-3}} = 26,58 m$$

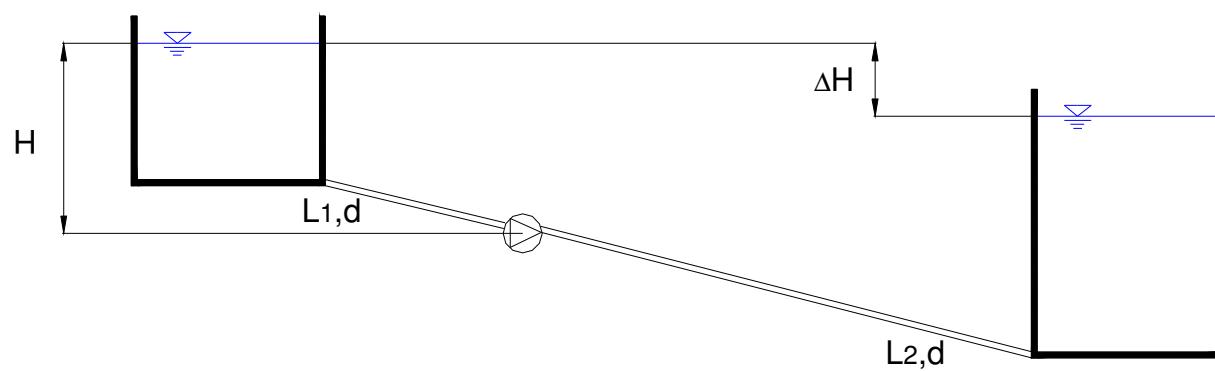
$$a + b - \Delta E_{VT} - \Delta E_1 + H_c + \Delta E_2 - \Delta E_i - H_2 + c = 0$$

$$H_2 = 8 + 1 + 26,58 - 15 - \frac{v_2^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + \frac{\lambda \cdot L_2}{d_2} + \xi_i \right)$$

$$H_2 = 20,58 - 0,78 \cdot \left( 0,5 + \frac{0,025 \cdot 15}{0,05} + \frac{0,025 \cdot 20}{0,05} + 1 \right) = 5,76 m$$

**1.20 (\*)Določi višinsko razliko med gladinama v posodi A in B.**

- a.) Črpamo max. možen pretok iz A v B.
- b.) Črpamo isti pretok (če je mogoče!) iz B v A.



Podatki:

$$H_1 = 5m$$

$$L_1 = 8m$$

$$L_2 = 5m$$

$$d_1 = 2cm$$

$$d_2 = 5cm$$

$$N_c = 150W$$

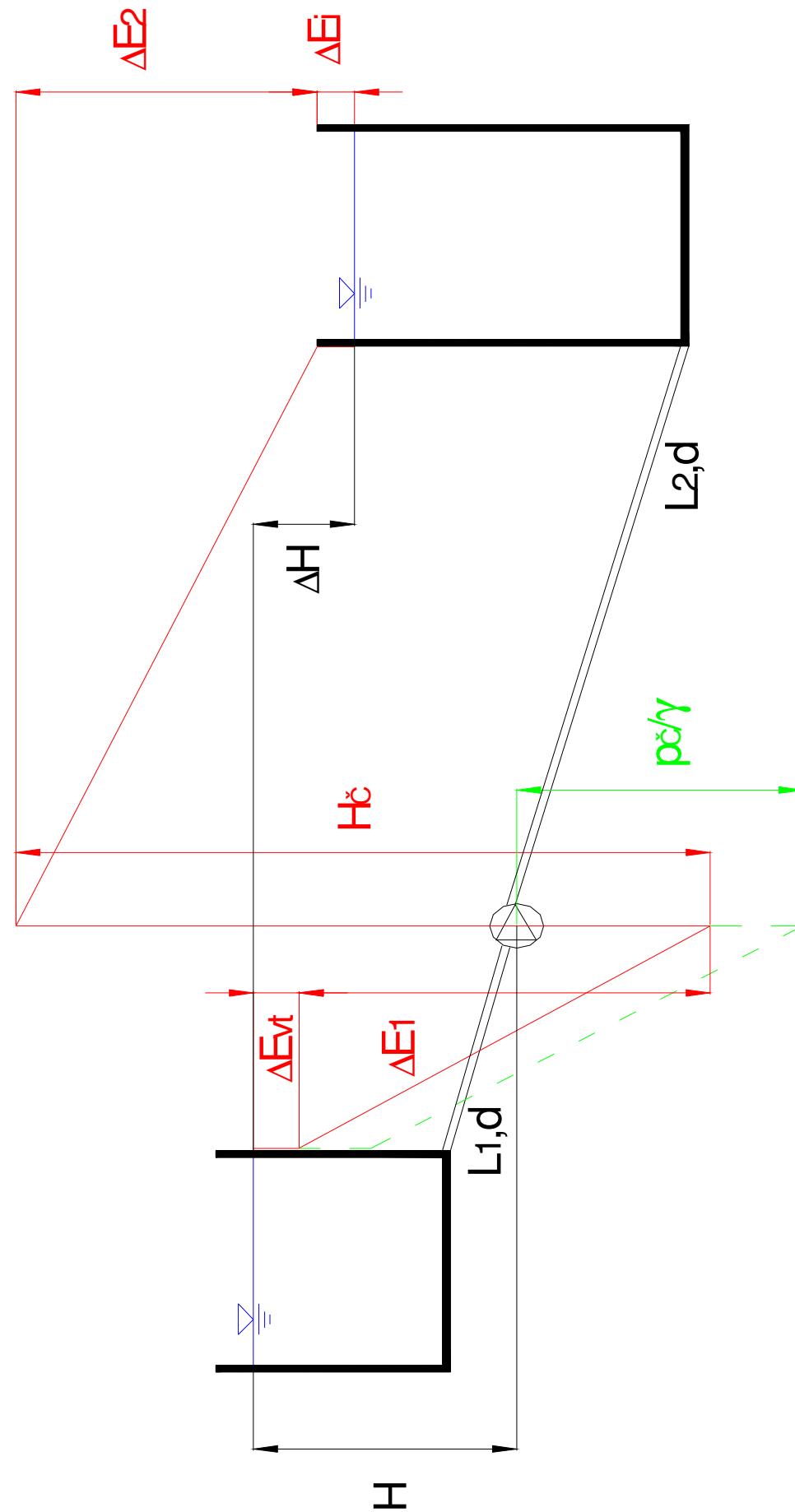
$$\eta_c = 0,82$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{min} = 3m$$

$$\xi_{VT} = 0,5$$

$$\lambda = 0,018$$

Rešitev:



a.)

1.) Izracun maksimalnega moznega pretoka iz A v B:

$$\Delta E_{VT} + \Delta E_1 + \frac{v_1^2}{2 \cdot g} - \left| \frac{p_c}{\rho \cdot g} \right|_{min} - H = 0$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + 1 \right) = \left| \frac{p_c}{\rho \cdot g} \right|_{min} + H \Rightarrow \text{izrazimo } v_1$$

$$v_1 = \sqrt{\frac{(3+5) \cdot 19,62}{0,5 + \frac{0,018 \cdot 8}{0,02} + 1}} = 4,25 \frac{m}{s}$$

$$Q_{max} = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 1,33 \frac{l}{s}$$

$$v_2 = \frac{Q_{max} \cdot 4}{d_2^2 \cdot \pi} = \frac{1,33 \cdot 10^{-3} \cdot 4}{0,05^2 \cdot \pi} = 0,68 \frac{m}{s}$$

2.) Izracun  $H_c$ :

$$N_c = \frac{Q_c \cdot H_c \cdot \rho \cdot g}{\eta_c} \Rightarrow H_c = \frac{\eta_c \cdot N_c}{Q_c \cdot \rho \cdot g} = \frac{150 \cdot 0,82}{0,00133 \cdot 9810} = 9,4m$$

3.) Izracun visinske razlike med A in B  $\Rightarrow \Delta H$ :

$$\Delta E_{VT} + \Delta E_1 - H_c + \Delta E_2 + \Delta E_i + -\Delta H = 0$$

$$\Delta H = \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} \right) - H_c + \frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + 1 \right)$$

$$\Delta H = \frac{4,25^2}{2 \cdot 9,81} \cdot \left( 0,5 + \frac{0,018 \cdot 8}{0,02} \right) - 9,4 + \frac{0,68^2}{2 \cdot 9,81} \cdot \left( \frac{0,018 \cdot 5}{0,05} + 1 \right) =$$

$$\Delta H = 7,09 - 9,4 + 0,066$$

$$\Delta H = -2,245m$$

b.)

1.) Ali je možen isti pretok, iste hitrosti, samo nasprotna smer :

$$Q = Q_{max} = 1,33 \frac{l}{s}$$

$$v_1 = 4,25 \frac{m}{s}$$

$$v_2 = 0,68 \frac{m}{s}$$

$$H_c = \frac{\eta_c \cdot N_c}{Q_c \cdot \rho \cdot g} = 9,4m \quad \text{isto}$$

$$-\Delta E_i - \Delta E_1 + H_c + \frac{v_1^2}{2 \cdot g} - \left| \frac{p_c}{\gamma} \right|_{dej} - H = 0$$

$$\left| \frac{p_c}{\rho \cdot g} \right| = H_c - \frac{v_1^2}{2 \cdot g} \cdot \left( 1 + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} - 5$$

$$\left| \frac{p_c}{\rho \cdot g} \right| = 9,4 - \frac{4,25^2}{2 \cdot 9,81} \cdot (1 + 7,2) + \frac{0,68^2}{2 \cdot 9,81} - 5 = -3,12m \quad \underline{\underline{OK}}$$

dejansko nadtlak 3,12m

2.) Izracun  $\Delta H$ :

$$-\Delta E_i - \Delta E_1 + H_c - \Delta E_2 - \Delta E_{VT} - \Delta H = 0$$

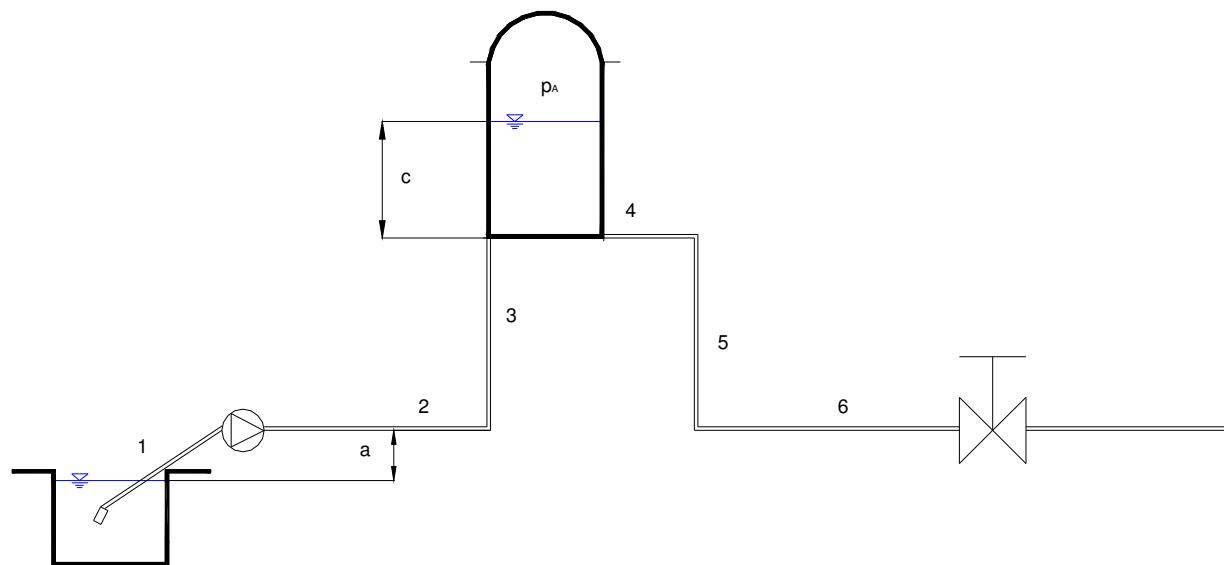
$$\Delta H = H_c - \frac{v_1^2}{2 \cdot g} \cdot \left( 1 + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} - H$$

$$\Delta H = H_c - \frac{v_1^2}{2 \cdot g} \cdot \left( 1 + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + \xi_{VT} \right)$$

$$\Delta H = 9,4 - \frac{4,25^2}{2 \cdot 9,81} \cdot (1 + 7,2) + \frac{0,68^2}{2 \cdot 9,81} \cdot \left( \frac{0,018 \cdot 5}{0,05} + 0,5 \right) = 9,4 - 7,55 - 0,05 = \underline{1,9m}$$

Nasprotna smer crpanja z istim pretokom in hitrostmi je mozna.

**1.21 Pri podanem pretoku po sistemu  $Q_i$  določi tlak v hidroforu ( $p_A$ ) in moč črpalki ter kontroliraj podtlake na črpalki!**



Podatki:

$$a = 4\text{m}$$

$$c = 3\text{m}$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{\min} = 5,5\text{m}$$

$$\eta_c = 0,75$$

$$Q_i = 2 \frac{l}{s}$$

$$d_1 = 5\text{cm}$$

$$d_2 = d_3 = d_7 = 2\text{cm}$$

$$L_1 = 5\text{m}$$

$$L_2 = L_6 = 4\text{m}$$

$$L_4 = L_7 = 1\text{m}$$

$$L_3 = 2\text{m}$$

$$L_5 = 2,5\text{m}$$

$$\lambda = 0,02$$

$$\xi_{ZAS} = 3,5$$

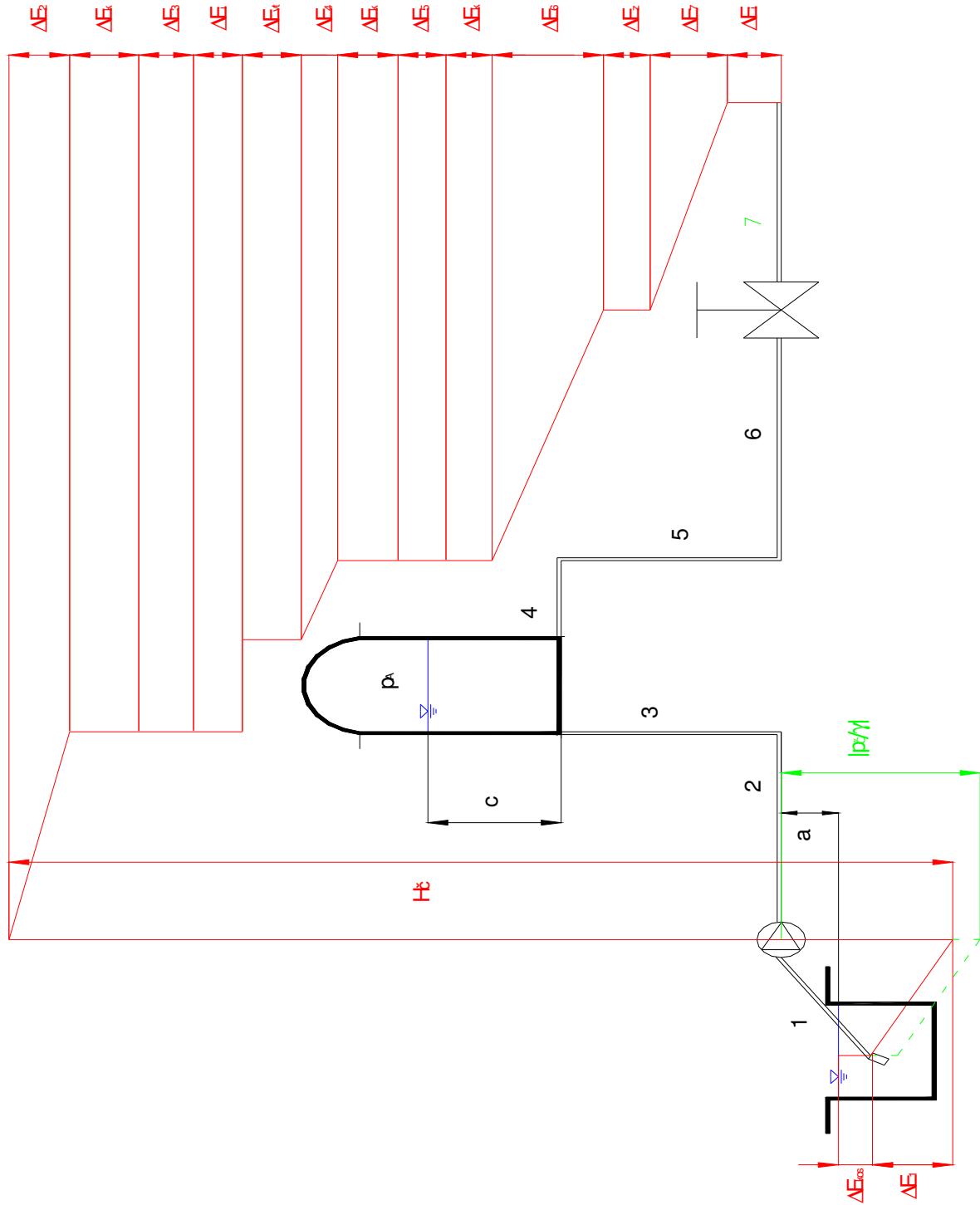
$$\xi_{VT} = 0,5$$

$$\xi_i = 1,0$$

$$\xi_K = 0,5$$

$$\xi_{KO\check{s}} = 6,0$$

Rešitve:



Dolocitev tlaka v hidroforu :

$$\frac{v_7^2}{2 \cdot g} \cdot \left( \xi_i + \frac{\lambda \cdot L_7}{d_7} + \xi_{ZAS} + \frac{\lambda \cdot L_6}{d_6} + \xi_K + \frac{\lambda \cdot L_5}{d_5} + \xi_K + \frac{\lambda \cdot L_4}{d_4} + \xi_{VT} \right) = \frac{p_A}{\rho \cdot g} + c + L_3$$

$$\frac{p_A}{\rho \cdot g} = 2,07 \cdot \left( 1,0 + \frac{0,02 \cdot (1+4+2,5+1)}{0,02} + 3,5 + 0,5 + 0,5 + 0,5 \right) - 5 = 25,015 m$$

$$p_A = \underline{2,5 bar}$$

$$v_7 = \frac{4 \cdot Q}{d_7^2 \cdot \pi} = \frac{4 \cdot 2 \cdot 10^{-3}}{0,02^2 \cdot \pi} = \underline{6,37 \frac{m}{s}}$$

Kontrola podtlakov :

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KO\check{S}} + \frac{\lambda \cdot L_1}{d_1} + 1 \right) - \frac{p_{\check{C}}}{\rho \cdot g} + a = 0$$

$$\left| \frac{p_A}{\rho \cdot g} \right| = 4 + \frac{1,02^2}{2 \cdot 9,81} \cdot \left( 6,0 + \frac{0,02 \cdot 5}{0,05} + 1 \right) = \underline{4,48 m} \quad \underline{\underline{OK}}$$

Dolocitev moci crpalke :

$$H_{\check{C}} \Rightarrow \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{KO\check{S}} + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_2}{d_2} + \xi_K + \frac{\lambda \cdot L_3}{d_3} + \xi_i \right) + \frac{p_A}{\rho \cdot g} + c + L_3 + a = H_{\check{C}}$$

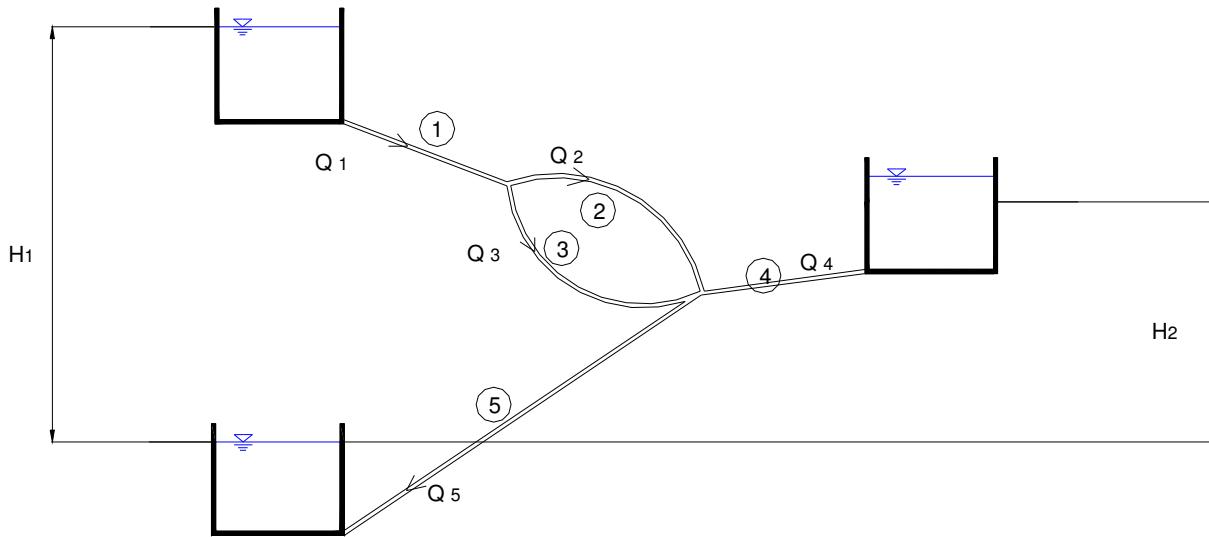
$$\frac{p_A}{\rho \cdot g} + c + L_3 + a = H_{ge} = 25,015 + 3 + 2 + 4 = \underline{34,015 m}$$

$$H_{\check{C}} = \frac{1,02^2}{2 \cdot 9,81} \cdot \left( 6,0 + \frac{0,02 \cdot 5}{0,05} \right) + \frac{6,37^2}{2 \cdot 9,81} \cdot \left( \frac{0,02 \cdot (4+2)}{0,02} + 0,5 + 1,0 \right) + H_{ge}$$

$$H_{\check{C}} = 15,94 + 34,01 = \underline{49,95 m}$$

$$N_{\check{C}} = \frac{Q_{\check{C}} \cdot H_{\check{C}} \cdot g \cdot \rho}{\eta_{\check{C}}} = \frac{2 \cdot 10^{-3} \cdot 49,95 \cdot 1000 \cdot 9,81}{0,75} = \underline{1307 W}$$

**1.22 Določi hidravlični sistem in višino  $H_1$ !**



Podatki:

$$d_1 = d_2 = d_3 = d_4 = d_5 = 10\text{cm}$$

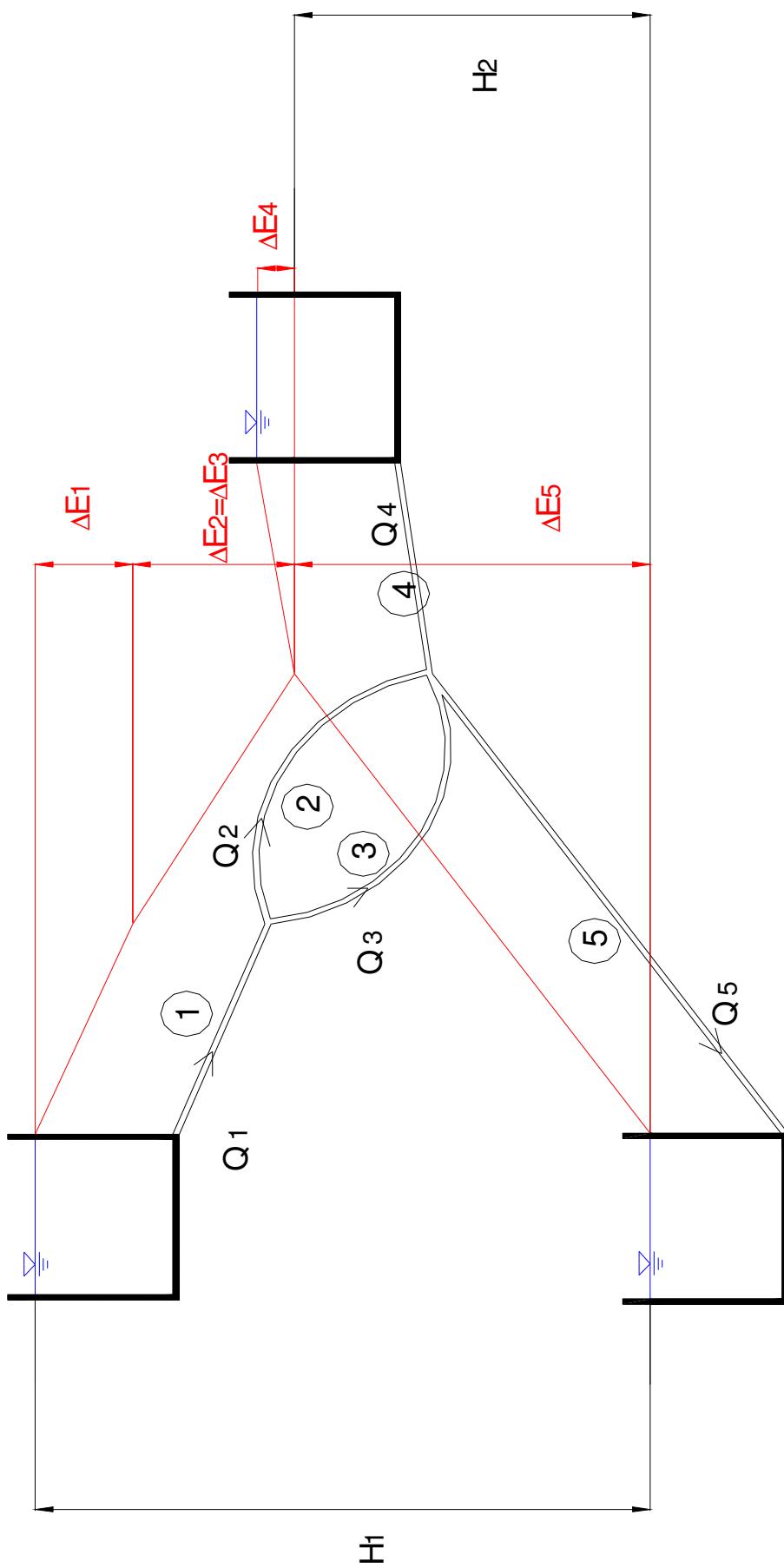
$$L_1 = L_2 = L_3 = L_4 = L_5 = 400\text{m}$$

$$Q_5 = 20 \frac{l}{s}$$

$$H_2 = 50\text{m}$$

$$\lambda = 0,03$$

Rešitev:





$$K = \frac{\lambda \cdot L}{d} = \frac{0,03 \cdot 400}{0,1} = \underline{120}$$

$$S = \frac{d^2 \cdot \pi}{4} = \underline{7,85 \cdot 10^{-3} m^2}$$

$$v_5 = \frac{Q_5}{S} = \underline{2,55 \frac{m}{s}}$$

$$\Delta E_5 = \frac{K \cdot v_5^2}{2 \cdot g} = \underline{39,77 m}$$

$$\Delta E_4 = H - \Delta E_5 = 50 - 39,67 = \underline{10,23 m}$$

$$\Delta E_4 = \frac{K \cdot v_4^2}{2 \cdot g} \Rightarrow v_4 = \sqrt{\frac{\Delta E_4 \cdot 2 \cdot g}{K}} = \sqrt{\frac{10,33 \cdot 2 \cdot 9,81}{120}} = \underline{1,3 \frac{m}{s}}$$

$$Q_4 = v_4 \cdot S = \underline{10,2 \frac{l}{s}}$$

$$Q_1 = Q_2 + Q_3 = Q_5 - Q_4 = \underline{9,8 \frac{l}{s}}$$

$$Q_2 = Q_3 = \underline{4,9 \frac{l}{s}}$$

$$v_2 = v_3 = \frac{Q_2}{S} = \underline{0,62 \frac{m}{s}}$$

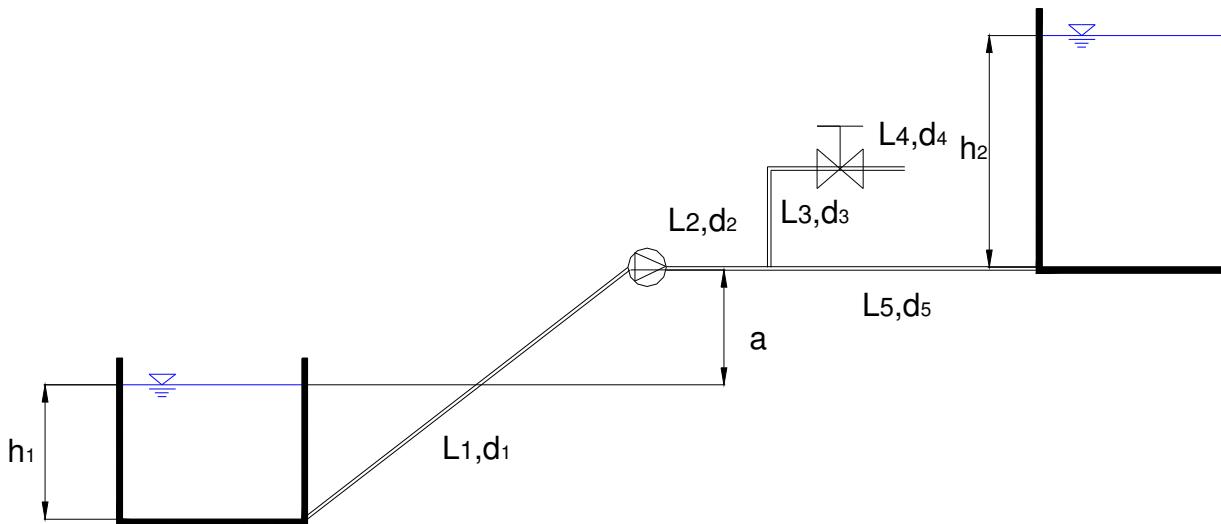
$$\Delta E_2 = \Delta E_3 = \frac{K \cdot v_2^2}{2 \cdot g} = \underline{2,35 m}$$

$$\Delta E_1 = \frac{K \cdot v_1^2}{2 \cdot g} = \underline{9,55 m}$$

$$v_1 = \frac{Q_1}{S} = \underline{1,25 \frac{m}{s}}$$

$$H_1 = \Delta E_1 + \Delta E_2 + \Delta E_5 = 9,55 + 2,35 + 39,77 = \underline{51,64 m}$$

1.23 (\*) Določi max. pretok  $Q_{\max}$ ! Določi višino  $h_2$  in  $\xi_z$ , če iz cevi 4 izteka  $Q_i = 15 \text{ l/s}$ !



Podatki:

i	$L_i [\text{m}]$	$d_i [\text{cm}]$
1	7	10
2	5	10
3	2	5
4	1	5
5	5	10

$$N_c = 10 \text{ kW}$$

$$\eta_c = 0,75$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{\min} = 7 \text{ m}$$

$$a = 3 \text{ m}$$

$$Q_4 = 15 \frac{\text{l}}{\text{s}}$$

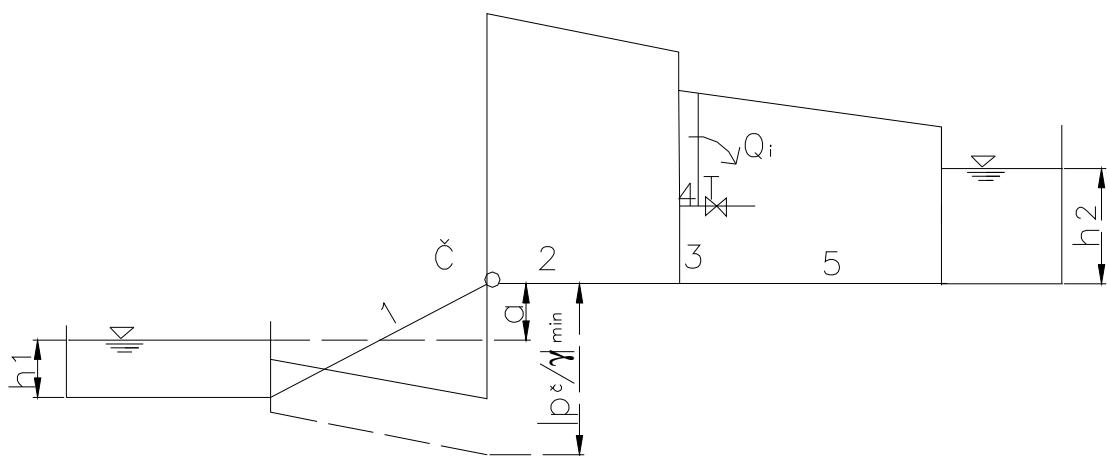
$$\xi_{VT} = 0,5$$

$$\xi_R = 0,6$$

$$\xi_K = 0,4$$

$$\lambda = 0,02$$

Rešitev:



Dolocitev maksimalnega pretoka :

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + 1 \right) - \left| \frac{p_c}{\rho \cdot g} \right|_{\min} + a = 0$$

$$v_1 = \sqrt{\left( \frac{4 \cdot 19,62}{0,5 + \frac{0,02 \cdot 7}{0,1} + 1} \right)} = 5,2 \frac{m}{s}$$

$$Q_{\max} = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = 40,8 \frac{l}{s}$$

$$Q_3 = Q_4 = 15 \frac{l}{s} \Leftarrow \text{podatek}$$

$$Q_5 = Q_{\max} - Q_4 = 25,8 \frac{l}{s}$$

$$H_c = \frac{N_c \cdot \eta_c}{\rho \cdot g \cdot Q_c} = \frac{10000 \cdot 0,75}{9,81 \cdot 40,8} = 18,74 m$$

$$v_3 = \frac{4 \cdot Q_3}{d_3^2 \cdot \pi} = 7,64 \frac{m}{s}$$

$$v_5 = \frac{4 \cdot Q_5}{d_5^2 \cdot \pi} = 3,28 \frac{m}{s}$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + \frac{\lambda \cdot L_2}{d_2} + \xi_R \right) - H_c + \frac{v_3^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_3}{d_3} + \frac{\lambda \cdot L_4}{d_4} + \xi_K + \xi_Z + 1,0 \right) + L_3 + a = 0$$

$$\frac{5,2^2}{2 \cdot 9,81} \cdot \left( 0,5 + \frac{0,02 \cdot 12}{0,1} + 0,6 \right) - 18,74 + \frac{7,64^2}{2 \cdot 9,81} \cdot \left( \frac{0,02 \cdot 3}{0,05} + 0,4 + \xi_Z + 1,0 \right) + 5 = 0$$

$$4,82 - 18,74 + \frac{7,64^2}{2 \cdot 9,81} \cdot (2,6 + \xi_Z) + 5 = 0$$

$$\xi_Z = 8,92 \cdot \frac{19,62}{7,64^2} - 2,6 = 0,4$$

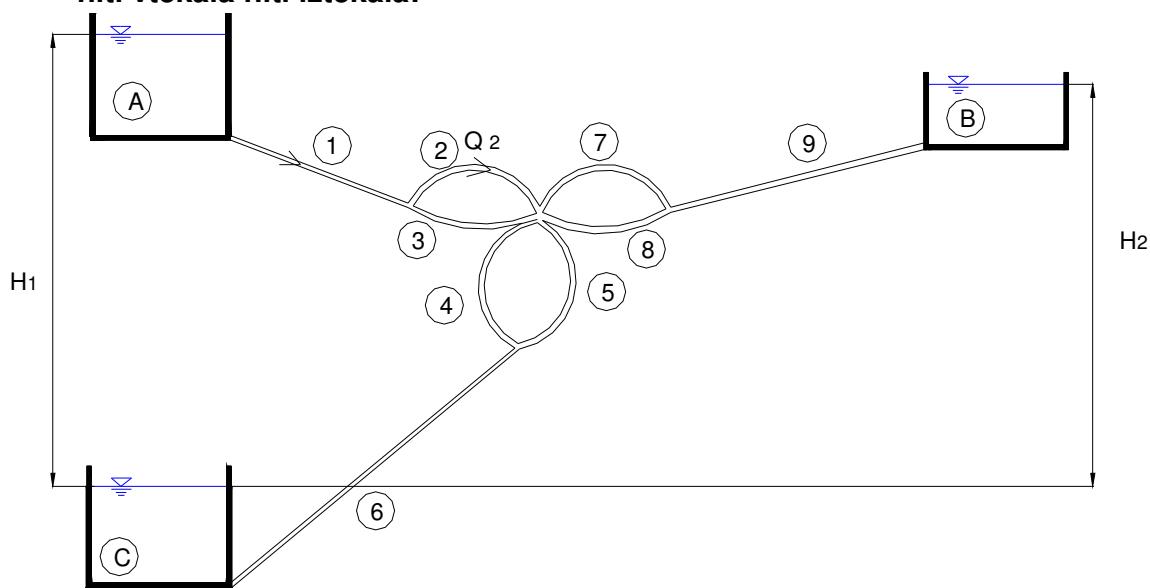
Dolocitev  $H_2$  :

