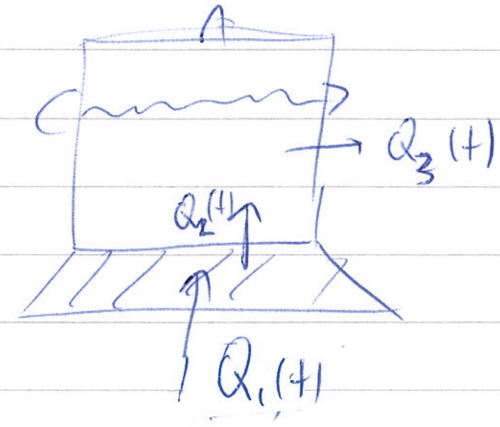
Oppg 1



a)

Antar $T_0 = 0°C$

$$dE(t) = Q_1(t) - Q_2(t)$$

$$dE_v(t) = Q_2(t) - Q_3(t)$$

$$E = m \cdot c_p \cdot T(t), \qquad E_v = m_v \cdot c_{p,v} \cdot T_v(t)$$
$$= \rho \cdot V_v \cdot c_{pv} \cdot T_v(t)$$

$$Q_1(t) = P(t)$$

$$Q_2(t) = h \cdot A \cdot (T(t) - T_v(t))$$

$$Q_3(t) = h_v \cdot A_v \cdot (T_v(t) - T_{omg}(t))$$

antar $m, c_p, \rho, V_v, c_{pv}$ konstant

$$m \cdot c_p \cdot \frac{dT(t)}{dt} = P(t) - hA\left(T(t) - T_v(t)\right)$$

$$\rho \cdot V_v \cdot c_{pv} \cdot \frac{dT_v(t)}{dt} = hA\left(T(t) - T_v(t)\right) - h_v A_v \left(T(t) - T_{omg}(t)\right)$$

$$\Downarrow$$

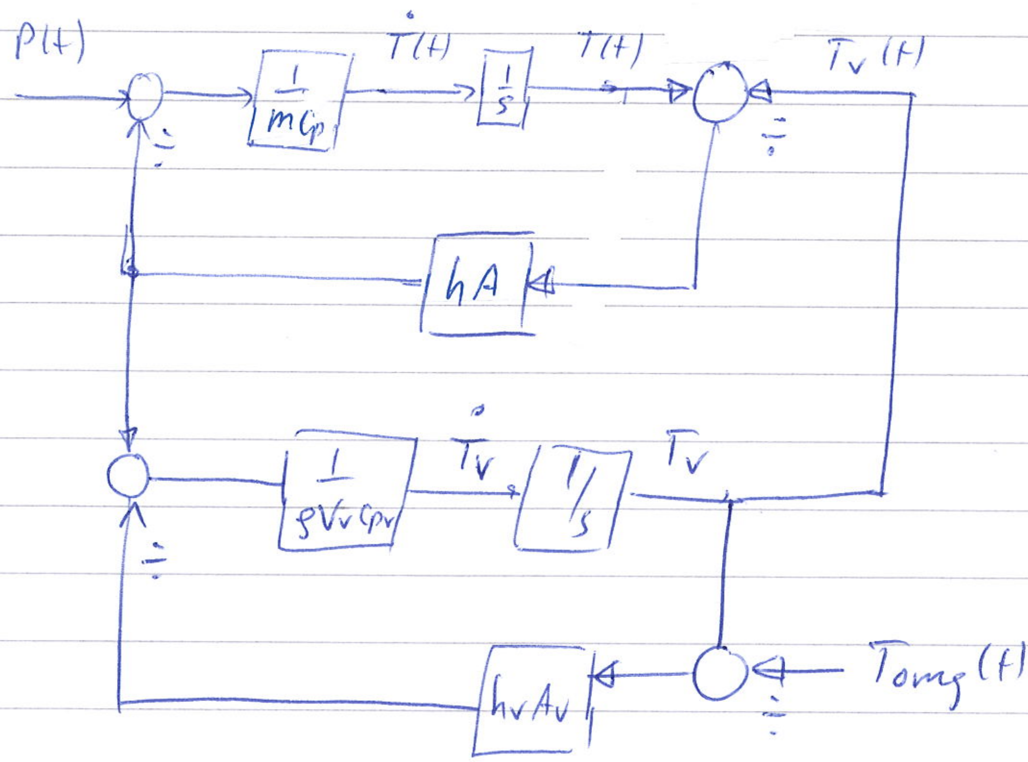
$$\frac{dT(t)}{dt} = \frac{1}{m \cdot c_p}\left(P(t) - hA\left(T(t) - T_v(t)\right)\right)$$

$$\frac{dT_v(t)}{dt} = \frac{1}{\rho V_v c_{pv}}\left(hA\left(T(t) - T_v(t)\right) - h_v A_v \left(T_v(t) - T_{omg}(t)\right)\right)$$

