1) a) $w_i = k(p_i - p)$ $\quad p = \frac{V}{c^2} p$

$\dot{p} = \frac{1}{c^2} \dot{p}$

$m = w_i - w_u$ $\quad \Rightarrow \quad \frac{V}{c^2}\dot{p} = k(p_i - p) - w_u$

$\dot{p} = \frac{\dot{m}}{V}$ $\quad \underline{\dot{p} = -\frac{c^2 k}{V} p + \frac{c^2 k}{V} p_i - \frac{c^2}{V} w_u}$

$m = \rho \cdot V$

b) $T = -\frac{1}{a} = -\frac{1}{-\frac{c^2 k}{V}} = \frac{V}{c^2 k} = \frac{\frac{m^3}{s^2}}{\frac{m^3}{s}} = \frac{m^3}{s^2} \cdot \frac{s}{m^3} = \frac{1}{s} = s$

c) $\dot{p} = -\frac{c^2 k}{V} p + \frac{c^2 k}{V} u$

$u = k_p e$

$\dot{p} = -\frac{c^2 k}{V} p + \frac{c^2 k}{V} k_p p_{ref} - \frac{c^2 k}{V} k_p p$

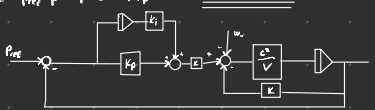
$0 = \frac{c^2 k}{V} p + \frac{c^2 k}{V} k_p p_{ref} - \frac{c^2 k}{V} k_p p$

$p(1 + k_p) = k_p \cdot p_{ref}$

$p = \frac{k_p}{1+k_p} \cdot p_{ref}$

$e = p_{ref} - p = p_{ref} - \frac{k_p}{1+k_p} \cdot p_{ref} = \underline{\left(1 - \frac{k_p}{1+k_p}\right) p_{ref}}$

d)



e) $\dot{p} = -\frac{c^2 k}{V} p + \frac{c^2 k}{V} u$ $\qquad e = (p_{ref} - p)$

$\dot{p} = -\frac{c^2 k}{V} p + \frac{c^2 k}{V} k_p e + \frac{c^2 k}{V} k_i \int e \, dt$ $\qquad p = p_{ref} - e$

$\ddot{p} = -\frac{c^2 k}{V} \dot{p} + \frac{c^2 k}{V} k_p \dot{e} + \frac{c^2 k}{V} k_i e$ $\qquad \dot{p} = -\dot{e}$

$-\dddot{e} = -\frac{c^2 k}{V} \ddot{e} + \frac{c^2 k}{V} k_p \ddot{e} + \frac{c^2 k}{V} k_i e$ $\qquad \ddot{p} = -\ddot{e}$

$\underline{\dddot{e} + \frac{c^2 k}{V}(1 + k_p)\ddot{e} + \frac{c^2 k k_i}{V} e = 0}$

f) setter $\dddot{e} = 0$ og $\ddot{e} = 0$

$\frac{c^2 k}{V} k_i e = 0$

$\frac{c^2 k}{V} k_i p = \frac{c^2 k k_i}{V} p_{ref}$

$\underline{p = p_{ref}}$

g) $\ddot{p} = -\frac{c^2 k}{V} \dot{p} + \frac{c^2 k}{V} k_p \dot{e} + \frac{c^2 k}{V} k_i e$

$\dddot{p} = -\frac{c^2 k}{V} \ddot{p} - \frac{c^2 k}{V} k_p \ddot{p} + \frac{c^2 k}{V} k_i p_{ref} - \frac{c^2 k}{V} k_i p$

$\dddot{p} + \left(\frac{c^2 k (1+k_p)}{V}\right)\ddot{p} + \frac{c^2 k}{V} k_i p = \frac{c^2 k}{V} k_i p_{ref}$

$w_0^2 = \frac{c^2 k}{V} k_i$ $\qquad 2\omega_0 S = \frac{c^2 k}{V} + \frac{c^2 k}{V} k_p$

$k_i = \frac{\omega_0^2 V}{c^2 k}$ $\qquad k_p = \frac{2\omega_0 S V}{c^2 k} - 1$

h) Å tune parameterne til ønsket system respons

i) $\frac{c^2 k}{V} + \frac{c^2 k}{V} k_p > 0$ $\qquad \frac{c^2 k}{V} k_i > 0$

$k_p > -1$ $\qquad \underline{k_i > 0}$

j) Vi ser at i e) at k_i må ref. mukt og da også tar hensyn til w_u

2) a) Energi balanse

b) $\dot{T} = -\frac{w}{\rho V} T + \frac{w}{\rho V} T_i$

$T = -\frac{1}{a} = -\frac{1}{-\frac{w}{\rho V}} = \frac{\rho V}{w} = \frac{0{,}175}{0{,}1} = \underline{1{,}75\,s}$

3) a) $x = d_2 + q_2 + \cos(q_1) \cdot l_1$

$y = d_1 + q_1 + \sin(q_1) \cdot l_1$

b) $q_1 = \operatorname{atan}(x, y)$

$x^2 + y^2 = (l_1 + q_2 + d_2)^2$

$\sqrt{x^2 + y^2} = l_1 + q_2 + d_2$

$q_2 = \sqrt{x^2 + y^2} - l_1 - d_2$

④ a) $\dot{x}_1 = -x_1 K_1 + K_p u$

$\dot{x}_2 = x_1 - k_2 x_2$

b) $K_{pk} = 0{,}315 \quad T_k =$

$k_0 = 0{,}6 \cdot 0{,}315 = 0{,}189$

$T_i = 0{,}5 \cdot 12 = 6$

$K_i = \frac{0{,}189}{6} = 0{,}032$

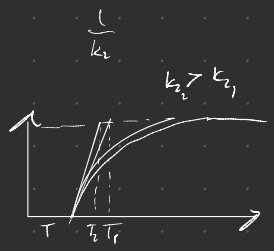
$T_d = 0{,}125 \cdot 12 = 1{,}5$

$K_p = 1{,}5 \cdot 0{,}315 = 0{,}473$

c) 4. ordens system

d) T er tidsforsinkelsen

k_2 er ansvarlig for tidskonstanten



⑤ a) $x_1(a - bx_2) = 0$

$x_2(-c + dx_1) = 0$

$\Rightarrow \quad a - bx_2 = 0$

$-c + dx_1$

$x_2 = \frac{a}{b} = \frac{1{,}5}{1} = 1{,}5$

$x_1 = \frac{c}{d} = \frac{3}{1} = 3$

$x_1 x_2 = (0,0)$

b) —//—

c) $x_1(n) = x_1(n-1) + h \cdot (a \cdot x_1(n-1) - b \cdot x_2(n-1))$

$x_2(n) = x_2(n-1) + h \cdot (-c \cdot x_2(n-1) - d \cdot x_2(n-1))$