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} + \frac{\lambda \cdot L_2}{d_2} + \xi_R \right) - H_c + \frac{v_5^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_5}{d_5} + 1,0 \right) + H_2 + a = 0$$

$$4,82 - 18,74 + \frac{3,28^2}{2 \cdot 9,81} \cdot \left( \frac{0,02 \cdot 5}{0,05} + 1,0 \right) + 3 = -H_2$$

$$H_2 = 9,27 m$$

**1.24 Določi pretoke po sistemu in višinski razliki  $H_1$  in  $H_2$  tako, da v bazen B ne bo voda niti vtekala niti iztekalna!**



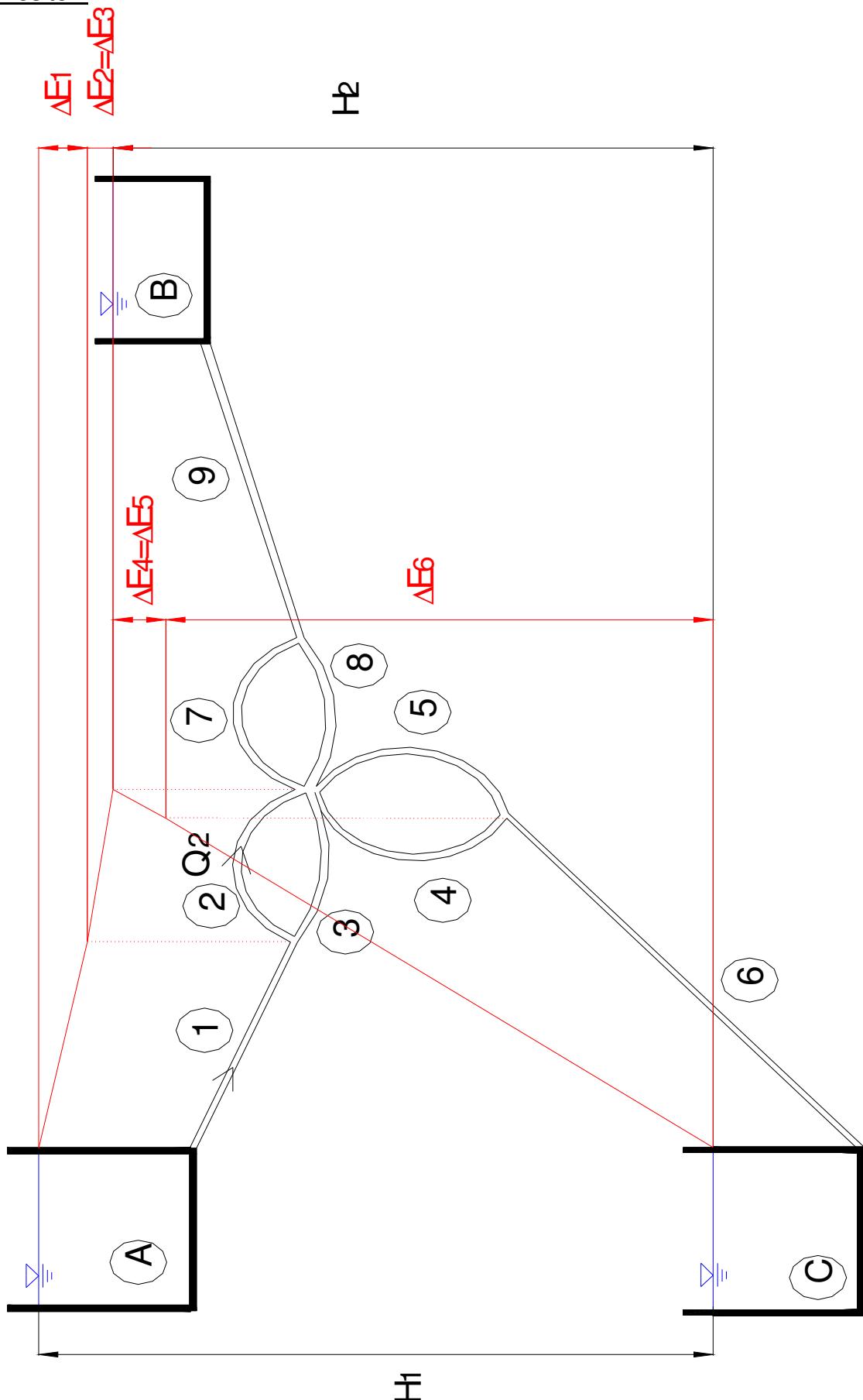
Podatki:

$$Q_2 = 7,5 \frac{l}{s}$$

$$\lambda = 0,018$$

i	$L_i$ [m]	$d_i$ [cm]
1	400	10
2	200	7
3	300	5
4	200	5
5	200	5
6	400	10
7	200	5
8	200	5
9	400	10

Rešitev:



$$v_2 = \frac{4 \cdot Q_2}{d_2^2 \cdot \pi} = 1,95 \frac{m}{s}$$

$$\frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} = \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g}$$

$$v_3 = v_2 \cdot \sqrt{\left( \frac{L_2 \cdot d_3}{L_3 \cdot d_2} \right)} = 1,95 \cdot \sqrt{\left( \frac{200 \cdot 0,05}{300 \cdot 0,07} \right)} = 1,35 \frac{m}{s}$$

$$Q_3 = \frac{v_3 \cdot d_3^2 \cdot \pi}{4} = \frac{1,35 \cdot 0,05^2 \cdot \pi}{4} = 2,65 \frac{l}{s}$$

$$Q_1 = Q_2 + Q_3 = 10,15 \frac{l}{s}$$

$$Q_1 = Q_6 = 10,15 \frac{l}{s}$$

$Q_7 = Q_8 = Q_9 = 0 \Leftarrow$  pogoj, v bazen B voda ne sme vtekat

$$v_1 = \frac{4 \cdot Q_1}{d_1^2 \cdot \pi} = \frac{4 \cdot 10,15 \cdot 10^{-3}}{0,1^2 \cdot \pi} = 1,29 \frac{m}{s}$$

$$v_6 = v_1 = 1,29 \frac{m}{s}$$

$v_7 = v_8 = v_9 = 0 \Leftarrow$  pogoj, v bazen B voda ne sme vtekat

$$Q_4 = Q_5 = \frac{Q_6}{2} = 5,075 \frac{l}{s}$$

$$v_4 = v_5 = \frac{4 \cdot Q_4}{d_4^2 \cdot \pi} = \frac{4 \cdot 5,075 \cdot 10^{-3}}{0,05^2 \cdot \pi} = 2,58 \frac{m}{s}$$

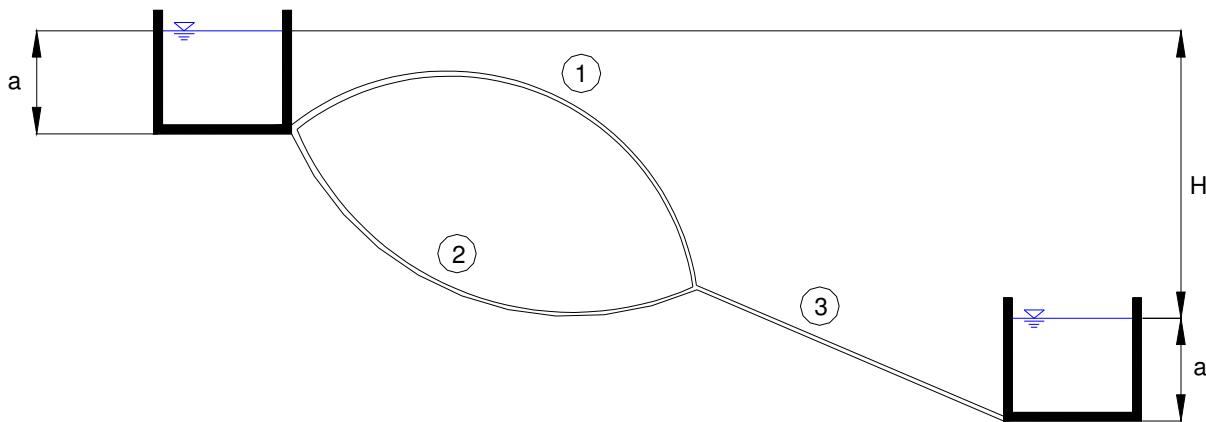
$$H_1 = \Delta E_1 + \Delta E_2 + \Delta E_4 + \Delta E_6$$

$$H_1 = \frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g} + \frac{\lambda \cdot L_4}{d_4} \cdot \frac{v_4^2}{2 \cdot g} + \frac{\lambda \cdot L_6}{d_6} \cdot \frac{v_6^2}{2 \cdot g} =$$

$$H_1 = \frac{0,18 \cdot 400}{0,1} \cdot \frac{1,29^2}{2 \cdot 9,81} + \frac{0,018 \cdot 200}{0,07} \cdot \frac{1,95^2}{2 \cdot 9,81} + \frac{0,018 \cdot 200}{0,05} \cdot \frac{2,58^2}{2 \cdot 9,81} + \frac{0,018 \cdot 400}{0,1} \cdot \frac{1,29^2}{2 \cdot 9,81} = 46,61 m$$

$$H_2 = H_1 - \Delta E_1 - \Delta E_2 = 46,61 - \frac{0,018 \cdot 400}{0,1} \cdot \frac{1,29^2}{2 \cdot 9,81} - \frac{0,018 \cdot 200}{0,07} \cdot \frac{1,95^2}{2 \cdot 9,81} = 30,53 m$$

**1.25 Za koliko se zmanjša pretok, če iz sistema izločimo cev 2? Dolgi cevovod!**



Podatki:

$$H = 20m$$

$$L_1 = L_2 = 300m$$

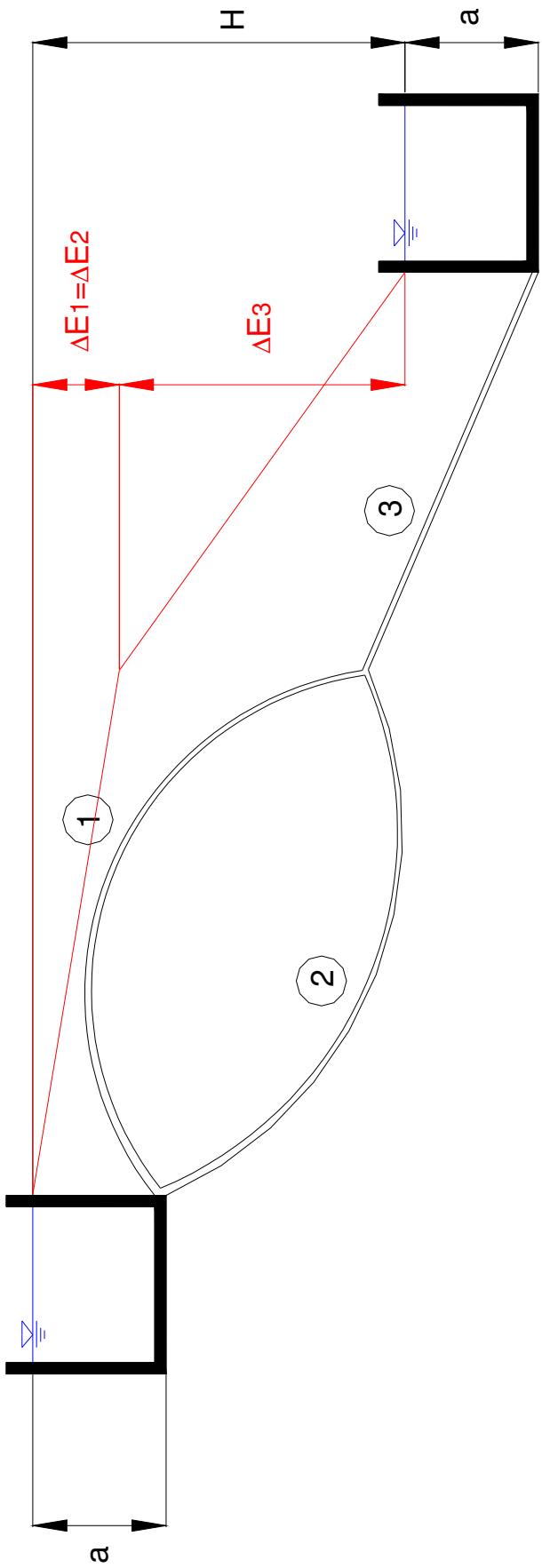
$$L_3 = 400m$$

$$d_1 = d_3 = 10cm$$

$$d_2 = 20cm$$

$$\lambda = 0,02$$

Rešitev:



Enacbe:

$$\Delta E_1 = \Delta E_2$$

$$\Delta E_1 + \Delta E_3 = H$$

$$Q_1 + Q_2 = Q_3$$

$$\frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} = \frac{\lambda \cdot L_2}{d_2} \cdot \frac{v_2^2}{2 \cdot g}$$

$$v_1 \cdot d_1^2 + v_2 \cdot d_2^2 = v_3 \cdot d_3^2$$

$$v_1 \cdot 0,1^2 + v_2 \cdot 0,2^2 = v_3 \cdot 0,1^2$$

$$v_1 \cdot 0,01 + v_2 \cdot 0,04 = v_3 \cdot 0,01$$

$$v_1 + 4 \cdot v_2 = v_3$$

$$v_1 + 5,66 \cdot v_1 = v_3$$

$$v_3 = 6,66 \cdot v_1 = 2,20 \frac{m}{s}$$

$$Q = \frac{v_3 \cdot d_3^2 \cdot \pi}{4} = 1,73 \frac{l}{s}$$

$$\frac{\lambda \cdot L_1}{d_1} \cdot \frac{v_1^2}{2 \cdot g} + \frac{\lambda \cdot L_3}{d_3} \cdot \frac{v_3^2}{2 \cdot g} = H$$

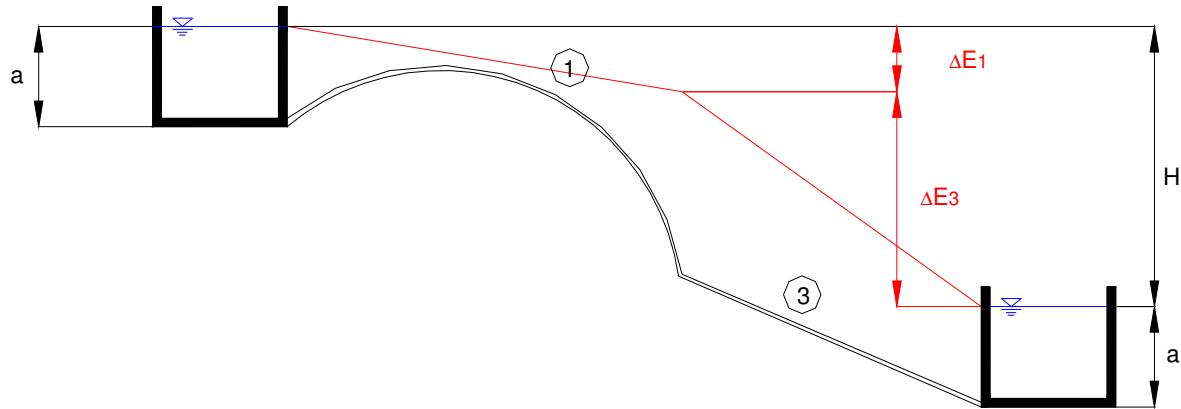
$$\frac{0,02 \cdot 300}{0,1} \cdot \frac{v_1^2}{2 \cdot 9,81} + \frac{0,02 \cdot 400}{0,1} \cdot \frac{6,66^2 \cdot v_1^2}{2 \cdot 9,81} = 20m \Rightarrow \text{izrazimo } v_1$$

$$3,058 \cdot v_1^2 + 180,85 \cdot v_1^2 = 20m$$

$$183,917 \cdot v_1^2 = 20$$

$$v_1 = \sqrt{\frac{20}{183,91}} = 0,330 \frac{m}{s}$$

$$v_2 = v_1 \cdot \sqrt{\left(\frac{d_2}{d_1}\right)} = 1,41 \cdot v_1 = 0,466 \frac{m}{s}$$



Izlocimo cev 2:

$$Q_1 = Q_3$$

$$d_1 = d_3$$

$$v_1 = v_3$$

$$\Delta E_1 + \Delta E_3 = H$$

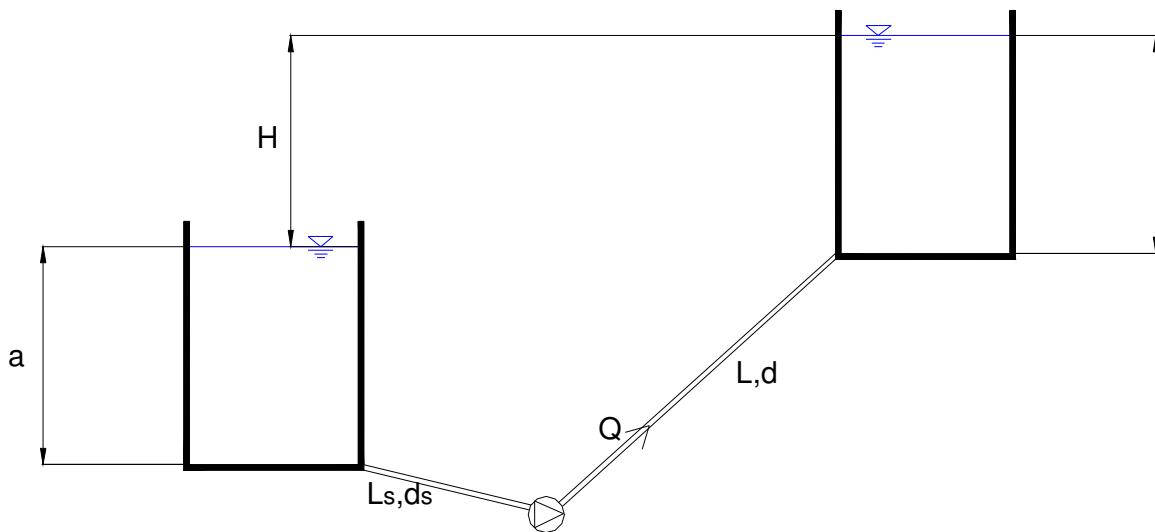
$$\frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + \frac{\lambda \cdot L_3}{d_3} \right) = H$$

$$\frac{v_1^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot (L_1 + L_3)}{d_1} \right) = H$$

$$v_1 = \sqrt{\left( \frac{2 \cdot g \cdot d_1 \cdot H}{\lambda \cdot (L_1 + L_3)} \right)} = \sqrt{\left( \frac{2 \cdot 9,81 \cdot 0,1 \cdot 20}{0,02 \cdot (300 + 400)} \right)} = 1,67 \frac{m}{s}$$

$$Q = \frac{v_1 \cdot d_1^2 \cdot \pi}{4} = \frac{1,67 \cdot 0,1^2 \cdot \pi}{4} = 13,1 \frac{l}{s}$$

**1.26 Navzgor črpamo  $Q = 15 \text{ l/s}$ . Določi največjo dolžino sesalne cevi  $l_s$  tako, da max. podtlaki niso prekoračeni. Kolikšna je višina  $H$ ?**



Podatki:

$$a = 1m$$

$$\left| \frac{p_c}{\rho \cdot g} \right|_{\min} = 7m$$

$$d_s = 5cm$$

$$L = 15m$$

$$N_c = 4kW$$

$$Q = 15 \frac{l}{s}$$

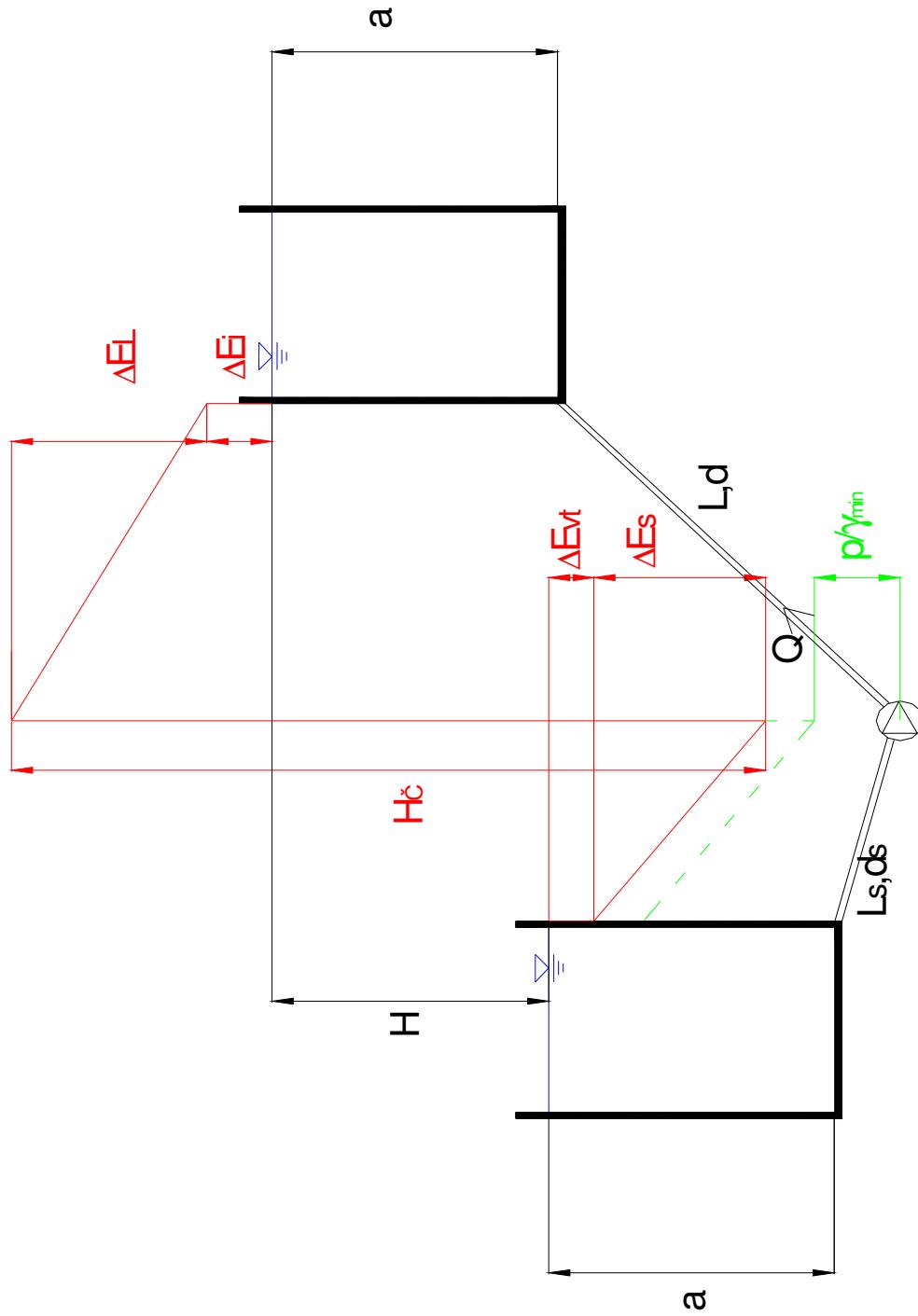
$$d = 10cm$$

$$\eta_c = 0,82$$

$$\xi_{VT} = 0,5$$

$$\lambda = 0,02$$

Rešitev:



Levi del :

Dolocitev sesalne cevi  $L_s$  ob pogoju, da maksimalni podtlaki niso prekoraceni:

$$\Delta E_{VT} + \Delta E_s + \frac{v_s^2}{2 \cdot g} - \left| \frac{p_c}{\rho \cdot g} \right|_{min} - a = 0$$

$$\frac{v_s^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_s}{d_s} + 1,0 \right) = \left| \frac{p_c}{\rho \cdot g} \right|_{min} + a = 8m \Rightarrow izrazimo L_s$$

$$v_s = \frac{4 \cdot Q}{d_s^2 \cdot \pi} = \frac{4 \cdot 15 \cdot 10^{-3}}{0,05^2 \cdot \pi} = 7,64 \frac{m}{s}$$

$$\frac{7,64^2}{2 \cdot 9,81} \cdot \left( 1,5 + \frac{0,02 \cdot L_s}{0,05} \right) = 8$$

$$2,974 \cdot (1,5 + 0,4 \cdot L_s) = 8$$

$$L_s = \left( \frac{8}{2,974} - 1,5 \right) \cdot \frac{1}{0,4} = 2,97 m$$

Cel sistem :

Izracun visine H:

$$\Delta E_{VT} + \Delta E_s - H_c + \Delta E_{VT} + \Delta E_l + \Delta E_i + H = 0$$

$$H_c \Rightarrow N_c = \frac{Q_c \cdot g \cdot \rho \cdot H_c}{\eta_c} \Rightarrow H_c = \frac{N_c \cdot \eta_c}{Q_c \cdot g \cdot \rho} = \frac{4000 \cdot 0,82}{9810 \cdot 15} = 22,29 m$$

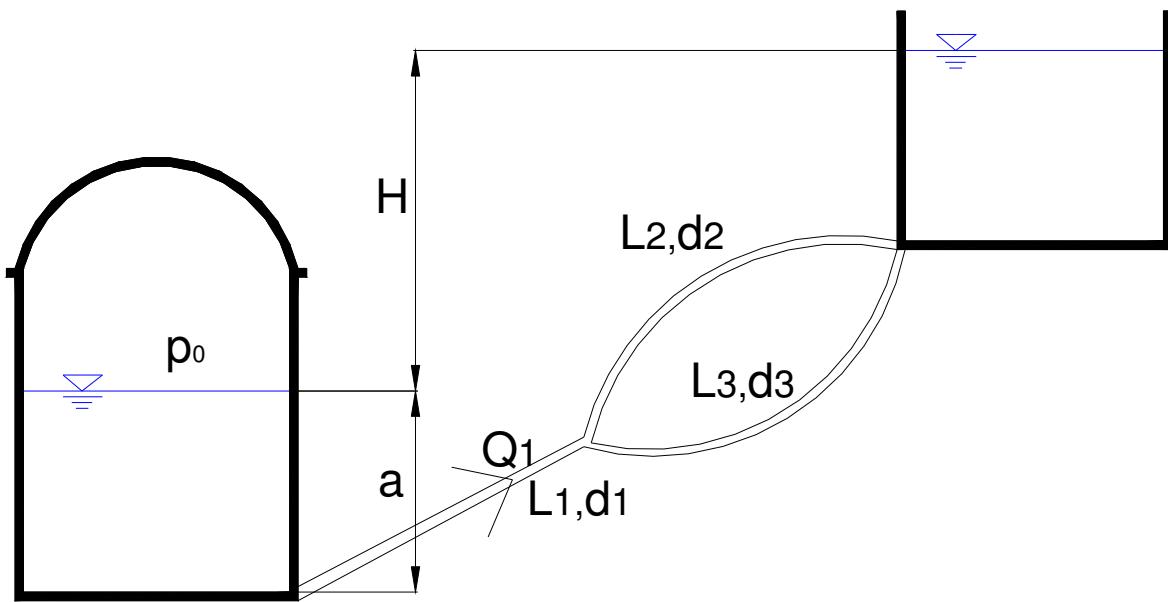
$$H = H_c - \frac{v_s^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_s}{d_s} \right) - \frac{v^2}{2 \cdot g} \cdot \left( 1,0 + \frac{\lambda \cdot L}{d} \right)$$

$$v = \frac{4 \cdot Q}{d^2 \cdot \pi} = \frac{4 \cdot 15 \cdot 10^{-3}}{0,1^2 \cdot \pi} = 1,91 \frac{m}{s}$$

$$H = 22,29 - \frac{7,64^2}{19,62} \cdot \left( 0,5 + \frac{0,02 \cdot 2,97}{0,05} \right) - \frac{1,91^2}{19,62} \cdot \left( 1,0 + \frac{0,02 \cdot 15}{0,1} \right)$$

$$H = 16,52 m$$

**1.27 Določi pretoke po sistemu! ( $Q_1, Q_2, Q_3$ )**



Podatki:

$$p_0 = 3 \text{ bar}$$

$$d_1 = 20 \text{ cm}$$

$$d_2 = d_3 = 15 \text{ cm}$$

$$L_1 = 250 \text{ m}$$

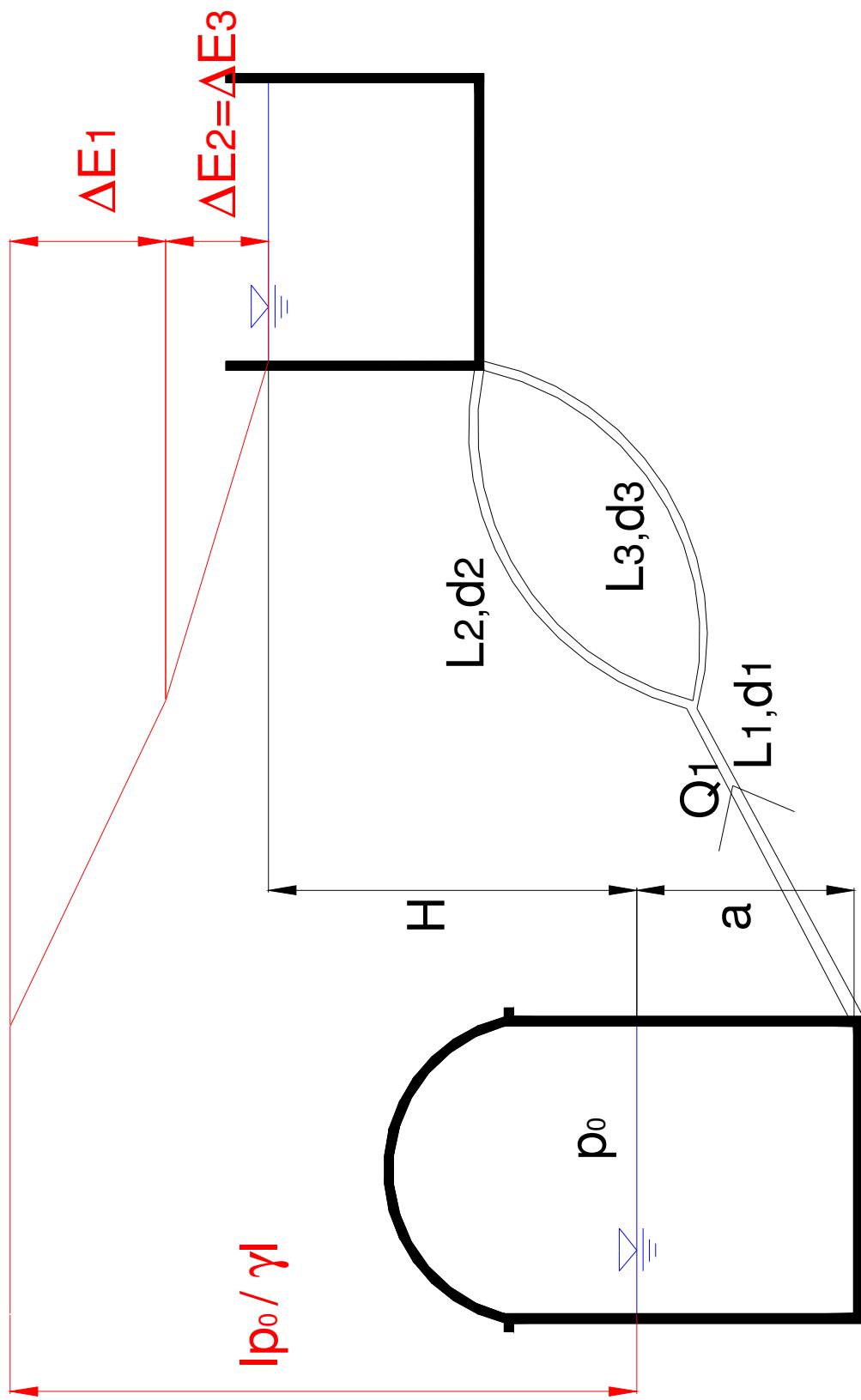
$$L_2 = 400 \text{ m}$$

$$L_3 = 500 \text{ m}$$

$$\lambda = 0,015$$

$$H = 15 \text{ m}$$

Rešitev:



Neznanke :  $Q_1, Q_2, Q_3$

Enacbe :

$$1.) \Delta E_2 = \Delta E_3$$

$$2.) Q_1 = Q_2 + Q_3$$

$$3.) \frac{p_0}{\rho \cdot g} - \Delta E_1 - \Delta E_2 - H = 0$$

iz enacbe 1.):

$$\frac{\lambda \cdot L_2 \cdot v_2^2}{d_2 \cdot 2 \cdot g} = \frac{\lambda \cdot L_3 \cdot v_3^2}{d_3 \cdot 2 \cdot g}$$

$$v_2 = v_3 \cdot \sqrt{\frac{L_3}{L_2}} = v_3 \cdot \sqrt{\frac{500}{400}} = 1,12 \cdot v_3$$

$$v_3 = \underline{0,89 \cdot v_2}$$

iz enacbe 2.):

$$v_1 \cdot d_1^2 = v_2 \cdot d_2^2 + v_3 \cdot d_3^2$$

$$v_1 \cdot 0,2^2 = v_2 \cdot 0,15^2 + 0,89 \cdot v_2 \cdot 0,15^2$$

$$v_1 \cdot 0,04 = (0,0225 + 0,89 \cdot 0,0225) v_2 = 0,0425 \cdot v_2$$

$$v_1 = \underline{1,063 \cdot v_2}$$

iz enacbe 3.):

$$30 - \frac{\lambda \cdot L_1 \cdot v_1^2}{d_1 \cdot 2 \cdot g} - \frac{\lambda \cdot L_2 \cdot v_2^2}{d_2 \cdot 2 \cdot g} - 15 = 0$$

$$15 = \frac{0,015 \cdot 250}{0,2} \cdot \frac{1,063^2 \cdot v_2^2}{19,62} + \frac{0,015 \cdot 400}{0,15} \cdot \frac{v_2^2}{19,62}$$

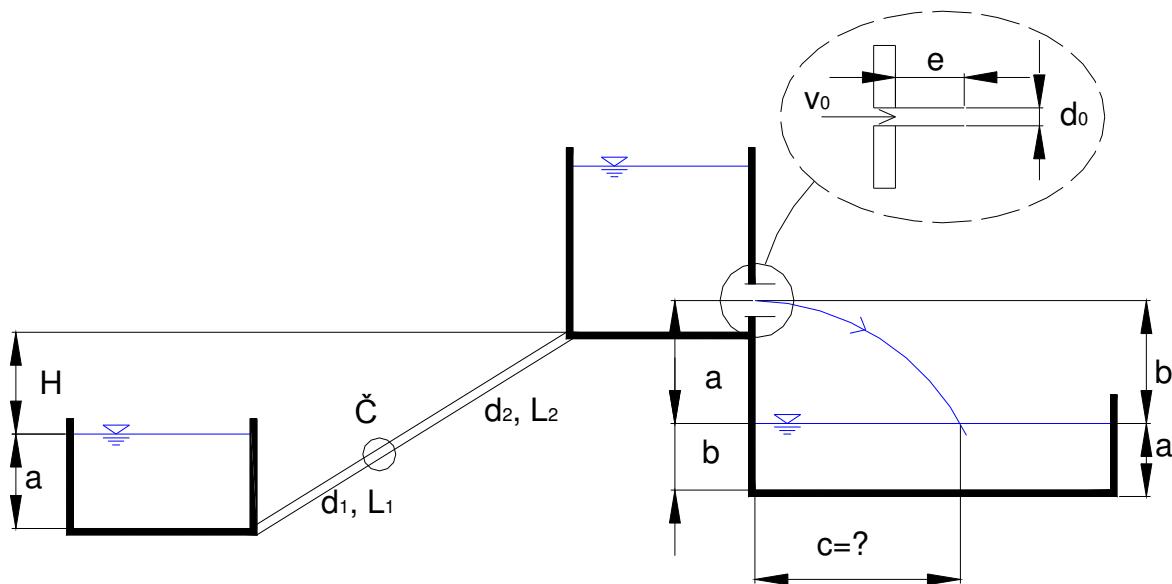
$$15 = 1,080 \cdot v_2^2 + 2,039 \cdot v_2^2 = 3,119 \cdot v_2^2$$

$$v_2 = 2,19 \frac{m}{s} \Rightarrow Q_2 = 38,7 \frac{l}{s}$$

$$v_1 = 2,33 \frac{m}{s} \Rightarrow Q_1 = 73,3 \frac{l}{s}$$

$$v_3 = 1,95 \frac{m}{s} \Rightarrow Q_3 = 34,6 \frac{l}{s}$$

**1.28 Izračunaj potrebno moč črpalke, podtlak na črpalki in domet curka, če voda iz zgornje posode izteka skozi nastavek dolžine  $l$  in premera  $d_o$  s hitrostjo  $v_o$ !**



