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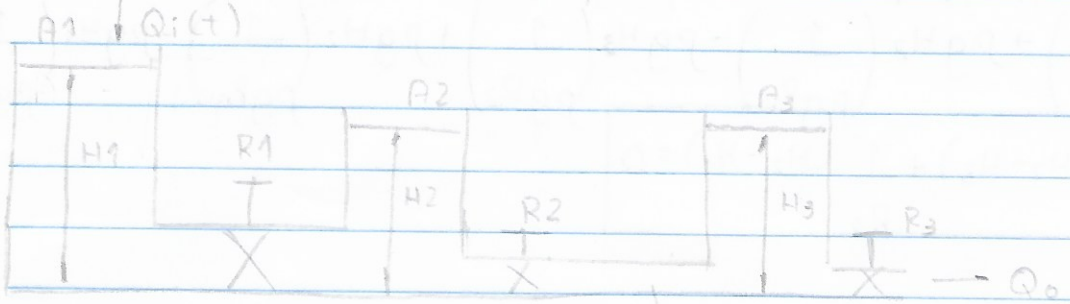
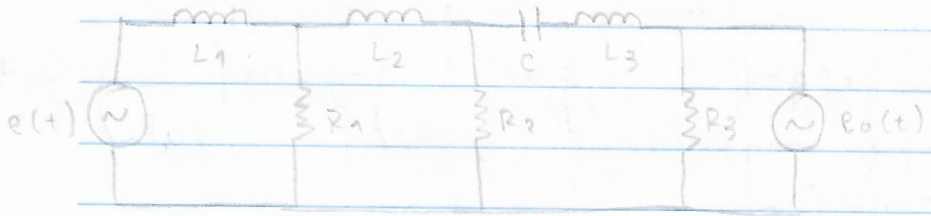
Sistemas fluídicos

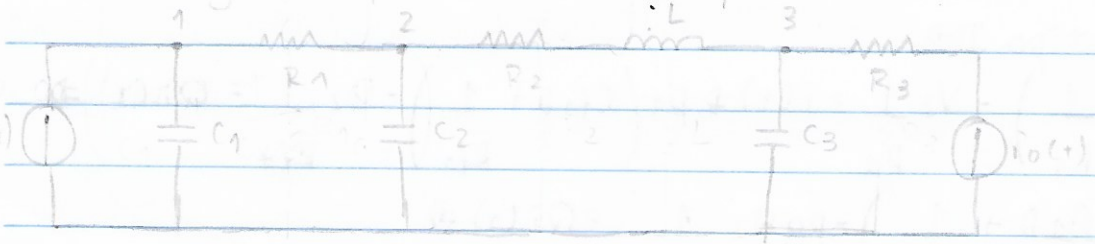


- regime laminar
- tubo muito longo L, d

a) Analogia tipo I ⇒ Q → V p → i



b) Analogia tipo II ⇒ Q → i p → V



c) Analogia tipo I ⇒

$V_{L1} + V_{R1} = e(t) \Rightarrow i_1 L_1 D + i_1 R_1 - i_2 R_1 = e(t) \Rightarrow$

$\Rightarrow p_1 C_{f1} D + p_1 \bar{R}_{f1} - p_2 \bar{R}_{f1} = Q_i(t) \Rightarrow \rho g H_1 \left(\frac{A_1 D}{\rho g}\right) + \rho g H_1 \left(\frac{1}{\rho g R_1}\right) -$

$- \rho g H_2 \left(\frac{1}{\rho g R_1}\right) = Q_i(t) \Rightarrow \boxed{A_1 \dot{H}_1 + \frac{1}{R_1}(H_1 - H_2) = Q_i(t)}$

$V_{L_2} + V_{R_2} + V_{R_1} = 0 \Rightarrow i_2 L_2 D + i_2 R_2 - i_3 R_2 + i_2 R_1 - i_1 R_1 = 0 \Rightarrow$

$\Rightarrow p_2 C_{f_2} D + p_2 \bar{R}_{f_2} - p_3 \bar{R}_{f_2} + p_2 \bar{R}_{f_1} - p_1 \bar{R}_{f_1} = 0 \Rightarrow$

$\Rightarrow \rho g H_2 \left(\frac{A_2}{\rho g} D\right) + \rho g H_2 \left(\frac{1}{\rho g R_2}\right) - \rho g H_3 \left(\frac{1}{\rho g R_2}\right) + \rho g H_2 \left(\frac{1}{\rho g R_1}\right) - \rho g H_1 \left(\frac{1}{\rho g R_1}\right) = 0 \Rightarrow$