- Orden = 2

- lineær

b) Blokkskjema:



c) $T(t) = x_1(t)$
$T_v(t) = x_2(t)$
$P(t) = u(t)$
$T_{amp}(t) = v(t)$

$$\dot{x}(t) = A \cdot x(t) + B \cdot u(t) + B_v \cdot v(t)$$

$$y = C \cdot x(t) + D \cdot u(t)$$

$$\dot{x}_1(t) = \frac{1}{m \cdot c_p} \cdot u(t) - \frac{hA}{mc_p} \cdot x_1(t) + \frac{hA}{mc_p} \cdot x_2(t)$$

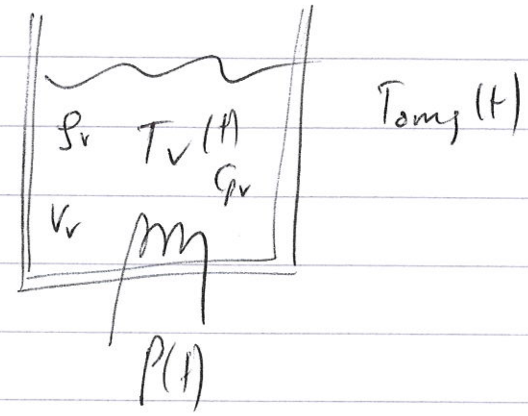
$$\dot{x}_2(t) = \frac{hA}{\rho \cdot V_v \cdot c_{pv}} \cdot x_1(t) - \frac{(hA + h_v A_v)}{\rho V_v c_{pv}} x_2(t) + \frac{h_v A_v}{\rho V_v c_{pv}} \cdot v(t)$$

$$y(t) = x_2(t)$$

$$A = \begin{bmatrix} -\frac{hA}{mc_p} & \frac{hA}{mc_p} \\ \frac{hA}{\rho V_v c_{pv}} & -\frac{(hA + h_v A_v)}{\rho V_v c_{pv}} \end{bmatrix}, \quad B = \begin{bmatrix} \frac{1}{mc_p} \\ 0 \end{bmatrix}, \quad B_v \begin{bmatrix} 0 \\ \frac{h_v A_v}{\rho V_v c_{pv}} \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 1 \end{bmatrix}, \quad D = \begin{bmatrix} 0 \end{bmatrix}$$

d)



$$\frac{dE_v(t)}{dt} = Q_{inn}(t) - Q_u(t)$$

$$= P(t) - h_v A_v \left(T_v(t) - T_{omg}(t) \right)$$

$E_v(t) = \rho_v \cdot V_v \cdot T_v(t) \cdot c_{p,v}$, $T_{v,0} = 0\ °C$

Antar ρ_v og V_v, c_{pv} konstant.

$$\frac{dT_v(t)}{dt} = \frac{1}{\rho_v V_v c_{pv}} \left(P(t) - h_v A_v \left(T_v(t) - T_{omg}(t) \right) \right)$$

Laplace: $s \cdot T_v(s) = \frac{1}{\rho_v V_v c_{pv}} \cdot P(s) - \frac{h_v A_v}{\rho_v V_v c_{pv}} \cdot T_v(s)$

$$+ \frac{h_v A_v}{\rho_v V_v c_{pv}} T_{omg}(s)$$

antar $T_{omg}(s) = 0$ for å finne $H_{p,1}(s)$

$$\left(s + \frac{h_v A_v}{\rho_v V_v c_{pv}}\right) T_v(s) = \frac{1}{\rho_v V_v c_{pv}} \cdot P(s)$$

$$H_{p,1}(s) = \frac{1/\rho_v V_v c_{p,v}}{s + \frac{h_v A_v}{\rho_v V_v c_{pv}}} = \frac{T_v(s)}{P(s)}$$