Podatki:

$$H = 12\text{m}$$

$$d_1 = 2,5\text{cm}$$

$$d_2 = 5\text{cm}$$

$$L_1 = 8\text{m}$$

$$L_2 = 16\text{m}$$

$$\eta_{\check{C}} = 0,85$$

$$\xi_{VT} = 0,5$$

$$\lambda = 0,03$$

$$e = 30\text{cm}$$

$$d_o = 2\text{cm}$$

$$v_o = 3 \frac{\text{m}}{\text{s}}$$

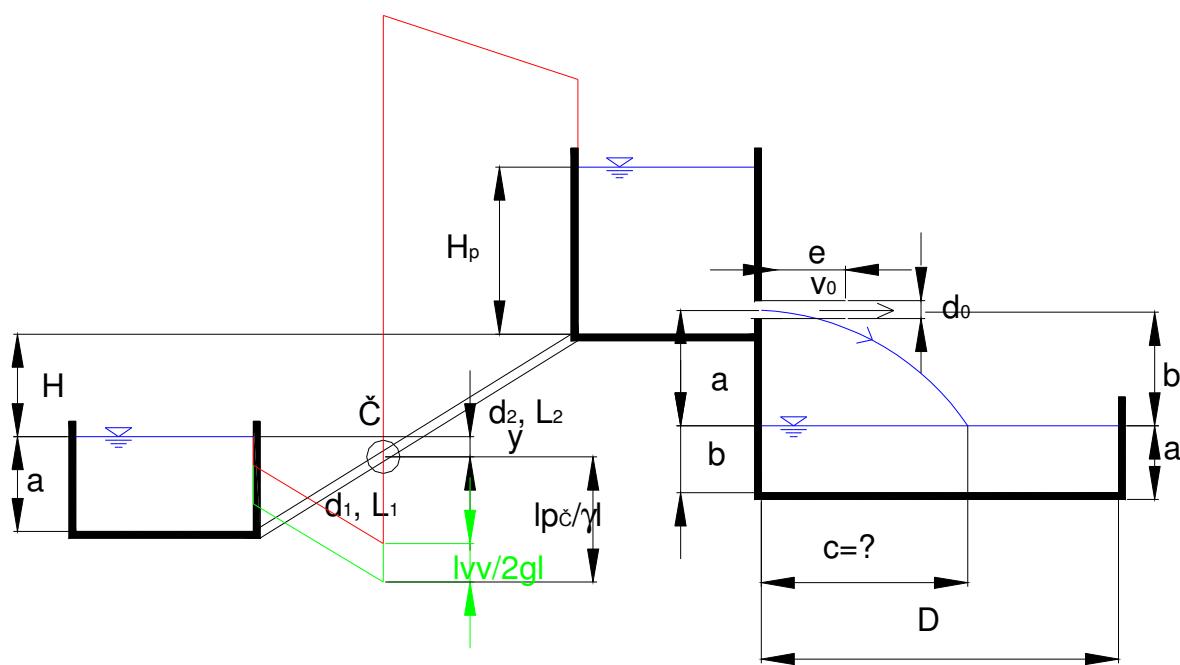
$$\left| \frac{p_{\check{C}}}{\rho \cdot g} \right|_{\min} = 7\text{m}$$

$$a = 1\text{m}$$

$$b = 4\text{m}$$

$$N_{\check{C}} = ?, \left| \frac{p_{\check{C}}}{\rho \cdot g} \right| = ?$$

Rešitev:



a)

$$\mu = 0,8$$

$$Q_0 = \mu \cdot v_0 \cdot S_0 = 0,8 \cdot 3 \cdot \frac{0,02^2 \cdot \pi}{4} = 0,75 \frac{l}{s}$$

$$b = \frac{g \cdot t^2}{2} \Rightarrow t = \sqrt{\frac{2 \cdot b}{g}} = \sqrt{\frac{8}{9,81}} = 0,9s$$

$$c = v_0 \cdot t + e = 0,9 \cdot 3 + 0,3 = 3,00m$$

b)

$$\Delta E_{VT} + \Delta E_1 - H_{\dot{C}} + \Delta E_2 + \Delta E_{IZ} + H_p + H = 0$$

$$v_0 = \sqrt{2 \cdot g \cdot (H_p - a)}$$

$$H_p = a + \frac{v_0^2}{2 \cdot g} = 1,0 + \frac{3^2}{19,62} = 1,46m$$

$$v_1 = \frac{Q_0 \cdot 4}{d_1^2 \cdot \pi} = 1,53 \frac{m}{s}$$

$$v_2 = \frac{Q_0 \cdot 4}{d_2^2 \cdot \pi} = 0,381 \frac{m}{s}$$

$$H_{\check{c}} = \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{VT} + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} \cdot \left( \frac{\lambda \cdot L_1}{d_1} + 1,0 \right) + 1,92 ? + 12 =$$

$$H_{\check{c}} = \frac{1,53^2}{19,62} \cdot \left( 0,5 + \frac{0,03 \cdot 8}{0,025} \right) + \frac{0,381^2}{19,62} \cdot \left( \frac{0,03 \cdot 16}{0,05} + 1,0 \right) + 1,46 ? + 12 = 14,74 m$$

$$N_{\check{c}} = \frac{Q_{\check{c}} \cdot H_{\check{c}} \cdot \rho \cdot g}{\eta_{\check{c}}} = \frac{Q_0 \cdot H_{\check{c}} \cdot \rho \cdot g}{\eta_{\check{c}}} = \frac{0,75 \cdot 10^{-3} \cdot 14,74 \cdot 9810}{0,85} \cong 129 W$$



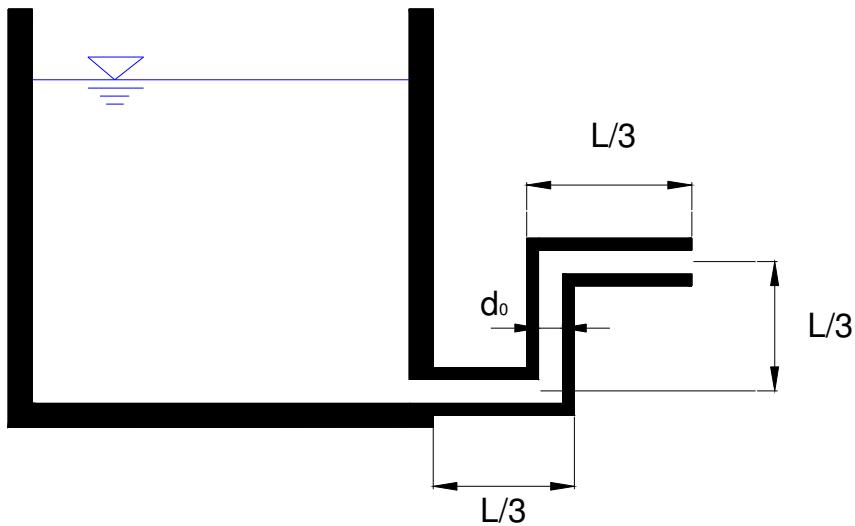
# **HIDRAVLIKA**

## **ZBIRKA REŠENIH NALOG**

**2 del: ODPRTINE IN PRELIVI**

## 2. ODPRTINE IN PRELIVI

2.1. Določi  $\mu$  in čas iztekanja iz posode T!



Podatki:

$$a = 1m$$

$$L = 1m$$

$$S_1 = 1m^2$$

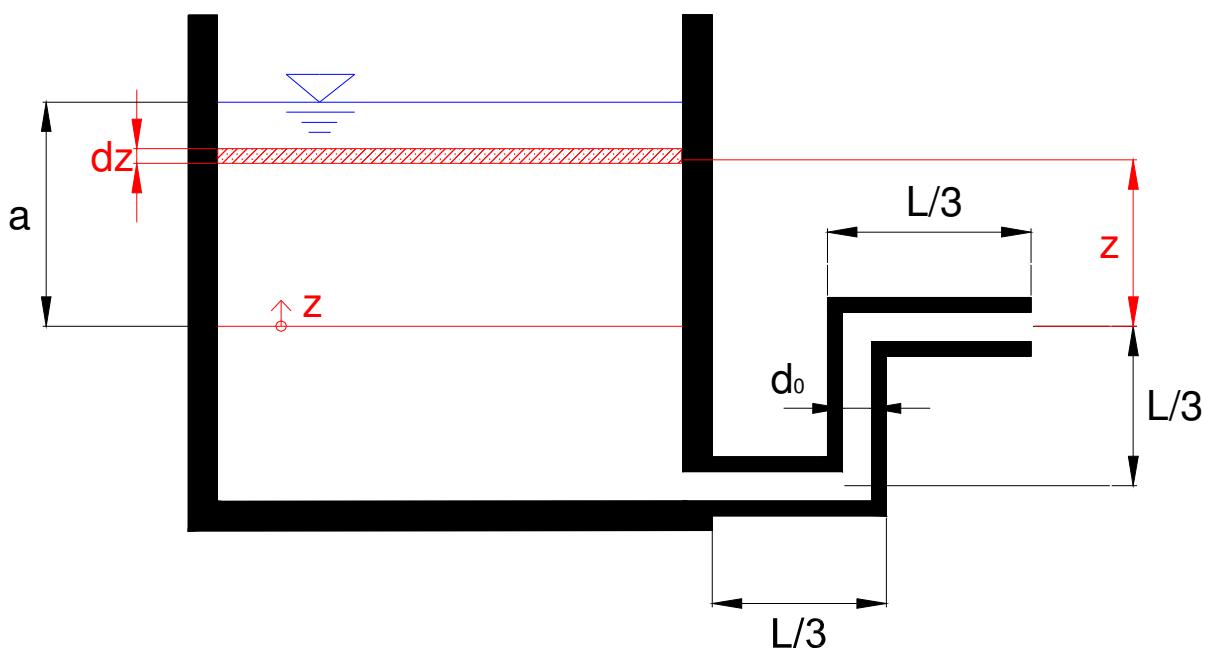
$$d_0 = 1cm$$

$$\xi_{vt} = 0,5$$

$$\xi_{kol} = 0,5$$

$$\lambda = 0,02$$

Rešitev:



$$\mu = \frac{1}{\sqrt{\left(1 + \xi_{vt} + 2 \cdot \xi_{\alpha} + \frac{\lambda \cdot L}{d}\right)}} = \frac{1}{\sqrt{\left(1 + 3 \cdot 0,5 + \frac{0,02 \cdot 1}{0,01}\right)}} = 0,47$$

$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot z} \cdot dt$$

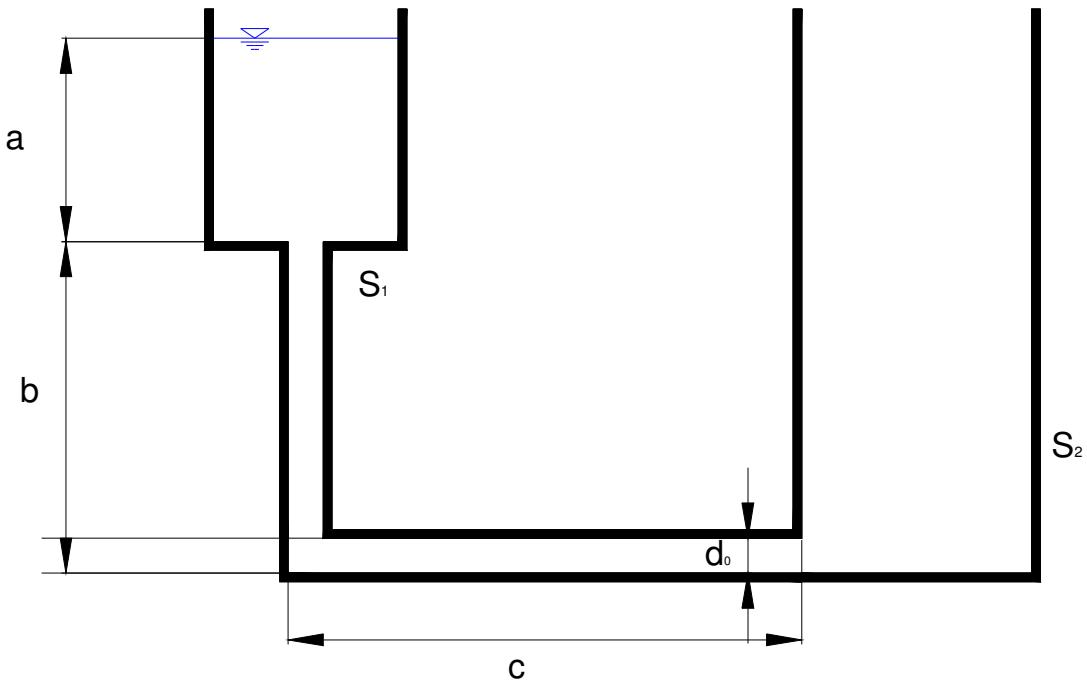
$$-\int_a^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot S_0 \cdot \sqrt{2 \cdot g}}{S_1} \cdot T$$

$$-\int_a^0 \frac{dz}{\sqrt{z}} = \frac{0,47 \cdot 0,01^2 \cdot \pi \cdot \sqrt{2 \cdot 9,81}}{4} \cdot T = 1,64 \cdot 10^{-4} \cdot T$$

$$2 \cdot \sqrt{z} \Big|_0^a = 2 \cdot \sqrt{a} - 2 \cdot \sqrt{0} = 2$$

$$T = \frac{2}{1,64 \cdot 10^{-4}} = 12195 \text{ s} = 3,39 \text{ h}$$

**2.2. (\*) Določi  $\mu$  in izračunaj, kdaj se gladini v posodah izenačita!**



Podatki:

$$S_1 = 4 \text{ m}^2$$

$$S_2 = 1 \text{ m}^2$$

$$\lambda = 0,03$$

$$\xi_k = 0,3$$

$$a = 1 \text{ m}$$

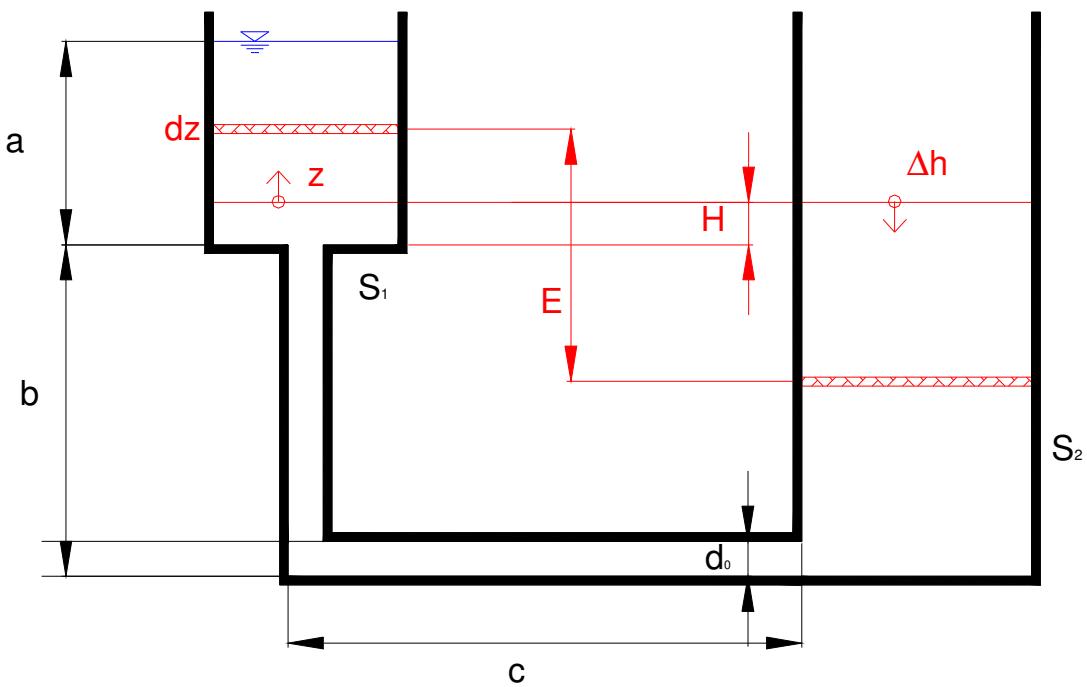
$$b = 0,2 \text{ m}$$

$$c = 0,25 \text{ m}$$

$$d = 1 \text{ cm}$$

$$\mu = ?, T = ?$$

Rešitev:



$$\mu = \frac{1}{\sqrt{1 + \xi_k + \frac{\lambda \cdot L}{d}}} = \frac{1}{\sqrt{1 + 0,3 + \frac{0,45}{0,01}}} = 0,614$$

Koncna gladina :

$$(a - H) \cdot S_1 = (H + b) \cdot S_2$$

$$a \cdot S_1 - H \cdot S_1 = H \cdot S_2 + b \cdot S_2$$

$$H \cdot (S_1 + S_2) = a \cdot S_1 - b \cdot S_2$$

$$H = \frac{a \cdot S_1 - b \cdot S_2}{S_1 + S_2} = \frac{4 - 0,2}{5} = 0,76m$$

Izenacevanje :

$$\Delta h = 4z$$

$$E = 5z$$

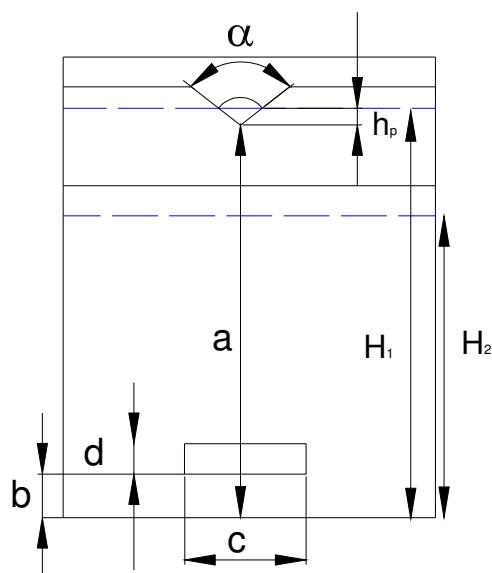
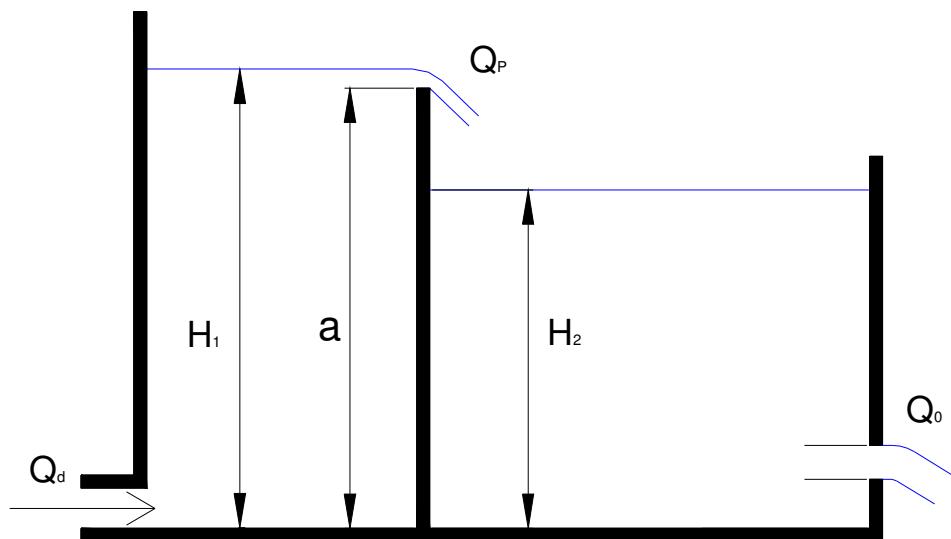
$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E} \cdot dt$$

$$-\int_{a-H}^0 \frac{dz}{\sqrt{dz}} = \frac{\mu \cdot S_0 \sqrt{10 \cdot g} \cdot T}{S_1}$$

$$2 \cdot \sqrt{z} \Big|_0^{a-H} = \frac{\mu \cdot S_0 \sqrt{10 \cdot g} \cdot T}{S_1}$$

$$T = \frac{2 \cdot \sqrt{a - H} \cdot S_1}{\mu \cdot S_0 \cdot \sqrt{10 \cdot g}} = \frac{2 \cdot \sqrt{0,24} \cdot 4}{0,64 \cdot \frac{0,01^2 \cdot \pi}{4} \cdot \sqrt{98,1}} = \underline{521,8s}$$

**2.3. Določi višino vode  $H_1$  in pretok po sistemu  $Q_d$ , ko se sistem umiri! (skica je narobe, višina  $h_t$  mora biti kotirana do sredine odprtine, gladina v prvi posodi pa je ravna!!!)**



Podatki:

$$H_2 = 1\text{m}$$

$$a = 1,5\text{m}$$

$$b = 30\text{cm}$$

$$d = 10\text{cm}$$

$$\mu_0 = \mu_o = 0,6$$

$$\alpha = 90^\circ$$

$$c = 30\text{cm}$$

Rešitev:

$$Q_0 = \mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot (H_2 - b - 0,5 \cdot d)}$$

$S_0$  = pravokoten prerez

$$Q_0 = 0,6 \cdot 0,1 \cdot 0,3 \cdot \sqrt{19,62 \cdot (1 - 0,3 - 0,05)}$$

$$Q_0 = 64,3 \frac{l}{s}$$

$$Q_d = Q_0 = Q_p$$

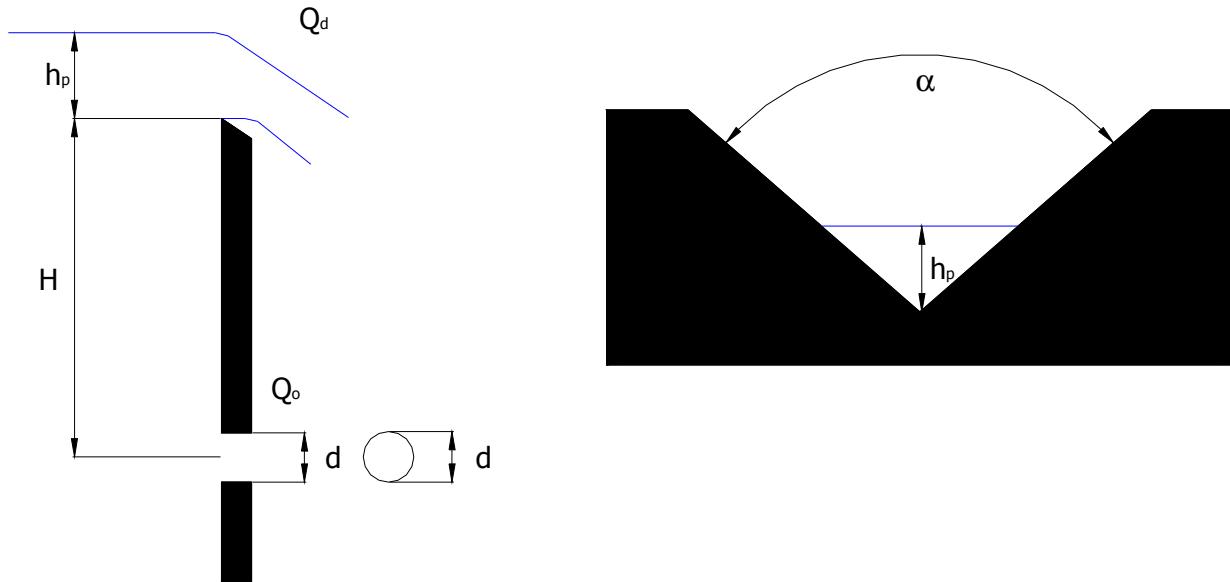
$$Q_d = 64,3 \frac{l}{s}$$

$$Q_p = \frac{8}{15} \cdot \mu_p \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_p^{\frac{5}{2}}$$

$$h_p = \left( \frac{15 \cdot Q_p}{8 \cdot \mu_p \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right)} \right)^{0,4} = \left( \frac{15 \cdot 64,3 \cdot 10^{-3}}{8 \cdot 0,6 \cdot \sqrt{19,62} \cdot \operatorname{tg} 45^\circ} \right)^{0,4} = 0,29m$$

$$H_1 = a + h_p = 1,79m$$

**2.4. (\*) Določi višino prelivanja na trikotnem prelivu, če zahtevamo, da sta pretoka čez preliv in skozi odprtino enaka! Izračunaj pretoka!**



Podatki:

$$\mu_p = \mu_0 = 0,6$$

$$\alpha_p = 90^\circ$$

$$H = 5\text{m}$$

$$d = 0,1\text{m}$$

$$Q_p = Q_0$$

$$h_p = ?$$

Rešitev:

$$S_0 = \frac{0,1^2 \cdot \pi}{4} \leftarrow \text{okrogel prerez}$$

$$Q_p = Q_0$$

$$h_t = H + h_p$$

$$\mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot h_t} = \frac{8}{15} \cdot \mu_p \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \sqrt{2 \cdot g} \cdot h_p^{\frac{5}{2}}$$

$$\frac{d_0 \cdot \pi}{4} \cdot \sqrt{2 \cdot g} \cdot \sqrt{H + h_p} = \frac{8}{15} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_p^{\frac{5}{2}}$$

$$7,85 \cdot 10^{-3} \sqrt{h_p + 5} = \frac{8}{15} \cdot h_p^{\frac{5}{2}} \leftarrow \text{kvadriramo}$$

$$6,17 \cdot 10^{-5} \cdot (5 + h_p) = 0,284 \cdot h_p^5$$

$$3,085 \cdot 10^{-4} + 6,17 \cdot 10^{-5} \cdot h_p = 0,284 \cdot h_p^5$$

$$h_p^5 = 2,17 \cdot 10^{-4} \cdot h_p + 1,086 \cdot 10^{-3}$$

Pomagamo si z excelom:

$$h_p = 0,30 \rightarrow 2,43 \cdot 10^{-3} = 1,15 \cdot 10^{-3}$$

$$h_p = 0,20 \rightarrow 3,20 \cdot 10^{-3} = 1,13 \cdot 10^{-3}$$

$$h_p = 0,25 \rightarrow 2,43 \cdot 10^{-3} = 1,15 \cdot 10^{-3}$$

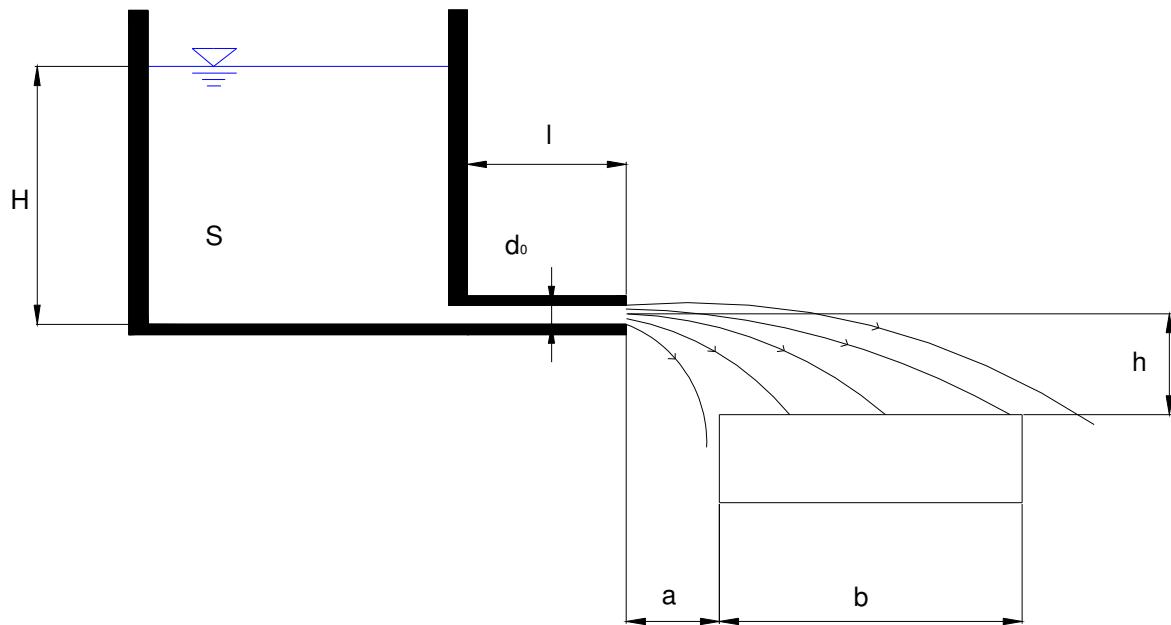
$$h_p = 0,26 \rightarrow 1,19 \cdot 10^{-3} = 1,14 \cdot 10^{-3}$$

$$h_p = 0,257 \rightarrow 1,12 \cdot 10^{-3} = 1,14 \cdot 10^{-3}$$

$$h_p = 0,258 \rightarrow 1,14 \cdot 10^{-3} = 1,14 \cdot 10^{-3}$$

$$Q_0 = Q_p = 0,048 \frac{m^3}{s}$$

**2.5.(\*) Izračunaj čas praznjenja posode A! Koliko iztekle vode ujamemo v posodo B?**



Podatki:

$$d_0 = 1\text{cm}$$

$$l = 50\text{cm}$$

$$a = 2,5\text{cm}$$

$$b = 4\text{m}$$

$$H = 3\text{m}$$

$$c = 5\text{m}$$

$$S = 2\text{m}^2$$

$$\mu = ?, T = ?, V = ?$$

Rešitev:

$$l = 0,5$$

$$d = 0,01$$

$$\frac{l}{d} = 50$$

$$v_x = \mu - \sqrt{2 \cdot g \cdot h}$$

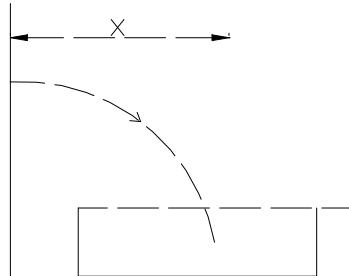
$$v_y \cdot t + \frac{g \cdot t^2}{2} = h$$

$$t = \sqrt{\frac{2 \cdot h}{g}} = \sqrt{\frac{2 \cdot 5}{9,81}} = \underline{1,01s}$$

$$x = v_x \cdot t$$

$$x_{\max} = 6 \Rightarrow v_{\max} = \frac{x_{\max}}{t} = \frac{6}{1,01} = \underline{5,94 \frac{m}{s}}$$

$$x_{\min} = 6 \Rightarrow v_{\min} = \frac{x_{\min}}{t} = \frac{2}{1,01} = \underline{1,98 \frac{m}{s}}$$



$$v_{x(\max)} = \mu \cdot \sqrt{2 \cdot g \cdot h_{\max}}$$

$$h_{\max} = \left( \frac{v_{x(\max)}}{\mu \cdot \sqrt{2 \cdot g}} \right)^2 = \frac{5,94^2}{0,8^2 \cdot 19,62} = \underline{2,81m}$$

$$h_{\min} = \frac{1,982^2}{0,8^2 \cdot 19,62} = \underline{0,31m}$$

$$\Delta h = h_{\max} - h_{\min} = 2,81 - 0,31 = \underline{2,5m}$$

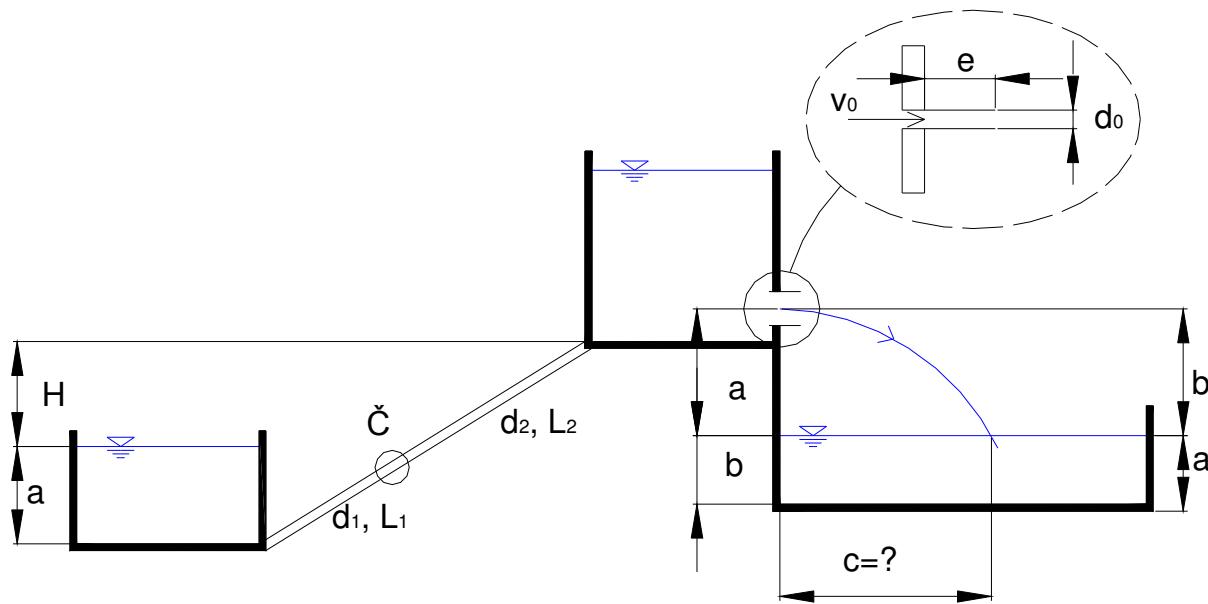
$$V = 2m^2 \cdot 2,5m = \underline{5m^3}$$

$$-S \cdot dz = \frac{\mu \cdot d_0^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot g \cdot z} \cdot dt$$

$$-\int_3^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot d_0^2 \cdot \pi}{4 \cdot S} \cdot \sqrt{2 \cdot g} \cdot T$$

$$\frac{2 \cdot \sqrt{3} \cdot 4 \cdot 2}{0,8 \cdot 0,01^2 \cdot \pi \cdot \sqrt{19,62}} = \frac{27,71281}{0,0011132} = T = \underline{24895s}$$

**2.6.(\*) Izračunaj potrebno moč črpalke, podtlak na črpalki in domet curka, če voda iz zgornje posode izteka skozi nastavek dolžine  $e$  in premera  $d_0$  s hitrostjo  $v_0$ !**