$\Rightarrow \boxed{A_2 \dot{H}_2 + \frac{1}{R_2}(H_2 - H_3) + \frac{1}{R_1}(H_2 - H_1) = 0}$

$V_{L_3} + V_C + V_{R_3} + V_{R_2} = e_0(t) \Rightarrow i_3 L_3 D + \frac{i_3}{CD} + i_3 R_3 + i_2 R_2 - i_1 R_2 = e_0(t) \Rightarrow$

$\Rightarrow p_3 C_{f_3} D + \frac{p_3}{L_f D} + p_3 \bar{R}_{f_3} - p_2 \bar{R}_{f_2} - p_1 \bar{R}_{f_2} = Q_0 \Rightarrow$

$\Rightarrow \rho g H_3 \left(\frac{A_3}{\rho g} D\right) + \cancel{\rho g H_3 \left(\frac{2}{\rho L}\right)} + \rho g H_3 \left(\frac{1}{\rho g R_3}\right) + \rho g H_2 \left(\frac{1}{\rho g R_2}\right) - \rho g H_1 \left(\frac{1}{\rho g R_2}\right) = Q_0 \Rightarrow$

$\Rightarrow \boxed{A_3 \dot{H}_3 + \frac{1}{R_3} H_3 + \frac{1}{R_2}(H_2 - H_1) = Q_0}$

Analogia tipo II $\Rightarrow$

$V_1 \left(C_1 D + \frac{1}{R_1}\right) - V_2 \frac{1}{R_1} = i(t) \Rightarrow p_1 \left(C_{f_1} D + \frac{1}{\bar{R}_{f_1}}\right) - p_2 \frac{1}{\bar{R}_{f_1}} = Q_i(t) \Rightarrow$

$\Rightarrow \rho g H_1 \left(\frac{A_1}{\rho g} D + \frac{1}{\rho g R_1}\right) - \rho g H_2 \frac{1}{\rho g R_1} = Q_i(t) \Rightarrow$

$\Rightarrow \boxed{A_1 \dot{H}_1 + \frac{1}{R_1}(H_1 - H_2) = Q_i(t)}$

$V_2 \left(C_2 D + \frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{LD}\right) - V_1 \frac{1}{R_1} - V_3 \left(\frac{1}{R_2} + \frac{1}{LD}\right) = 0 \Rightarrow$

$\Rightarrow p_2 \left(C_{f_2} D + \frac{1}{\bar{R}_{f_2}} + \frac{1}{\bar{R}_{f_1}} + \frac{1}{L_f D}\right) - p_1 \frac{1}{\bar{R}_{f_1}} - p_3 \left(\frac{1}{\bar{R}_{f_2}} + \frac{1}{L_f D}\right) = 0 \Rightarrow$

$\Rightarrow \rho g H_2 \left(\frac{A_2}{\rho g} D + \frac{1}{\rho g R_2} + \frac{1}{\rho g R_1} + \cancel{\frac{a}{\rho L D}}\right) - \rho g H_1 \frac{1}{\rho g R_1} - \rho g H_3 \left(\frac{1}{\rho g R_2} + \cancel{\frac{2}{\rho L D}}\right) = 0 \Rightarrow$

$$A_2 \dot{H}_2 + \frac{1}{R_3}(H_2 - H_3) + \frac{1}{R_1}(H_2 - H_1) = 0$$

$$V_3\left(C_3 D + \frac{1}{R_3} + \frac{1}{R_2} + \frac{1}{LD}\right) - V_2\left(\frac{1}{R_2} + \frac{1}{LD}\right) = e_0(t) \Rightarrow$$

$$P_3\left(C_{f_3} D + \frac{1}{\bar{R}f_3} + \frac{1}{\bar{R}f_2} + \frac{1}{LfD}\right) - P_2\left(\frac{1}{\bar{R}f_2} + \frac{1}{LfD}\right) = Q_0 \Rightarrow$$

$$\rho g H_3\left(A_3 D + \frac{1}{\rho g} + \frac{1}{\rho g R_3} + \frac{1}{\rho g R_2} + \frac{2}{\rho LD}\right) - \rho g H_2\left(\frac{1}{\rho g R_2} + \frac{2}{\rho LD}\right) = Q_0 \Rightarrow$$

$$A_3 \dot{H}_3 + \frac{1}{R_3} H_3 + \frac{1}{R_2}(H_3 - H_2) = Q_0$$