$$= \frac{\frac{1}{h_v A_v}}{\frac{\rho_v V_v c_{pv}}{h_v A_v} s + 1}$$

$2/1000 \; [m^3]$

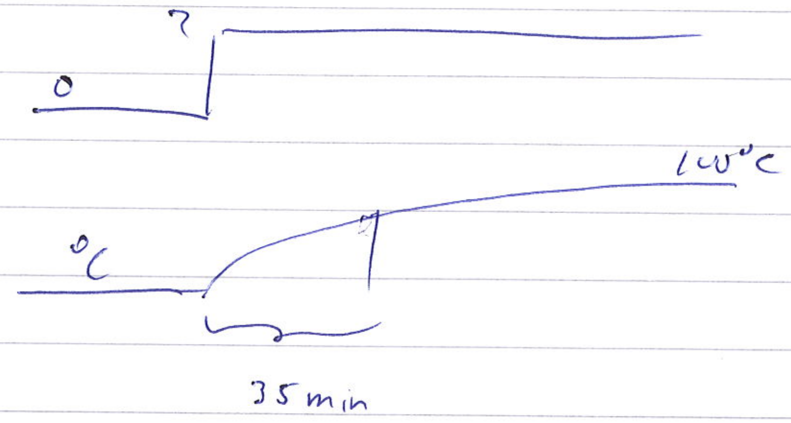
$$T = \frac{\rho_v V_v c_{p,v}}{h_v A_v} = \frac{1000 \cdot 0.002 \cdot 4200}{40 \cdot 0.1} = \frac{8400}{4}$$

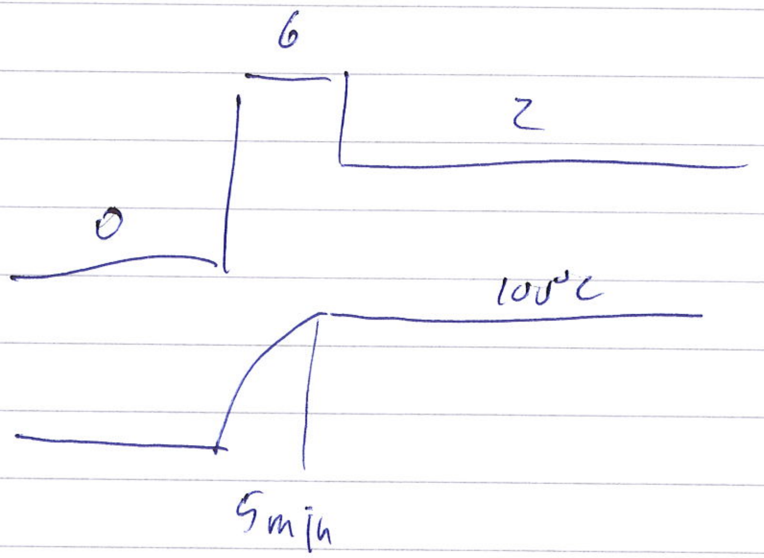
Verdien : $T = \cancel{2}1\!00$ sekund

f) Tidskonstanten er et tregt begrep.

Siden vann koker ~~når~~ på en komfyr når pådraget er på typisk 2, vil det ~~ta~~ 35 min før det koker.

Dersom du gir gass, (dvs setter plata på 6), vil temperaturen stige raskere, og når den koker, slår du ned på 2.