Podatki:

$$H = 12\text{m}$$

$$d_1 = 2,5\text{cm}$$

$$d_2 = 5\text{cm}$$

$$L_1 = 8\text{m}$$

$$L_2 = 16\text{m}$$

$$\eta_C = 0,85$$

$$\xi_{vt} = 0,5$$

$$\lambda = 0,03$$

$$e = 30\text{cm}$$

$$d_0 = 2\text{cm}$$

$$v_0 = 3 \frac{\text{m}}{\text{s}}$$

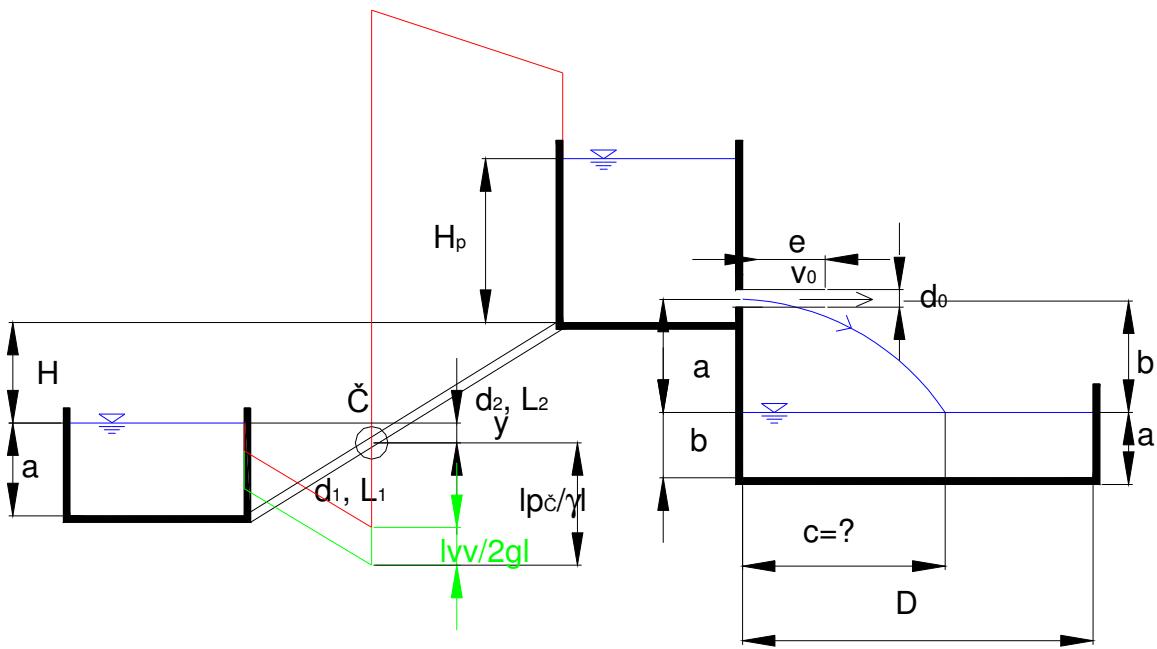
$$\left| \frac{p_C}{\gamma} \right|_{\min} = 7\text{m}$$

$$a = 1\text{m}$$

$$b = 4\text{m}$$

$$N_C = ?, \left| \frac{p_C}{\gamma} \right| = ?$$

Rešitev:



$$\mu = 0,8$$

$$Q_0 = \mu \cdot v_0 \cdot S_0 = \frac{0,8 \cdot 3 \cdot 0,02^2 \cdot \pi}{4} = 0,75 \frac{l}{s}$$

$$b = \frac{g \cdot t^2}{2} \Rightarrow t = \sqrt{\frac{2 \cdot b}{g}} = \sqrt{\frac{8}{9,81}} = 0,9s$$

$$c = v_0 \cdot t + e = 0,9 \cdot 3 + 0,3 = 3,00m$$

$$\Delta E_{vt} + \Delta E_1 - H_{\check{C}} + \Delta E_2 + \Delta E_{iz} + H_p + H = 0$$

$$v_0 = \sqrt{2 \cdot g \cdot (H_p - a)} \Rightarrow H_p = a + \frac{v_0^2}{2 \cdot g} = 1,0 + \frac{3^2}{2 \cdot 9,81} = 1,46m$$

$$v_1 = \frac{Q_0 \cdot 4}{d_1^2 \cdot \pi} = 1,53m$$

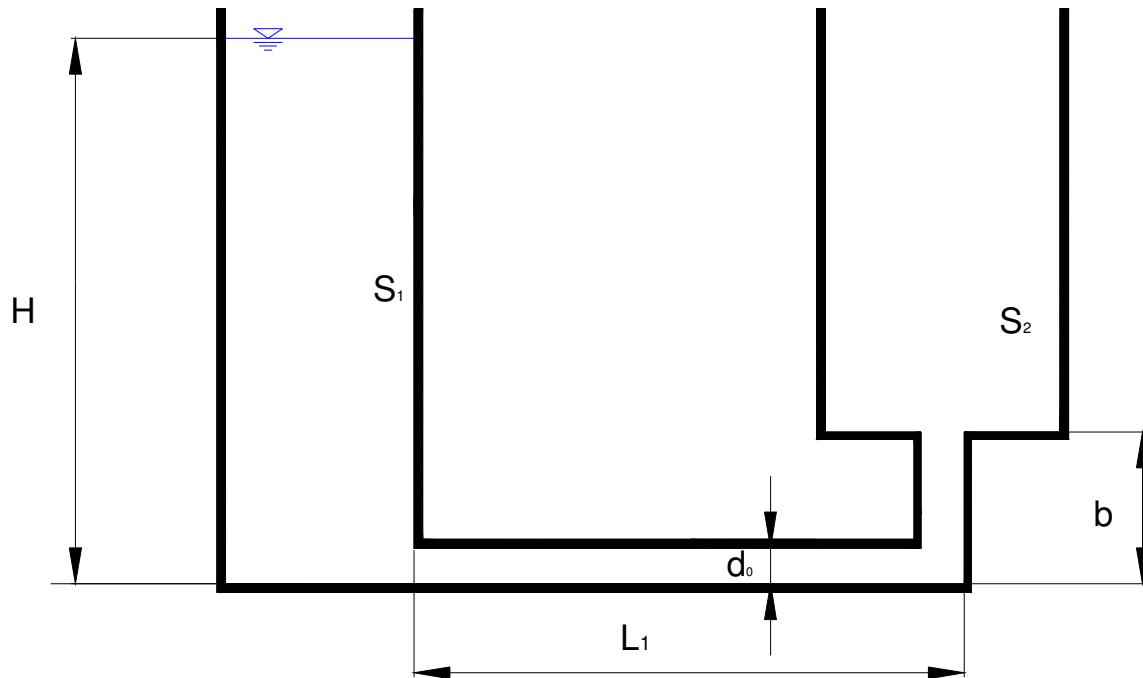
$$v_2 = \frac{Q_0 \cdot 4}{d_2^2 \cdot \pi} = 0,381m$$

$$H_{\check{C}} = \frac{v_1^2}{2 \cdot g} \cdot \left( \xi_{vt} + \frac{\lambda \cdot L_1}{d_1} \right) + \frac{v_2^2}{2 \cdot g} \cdot \left( 1,0 + \frac{\lambda \cdot L_2}{d_2} \right) + 1,46 + 12$$

$$H_{\check{C}} = \frac{1,53^2}{2 \cdot 9,81} \cdot \left( 0,5 + \frac{0,03 \cdot 8}{0,025} \right) + \frac{0,381^2}{2 \cdot 9,81} \cdot \left( 1,0 + \frac{0,03 \cdot 16}{0,05} \right) + 1,46 + 12 = 14,74m$$

$$N_{\check{C}} = \frac{Q_{\check{C}} \cdot H_{\check{C}} \cdot \rho \cdot g}{\eta_{\check{C}}} = \frac{Q_0 \cdot H_{\check{C}} \cdot \rho \cdot g}{\eta_{\check{C}}} = \frac{0,75 \cdot 10^{-3} \cdot 14,74 \cdot 1000 \cdot 9,81}{0,75} \cong 127W$$

**2.7. (\*) V kolikšnem času se gladini v obeh posodah izenačita?**



Podatki:

$$S_1 = S_2 = 2m^2$$

$$L = 2m$$

$$d_0 = 1cm$$

$$H = 5m$$

$$b = 1m$$

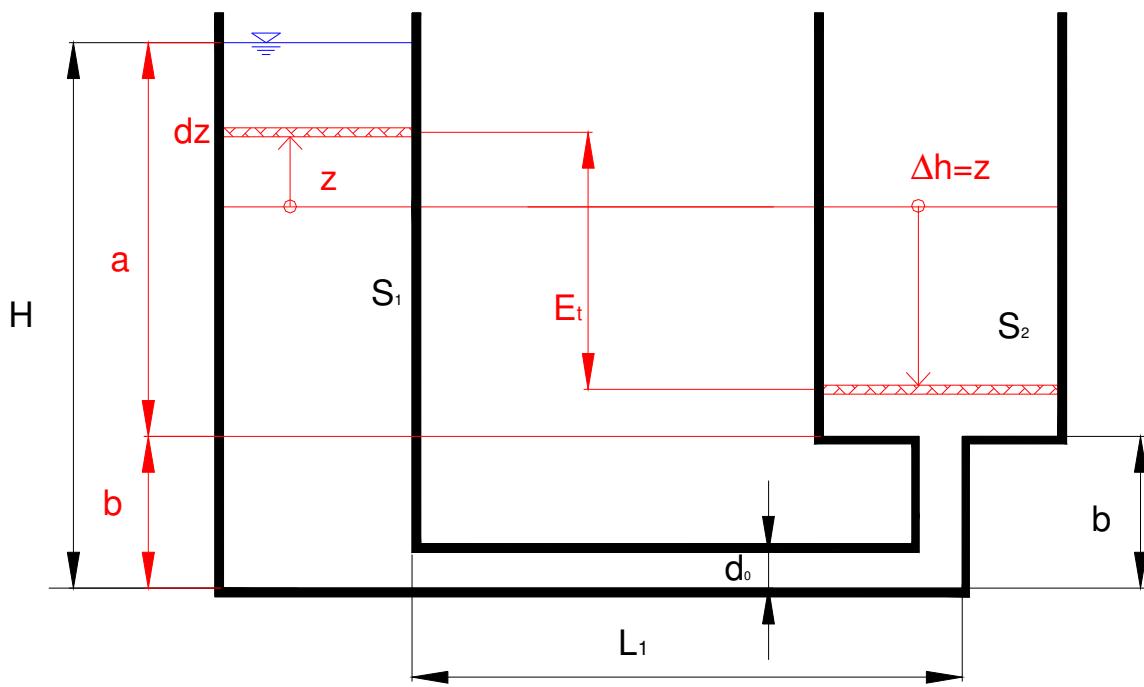
$$\xi_{vt} = 0,5$$

$$\xi_k = 0,3$$

$$\lambda = 0,018$$

$$\mu = ?, T = ?$$

Rešitev:



$$\mu = \frac{1}{\sqrt{1 + \xi_{vt} + \xi_k + \frac{\lambda \cdot (L+b)}{d_0}}} = \frac{1}{\sqrt{1 + 0,5 + 0,3 + \frac{0,018 \cdot 3}{0,01}}} = \frac{1}{\sqrt{1,72}} = 0,373$$

$$-dV_1 = dV_2 = Q \cdot dt$$

$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E_t} \cdot dt$$

$$-S_1 \cdot dz = \mu \cdot \frac{d_0^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot g \cdot 2 \cdot z} \cdot dt$$

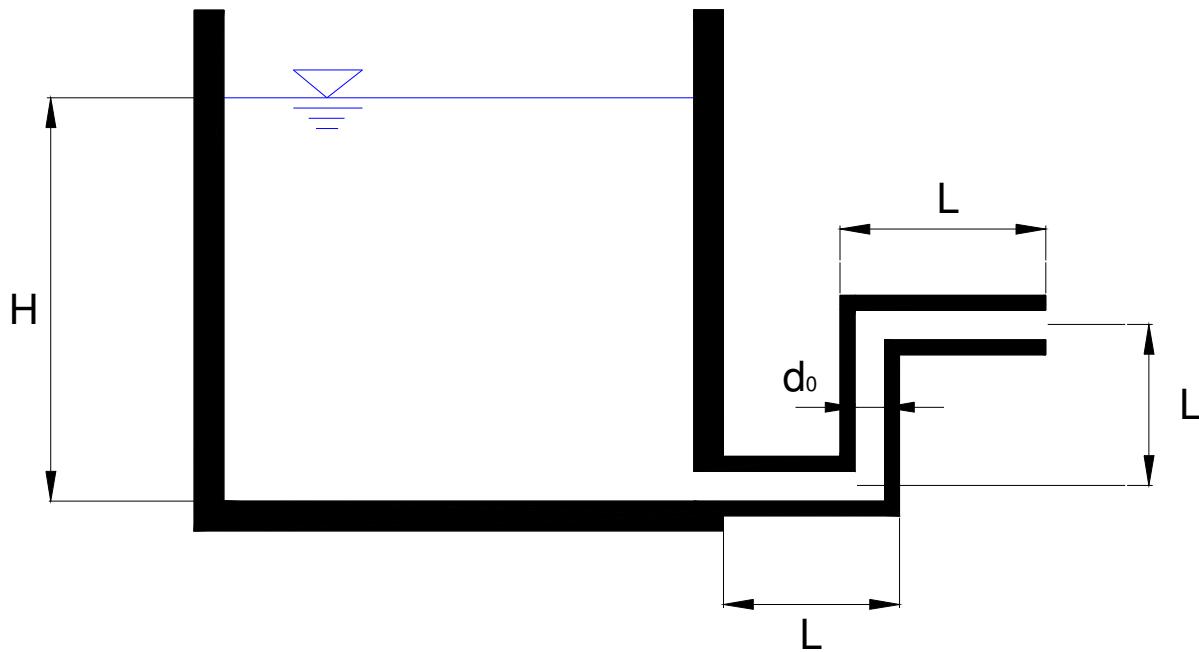
$$-\int_{\frac{a}{2}}^0 \frac{dz}{\sqrt{z}} = \mu \cdot \frac{d_0^2 \cdot \pi}{4 \cdot S_1} \cdot \sqrt{4 \cdot g} \cdot T$$

$$2 \cdot \sqrt{z} \Big|_0^{\frac{a}{2}} = 0,373 \cdot \frac{0,01^2 \cdot \pi}{4 \cdot 2} \cdot \sqrt{4 \cdot 9,81} \cdot T$$

$$2 \cdot \sqrt{2} = 2,83 = 9,175 \cdot 10^{-5} \cdot T$$

$$T = 30827,54 \text{ s} = \underline{8,56 \text{ h}}$$

**2.8. Izračunaj  $\mu$  in čas, ko preneha iztekanje iz posode!**



Podatki:

$$H = 5m$$

$$S_1 = 1,5m^2$$

$$L = 0,5m$$

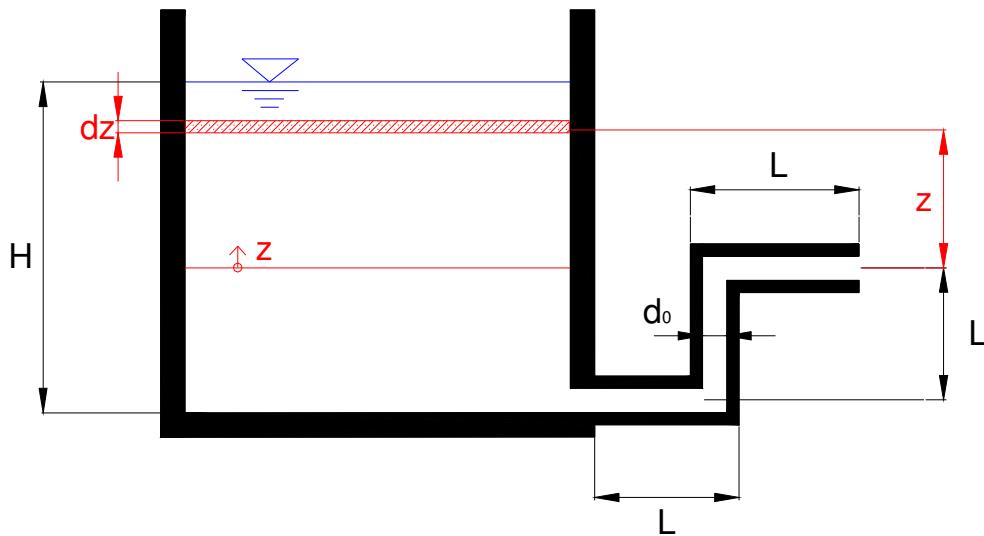
$$d_0 = 1cm$$

$$\xi_{vt} = 0,5$$

$$\xi_{kol} = 0,3$$

$$\lambda = 0,02$$

Rešitev:



$$\mu = \sqrt{\frac{1}{\sum \xi_i + \sum \frac{\lambda \cdot L_i}{d_i} + 1}} = \sqrt{\frac{1}{\xi_{vt} + \xi_k + \xi_k + \sum \frac{3 \cdot \lambda \cdot L}{d} + 1}} =$$

$$\mu = \sqrt{\frac{1}{0,5 + 0,6 + \sum \frac{3 \cdot 0,02 \cdot 0,5}{0,01} + 1}} = 0,443$$

$$E = z$$

$$E_z = H - L$$

$$E_k = 0$$

$$-dV = Q \cdot dt$$

$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E} \cdot dt$$

$$-\int_{H-L}^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot S_0}{S_1} \cdot \sqrt{2 \cdot g} \cdot T$$

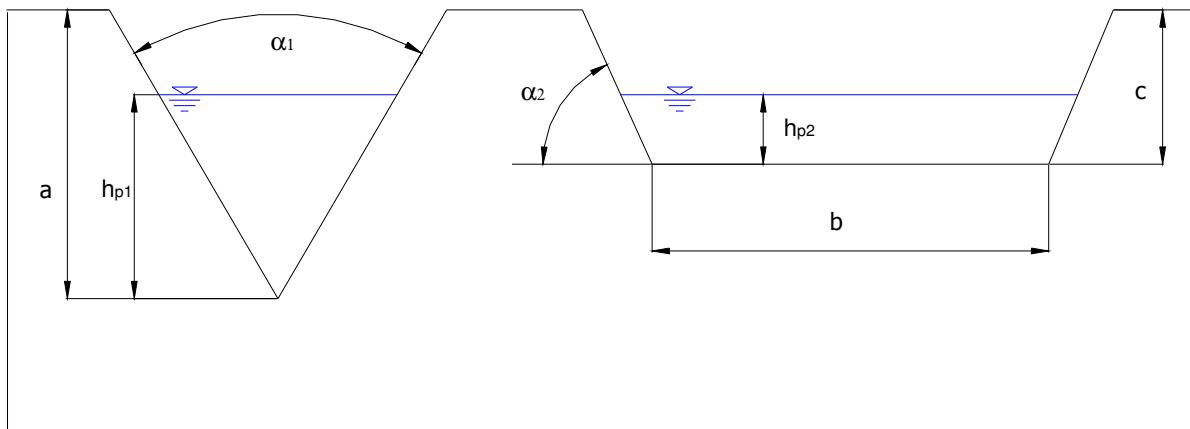
$$\int_0^{4,5} \frac{dz}{\sqrt{z}} = 2 \cdot \sqrt{z} \Big|_0^{4,5} = 2 \cdot \sqrt{4,5} = 4,24$$

$$4,24 = \frac{0,433 \cdot 0,01^2 \cdot \pi}{4 \cdot 1,5} \cdot \sqrt{19,62} \cdot T$$

$$4,24 = 1,026 \cdot 10^{-4} \cdot T$$

$$T = 41285 \text{ s} = 11,46 \text{ h}$$

**2.9. Kolikšna mora biti višina  $a$ , da oba preliva prevajata enak pretok?**



Podatki:

$$b = 0,3m$$

$$c = 0,5m$$

$$h_{p2} = 0,2m$$

$$\mu_1 = \mu_2 = 0,6$$

$$\underline{\alpha_1 = \alpha_2 = 60^\circ}$$

$$a = ?$$

Rešitev:

$$Q_2 = \frac{2}{3} \cdot \mu_p \cdot b_0 \cdot \sqrt{2 \cdot g} \cdot h_{p2}^{\frac{3}{2}} + \frac{8}{15} \cdot \mu_p \cdot \operatorname{tg}(90^\circ - \alpha) \cdot \sqrt{2 \cdot g} \cdot h_{p2}^{\frac{5}{2}}$$

$$Q_2 = \frac{2}{3} \cdot 0,6 \cdot 0,3 \cdot \sqrt{2 \cdot 9,81} \cdot 0,2^{\frac{3}{2}} + \frac{8}{15} \cdot 0,6 \cdot \operatorname{tg}(30^\circ) \cdot \sqrt{2 \cdot 9,81} \cdot 0,2^{\frac{5}{2}}$$

$$Q_2 = 0,0475 + 0,0146 = 62,1 \frac{l}{s}$$

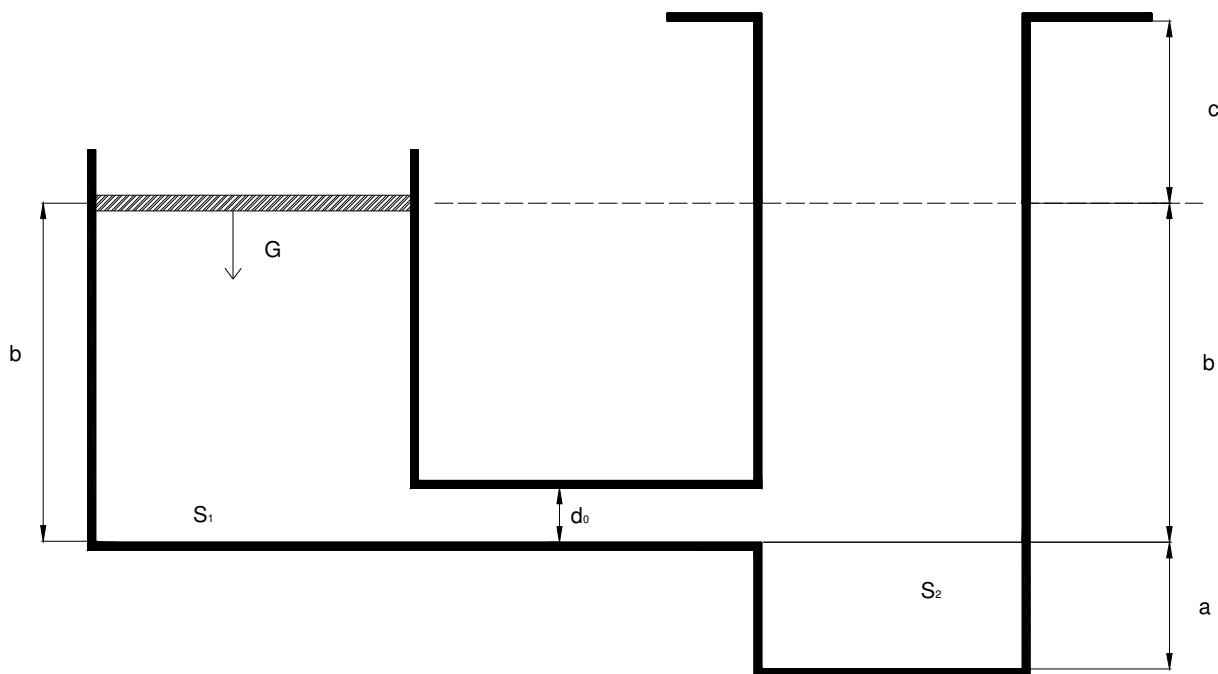
$$Q_1 = Q_2$$

$$Q_1 = \frac{8}{15} \cdot 0,6 \cdot \operatorname{tg}(30^\circ) \cdot \sqrt{2 \cdot 9,81} \cdot h_{p1}^{\frac{5}{2}}$$

$$h_{p1} = \left( \frac{15 \cdot Q}{8 \cdot 0,6 \cdot \operatorname{tg}(30^\circ) \cdot \sqrt{2 \cdot 9,81}} \right)^{\frac{2}{5}} = 0,357m$$

$$a = h_{p1} + c - h_{p2} = 0,657m$$

**2.10.(\*) Določi višino vode v obeh posodah in čas, ko se sistem umiri!**



Podatki:

$$S_1 = 2m^2$$

$$S_2 = 1m^2$$

$$a = 1m$$

$$b = 2m$$

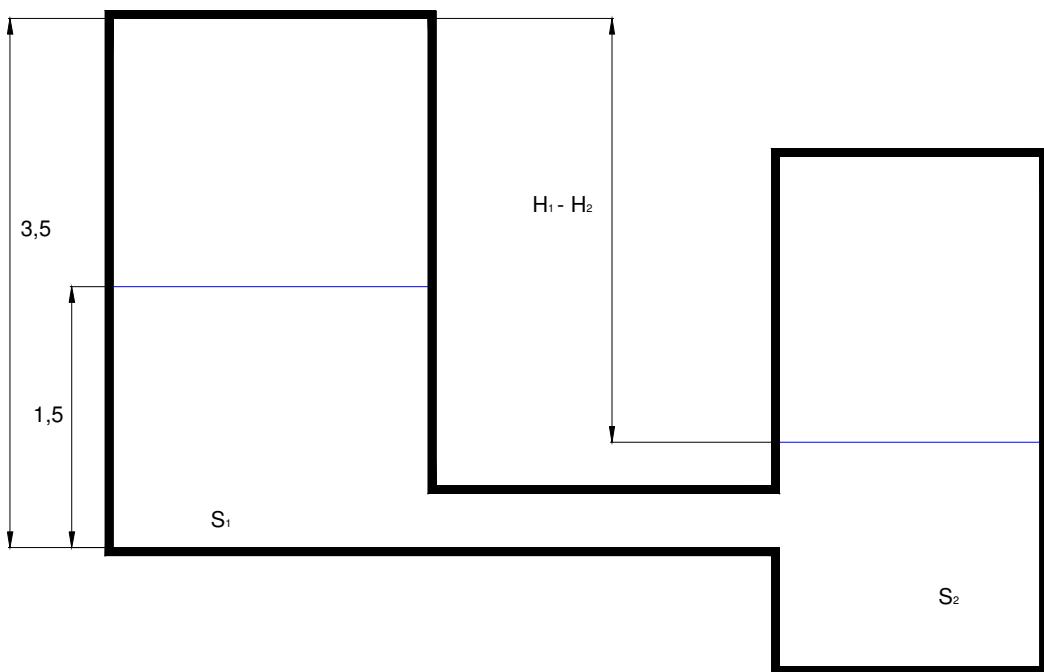
$$c = 1m$$

$$G = 40kN$$

$$d_0 = 5cm$$

$$\mu = 0,6$$

Rešitev:



a) Iztok na prosto :

$$\frac{p}{\gamma} = \frac{G}{S \cdot \gamma} = \frac{40kN}{2m^2 \cdot 10 \frac{kN}{m^3}} = \underline{2m}$$

$$Q \cdot dt = -S_1 \cdot dh = \frac{\mu \cdot d_0^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot g \cdot \left( \frac{h+p}{\gamma} \right)} \cdot dt$$

$$\frac{\mu \cdot d_0^2 \cdot \pi}{4 \cdot S_1} \cdot \sqrt{2 \cdot g \cdot \left( \frac{h+p}{\gamma} \right)} \cdot dt = - \int_{h_0}^{h_1} \frac{dh}{\sqrt{h + \frac{p}{\gamma}}} = 2 \cdot \sqrt{h_1 + \frac{p}{\gamma}} \Big|_{h_0}^{h_1} = 2 \cdot \sqrt{h_1 + 2}$$

$$h_1 = \underline{1,5m}$$

$$\frac{0,6 \cdot 0,05^2 \cdot \pi}{4 \cdot 2} \cdot \sqrt{2 \cdot 9,81} \cdot t = 2 \cdot \left( \sqrt{h_0 + 2} - \sqrt{h_1 + 2} \right)$$

$$5,218 \cdot 10^{-3} \cdot t = 2 \cdot (\sqrt{4} - \sqrt{3,5}) = 0,258$$

$$t_1 = 49,51 \cdot 2 = \underline{99s}$$

b) iznenacevanje gladin :

$$S_1 = (H_1 - H_2) = S_2 \cdot H_2$$

$$H_2 \cdot (S_1 + S_2) = H_1 \cdot S_1$$

$$H_2 = \frac{H_1 \cdot S_1}{S_1 + S_2} = \frac{3,5 \cdot 2}{3} = \underline{2,33m}$$

$$V_2 = \underline{2,33m^3}$$

$$H_1 = \underline{0,33m}$$

$$V_1 = \underline{0,67m^3}$$

$$V_{sp} = 1m^3$$

$$\sum V = 4m^3$$

$$dV_1 = S_1 \cdot dh_1$$

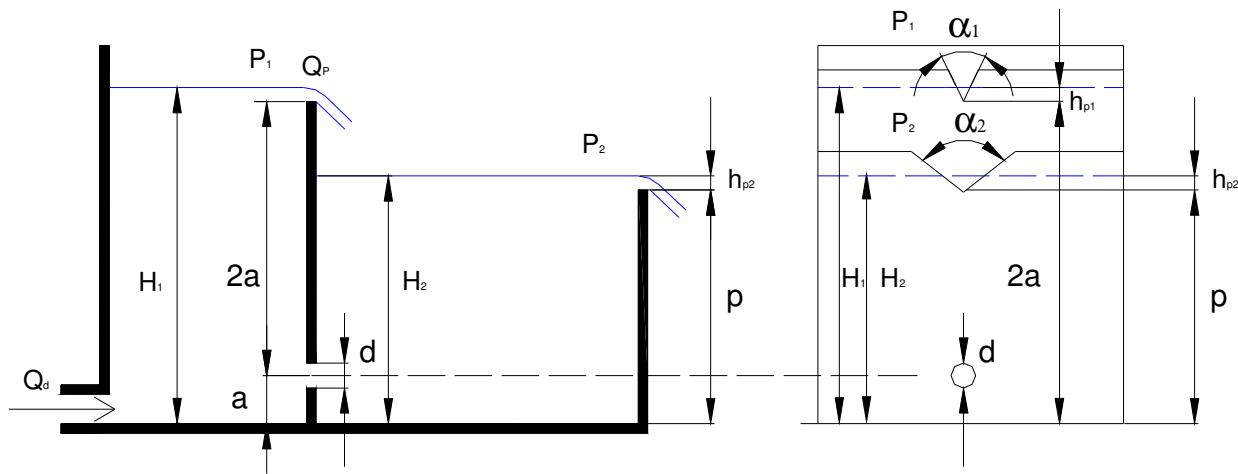
$$dV_2 = S_2 \cdot dh_2$$

$$- S_1 \cdot \int_{h_1}^{h_2} dh_1 = S_2 \cdot \int_0^{h_2} dh_2$$

$$h_2 = - \frac{S_1}{S_2} \cdot (H_2 - h_1) = \frac{S_1}{S_2} \cdot (h_1 - H_2)$$

$$-\int S_1 \cdot dh_1 = \mu \cdot \frac{d_0^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot g \cdot \left( h_1 + \frac{S_1}{S_2} \cdot (h_1 - H_1) \right)} \cdot dt_2$$

**2.11. Določi premer odprtine d tako, da bosta višini prelivanja v razmerju 2:1 ( $h_{p1}/h_{p2} = 2$ )!**



Podatki:

$$a = 25\text{cm}$$

$$Q_d = 14 \frac{l}{s}$$

$$\alpha_{p1} = 15^\circ$$

$$\alpha_{p2} = 120^\circ$$

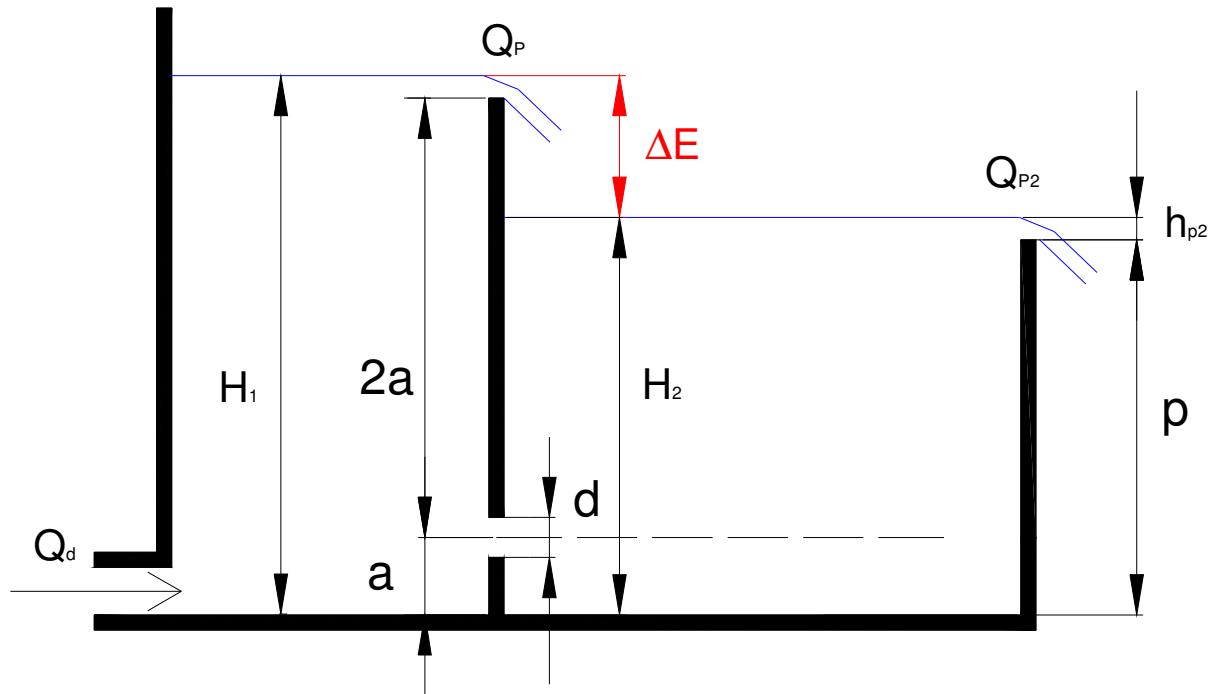
$$\mu_{p1} = 0,6$$

$$\mu_{p2} = 0,5$$

$$\mu_0 = 0,55$$

$$p = 0,5m$$

Rešitev:



$$Q_{p2\pi} = Q_d = \frac{8}{15} \cdot \mu_2 \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_{p2}^{\frac{5}{2}}$$

$$h_{p2} = \left( \frac{15 \cdot Q_d}{8 \cdot \mu_2 \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg} 60^\circ} \right)^{0,4} = \left( \frac{15 \cdot 14 \cdot 10^{-3}}{8 \cdot 0,5 \cdot \sqrt{2 \cdot 9,81} \cdot \operatorname{tg} 60^\circ} \right)^{0,4} = 0,136m$$

$$h_{p1} = 2 \cdot h_{p2} = 0,272m$$

$$H_1 = 3 \cdot a + h_{p1} = 0,75 + 0,272 = 1,022m$$

$$H_2 = p + h_{p2} = 0,5 + 0,136 = 0,636m$$

$$\Delta E = H_1 - H_2 = 0,386m$$

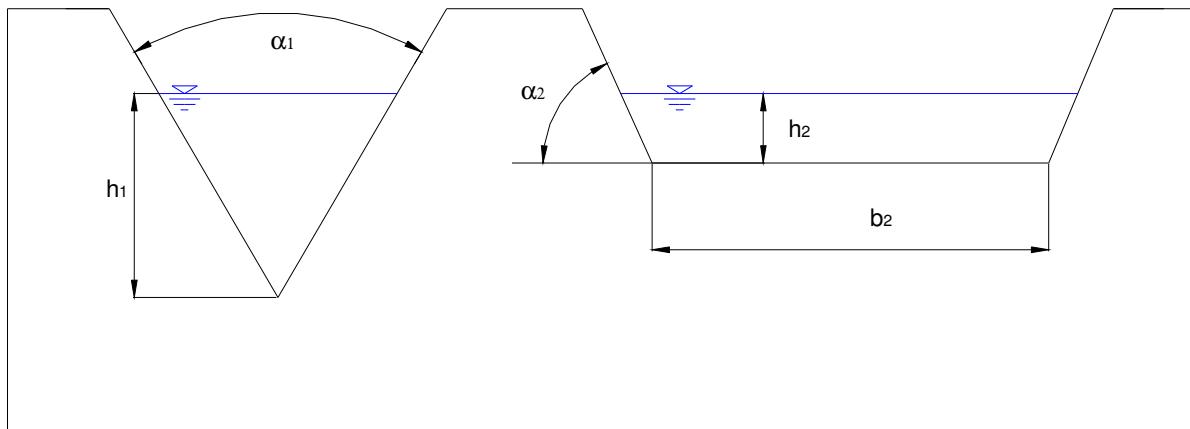
$$Q_0 = Q_d - Q_{p1} = 14 - 7,2 = 6,8 \cdot 10^{-3} \frac{m^3}{s}$$

$$Q_{p1} = \frac{8}{15} \cdot \mu_1 \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_{p1}^{\frac{5}{2}} = \frac{8}{15} \cdot 0,6 \cdot \sqrt{2 \cdot 9,81} \cdot \operatorname{tg}\left(\frac{15^\circ}{2}\right) \cdot 0,272^{\frac{5}{2}} = 7,2 \cdot 10^{-3} \frac{m^3}{s}$$

$$Q_0 = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot \Delta E} = \mu \cdot \frac{d^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot g \cdot \Delta E}$$

$$d = \sqrt{\frac{4 \cdot Q_0}{\mu \cdot \pi \cdot \sqrt{2 \cdot g \cdot \Delta E}}} = \sqrt{\frac{4 \cdot 6,8 \cdot 10^{-3}}{0,55 \cdot \pi \cdot \sqrt{2 \cdot 9,81 \cdot 0,386}}} = 7,56cm$$

**2.12. Voda izteka čez preliva P<sub>1</sub> in P<sub>2</sub>. Določi kot  $\alpha_1$ , da čez P<sub>1</sub> izteka Q<sub>1</sub> vode in širino b<sub>2</sub>, da čez P<sub>2</sub> izteka Q<sub>2</sub> vode!**



Podatki:

$$Q_1 = 60 \frac{l}{s}$$

$$Q_2 = 120 \frac{l}{s}$$

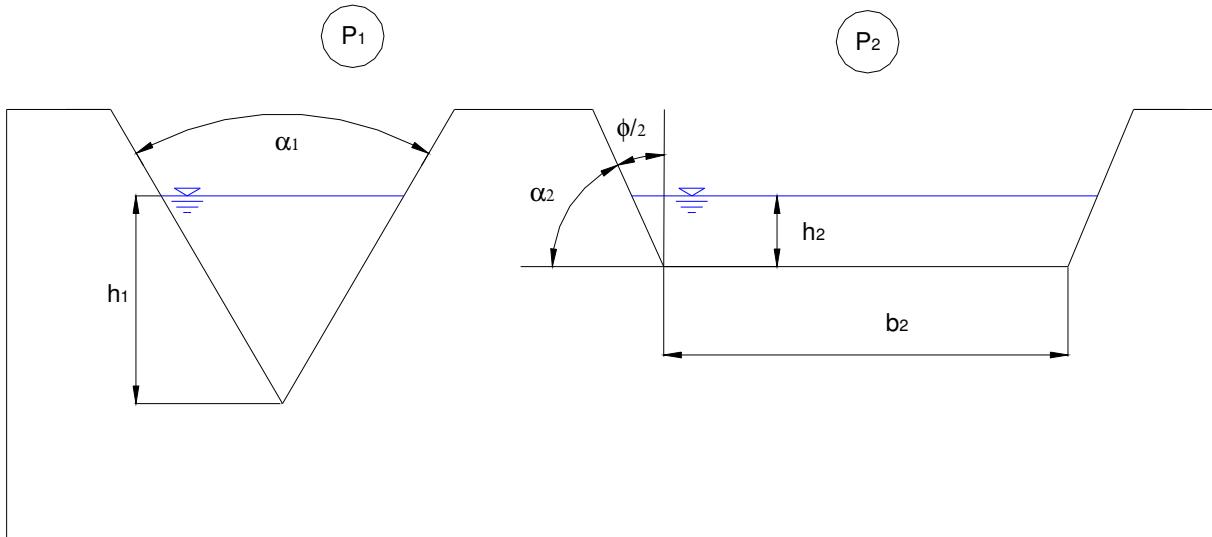
$$h_1 = 40\text{cm}$$

$$h_2 = 20\text{cm}$$

$$\mu_1 = \mu_2 = 0,6$$

$$\alpha_2 = 60^\circ$$

Rešitev:



Za preliv  $P_1$  izracunamo kot  $\alpha$  :

$$Q_1 = \frac{8}{15} \cdot \mu_1 \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_{p1}^{\frac{5}{2}}$$

$$\operatorname{tg}\left(\frac{\alpha}{2}\right) = \frac{15 \cdot Q_1}{8 \cdot \mu_1 \cdot \sqrt{19,62} \cdot h_1^{\frac{5}{2}}} = \frac{15 \cdot 0,060}{8 \cdot 0,6 \cdot \sqrt{19,62} \cdot 0,4^{\frac{5}{2}}} = 0,42$$

$$\frac{\alpha}{2} = 22,7^\circ \Rightarrow \alpha = \underline{45,4^\circ}$$

Za preliv  $P_2$  izracunamo  $b$  :

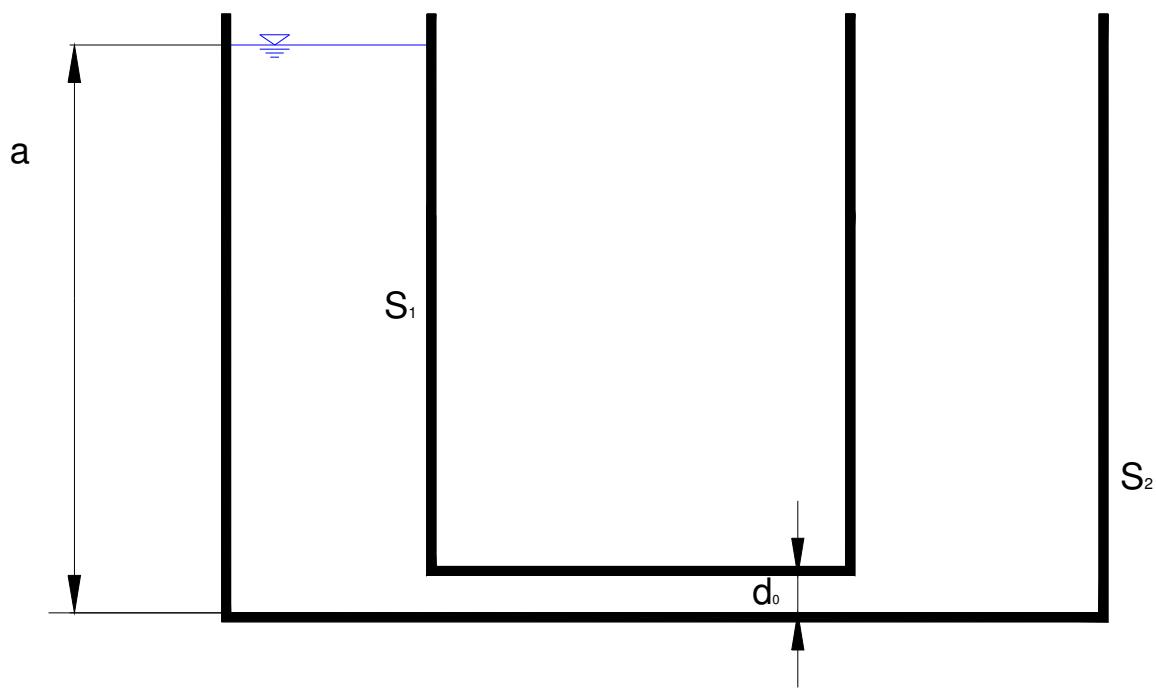
$$Q_2 = \frac{2}{3} \cdot \mu_2 \cdot b \cdot \sqrt{2 \cdot g} \cdot h_2^{\frac{3}{2}} + \frac{8}{15} \cdot \mu_2 \cdot b \cdot \sqrt{2 \cdot g} \cdot h_2^{\frac{5}{2}} \cdot \operatorname{tg}\left(\frac{\Phi}{2}\right)$$

$$b = \left( Q_2 - \frac{8}{15} \cdot \mu_2 \cdot \sqrt{2 \cdot g} \cdot h_2^{\frac{5}{2}} \cdot \operatorname{tg}\left(\frac{\Phi}{2}\right) \right) \cdot \frac{3}{2 \cdot \mu_2 \cdot b \cdot \sqrt{2 \cdot g} \cdot h_2^{\frac{3}{2}}}$$

$$b = \left( 0,120 - \frac{8}{15} \cdot 0,6 \cdot \sqrt{2 \cdot g} \cdot 0,2^{\frac{5}{2}} \cdot \operatorname{tg} 30^\circ \right) \cdot \frac{3}{2 \cdot 0,6 \cdot \sqrt{2 \cdot g} \cdot 0,2^{\frac{3}{2}}}$$

$$b = \underline{0,66m}$$

2.13. (\*) Določi premer cevi  $d$  tako, da se bosta gladini izenačili po 1h!



Podatki:

$$S_1 = 1m^2$$

$$S_2 = 3m^2$$

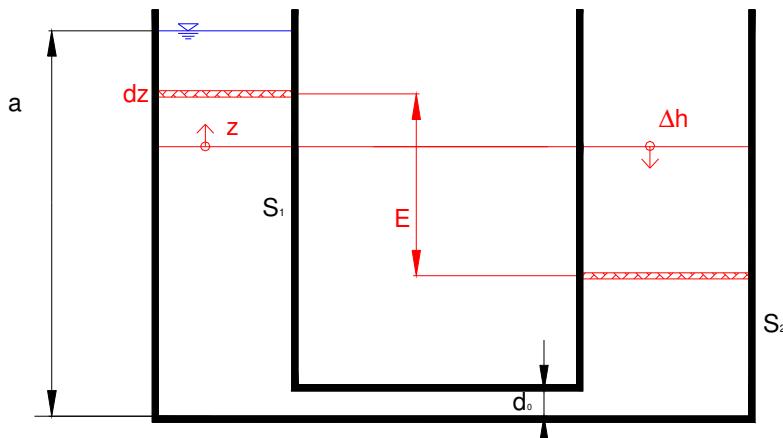
$$a = 2,5m$$

$$\mu = 0,7$$

$$T = 1h$$

$$d = ?$$

Rešitev:



Končno stanje :

$$(a - H) \cdot S_1 = H - S_2$$

$$H = \frac{a \cdot S_1}{S_1 + S_2} = \frac{2,5}{3} = 0,833m$$

Izenacevanje gladin :

$$E = z + \Delta h$$

$$dV_1 = dV_2$$

$$z \cdot S_1 = \Delta h \cdot S_2$$

$$\Delta h = \frac{z \cdot S_1}{S_2} = 0,5 \cdot z$$

$$E = z \cdot (1 + 0,5) = 1,5 \cdot z$$

$$dV = Q \cdot dt$$

$$dV = -S_1 \cdot dz$$

$$-S_1 \cdot dz = Q \cdot dt$$

$$-\int_{a-H}^0 \frac{dz}{\sqrt{z}} = \int_0^T \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E} \cdot dt$$

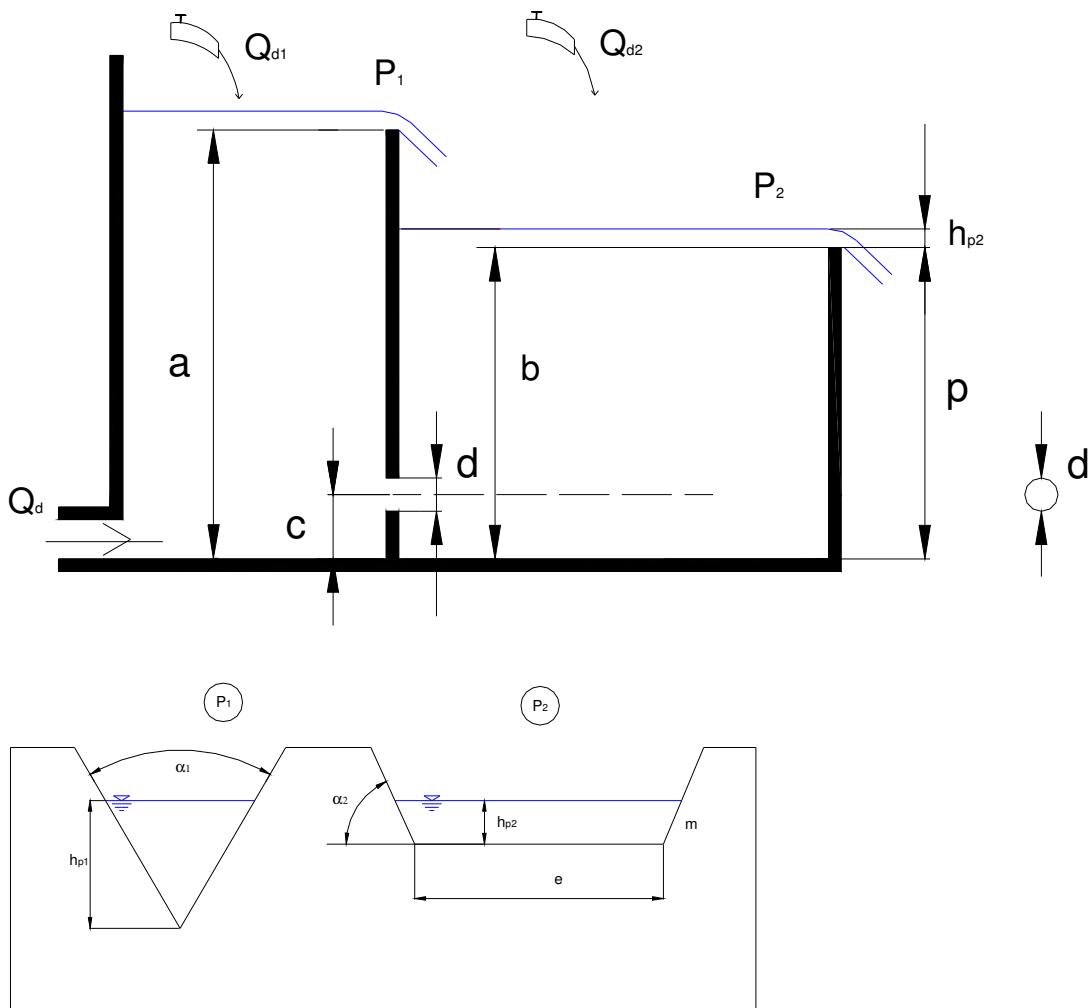
$$-\int_{a-H}^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot 1,5}}{S_1} \int_0^T dt$$

$$2 \cdot \sqrt{z} \Big|_0^{a-H} = 2 \cdot \sqrt{a-H} = \frac{\mu \cdot S_0 \cdot \sqrt{3 \cdot g}}{S_1} \cdot T$$

$$2 \cdot \sqrt{z} \Big|_0^{a-H} = 2 \cdot \sqrt{a-H} = \frac{\mu \cdot \frac{d_0^2 \cdot \pi}{4} \cdot \sqrt{3 \cdot g}}{S_1} \cdot T$$

$$d = \sqrt{\frac{8 \cdot S_1 \sqrt{a-H}}{\mu \cdot \pi \cdot T \cdot \sqrt{3 \cdot g}}} = \sqrt{\frac{8 \cdot S_1 \cdot \sqrt{2,5 - 0,833}}{0,7 \cdot \pi \cdot 3600 \cdot \sqrt{3 \cdot 9,81}}} = 15,5mm$$

**2.14. Iz posode 1 v posodo 2 se voda preliva prek trikotnega preliva skozi odprtino  $O_1$  in prek preliva  $P_1$ . Iz posode 2 se preliva prek trapeznega preliva  $P_2$ . Izračunaj potrebna dodatna dotoka v posodi 1 in 2, če želimo vzdrževati stacionarno stanje!**



Podatki:

$$a = 2\text{m}$$

$$b = 1\text{m}$$

$$c = 0,5\text{m}$$

$$d = 0,15\text{m}$$

$$e = 0,2\text{m}$$

$$\mu_{p1} = \mu_{p2} = 0,6$$

$$\mu_0 = 0,5$$

$$\alpha_1 = 75^\circ$$

$$m = 1$$

$$h_{p1} = h_{p2} = 0,3\text{m}$$

$$Q_{d1} = ?, Q_{d2} = ?$$

Rešitev:

$$Q_{p1} = \frac{8}{15} \cdot \mu_{p1} \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_{p1}^{\frac{5}{2}} = \frac{8}{15} \cdot 0,6 \cdot \sqrt{2 \cdot 9,82} \cdot \operatorname{tg} 37,5^\circ \cdot 0,3^{\frac{5}{2}} = 53,6 \frac{l}{s}$$

$$E = a + h_{p1} - b - h_{p2} = 1m$$

$$Q_0 = \mu_0 \cdot \pi \cdot \frac{d^2}{4} \cdot \sqrt{2 \cdot g} = 0,5 \cdot \pi \cdot \frac{0,15^2}{4} \cdot \sqrt{2 \cdot 9,81} = 39,1 \frac{l}{s} \quad \text{teziscna enacba je OK}$$

$$Q_{d1} = Q_{p1} + Q_0 = 53,6 + 39,1 = 92,7 \frac{l}{s}$$

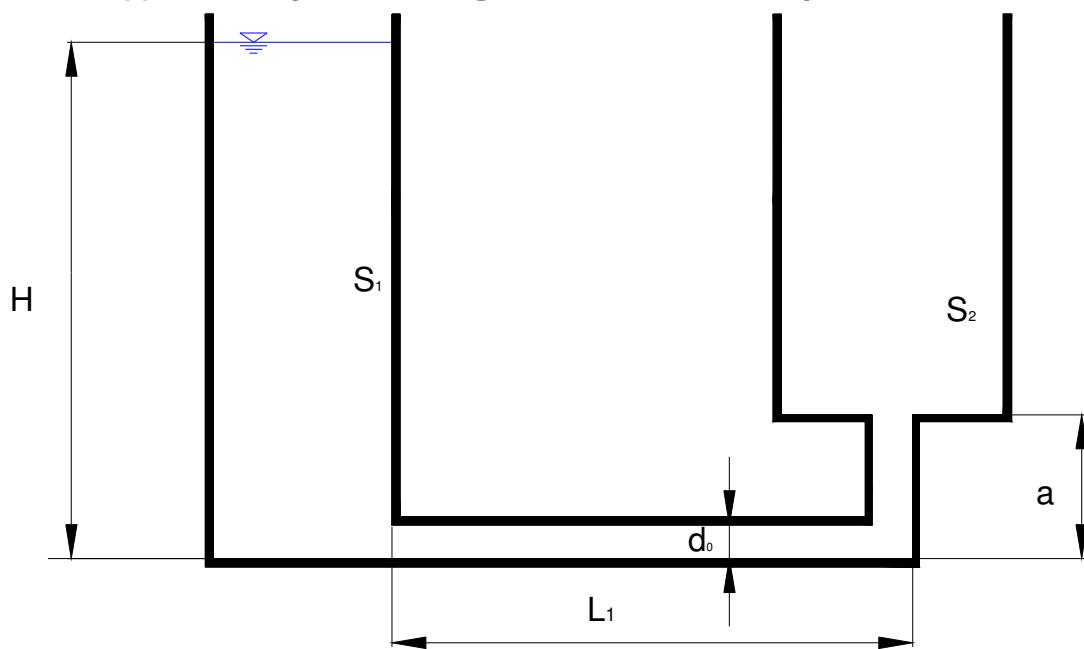
$$Q_{p2} = \frac{2}{3} \cdot \mu_{p2} \cdot e \cdot \sqrt{2 \cdot g} \cdot h_{p2}^{\frac{3}{2}} + \frac{8}{15} \cdot \mu_{p2} \cdot \operatorname{tg}\left(\frac{\Phi}{2}\right) \cdot \sqrt{2 \cdot g} \cdot h_{p2}^{\frac{5}{2}}$$

$$Q_{p2} = \frac{2}{3} \cdot 0,6 \cdot 0,2 \cdot \sqrt{2 \cdot 9,81} \cdot 0,3^{\frac{3}{2}} + \frac{8}{15} \cdot 0,6 \cdot 1 \cdot \sqrt{2 \cdot 9,81} \cdot 0,3^{\frac{5}{2}}$$

$$Q_{p2} = 58,2 + 69,9 = 128,1 \frac{l}{s}$$

$$Q_{d2} = Q_{p2} - Q_{p1} - Q_0 = 128,1 - 53,6 - 39,1 = 35,4 \frac{l}{s}$$

**2.15. (\*) Izračunaj čas, ko se gladini v levi in desni posodi izenačita!**



Podatki:

$$S_1 = S_2 = 3 \text{ m}^2$$

$$L_1 = 1,5 \text{ m}$$

$$d_0 = 1 \text{ cm}$$

$$H = 5 \text{ m}$$

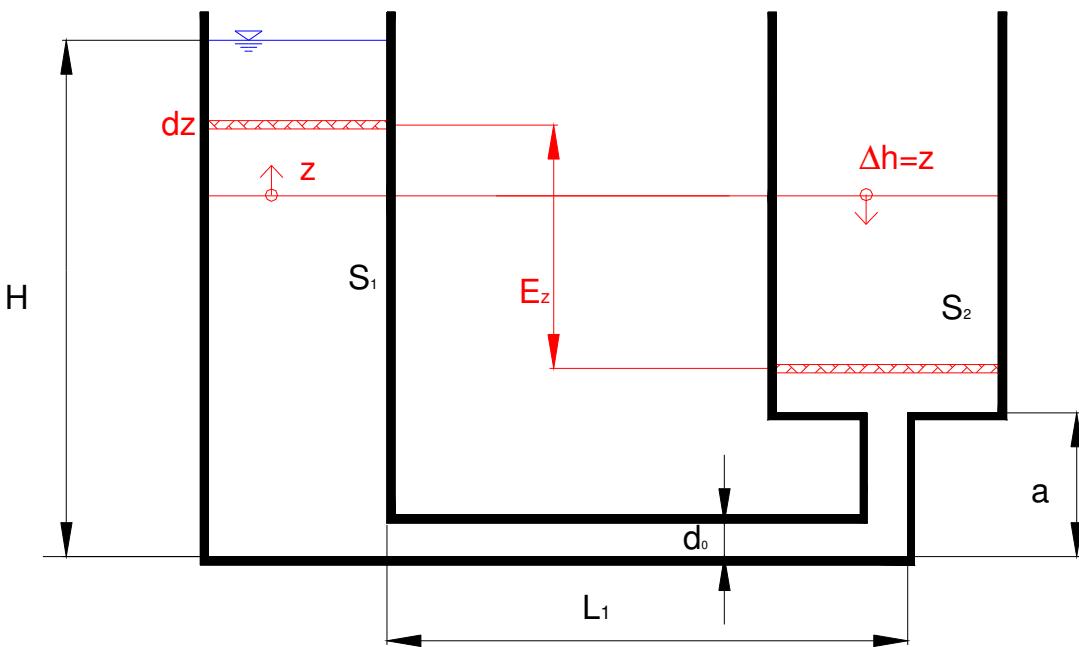
$$a = 1 \text{ m}$$

$$\xi_{vt} = 0,4$$

$$\xi_k = 0,3$$

$$\lambda = 0,02$$

Rešitev:



$$S_1 = S_2$$

$$z = \Delta h$$

$$E_t = 2 \cdot z$$

$$\mu = \frac{1}{\sqrt{1 + \xi_{vt} + \xi_k + \frac{\lambda \cdot (L_1 + b)}{d}}} = \frac{1}{\sqrt{1 + 0,4 + 0,3 + \frac{0,02 \cdot 2,5}{0,01}}} = 0,386$$

$$-dV_1 = Q \cdot dt$$

$$-S_1 \cdot dz = \mu \cdot \frac{d_0^2 \cdot \pi}{4} \sqrt{2 \cdot g \cdot 2 \cdot z} \cdot dt$$

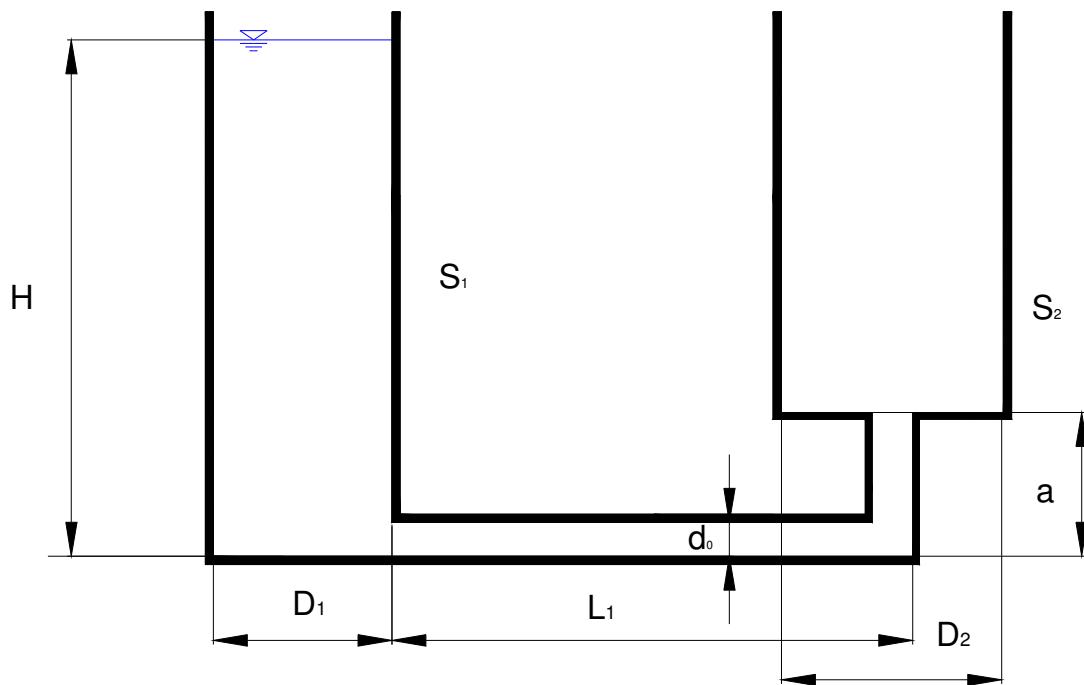
$$-\int_{\frac{a}{2}}^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot d_0^2 \cdot \pi}{4 \cdot S_1} \cdot \sqrt{4 \cdot g} \cdot dt$$

$$2 \cdot \sqrt{z} \Big|_0^{\frac{a}{2}} = \frac{0,386 \cdot 0,01^2 \cdot \pi}{4 \cdot 3} \cdot \sqrt{4 \cdot 9,81} \cdot T$$

$$2,83 = 6,33 \cdot 10^{-5} \cdot T$$

$$T = 44706 \text{ s} = 12,4 \text{ h}$$

**2.16. (\*) Valjasti posodi sta povezani s cevko premera d. Na kateri koti se gladini izenačita in po kolikšnem času?**



Podatki:

$$D_1 = 0,5\text{m}$$

$$D_2 = 0,3\text{m}$$

$$L_1 = 2\text{m}$$

$$L_2 = 0,3\text{m}$$

$$a = 2\text{m}$$

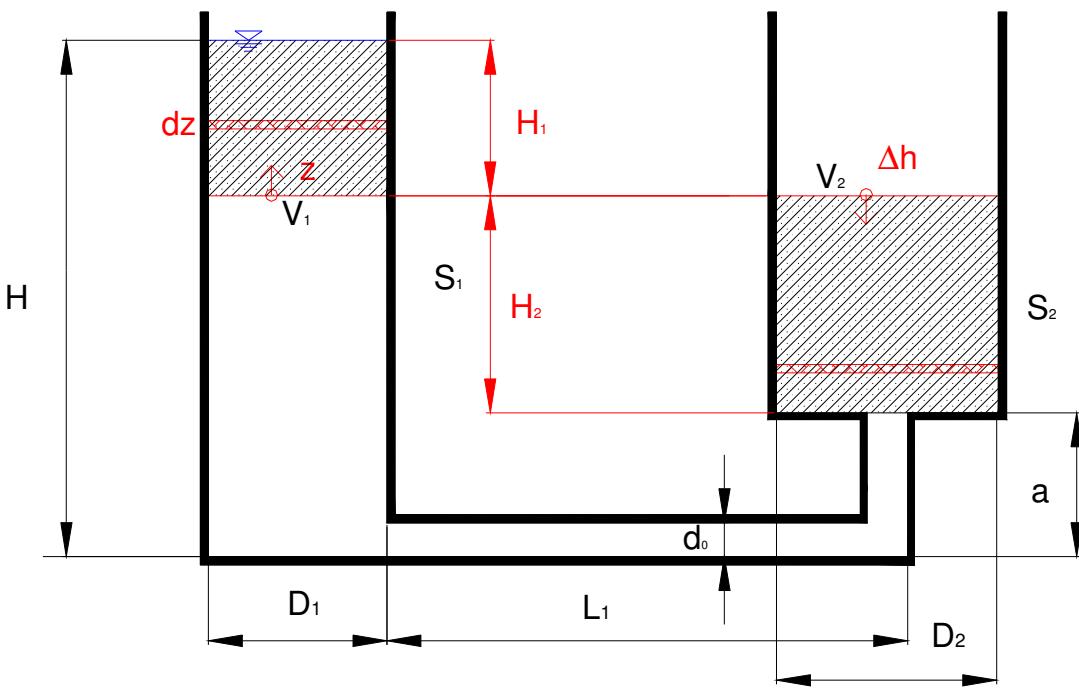
$$d = 1\text{cm}$$

$$\lambda = 0,02$$

$$\xi_{vt} = 0,5$$

$$\xi_k = 0,4$$

Rešitev:



$$\mu = \frac{1}{\sqrt{1 + \frac{\lambda \cdot (L_1 + L_2)}{d} + \xi_{vt} + \xi_k}} = \frac{1}{\sqrt{1 + \frac{0,02 \cdot 2,3}{0,01} + 0,9}} = 0,39$$

$$V_1 = V_2$$

$$\frac{D_1^2 \cdot \pi}{4} \cdot H_1 = \frac{D_2^2 \cdot \pi}{4} \cdot (a - L_2 - H_1)$$

$$0,27 \cdot H_1 = 0,07 \cdot (2 - 0,3)$$

$$H_1 = 0,45 \text{ m}$$

$$H_2 = a - L_2 - H_1 = 1,25 \text{ m}$$

$$\frac{H_1}{H_2} = \frac{z}{\Delta h} \Rightarrow \Delta h = \frac{z \cdot H_2}{H_1} = \frac{z \cdot 1,25}{0,45} = 2,8 \cdot z$$

$$E = z + \Delta h = 3,8 \cdot z$$

$$-dV = Q \cdot dt$$

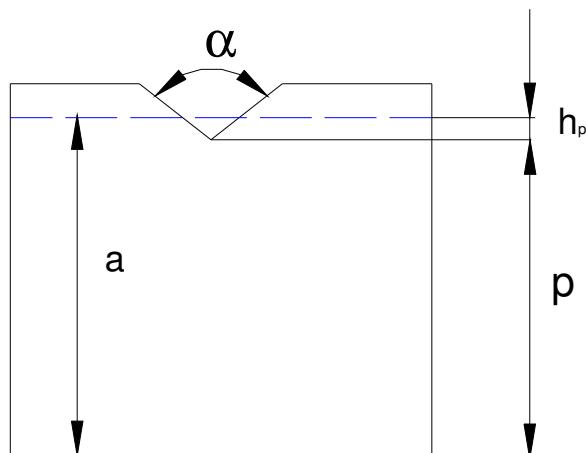
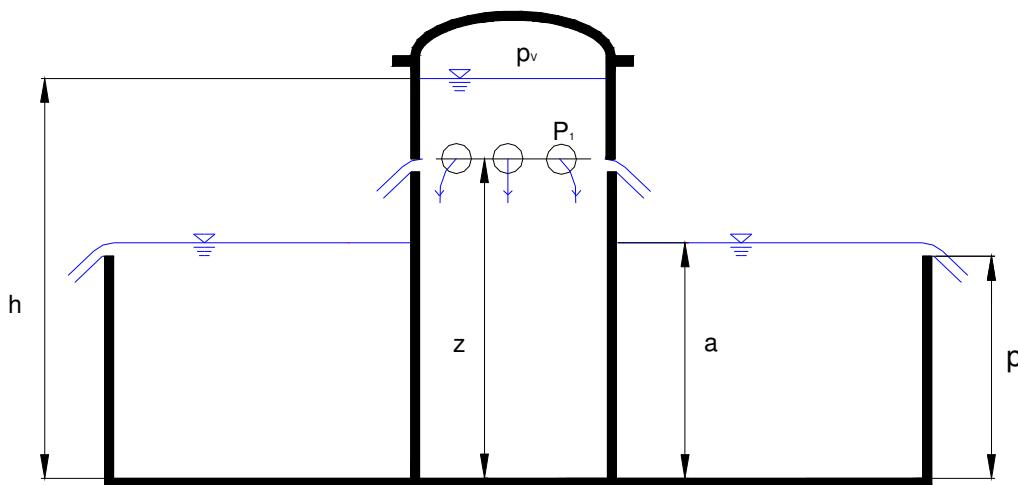
$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E} \cdot dt$$

$$-S_1 \cdot dz = \mu \cdot S_0 \cdot \sqrt{2 \cdot 3,8 \cdot z} \cdot dt$$

$$2 \cdot \sqrt{H_1} = \frac{\mu \cdot d_0^2 \cdot \pi \cdot 4 \cdot \sqrt{7,6 \cdot g}}{4 \cdot D_1^2 \cdot \pi} \cdot T$$

$$T = 996 \text{ s}$$

**2.17.** Iz notranjega valja izteka voda skozi 10 ostrorobih odprtin premera  $d_o$ . Zunanja posoda ima na robovih 4 trikotne prelive. Določi višino vode v zunanji posodi a in potreben dotok  $Q$ , da vzdržujemo stacionarno stanje.



Podatki:

$$p_v = 0,5 \text{ bar}$$

$$h = 1,5 \text{ m}$$

$$n_0 = 10$$

$$n_p = 4$$

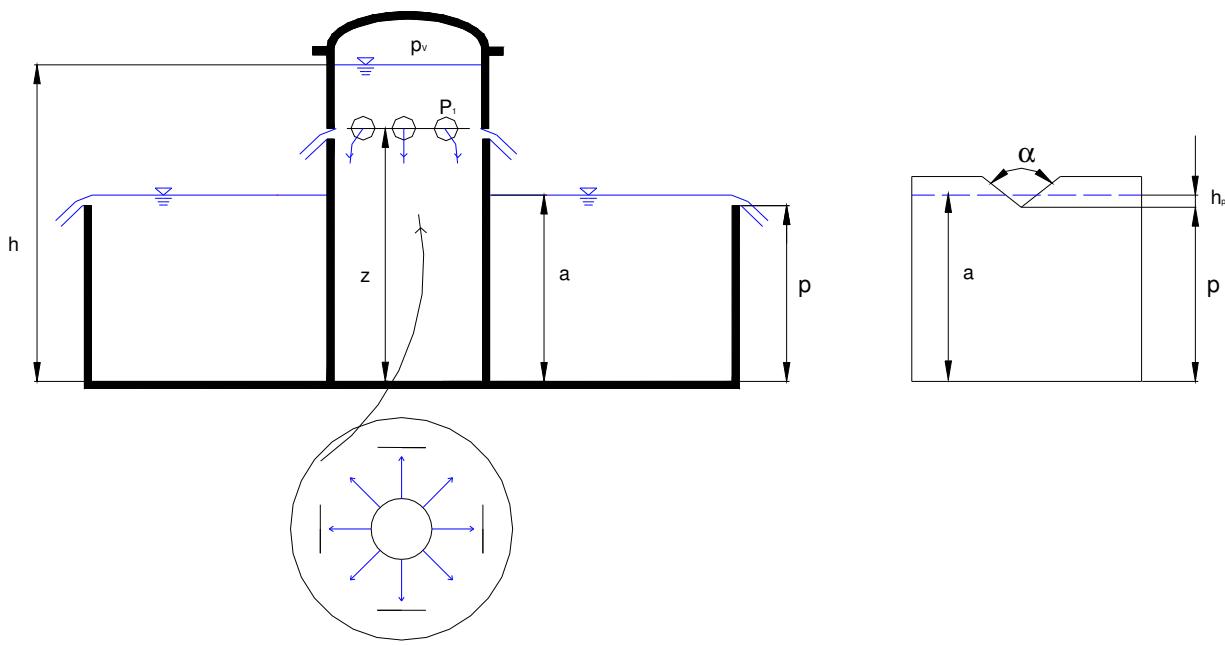
$$\mu_0 = \mu_p = 0,6$$

$$d_0 = 1 \text{ cm}$$

$$p = 0,5 \text{ m}$$

$$\alpha = 90^\circ$$

Rešitev:



Iztok iz notranjih 10 odprtin  $\Rightarrow Q_{\text{potrebni}}$

$$Q = n_0 \cdot \mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot \left( h - z + \frac{p_v}{\gamma} \right)} = 10 \cdot 0,6 \cdot \frac{0,01^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot 9,81 \cdot 5,5} = 4,9 \frac{l}{s}$$

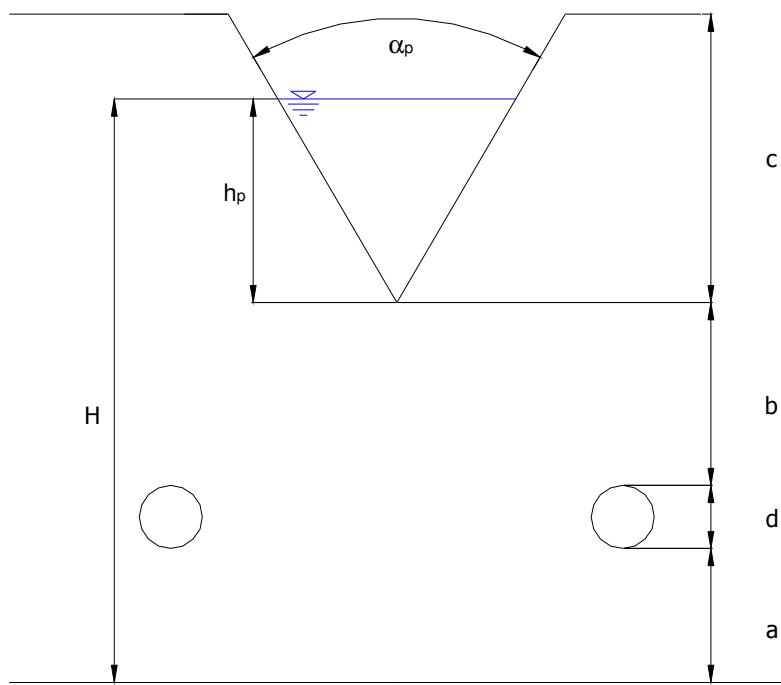
$\frac{Q}{4}$ , ker so 4 trikotni prelivи:

$$\frac{Q}{4} = \frac{8}{15} \cdot \mu_p \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg}\left(\frac{\alpha}{2}\right) \cdot h_p^{\frac{5}{2}}$$

$$h_p = \left[ \frac{15 \cdot Q}{32 \cdot \mu_p \cdot \sqrt{2 \cdot g} \operatorname{tg}\left(\frac{\alpha}{2}\right)} \right]^{0,4} = 3,28 \text{ cm}$$

$$a = p + h_p = 53,3 \text{ cm}$$

**2.18. (\*) Določi globino v posodi H tako, da bo skupni iztok skozi obe odprtini in čez preliv enak Q!**



Podatki:

$$a = 2 \text{ m}$$

$$b = 1,5 \text{ m}$$

$$c = 1 \text{ m}$$

$$d = 10 \text{ cm}$$

$$Q = 50 \text{ l/s}$$

$$\mu_p = 0,6$$

$$\mu_o = 0,6$$

$$\alpha_p = 75^\circ$$

---


$$H = ?$$

### **REŠITEV:**

Pozor – 4 možnosti

- a.) odprtina deluje kot preliv
- b.) 1. sodeluje samo odprtina (potopljena – splošna enačba)
  - 2. sodeluje samo odprtina (potopljena – težiščna enačba)
- c.) sodelujeta odprtina in preliv
- d.) višina c ne zadošča in se voda preliva čez rob nad prelivom

Poskusimo z varianto b2.), ki je najlažja. Če dobimo ustrezen rezultat, je naloga rešena.

$$Q_0 = 25 \frac{l}{s} = \frac{Q}{2}$$

$$h_T = b + \frac{d}{2} = \underline{1,55m}$$

$$Q_{0\max} = \mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot h_T} = 0,6 \cdot \frac{0,1^2 \cdot \pi}{4} \cdot \sqrt{2 \cdot 9,81 \cdot 1,55} = 25,98 \frac{l}{s}$$

$$Q_0 = \mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot h_T}$$

$$h_T = \sqrt{\frac{Q_0}{\mu_0 \cdot S_0}} \cdot \frac{1}{2 \cdot g} = \sqrt{\frac{2,5 \cdot 10^{-3} \cdot 4}{0,6 \cdot 0,1^2 \cdot \pi}} \cdot \frac{1}{2 \cdot 9,81} = \underline{1,43m}$$

$$H = h_T + \frac{d}{2} + a = 1,43 + 0,05 + 2 = \underline{3,48m}$$

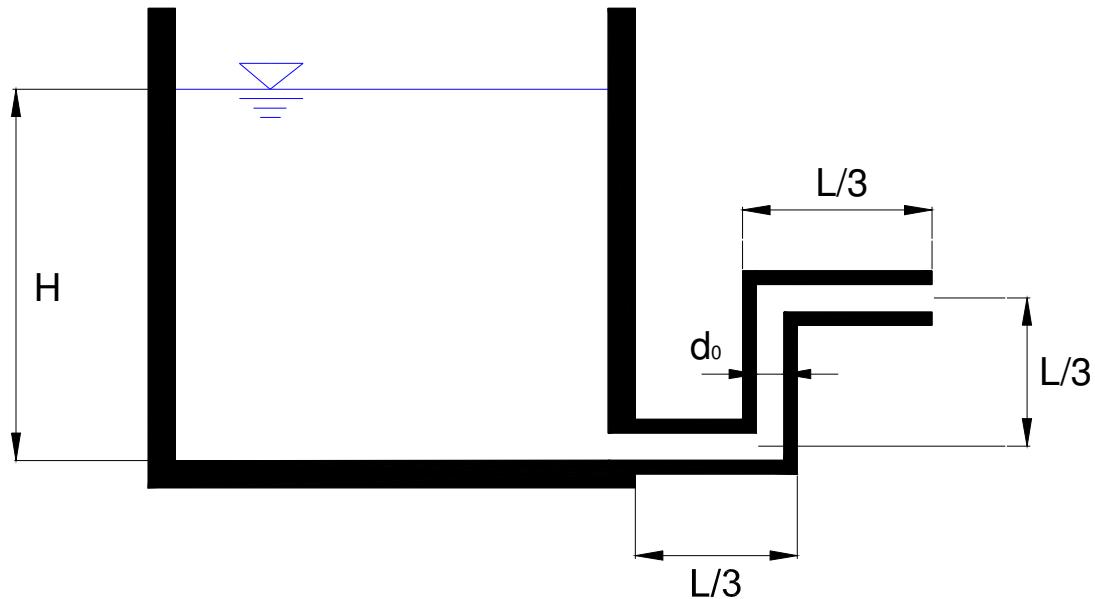
Če je  $(a + d + d/2) < H < (a + d + b)$  je naloga rešena.

$$a + d + \frac{d}{2} = \underline{2,15m}$$

$$a + d + b = \underline{3,60m}$$

Rezultat ustreza, sodelujeta samo odprtini in težiščna enačba je ustrezna.

2.19. Izračunaj dolžino cevi L tako, da bo  $\mu = 0,6$ ! Izračunaj, kdaj voda preneha iztekat iz posode!



Podatki:

$$\xi_k = 0,3$$

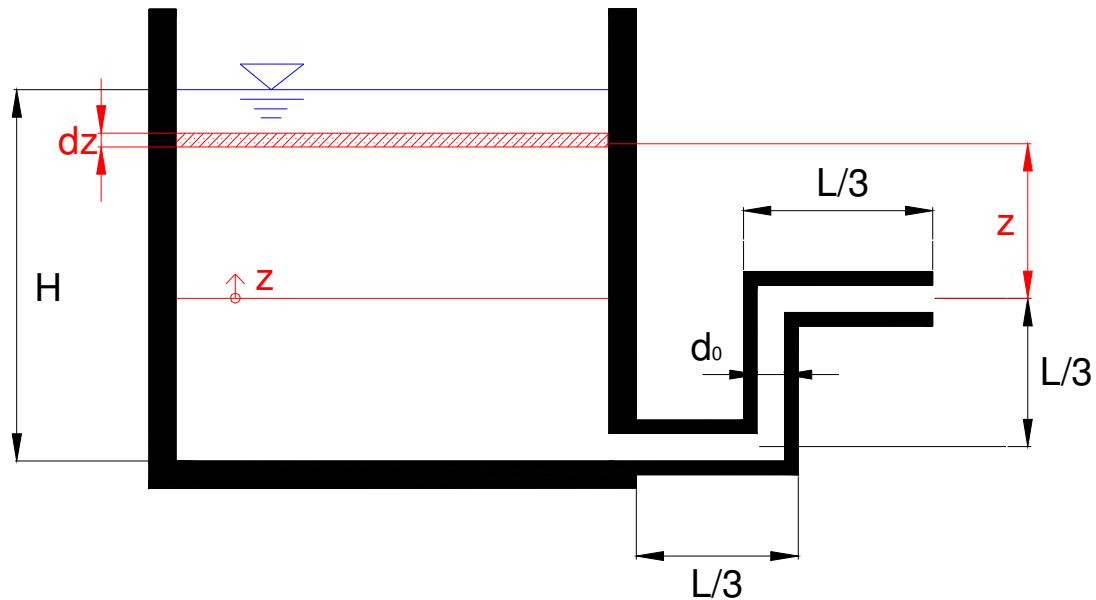
$$\lambda = 0,03$$

$$d = 0,02$$

$$H = 1m$$

$$S = 1m^2$$

Rešitev:



Meje integriranja :

$$-\int_{0,74}^0$$

$$\mu = \frac{1}{\sqrt{2 \cdot \xi_k + \frac{\lambda \cdot L}{d}}} = 0,6$$

$$\frac{1}{0,6} = \sqrt{0,6 + \frac{0,03 \cdot L}{0,02}} \Rightarrow$$

$$\Rightarrow L = \frac{\left( \sqrt{\frac{1}{0,6}} - 0,6 - 1 \right) \cdot 0,02}{0,03} = 0,785m \Rightarrow \frac{L}{3} = 26cm$$

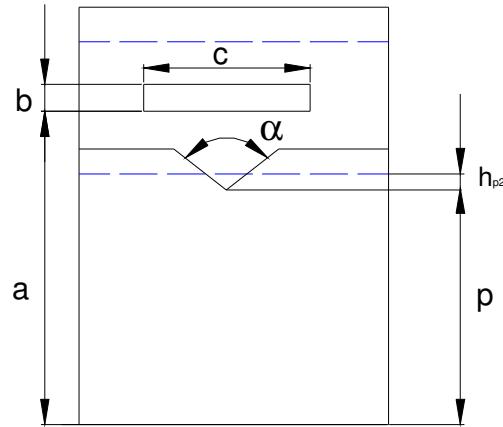
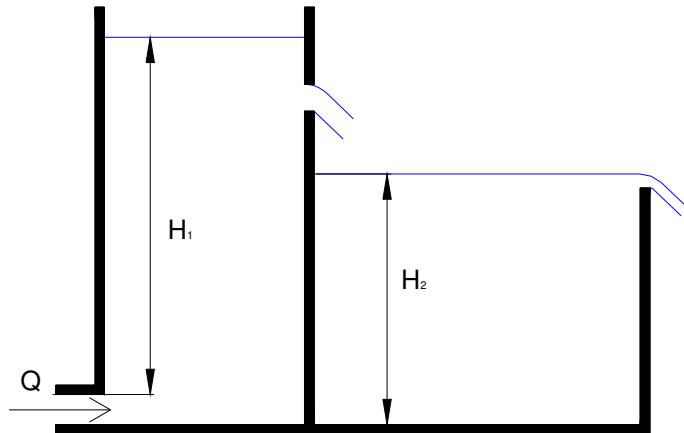
$$- S \cdot dz = \mu_0 \cdot S_0 \sqrt{2 \cdot g \cdot z} \cdot dt$$

$$- \int_{0,74}^0 \frac{dz}{\sqrt{z}} = \frac{\mu \cdot S_0}{S} \cdot \sqrt{2 \cdot g} \cdot \int_0^T dt$$

$$2 \cdot \sqrt{z} \Big|_0^{0,74} = \frac{\mu \cdot S_0}{S} \cdot \sqrt{2 \cdot g} \cdot T$$

$$T = \frac{2 \cdot \sqrt{0,74} \cdot 1}{0,6 \cdot 0,02^2 \cdot \pi \cdot \frac{4}{\sqrt{19,62}}} = 2060s$$

**2.20. Določi globino vode  $H_1$  in  $H_2$ , če v prvo posodo dovajamo  $Q = 50 \text{ l/s}$  vode in vzdržujemo stacionarno stanje!**



Podatki za OSTROROBO odprtino :

$$a = 1m$$

$$b = 5cm$$

$$c = 20cm$$

$$\mu_0 = 0,6$$

Podatki za OSTROROBI TRIKOTNI preliv :

$$\alpha = 120^\circ$$

$$p = 0,5m$$

$$\mu_p = 0,6$$

$$\overline{H_1 = ?, H_2 = ?}$$

Rešitev:

Ce velja teziscna enacba, potem :

*Odprtina :*

$$Q = \mu_0 \cdot S_0 \cdot \sqrt{2 \cdot g \cdot h_t}$$

$$h_t = \left( \frac{Q}{\mu_0 \cdot S_0} \right)^2 \cdot \frac{1}{2 \cdot g} = \left( \frac{0,05}{0,6 \cdot 0,05 \cdot 0,2?} \right)^2 \cdot \frac{1}{2 \cdot 9,81} = 3,54m$$

$$H_1 = a + \frac{b}{2} + h_t = 1,025 + 3,540 = 4,565m$$

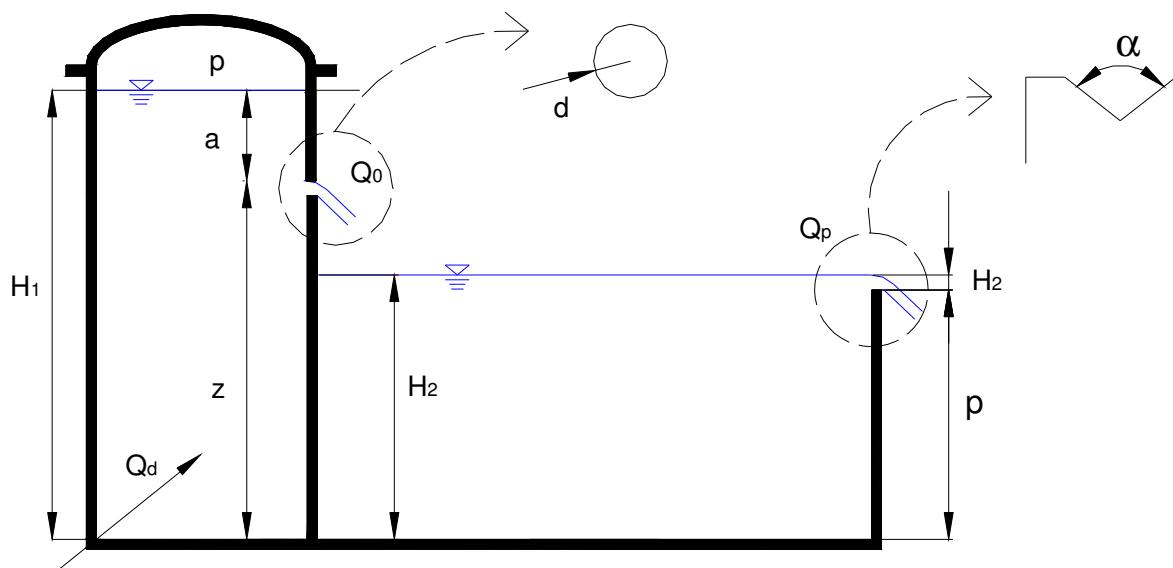
teziscna enacba velja!

Preliv :

$$Q_p = \frac{8}{15} \cdot \mu_p \cdot \operatorname{tg} \left( \frac{\alpha}{2} \right) \cdot \sqrt{2 \cdot g} \cdot h_p^{\frac{5}{2}} \Rightarrow$$
$$\Rightarrow h_p = \left[ \frac{15 \cdot Q_p}{8 \cdot \operatorname{tg} 60^\circ \cdot \sqrt{2 \cdot g}} \right]^{0,4} = 0,172m$$

$$H_2 = p + h_p = 0,5 + 0,172 = 0,672m$$

**2.21. Določi višini  $H_1$  in  $H_2$  pod pogojem, da vzdržujemo stacionarno stanje!**



Podatki:

$$Q_d = 1 \frac{l}{s}$$

$$p = 0,4 \text{ bar}$$

$$\mu_0 = \mu_p = 0,6$$

$$\alpha = 60^\circ$$

$$d = 1,25 \text{ cm}$$

$$z = 0,6 \text{ m}$$

Rešitev:

$$Q_0 = Q_p = Q$$

$$Q_0 = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot E} = \mu \cdot S_0 \cdot \sqrt{2 \cdot g \cdot (a + 4)} \Rightarrow$$

$$\Rightarrow a = \left[ \left( \frac{Q_0}{\mu \cdot S_0} \right)^2 \cdot \frac{1}{2 \cdot g} \right] - 4 = \left[ \left( \frac{0,001 \cdot 4}{0,6 \cdot 0,0125 \cdot \pi} \right)^2 \cdot \frac{1}{2 \cdot 9,81} \right] - 4 = \underline{5,4m}$$

$$H_1 = a + z = \underline{6,0m}$$

$$H_2 = b + h_p = 0,35 + 0,068 = \underline{0,418m}$$

$$Q_p = \frac{8}{15} \cdot \mu_p \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg} \left( \frac{\alpha}{2} \right) \cdot h_p^{\frac{5}{2}} \Rightarrow$$

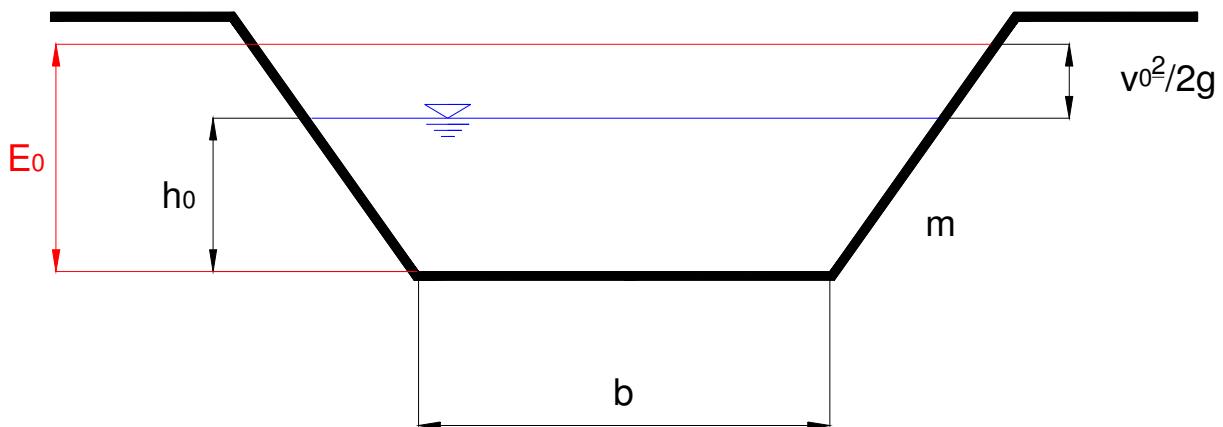
$$\Rightarrow h_p = \left[ \frac{15 \cdot Q}{8 \cdot \mu_p \cdot \sqrt{2 \cdot g} \cdot \operatorname{tg} \left( \frac{\alpha}{2} \right)} \right]^{\frac{2}{5}} = \left[ \frac{15 \cdot 0,001}{8 \cdot 0,6 \cdot \sqrt{2 \cdot 9,81} \cdot \operatorname{tg} 30^\circ} \right]^{\frac{2}{5}} = \underline{0,068m}$$

# **HIDRAVLIKA**

## **ZBIRKA REŠENIH NALOG**

3 del: TOK S PROSTO GLADINO

**3.1. Določi pretok v trapeznem koritu, kritične količine po Kolupaili ( $B$ ,  $h_{KR}$ ) in min. pripadajočo energijo!**



Podatki:

$$b = 8 \text{ m}$$

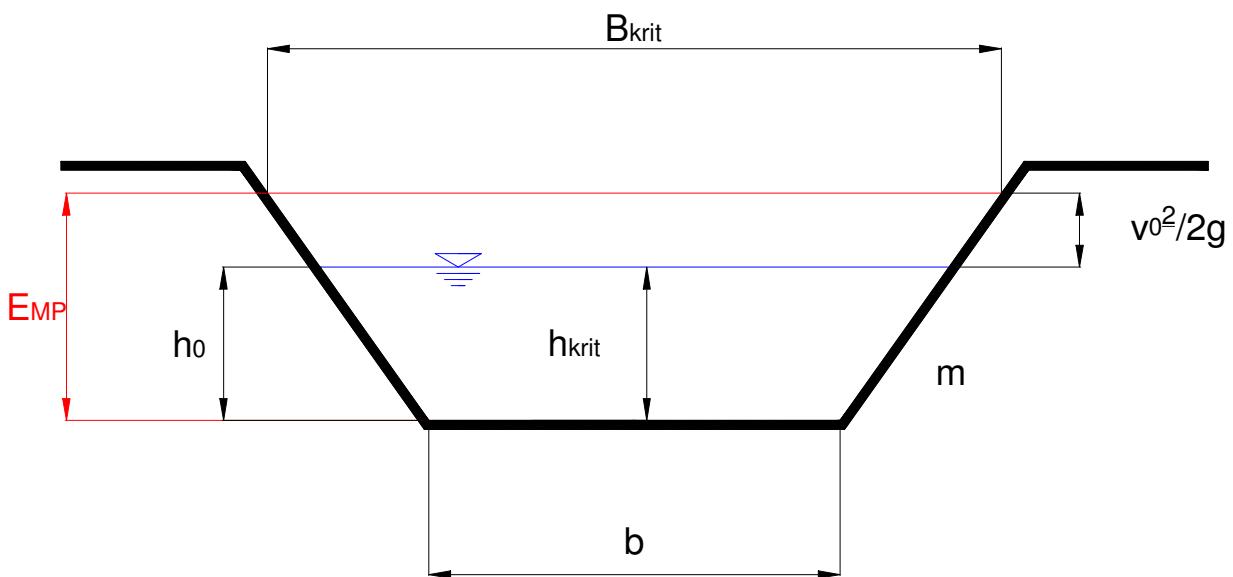
$$h_0 = 4 \text{ m}$$

$$I_0 = 0,8\%$$

$$n_G = 0,04$$

$$m = 1,5$$

Rešitev:



Dolocitev pretoka po trapeznem koritu :

$$S = b \cdot h + m \cdot h^2 = 8 \cdot 4 + 1,5 \cdot 16 = \underline{56m^2}$$

$$O = b + 2 \cdot h \sqrt{(1 + m^2)} = 8 + 2 \cdot 4 \cdot \sqrt{3,25} = \underline{22,42m}$$

$$Q = \frac{\sqrt{l_0}}{n_g} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{8 \cdot 10^{-4}}}{0,04} \cdot \frac{56^{\frac{5}{3}}}{22,42^{\frac{2}{3}}} = \underline{72,89 \frac{m^3}{s}}$$

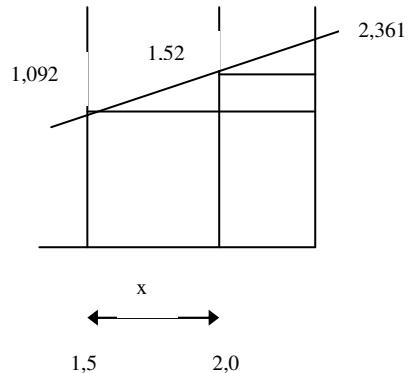
Dolocitev kriticnih kolicin po Kolupaili :

$$4 \cdot m \cdot \sqrt[3]{\frac{Q^2}{g \cdot b^5}} = 4 \cdot 1,5 \cdot \sqrt[3]{\frac{72,89^2}{9,81 \cdot 8^5}} = \underline{1,5283}$$

$$\frac{B}{b} = 1,5 \dots 1,092$$

$$\frac{B}{b} = 2,0 \dots 2,361$$

$$\frac{(2,361 - 1,092)}{(2,0 - 1,5)} = \frac{(1,528 - 1,092)}{(x - 1,5)}$$



$$1,269 \cdot (x - 1,5) = 0,218$$

$$1,269 \cdot x = 0,218 + 1,9035$$

$$\frac{B}{b} = x = 1,67$$

$$B_{KR} = 1,67 \cdot b = 1,67 \cdot 8 = \underline{13,37m}$$

$$B_{KR} = b + 2 \cdot m \cdot h_{KR} \Rightarrow \text{izrazim } h_{KR}$$

$$h_{KR} = \frac{B_{KR} - b}{2 \cdot m} = \frac{13,37 - 8}{3} = \underline{1,79m}$$

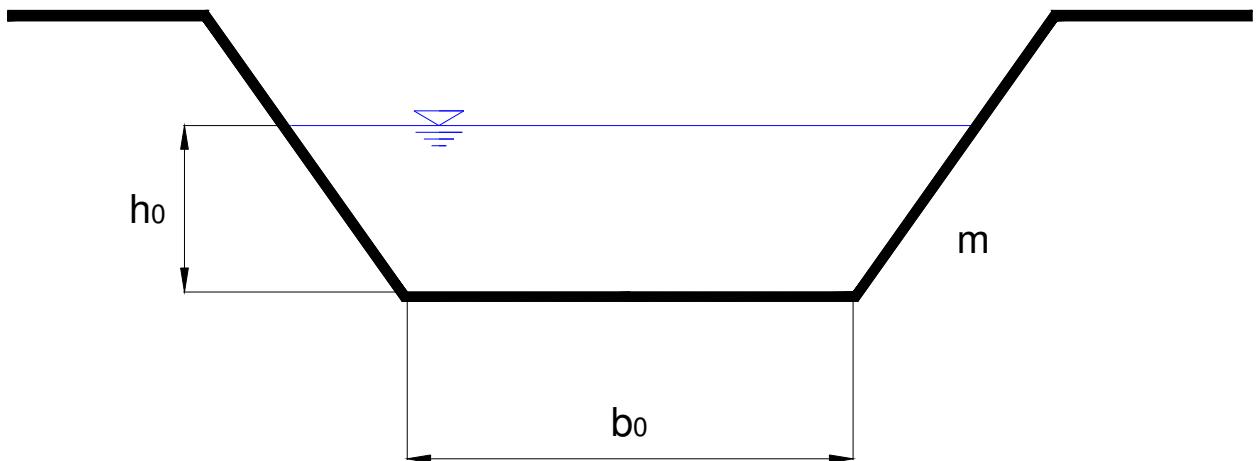
$E_{MP}$  :

$$S_{KR} = b \cdot h_{KR} + m \cdot h_{KR}^2 = 8 \cdot 1,79 + 1,5 \cdot 1,79^2 = \underline{19,13m^2}$$

$$V_{KR} = \frac{Q}{S_{KR}} = \frac{7289}{19,13} = \underline{3,81 \frac{m}{s}}$$

$$E_{MP} = h_{KR} + \frac{V_{KR}}{2} = \underline{2,52m}$$

**3.2. Določi pretok po trapeznem koritu, kritično globino po Kolupaili in pripadajočo min. energijo  $E_{min}$ !**



Podatki:

$$I_0 = 2\% \text{ oo}$$

$$b_0 = 10 \text{ m}$$

$$h_0 = 2 \text{ m}$$

$$m = 1,5$$

$$n_G = 0,022$$

Rešitev:

Dolocitev pretoka po trapeznem koritu :

$$Q = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{2 \cdot 10^{-3}}}{0,022} \cdot \frac{26^{\frac{5}{3}}}{17,21^{\frac{2}{3}}} = 69,6 \frac{\text{m}^3}{\text{s}}$$

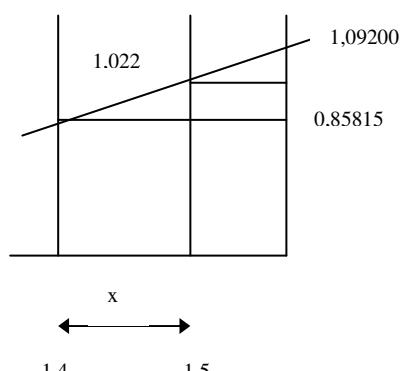
$$S = b_0 \cdot h + mh_0^2 = 10 \cdot 2 + 1,5 \cdot 4 = 26 \text{ m}^2$$

$$O = b_0 + 2 \cdot h \sqrt{1 + m^2} = 10 + 2 \cdot 2 \cdot \sqrt{3,25} = 17,21 \text{ m}$$

Dolocitev kriticnih kolicin po Kalupaili :

$$4 \cdot m \cdot \sqrt[3]{\frac{Q^2}{g \cdot b^5}} = 4 \cdot 1,5 \cdot \sqrt[3]{\frac{69,6^2}{9,81 \cdot 10^5}} = 1,0217$$

$B/b$	
1,4	0,85815
1,5	1,09200



$$\frac{x}{1,0217 - 0,85815} = \frac{0,1}{1,09200 - 0,85815}$$

$$x = 0,07$$

$$\frac{B}{b} = 1,47$$

$$B = \underline{14,7\text{m}}$$

$$B_{KR} = b + 2 \cdot m \cdot h_{KR}$$

$$h_{KR} = \frac{B - b}{2 \cdot m} = \frac{4,7}{3} = \underline{1,56\text{m}}$$

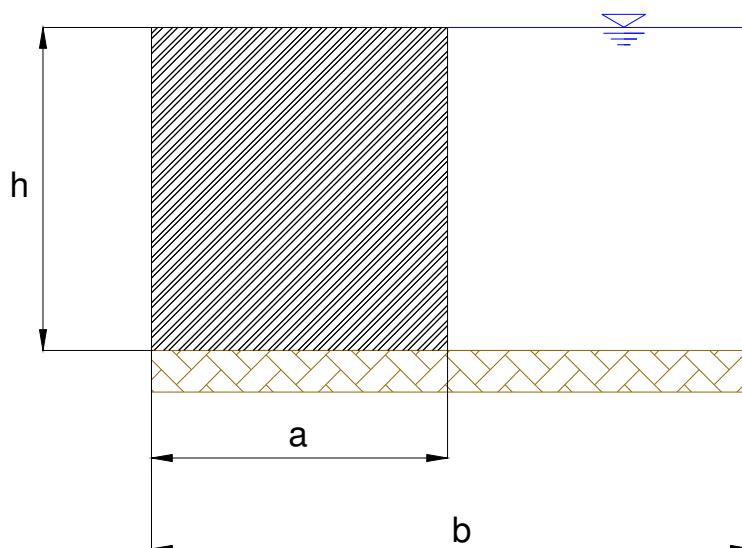
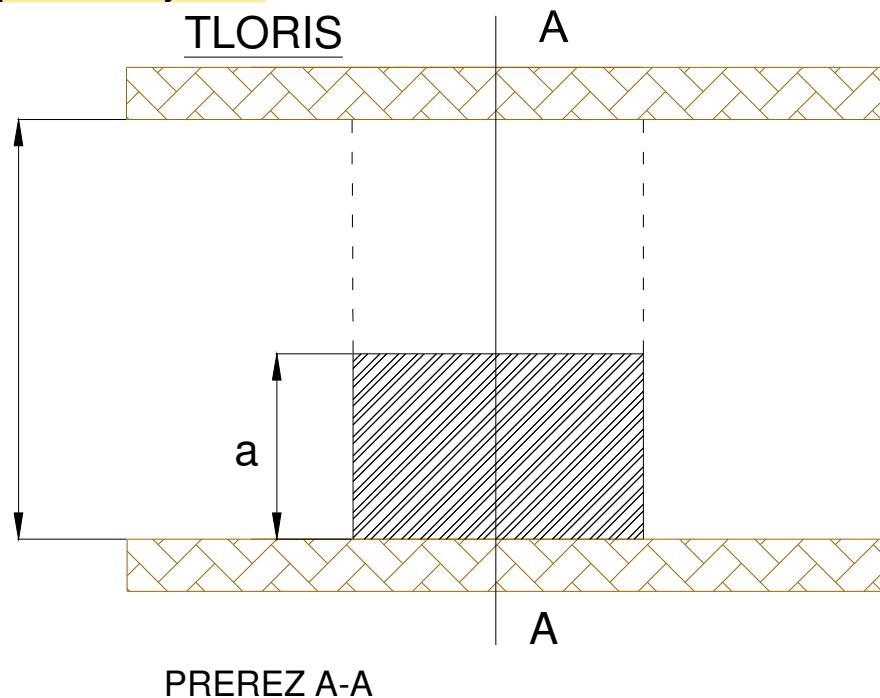
Izracun pripadajoce minimalne energije  $E_{\min\text{prip}}$  :

$$S_{KR} = b \cdot h_{KR} + m \cdot h_{KR}^2 = 10 \cdot 1,56 + 1,5 \cdot 1,56^2 = \underline{19,28\text{m}^2}$$

$$v_{KR} = \frac{Q}{S_{KR}} = \frac{69,6}{19,28} = 3,61 \frac{\text{m}}{\text{s}}$$

$$E_{\min\text{prip}} = h_{KR} + \frac{v_{KR}^2}{2 \cdot g} = 1,56 + \frac{3,61^2}{2 \cdot 9,81} = \underline{2,22\text{m}}$$

**3.3. Pravokotno korito želimo zaradi gradbene jame zožiti za polovico. Ali pri tem pride do zajezebe? Kolikšna je največja dovoljena zožitev korita, da še ne pride do zajezebe?**



Podatki:

$$b = 14\text{m}$$

$$h = 6,50\text{m}$$

$$a = 7\text{m}$$

$$I_0 = 2\%$$

$$n_g = 0,025$$

$$\underline{\underline{\text{zajezeba} = ?, a_{\max} = ?}}$$

Rešitev:

Izracun razpolozljive energije :

$$S = b \cdot h = 91m^2$$

$$O = b + 2 \cdot h = 27m$$

$$Q = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{2 \cdot 10^{-3}}}{0,025} \cdot \frac{91^{\frac{5}{3}}}{27^{\frac{2}{3}}} = 365,9 \frac{m^3}{s}$$

$$v = \frac{Q}{S} = \frac{365,9}{91} = 4,0 \frac{m}{s}$$

$$\frac{v^2}{2 \cdot g} = 0,82m$$

$$E = 6,5 + 0,82 = 7,32m$$

Izracun kriticnih kolicin :

$$\frac{Q^2 \cdot B}{g \cdot S^3} = 1$$

$$\frac{Q^2}{g \cdot (b_n^2 \cdot h_k)^3} = 1$$

$$h_k = \sqrt[3]{\frac{Q^2}{b_n^2 \cdot g}}$$

$$\frac{Q^2}{b^2 \cdot h_k^2 \cdot 2 \cdot g} + h_k = E$$

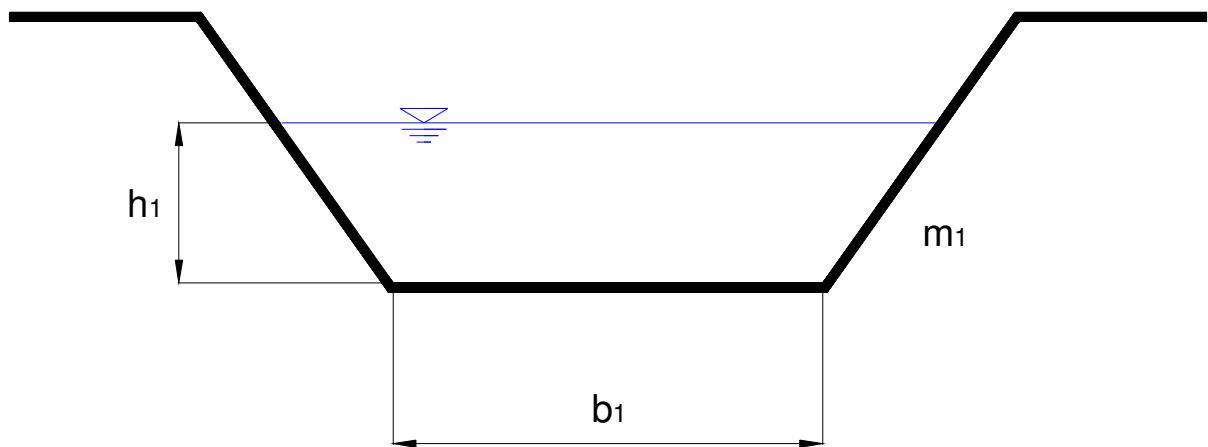
$$3 \cdot Q^2 = 3 \cdot g^{\frac{1}{3}} \cdot E \cdot Q^{\frac{4}{3}} \cdot b^{\frac{2}{3}}$$

$$b_{\min} = \frac{3 \cdot Q^{\frac{2}{3}}}{\left(2 \cdot g^{\frac{1}{3}} \cdot E\right)^{1,5}} = \frac{3 \cdot 365,9^{\frac{2}{3}}}{\left(2 \cdot 9,81^{\frac{1}{3}} \cdot 7,32\right)^{1,5}} = 11,64m$$

$$a_{\max} = b - b_{\min} = 14 - 11,64 = 2,56m$$

Do zajeze pride.

**3.4. Pretok, ki ga prevaja jarek trapezne oblike, želimo speljati skozi cevni prepust. Kakšno cev bomo uporabili za izdelavo prepusta, če cev ne sme biti bolj polna od 70%?**



Podatki:

$$b_1 = 2m$$

$$h_1 = 1,25m$$

$$I_{01} = 6\%$$

$$n_{G1} = 0,04$$

$$I_{02} = 1\%$$

$$n_{G2} = 0,03$$

$$m = 1,5$$

$$\frac{h}{D} = 0,7$$

MOZNI TIPI CEVI:

Φ100

Φ150

Φ200

Φ250

Φ300

Φ400

Rešitev:

Izracun pretoka po trapeznem koritu :

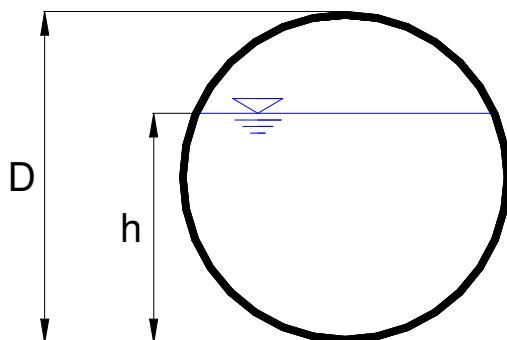
$$Q = \frac{\sqrt{I_{01}}}{n_{G1}} \cdot \frac{S^{\frac{5}{2}}}{O^{\frac{3}{2}}}$$

$$S = b \cdot h + m \cdot h_1^2 = 2 \cdot 1,25 + 1,5 \cdot 1,25^2 = 4,84 \text{ m}^2$$

$$O = b + 2 \cdot h \cdot \sqrt{1 + m^2} = 2 + 2 \cdot 1,25 \cdot \sqrt{3,25} = 6,51 \text{ m}$$

$$Q = \frac{\sqrt{6 \cdot 10^{-3}}}{0,04} \cdot \frac{4,84^{\frac{5}{2}}}{6,51^{\frac{3}{2}}} = 7,69 \frac{\text{m}^3}{\text{s}}$$

Izracun premera cevi, ki prevaja isti pretok :



$$Q_{pTIP} = \frac{1}{n_{G2}} \cdot \sqrt{I_{02}} \cdot D^{\frac{8}{3}} \cdot a$$

$$\frac{h}{D} = 0,7 \Rightarrow a = 0,2611$$

$$D = \left( \frac{Q \cdot n_{G2}}{\sqrt{I_{02}} \cdot a} \right)^{\frac{3}{8}} = \left( \frac{7,69 \cdot 0,03}{\sqrt{1 \cdot 10^{-3}} \cdot 0,2611} \right)^{\frac{3}{8}} = 3,48$$

TIP  $\Phi 400$ .

**3.5. (\*) Po trikotnem koritu teče  $Q_1$  vode. Določi  $n_G$  v prvotnem koritu, globino  $h_2$ , če pretok povečamo na  $Q_2$  in preveri, če pride do zajezbe, če plaz zasuje polovico prereza!**

Podatki:

$$h_1 = 4,0 \text{ m}$$

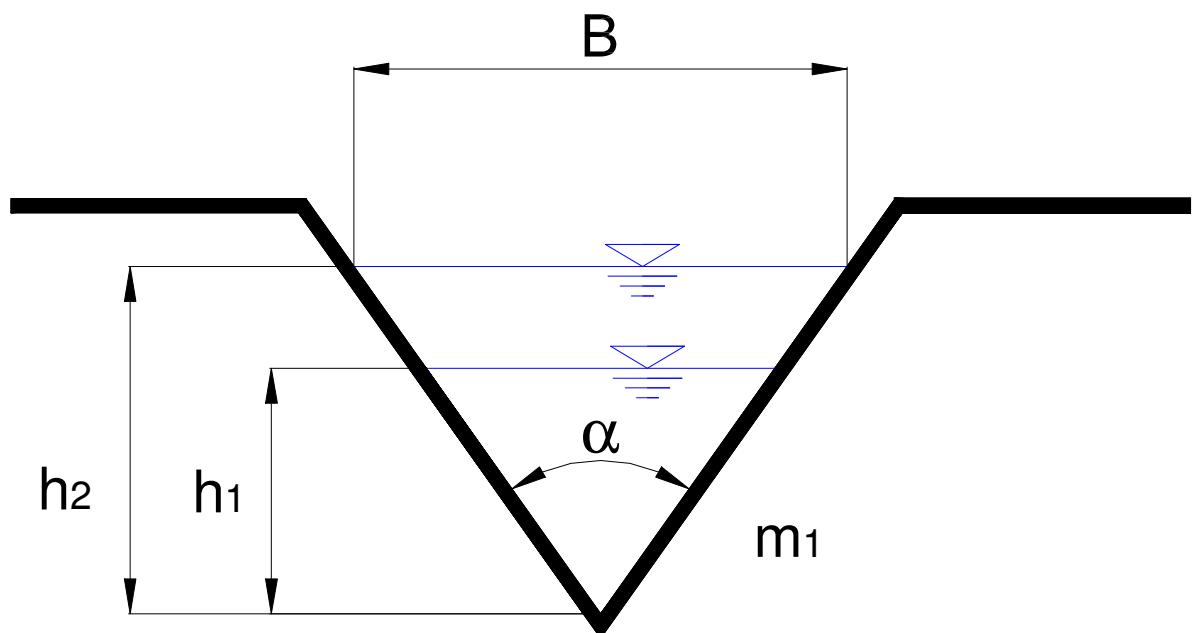
$$I_0 = 1\%_{oo}$$

$$\alpha = 90^\circ$$

$$Q_1 = 25 \frac{\text{m}^3}{\text{s}}$$

$$Q_2 = 80 \frac{\text{m}^3}{\text{s}}$$

$$n_G = ?, h_2 = ?, E_{razp} < > E_{potr} = ?$$



Rešitev:

a) Določitev  $n_G$  po prvotnem koritu :

$$S = \frac{B \cdot h_1}{2} = 16m^2 \Rightarrow S = h_1^2$$

$$O = 2 \cdot h_1 \cdot \sqrt{2} = 11,31m \Rightarrow O = 2 \cdot \sqrt{2} \cdot h_1$$

$$Q_1 = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} \Rightarrow n_G = \frac{\sqrt{I_0}}{Q_1} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{1 \cdot 10^{-3}}}{25} \cdot \frac{16^{\frac{5}{3}}}{11,31^{\frac{2}{3}}} = \frac{3,21}{126} = \underline{0,0255}$$

b) Določitev  $h_2$ , ce povecamo pretok na  $Q_2$  :

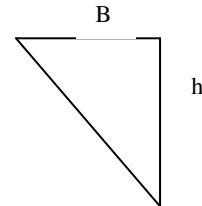
$$Q_2 = \frac{\sqrt{I_0}}{n_G} \cdot \frac{h_2^{\frac{10}{3}}}{(2 \cdot \sqrt{2})^{\frac{2}{3}} \cdot h_2^{\frac{2}{3}}} \Rightarrow h_2 = \left( \frac{80 \cdot 0,0255 \cdot (2 \cdot \sqrt{2})^{\frac{2}{3}}}{\sqrt{1 \cdot 10^{-3}}} \right)^{\frac{3}{8}} = \underline{6,19m}$$

c) zaježba :

$$E_{razp} = h_2 + \frac{v_2^2}{2 \cdot g} = 6,19 + 0,22 = \underline{6,41m}$$

$$v_2 = \frac{Q_2}{S_2} = \frac{80}{38,28} = \underline{2,09 \frac{m}{s}}$$

$$S_2 = h_2^2 = 6,19^2 = \underline{38,28m^2}$$

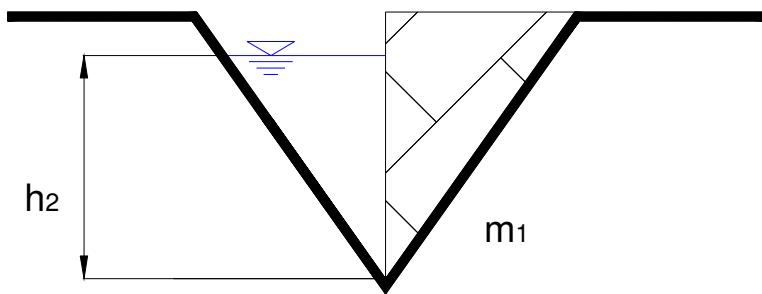


$$E_{min\ poti} = h_{krit} + \frac{v_{krit}^2}{2 \cdot g} = 5,54 + 1,385 = 6,92 > E_{razp} \Rightarrow \underline{zaježba bo!}$$

Izracun kriticnih kolicin :  $Fr = 1$

$$\frac{Q^2 \cdot B}{g \cdot S^3} = 1$$

$$\frac{Q^2 \cdot h_{krit}}{g \cdot \left(\frac{h_{krit}}{2}\right)^3} = 1$$

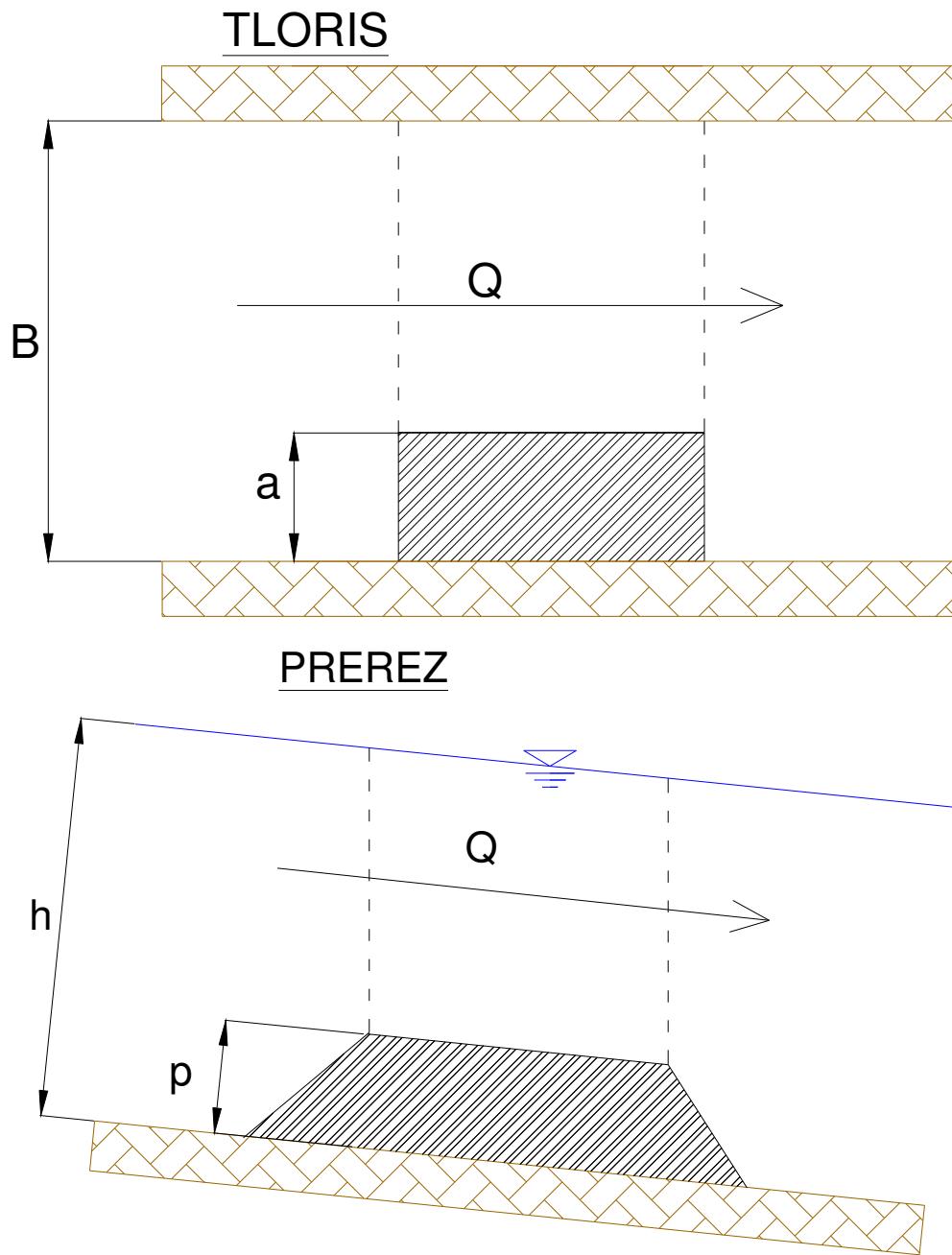


$$\frac{Q^2 \cdot 8 \cdot h_{krit}}{g \cdot h_{krit}^6} = 1$$

$$h_{krit} = \sqrt[5]{\frac{Q^2 \cdot 8}{g}} = \sqrt[5]{\frac{80^2 \cdot 8}{9,81}} = 5,54m$$

$$v_{krit} = \frac{Q}{S_{krit}} = \frac{80}{\frac{b \cdot h_{krit}}{2}} = \frac{80 \cdot 2}{h_{krit}^2} = 5,21 \frac{m}{s}$$

**3.6. Določi najvišji prag p ob hkratni zožitvi struge, da še ne pride do zajezbe!**



Podatki:

$$I_0 = 0,6\%$$

$$n_G = 0,03$$

$$B = 15m$$

$$a = 2m \text{ ali } 4m$$

$$h = 6m$$

$$\frac{b_{\max}}{b} = ?$$

Rešitev:

Izracun razpolozljive energije:

$$Q = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{2}}}{O^{\frac{2}{3}}} = \frac{\sqrt{6 \cdot 10^{-4}}}{0,03} \cdot \frac{90^{\frac{5}{3}}}{27^{\frac{2}{3}}} = 164 \frac{m^3}{s}$$

$$v = \frac{Q}{S} = \frac{164}{90} = 18,82 \frac{m}{s}$$

$$E = h + \frac{v^2}{2 \cdot g} = 6 + \frac{1,82^2}{2 \cdot 9,81} = 6,17 m$$

zajezba pri a = 2m :

$$b_2 = B - a = 13 m$$

$$h_{krit} = \sqrt[3]{\frac{Q^2}{g \cdot b_2^2}} = \sqrt[3]{\frac{164^2}{9,81 \cdot 13^2}} = 2,53 m$$

$$v_{krit} = \frac{Q}{b_2 \cdot h_{krit}} = \frac{164}{13 \cdot 2,53} = 4,98 \frac{m}{s}$$

$$E_{min\ poti} = 2,53 + \frac{4,98^2}{19,62} = 3,80 m$$

$$E = E_{min\ poti} + p_{max}$$

$$p_{max} = 6,17 m - 3,80 m = 2,37 m$$

zajezba pri a = 4 m :

$$b_2 = 11 m$$

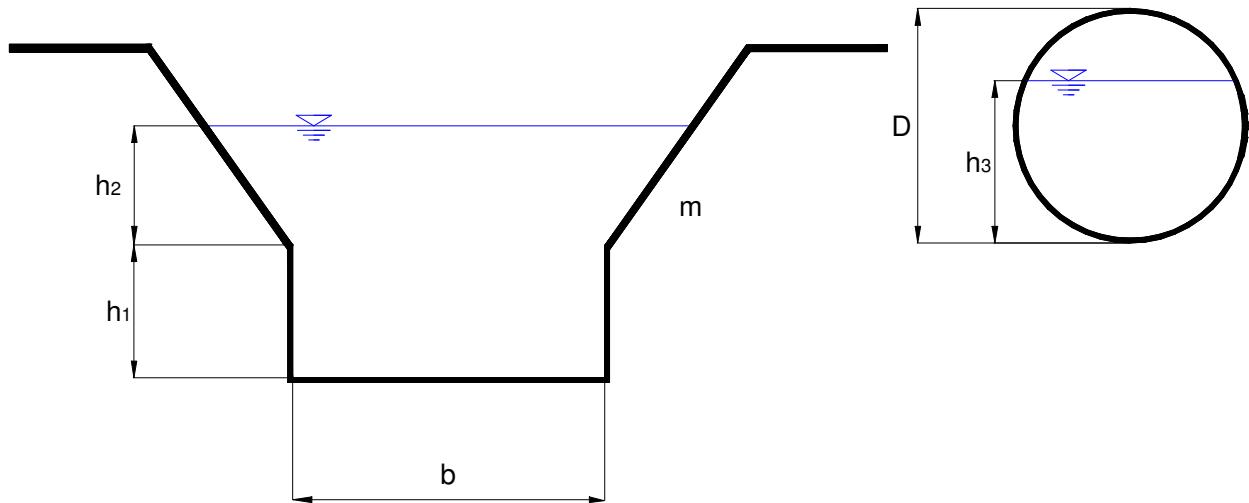
$$h_{krit} = 2,83 m$$

$$v_{krit} = 5,26 m$$

$$E_{min\ pot} = 4,24 m$$

$$p_{max} = 1,92 m$$

**3.7. Dimenzioniraj prepust ( $D=?$ ), ki bi prevajal enak pretok kot sestavljeni korito pod pogojem, da je  $\frac{h_3}{D} \leq 0,75!$**



Podatki:

$$n_{G1} = 0,03$$

$$n_{G2} = 0,02$$

$$I_{01} = 0,8\%$$

$$I_{02} = 1\%$$

$$b = 2m$$

$$h_1 = 0,5m$$

$$h_2 = 2m$$

$$m = 1,5$$

$$\left| \frac{h_3}{D_{\max}} \right| = 0,75$$

Rešitev:

Izracun pretoka po sestavljenem koritu :

$$S = b \cdot (h_1 + h_2) + m \cdot h_2^2 = 2 \cdot 2,25 + 1,5 \cdot 4 = \underline{11m^2}$$

$$O = b + 2 \cdot h_1 + 2 \cdot h_2 \sqrt{(1 + m^2)} = 2 + 1 + 4 \cdot \sqrt{3,25} = \underline{10,21m}$$

$$Q = \frac{\sqrt{I_{01}}}{n_{G1}} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{0,8 \cdot 10^{-3}}}{0,03} \cdot \frac{11^{\frac{5}{3}}}{10,21^{\frac{2}{3}}} = \underline{10,9 \frac{m^3}{s}}$$

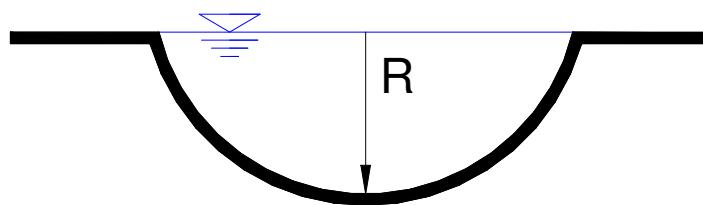
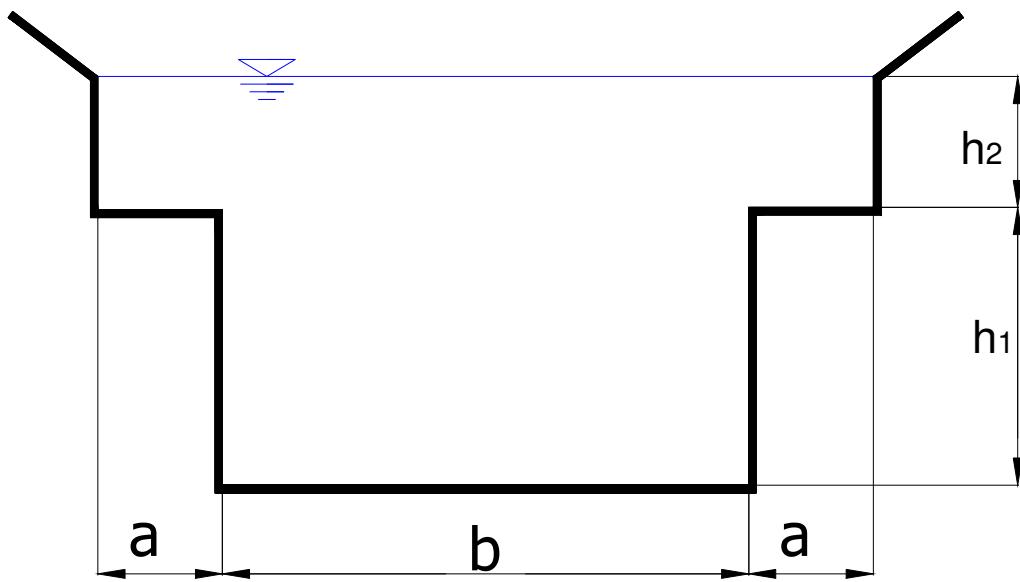
Izracun cevi, ki prevaja isti pretok :

$$\frac{h}{D} = 0,75 \Rightarrow \underline{a = 0,2843}$$

$$Q = \frac{1}{n_g} \cdot \sqrt{I_{02}} \cdot D^{\frac{3}{8}} \cdot a$$

$$D = \left( \frac{Q \cdot n_{G2}}{\sqrt{I_{02}} \cdot a} \right)^{\frac{3}{8}} = \left( \frac{10,9 \cdot 0,02}{\sqrt{0,001} \cdot 0,2843} \right)^{0,375} = \underline{3,31m}$$

**3.8. Določi pretok po koritu! Določi dimenzije polkrožnega korita, ki pri istem padcu  $I_0$  in koeficientu  $n_G$  prevaja enak pretok!**



Podatki:

$$I_0 = 0,6 \text{ ‰}$$

$$b = 3m$$

$$c = 1m$$

$$h_1 = 1,5m$$

$$h_2 = 0,75m$$

$$n_G = 0,03$$

Reševanje:

Izracun pretoka po sestavljenem koritu :

$$S = b \cdot h_1 + (b + 2 \cdot c) \cdot h_2 = 3 \cdot 1,5 + 5 \cdot 0,75 = \underline{8,25 m^2}$$

$$O = b + 2 \cdot h_1 + 2 \cdot c + 2 \cdot h_2 = 3 + 3 + 2 + 1,5 = \underline{9,5 m}$$

$$Q = \frac{\sqrt{I_0} \cdot S^{\frac{5}{3}}}{n_G \cdot O^{\frac{2}{3}}} = \frac{\sqrt{0,6 \cdot 10^{-3}} \cdot \frac{8,25^{\frac{5}{3}}}{9,5^{\frac{2}{3}}}}{0,03} = 6,19 \frac{m^3}{s}$$

Izracun polmera polkroznega korita, ki ustreza pogojema :

$$O = 2 \cdot \pi \cdot R$$

$$S = \pi \cdot R^2$$

$$O = \pi \cdot R$$

$$S = \frac{\pi \cdot R}{2}$$

$$Q = \frac{\sqrt{I_0} \cdot \left( D^2 \cdot \frac{\pi}{8} \right)^{\frac{5}{3}}}{n_G \cdot \left( \pi \cdot \frac{D}{2} \right)^{\frac{2}{3}}} = \frac{\sqrt{I_0} \cdot \left( R^{\frac{10}{3}} \cdot \left( \frac{\pi}{2} \right)^{\frac{5}{3}} \right)}{n_G \cdot (\pi \cdot R)^{\frac{2}{3}}} = \frac{\sqrt{I_0} \cdot \left( \frac{\pi}{2} \right)^{\frac{5}{3}}}{n_G \cdot \pi^{\frac{2}{3}}} \cdot R^{\frac{8}{3}} \Rightarrow izrazimo.R$$

$$R = \left( \frac{Q \cdot n_G \cdot \pi^{\frac{2}{3}}}{\sqrt{I_0} \cdot \left( \frac{\pi}{2} \right)^{\frac{5}{3}}} \right)^{\frac{3}{8}} = \left( \frac{6,19 \cdot 0,03 \cdot \pi^{\frac{2}{3}}}{\sqrt{0,6 \cdot 10^{-3}} \cdot \left( \frac{\pi}{2} \right)^{\frac{5}{3}}} \right)^{\frac{3}{8}} = \underline{2,15 m}$$

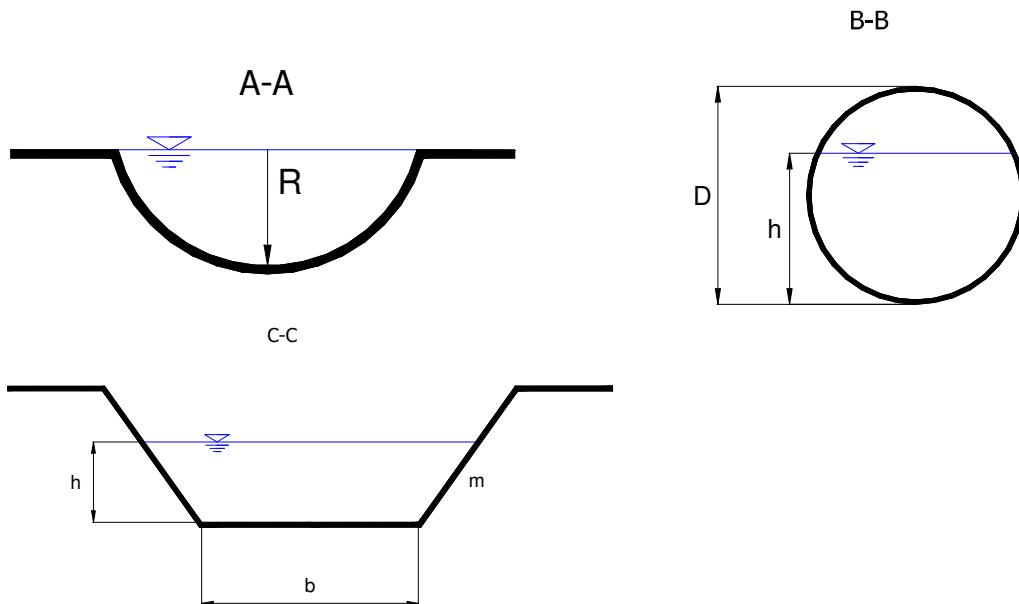
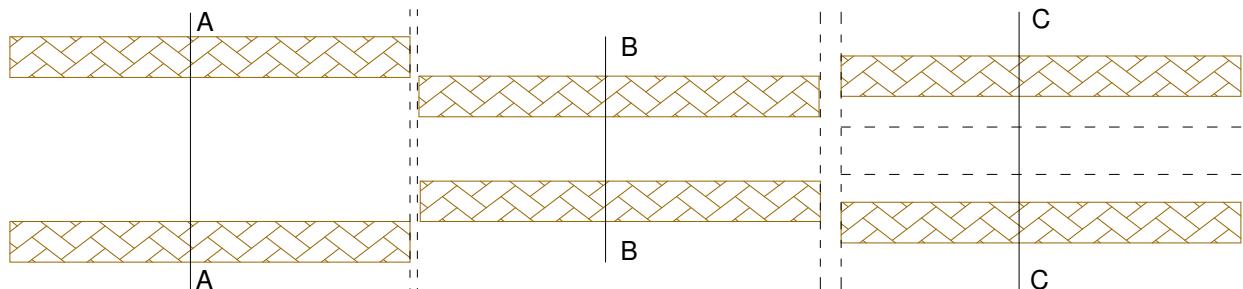
Kontrola:

$$Q = \frac{\sqrt{0,6 \cdot 10^{-3}} \cdot 7,24^{\frac{5}{3}}}{0,03 \cdot 6,74^{\frac{2}{3}}} = \frac{0,663}{0,1071} = 6,19 \frac{m^3}{s}$$

$$S = \frac{2,15^2 \cdot \pi}{2} = 7,24$$

$$O = \pi \cdot 2,15 = 6,74$$

**3.9. Korito polkrožnega prereza je s cevnim prepustom povezano s HIDRAVLično NAJUGODNEJŠIM trapeznim koritom, ki prevaja enak pretok! Dimenzioniraj trapezno korito. Dimenzioniraj prepust, da bo pod pogojem  $\frac{H}{D} \leq 0,75$  prevajal izračunani pretok!**



Podatki:

$$R = 1\text{ m}$$

$$I_{01} = 2\%$$

$$I_{02} = 1\%$$

$$I_{03} = 1,5\%$$

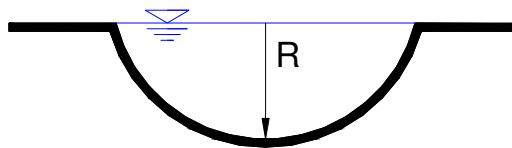
$$n_{G1} = 0,025$$

$$n_{G2} = 0,018$$

$$n_{G3} = 0,03$$

Rešitev:

A-A



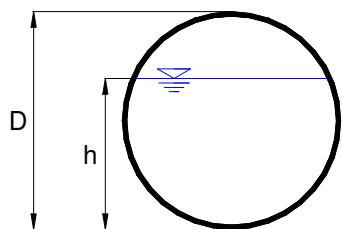
a) Dolocitev pretoka po polkroznem koritu :

$$S_1 = \frac{D^2 \cdot \pi}{4 \cdot 2} = 1,57 m^2$$

$$Q_1 = R \cdot \pi = 3,14 m$$

$$Q_1 = \frac{\sqrt{I_{01}}}{n_{G1}} \cdot \frac{S_1^{\frac{5}{2}}}{O_1^{\frac{3}{2}}} = 1,77 \frac{m^3}{s}$$

B-B



b) Dolocitev cevi, ki prevaja isti pretok kot osnovno korito :

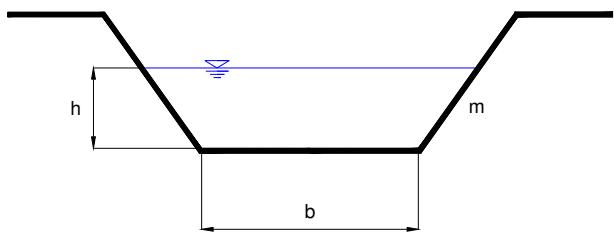
$$\frac{H}{D} = 0,75 \Rightarrow a = 0,2848$$

$$Q = \frac{\sqrt{I_{02}}}{n_{G2}} \cdot D^{\frac{8}{3}} \cdot a$$

$$D = \left( \frac{n_{G2} \cdot Q}{\sqrt{I_{02}} \cdot a} \right)^{\frac{3}{8}} = D = \left( \frac{1,77 \cdot 0,018}{\sqrt{10^{-3}} \cdot 0,2848} \right)^{\frac{3}{8}} = 1,61 m$$

Izberemo  $\Phi 200$ .

C-C



c) Dolocitev HNK trapezne oblike, ki prevaja isti pretok kot osnovno korito :

$$S_3 = \frac{3 \cdot b^2 \cdot \sqrt{3}}{4}$$

$$O_3 = 3 \cdot b$$

$$h = \frac{b \cdot \sqrt{3}}{2}$$

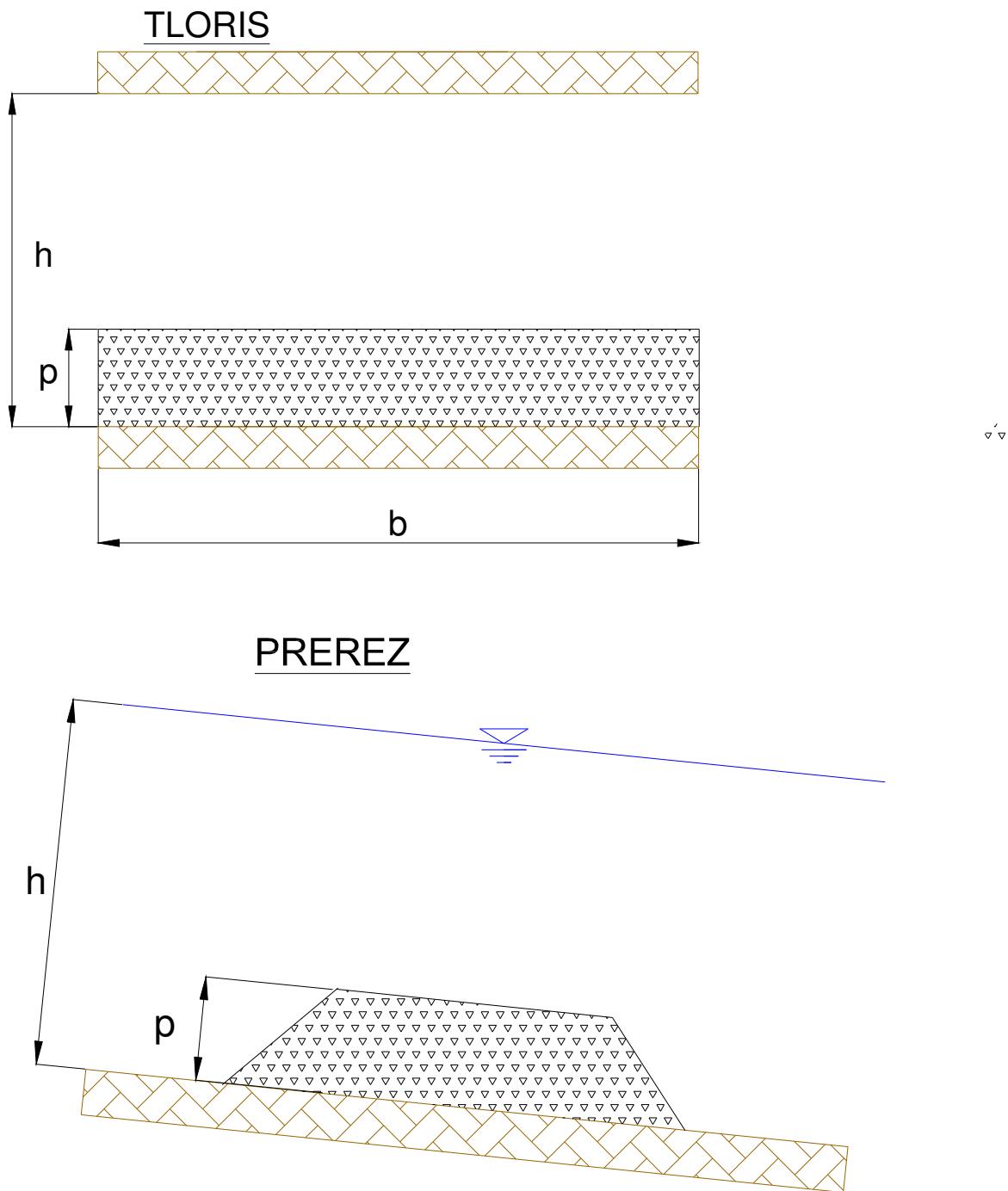
$$Q = \frac{\sqrt{I_{03}}}{n_{G3}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)^{\frac{5}{3}} \cdot \frac{b^{\frac{10}{3}}}{3^{\frac{10}{3}} \cdot b^{\frac{2}{3}}}$$

$$b = \left( \frac{Q \cdot n_{G3} \cdot 3^{\frac{2}{3}}}{\sqrt{I_{03}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)^{\frac{5}{3}}} \right)^{\frac{3}{8}}$$

$$b = 1,26m$$

$$h = 1,09m$$

**3.10. Ali prag višine  $p$  povzroči zaježbo v pravokotnem koritu? Kolikšna je višina  $p_{max}$ , ki še ne povzroči zajeze?**



Podatki:

$$b = 12\text{m}$$

$$h = 5\text{m}$$

$$p = 1\text{m}$$

$$I_0 = 3\%$$

$$n_G = 0,03$$

Rešitev:

Izracun razpolozljive energije :

$$S = b \cdot h = 60m^2$$

$$O = b + 2 \cdot h = 22m$$

$$Q = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{3 \cdot 10^{-3}}}{0,03} \cdot \frac{60^{\frac{5}{3}}}{22^{\frac{2}{3}}} = 213,8 \frac{m^3}{s}$$

$$v = \frac{Q}{S} = \frac{213,8}{60} = 3,56 \frac{m}{s}$$

$$E = h + \frac{v^2}{2 \cdot g} = 5 + \frac{3,56^2}{2 \cdot 9,81} = 5,65m$$

Izracun kriticnih kolicin in  $p_{max}$  :

$$Fr^2 = 1$$

$$\frac{Q^2 \cdot b}{g \cdot S^3} = 1$$

$$h_{krit} = \sqrt[3]{\frac{Q^2}{b^2 \cdot g}} = \sqrt[3]{\frac{213,8^2}{12^2 \cdot 9,81}} = 3,38m$$

$$v = \frac{Q}{b \cdot h_{krit}} = \frac{213,8}{12 \cdot 3,38} = 5,60 \frac{m}{s}$$

$$\frac{v^2}{2 \cdot g} = 1,59m$$

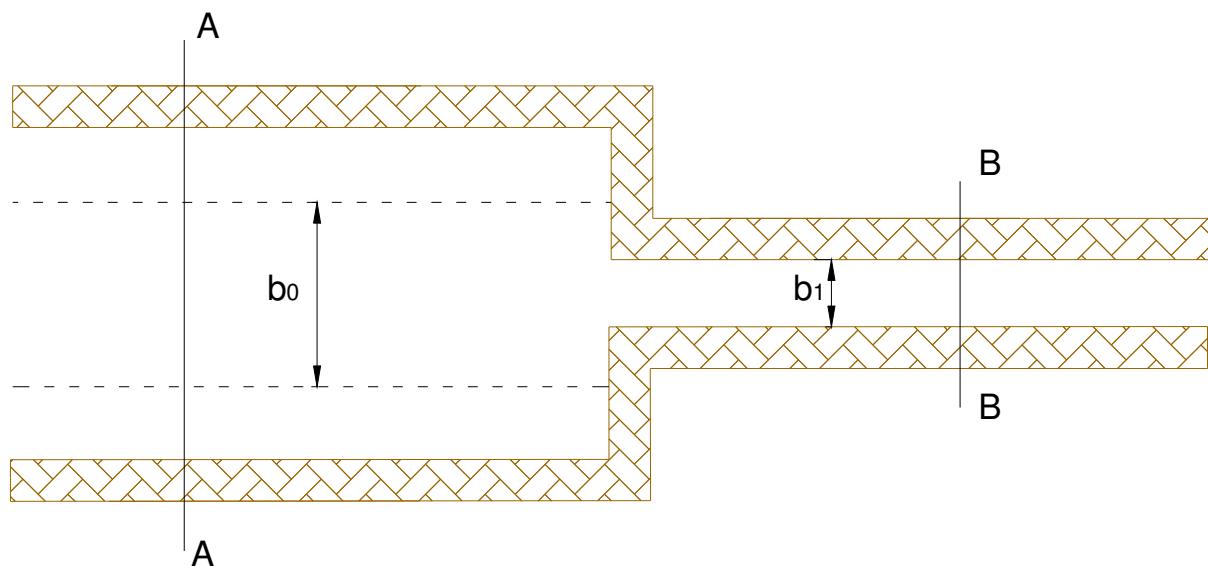
$$E = h_{krit} + \frac{v^2}{2 \cdot g} + p_{max}$$

$$p_{max} = E - h_{krit} - \frac{v^2}{2 \cdot g} = 5,60 - 3,38 - 1,59 = 0,68m < 1m = p$$

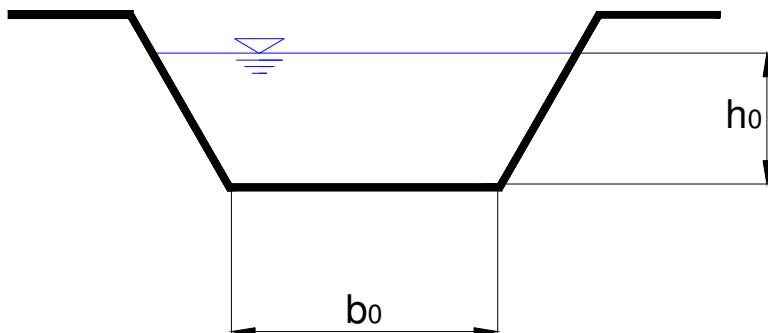
Prag povzroci zajezbo!

**3.11. Trapezno korito se zoži v korito pravokotnega prereza. Ali pri danih podatkih pride do zajezebe?**

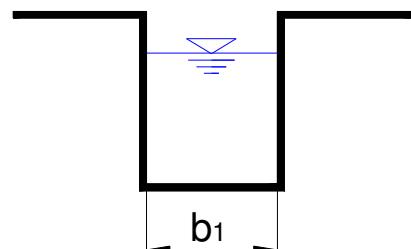
TLORIS



PREREZ A-A



PREREZ B-B



Podatki:

$$I_0 = 1,2 \text{ ‰}$$

$$n_g = 0,031$$

$$b_0 = 14 \text{ m}$$

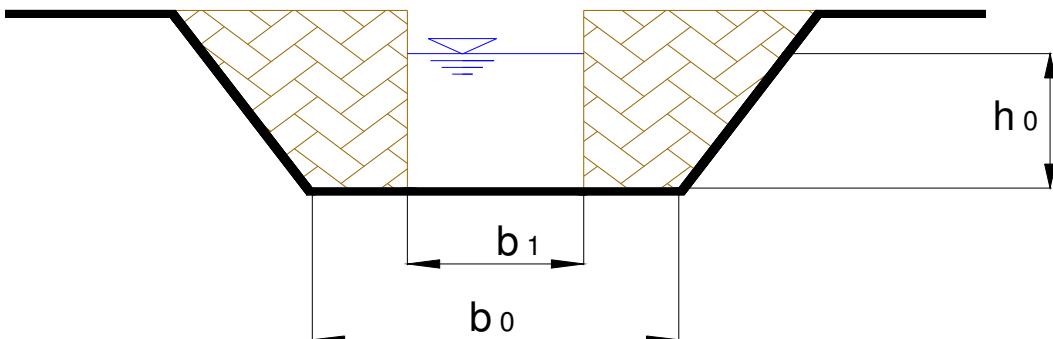
$$h_0 = 4,30 \text{ m}$$

$$m = 1,5$$

$$b_1 = 8 \text{ m}$$

Rešitev:

### P R E R E Z A-A po zožitvi



Izracun pretoka po trapeznem koritu in razpolozljive energije :

$$S = b_0 \cdot h_0 + m \cdot h_0^2 = 14 \cdot 4,3 + 1,5 \cdot 4,3^2 = 87,935 \text{ m}^2$$

$$O = b_0 + 2 \cdot h_0 \cdot \sqrt{1 + m^2} = 14 + 2 \cdot 4 \cdot \sqrt{3,25} = 29,50 \text{ m}$$

$$Q = \frac{\sqrt{l_0} \cdot S^{\frac{5}{2}}}{n_G \cdot O^{\frac{2}{3}}} = \frac{\sqrt{1,2 \cdot 10^{-3}} \cdot 87,935^{\frac{5}{2}}}{0,031 \cdot 29,5^{\frac{2}{3}}} = 203,52 \frac{\text{m}^3}{\text{s}}$$

$$E_{razp} = \left( \frac{Q}{S} \right)^2 \cdot \frac{1}{2 \cdot g} + h_0 = 4,57 \text{ m}$$

Ali pride do zajezebe :

$$E_{MP} = h_{krit} + \frac{v_{krit}^2}{2 \cdot g}$$

Pogoj :

$$Fr^2 = \frac{v^2 \cdot B}{g \cdot S} = \frac{Q^2 \cdot B_{krit}}{g \cdot S_{krit}^3} = 1$$

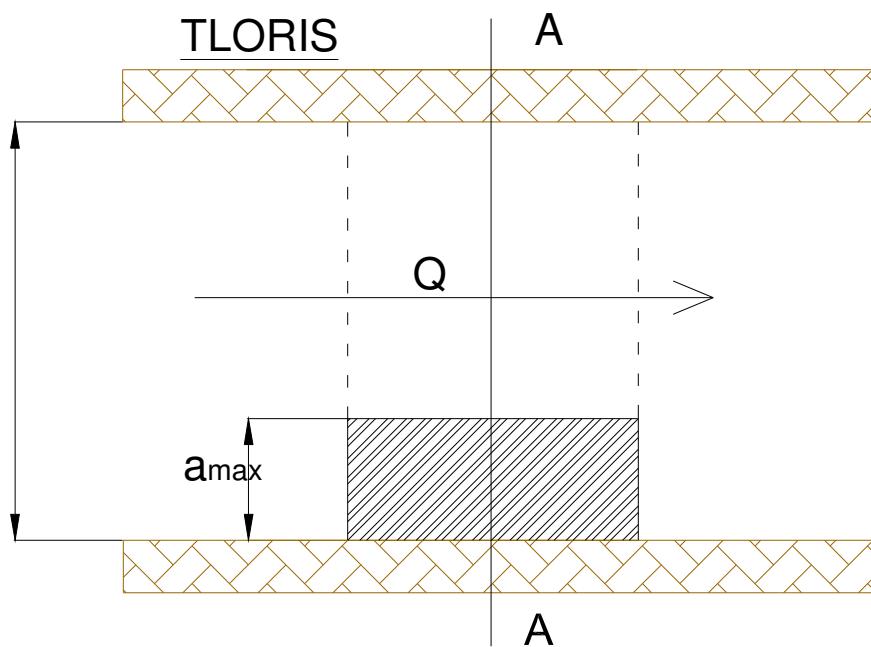
$$h_{krit} = \sqrt[3]{\frac{Q^2}{g \cdot b_1^2}} = \sqrt[3]{\frac{203,51^2}{9,81 \cdot 8^2}} = 4,04 \text{ m}$$

$$v_{krit} = \frac{Q}{S_{krit}} = \frac{203,51}{b_1 \cdot h_{krit}} = \frac{203,51}{8 \cdot 4,04} = 6,3 \frac{\text{m}}{\text{s}}$$

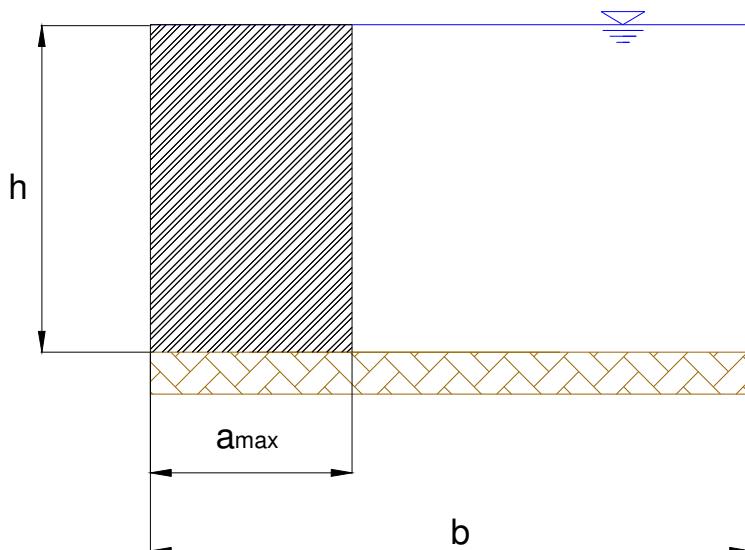
$$E_{MP} = 4,04 + \frac{6,3^2}{19,62} = 6,06 \text{ m} > 4,57 \text{ m} = E_{razp}$$

$E_{MP} > E_{razp}$ , do zajezebe pride!

**3.12. Pravokotno korito želimo zožiti zaradi gradbene jame. Določi največjo dopustno zožitev, da še ne pride do zajezebe!**



PREREZ A-A



Podatki:

$$b = 12m$$

$$h = 4m$$

$$I_0 = 1,2 \%$$

$$n_G = 0,035$$

Rešitev:

Izracun razpolozljive energije :

$$S = \underline{48m^2}$$

$$O = \underline{20m}$$

$$Q = \frac{\sqrt{I_0} \cdot S^{\frac{5}{3}}}{n_G \cdot O^{\frac{2}{3}}} = \frac{\sqrt{1,2 \cdot 10^{-3}} \cdot 48^{\frac{5}{3}}}{0,035 \cdot 20^{\frac{2}{3}}} = \underline{85,16 \frac{m^3}{s}}$$

$$\frac{V^2}{2 \cdot g} = \underline{0,16m}$$

$$E = h + \frac{V^2}{2 \cdot g} = \underline{4,16m}$$

Izracun kriticnih kolicin :

$$Fr^2 = 1$$

$$\frac{Q \cdot B}{g \cdot S^3} = 1$$

$$\frac{Q^2 \cdot b_n}{g \cdot b_n^3 \cdot h_{krit}^3} = 1$$

$$h_{krit} = \sqrt[3]{\frac{Q^2}{b^2 \cdot g}}$$

$$\frac{Q^2}{b^2 \cdot h_{krit}^2 \cdot 2 \cdot g} + h_{krit} = E$$

$$Q^2 + b^2 \cdot h_{krit}^2 \cdot 2 \cdot g = E \cdot b^2 \cdot h_{krit}^2 \cdot 2 \cdot g$$

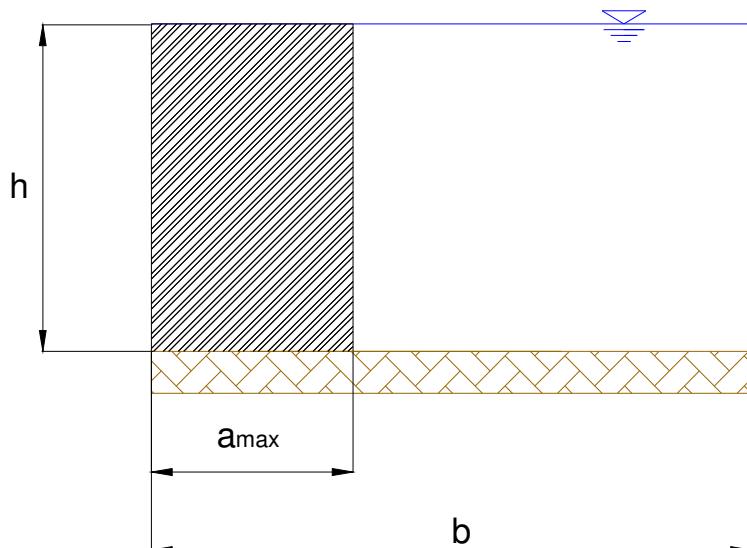
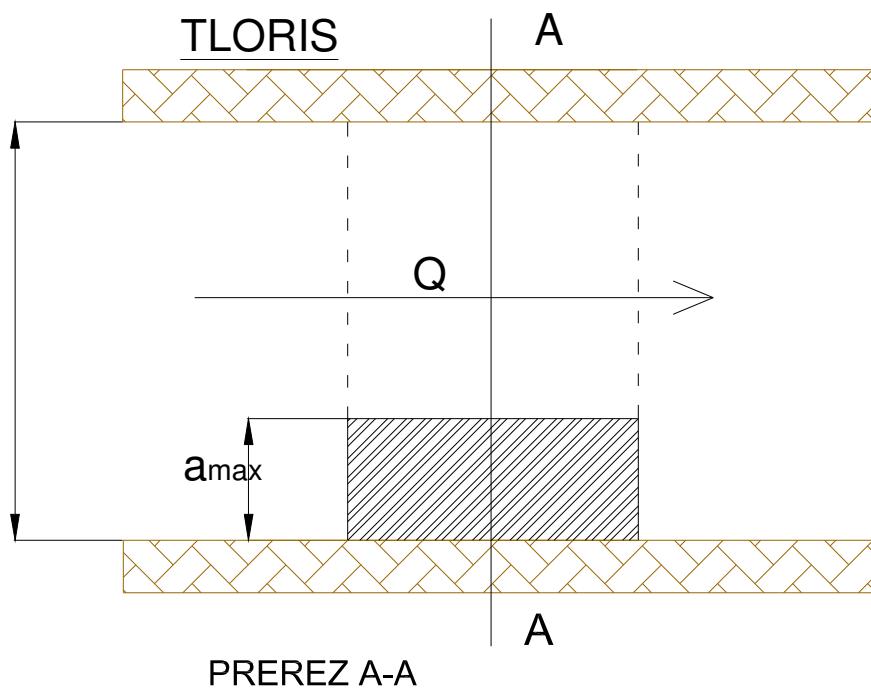
$$Q^2 + b^2 \cdot \frac{Q^2}{b^2 \cdot g} \cdot 2 \cdot g = E \cdot b^2 \cdot \frac{Q^{\frac{4}{3}}}{b^{\frac{4}{3}} \cdot g^{\frac{2}{3}}} \cdot 2 \cdot g$$

$$3 \cdot Q^2 = E \cdot b^{\frac{2}{3}} \cdot Q^{\frac{4}{3}} \cdot 2 \cdot \sqrt[3]{g}$$

$$b_{min} = \left( \frac{3 \cdot Q^{\frac{2}{3}}}{E \cdot 2 \cdot \sqrt[3]{g}} \right)^{\frac{3}{2}} = \left( \frac{3 \cdot 85,16^{\frac{2}{3}}}{4,16 \cdot 2 \cdot \sqrt[3]{9,81}} \right)^{\frac{3}{2}} = \underline{5,88 m}$$

$$a_{max} = b - b_{min} = \underline{6,12 m}$$

**3.13. (\*) Ali v podanem pravokotnem koritu zožitev povzroči zajezbo? Kolikšna je višina zajezbe?**



Podatki:

$$I_g = I_d = I_E = I_0$$

$$b = 25m$$

$$h = 4m$$

$$a = 10m$$

$$I_0 = 3\%$$

$$n_G = 0,025$$

Rešitev:

Izracun razpolozljive energije :

$$Q = \frac{\sqrt{I_0} \cdot S^{\frac{5}{3}}}{n_G \cdot O^{\frac{2}{3}}} = \frac{\sqrt{3 \cdot 10^{-3}} \cdot 100^{\frac{5}{3}}}{0,025 \cdot 33^{\frac{2}{3}}} = 458,8 \frac{m^3}{s}$$

$$v = \frac{Q}{S} = 4,59 \frac{m}{s}$$

$$E_{razp} = 4 + \frac{4,59^2}{19,62} = 5,07 m$$

$$E_{MP} = h_{krit} + \frac{v_{krit}^2}{2 \cdot g} = h_{krit} \cdot \frac{3}{2}$$

Kochova krivulja :

$$q_{e\max} = 1,706 \Leftarrow \text{tabela (Steinman : Hidravlika, str.172)}$$

$$q = \frac{458,8}{15} = 30,59 \frac{m^2}{s}$$

$$E_{MP} = \left( \frac{q}{q_{e\max}} \right)^{\frac{2}{3}} = \left( \frac{30,59}{1,706} \right)^{\frac{2}{3}} = 6,85 m$$

$$\frac{Q^2 \cdot B_{krit}}{g \cdot S_{krit}^3} = 1$$

$$\frac{Q^2 \cdot (b-a)}{g \cdot (b-a)^3 \cdot h_{krit}^3} = 1$$

$$h_{krit} = \sqrt[3]{\frac{Q^2}{g \cdot (b-a)^2}} = \sqrt[3]{\frac{458,8^2}{9,81 \cdot 15^2}} = 4,56 m$$

$$v_{krit} = \frac{Q}{(b-a) \cdot h_{krit}} = \frac{458,8}{15 \cdot 4,56} = 6,69 \frac{m}{s}$$

$$E_{MP} = 4,56 + \frac{6,69^2}{19,62} = 6,84 m > E_R$$

Zajezba bo!

Izracun visine zajezebe:

$$E_{MP} = h_z + \frac{v_z^2}{2 \cdot g} = h_z + \frac{Q_z^2}{b^2 \cdot h_z^2 \cdot 2 \cdot g}$$

$$E_{MP} \cdot b^2 \cdot h_z^2 \cdot 2 \cdot g = h_z \cdot b^2 \cdot h_z^2 \cdot 2 \cdot g + Q_z^2$$

$$h_z^3 \cdot (3 \cdot g \cdot b^2) - h_z^2 \cdot (E_{MP} \cdot b^2 \cdot 2 \cdot g) + Q^2 = 0$$

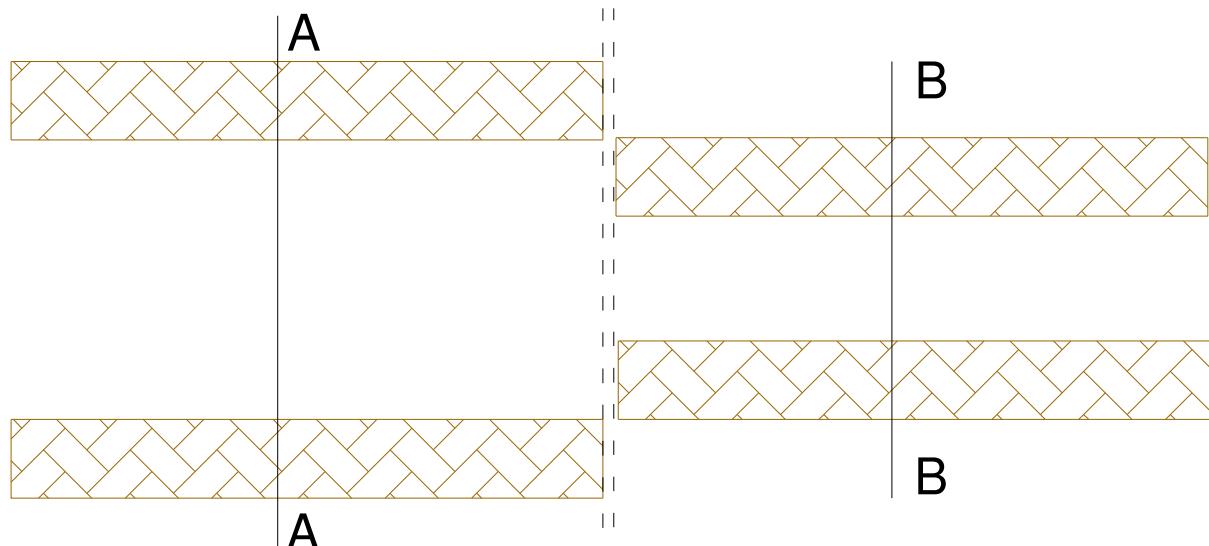
$$h_z^3 \cdot 12262,5 - h_z^2 \cdot 83998 + 210497 = 0$$

$$h_z = \sqrt[3]{6,85 \cdot h_z^2 - 17,17}$$

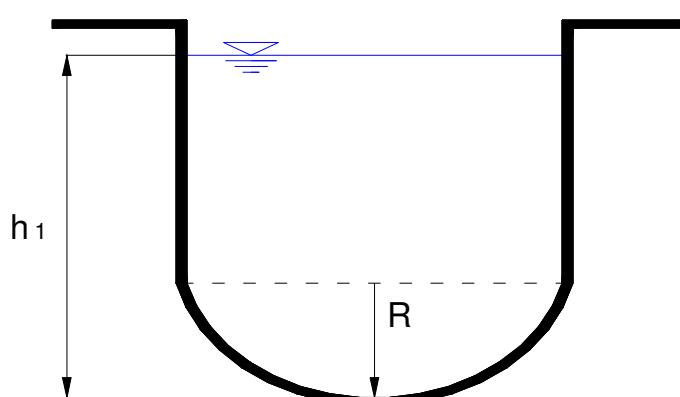
Izracunamo z iteracijami npr. excel!

$$h_z = 2,5065m$$

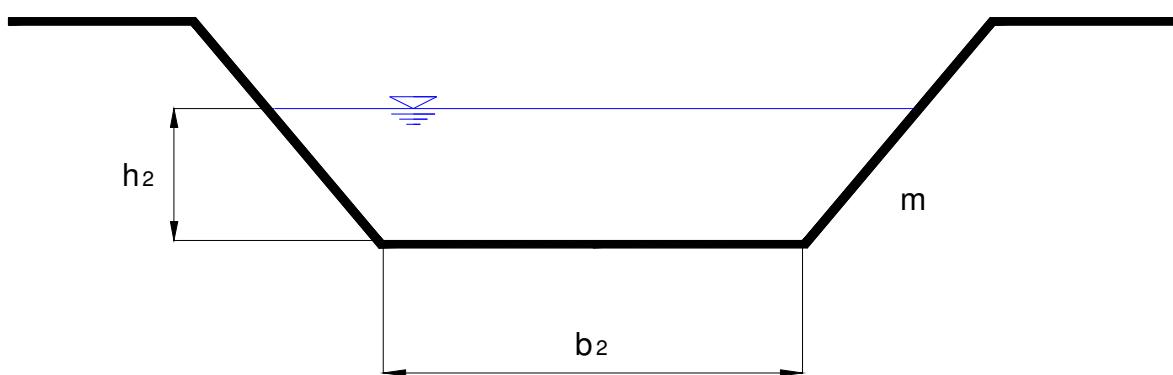
**3.14. Jarka oblike (A-A)in (B-B) sta povezana s prepustom. Določi dimenzije  $b_2$  in  $h_2$ , če je podano razmerje  $b_2/h_2$ ! Če je v prerezu (B-B) mogoče izbrati hidravlično ugodnejše trapezno korito (HNK), določi dimenzije!**



A - A



B - B



Podatki:

$$I_{01} = 1,3 \text{ } \cancel{o/o}$$

$$I_{02} = 2 \text{ } \cancel{o/o}$$

$$n_{G1} = 0,02$$

$$n_{G2} = 0,03$$

$$R = 1,20m$$

$$h_1 = 2,0m$$

$$m = 1$$

$$\frac{b_2}{h_2} = 2$$

Rešitev:

(A – A) Izracun pretoka po sestavljenem koritu :

$$S_1 = \frac{R^2 \cdot \pi}{2} + 2 \cdot R \cdot (h_1 - R) = \frac{1,2^2 \cdot \pi}{2} + 2 \cdot 1,2 \cdot 0,8 = \underline{4,18m^2}$$

$$O_1 = \pi \cdot R + 2 \cdot (h_1 - R) = \pi \cdot 1,2 + 2 \cdot 0,8 = \underline{5,37m}$$

$$Q = \frac{\sqrt{I_{01}} \cdot S_1^{\frac{5}{3}}}{n_{G1} \cdot O_1^{\frac{2}{3}}} = \frac{\sqrt{1,3 \cdot 10^{-3}} \cdot 4,18^{\frac{5}{3}}}{0,02 \cdot 5,37^{\frac{2}{3}}} = 6,38 \frac{m^3}{s}$$

(B – B) Doloci dimenzije trapeznega korita, ce je podano razmerje  $\frac{b_2}{h_2} = 2$  :

$$\frac{b_2}{h_2} = 2 \Rightarrow b_2 = 2 \cdot h_2$$

$$S_2 = b \cdot h + m \cdot h^2 = 2 \cdot h^2 + h^2 = 3 \cdot h^2$$

$$O_2 = b + 2 \cdot h \cdot \sqrt{1+m^2} = 2 \cdot h + 2 \cdot h \cdot \sqrt{2} = 4,82 \cdot h$$

$$Q = \frac{\sqrt{I_{02}}}{n_{G2}} \cdot \frac{3^{\frac{5}{3}}}{4,82^{\frac{2}{3}} \cdot h^3}$$

$$h = \left( \frac{Q \cdot n_{G2} \cdot 4,82^{\frac{2}{3}}}{\sqrt{I_{02}} \cdot 3^{\frac{5}{3}}} \right)^{\frac{3}{8}} = \left( \frac{6,38 \cdot 0,03 \cdot 4,82^{\frac{2}{3}}}{\sqrt{2 \cdot 10^{-3}} \cdot 3^{\frac{5}{3}}} \right)^{\frac{3}{8}} = \underline{1,29m}$$

$$b_2 = 2 \cdot h_2 = \underline{2,58m}$$

(B – B) – Izracun HNK trapezne oblike, ki prevaja isti pretok :

$$S = \frac{3 \cdot b^2 \cdot \sqrt{3}}{4}$$

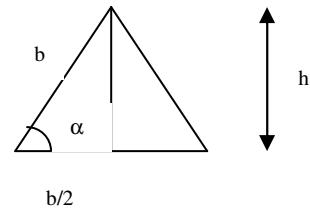
$$O = 3 \cdot b^2$$

$$Q = \frac{\sqrt{I_{02}} \cdot S^{\frac{5}{3}}}{n_{G2} \cdot O^{\frac{2}{3}}} = \left[ \frac{\sqrt{I_{02}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)^{\frac{5}{3}} \cdot b_2^{\frac{10}{3}}}{n_{G2} \cdot 3^{\frac{2}{3}} \cdot b_2^{\frac{2}{3}}} \right]^{\frac{8}{3}} \Rightarrow \text{izrazimo } b$$

$$b = \left[ \frac{Q \cdot n_{G2} \cdot 3^{\frac{2}{3}}}{\sqrt{I_{02}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)^{\frac{5}{3}}} \right]^{\frac{3}{8}} = \left[ \frac{6,38 \cdot 0,03 \cdot 3^{\frac{2}{3}}}{\sqrt{2 \cdot 10^{-3}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)^{\frac{5}{3}}} \right]^{\frac{3}{8}} = 1,93m$$

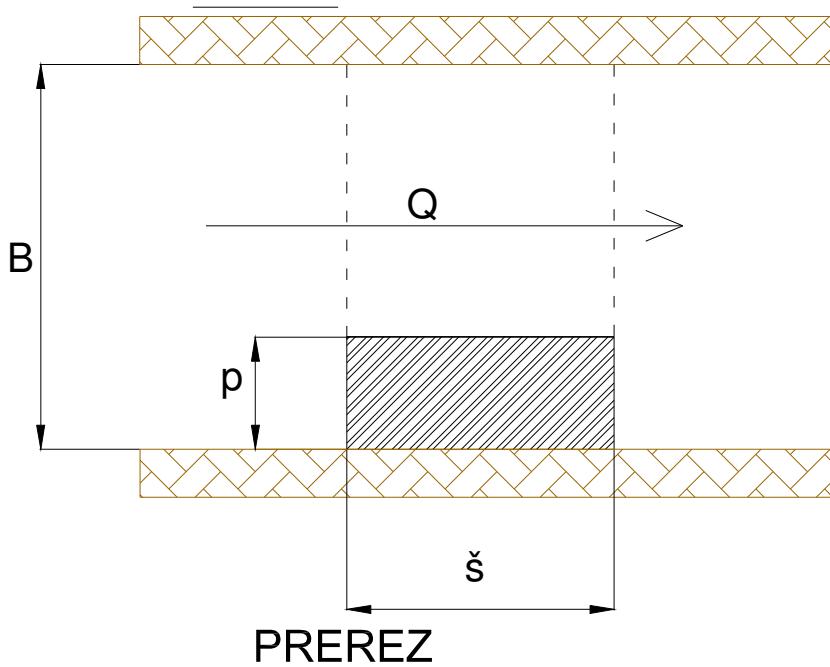
$\Rightarrow h$  izrazimo s pomocjo skice

$$h = \sqrt{b^2 - \left( \frac{b}{2} \right)^2} = \sqrt{b^2 - \frac{b^2}{4}} = \frac{1,93}{2} \cdot \sqrt{3} = 1,67m$$

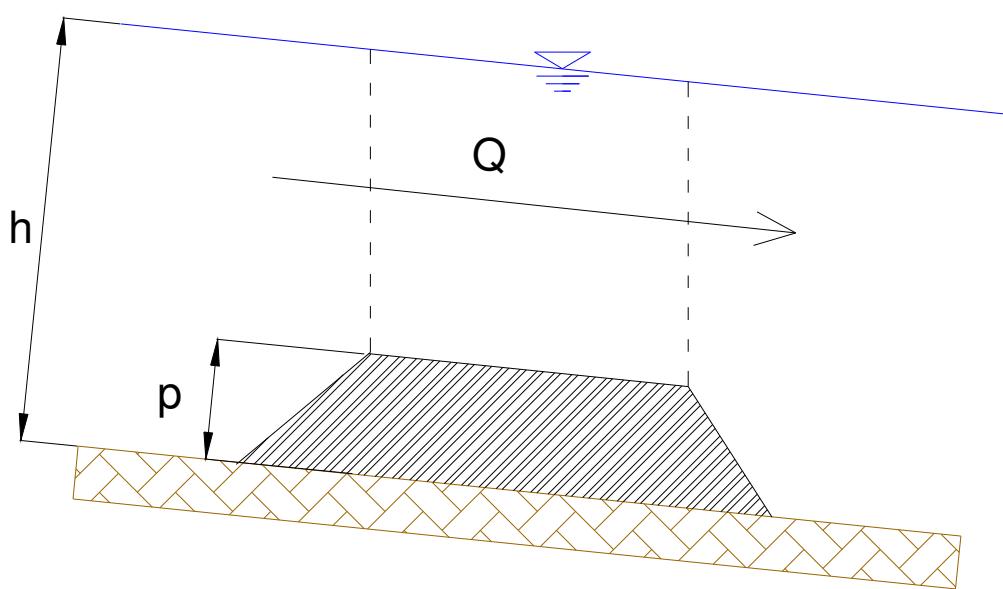


**3.15. Ali prag danih dimenzij povzroči zaježbo v pravokotnem koritu?**

TLORIS



PREREZ



Podatki:

$$h = 4m$$

$$B = 10m$$

$$I_0 = 0,6 \text{ ‰}$$

$$n_G = 0,03$$

$$p = 1,20m$$

$$\check{s} = 4m$$

Rešitev:

Izracun razpolozljive energije :

$$S = b \cdot h = 40m^2$$

$$O = b + 2 \cdot h = 18m$$

$$Q = \frac{\sqrt{I_0}}{n_G} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{0,6 \cdot 10^{-3}}}{0,03} \cdot \frac{40^{\frac{5}{3}}}{18^{\frac{2}{3}}} = 55,6 \frac{m^3}{s}$$

$$v = \frac{Q}{S} = \frac{55,6}{40} = 1,39 \frac{m}{s}$$

$$E_{razp} = h + \frac{v^2}{2 \cdot g} = 4 + \frac{1,39^2}{2 \cdot 9,81} = 4,10m$$

Izracunkriticniholicininp<sub>max</sub>:

$$Fr^2 = 1$$

$$\frac{Q^2 \cdot B}{g \cdot S^3} = 1$$

$$\frac{Q^2 \cdot B}{g \cdot B^3 \cdot h^3} = 1$$

$$h_{krit} = \sqrt[3]{\frac{Q^2}{g \cdot B^2}} = \sqrt[3]{\frac{55,6^2}{g \cdot 10^2}} = 1,47m$$

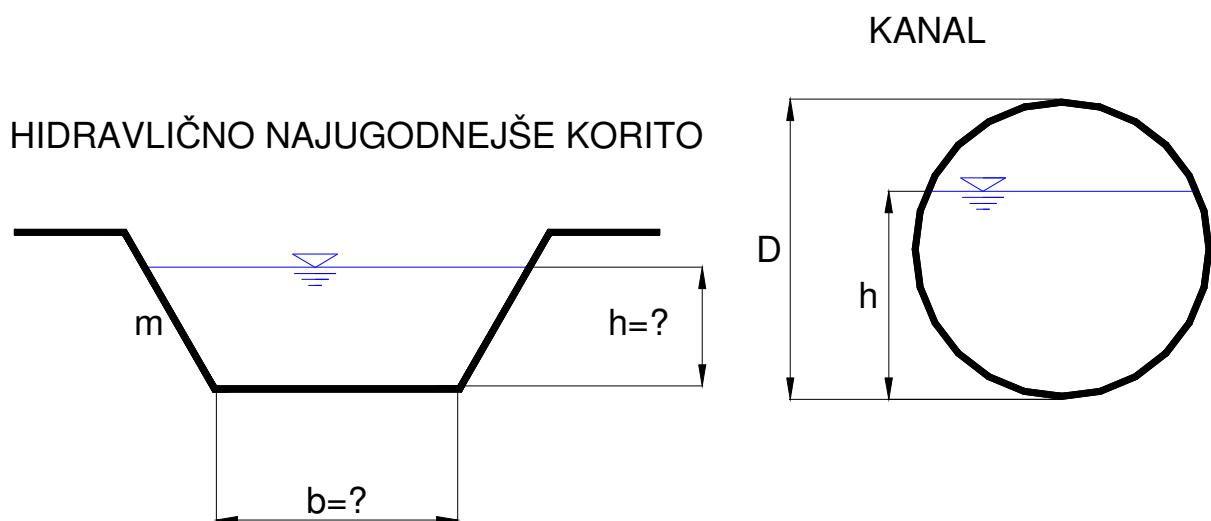
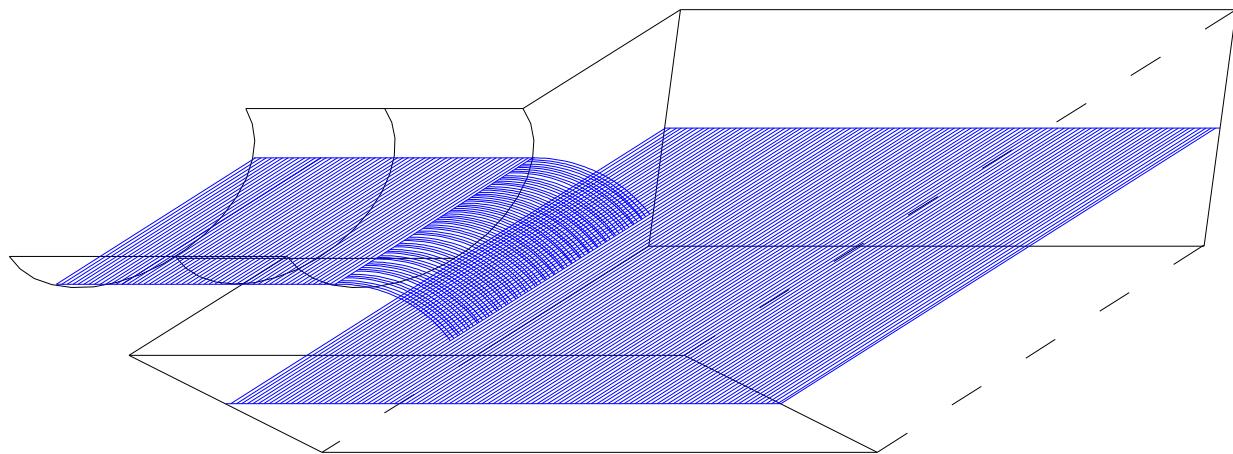
$$v_{krit} = \frac{Q}{S_{krit}} = \frac{Q}{B \cdot h_{krit}} = \frac{55,6}{10 \cdot 1,47} = 3,79 \frac{m}{s}$$

$$E_{razp} = h_{krit} + \frac{v_{krit}^2}{2 \cdot g} + p_{max}$$

$$p_{max} = E_{razp} - h_{krit} - \frac{v_{krit}^2}{2 \cdot g} = 4,10 - 1,47 - \frac{3,79^2}{2 \cdot 9,81} = 1,90m < p = 1,20m$$

$p < p_{max} \Rightarrow$  zaježbenil

**3.16. Okrogel kanal se izliva v trapezno korito. Določi hidravlično najugodnejše trapezno korito, ki prevaja pretok, ki priteče iz kanala!**



Podatki:

$$D = 2m$$

$$h = 0,90m$$

$$I_{01} = 0,5\%_{oo}$$

$$I_{02} = 0,8\%_{oo}$$

$$n_{G1} = 0,02$$

$$n_{G2} = 0,03$$

$$\underline{b = ?, h = ?}$$

Rešitev:

Izracun pretoka po okroglem kanalu :

$$\frac{h}{D} = 0,45 \Rightarrow a = 0,1298$$

$$Q = \frac{\sqrt{I_{01}}}{n_{G1}} \cdot D^{\frac{8}{3}} \cdot a = \frac{\sqrt{5 \cdot 10^{-4}}}{0,02} \cdot 2^{\frac{8}{3}} \cdot 0,1298 = 0,9214 \frac{m^3}{s}$$

Izracun hidravlicno najugodnejše trapeznega korita, ki prevaja isti pretok :

$$S = \frac{3 \cdot b^2 \cdot \sqrt{3}}{4}$$

$$O = 3 \cdot b$$

$$h = \frac{b \cdot \sqrt{3}}{2} = 0,96m$$

$$Q = \frac{\sqrt{I_{02}}}{n_{G2}} \cdot \frac{S^{\frac{5}{3}}}{O^{\frac{2}{3}}} = \frac{\sqrt{I_{02}}}{n_{G2}} \cdot \frac{\left(\frac{3 \cdot \sqrt{3}}{4}\right)^{\frac{5}{3}} \cdot b^{\frac{10}{3}}}{3^{\frac{2}{3}} \cdot b^{\frac{2}{3}}} \Rightarrow \text{izrazimo } b$$

$$b = \left[ \frac{Q \cdot n_{G2} \cdot 3^{\frac{2}{3}}}{\sqrt{I_0} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)} \right]^{\frac{3}{8}} = \left[ \frac{0,9214 \cdot 0,03 \cdot 3^{\frac{2}{3}}}{\sqrt{8 \cdot 10^{-4}} \cdot \left( \frac{3 \cdot \sqrt{3}}{4} \right)} \right]^{\frac{3}{8}} = 1,11m$$