8

g) Overdempet system $\boxed{T_v \approx T_1 + T_2}$

$$H_p(s) = H_{p11}(s) \cdot H_{p12}(s)$$

$T_v \approx 5400$

$T_2 = T_v - T_1$

$= 5400 - 2100$

$= 3300$

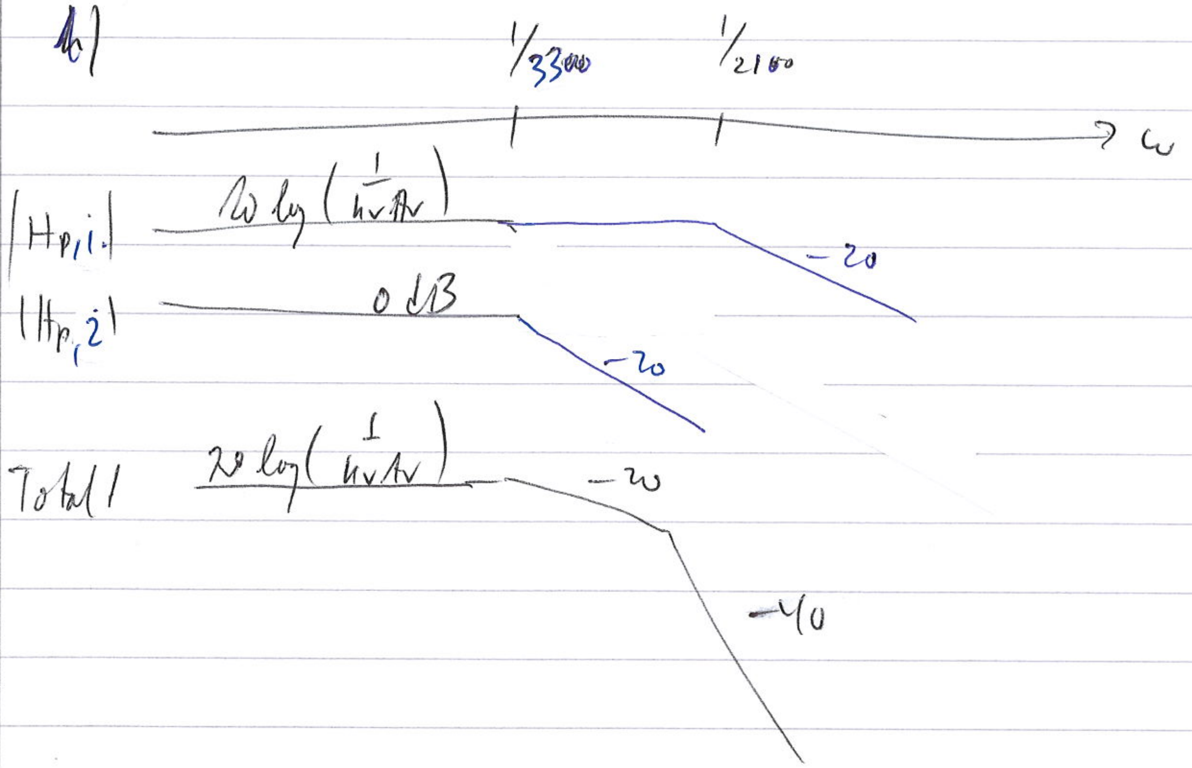
$$H_{p2}(s) = \frac{1}{3300s+1}$$

avlest, se neste ark, s 10

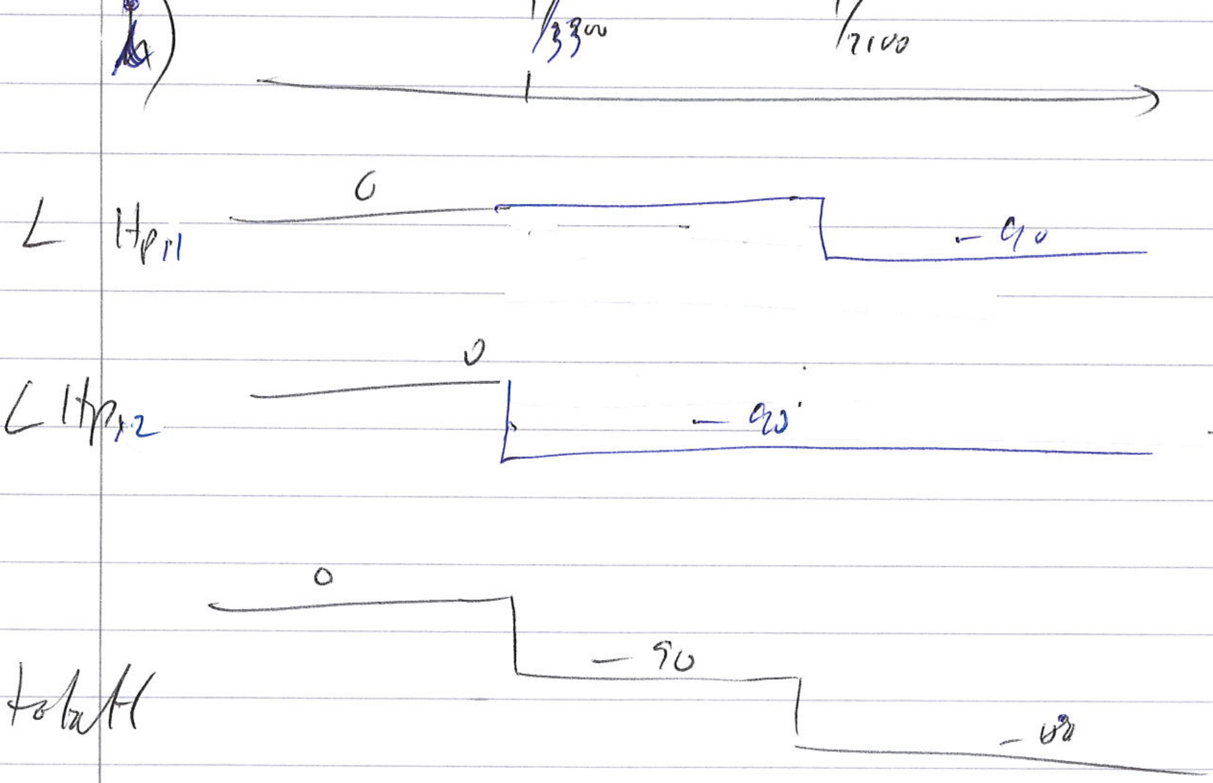
$$H_p(s) = H_{p11}(s) \cdot H_{p12}(s)$$

h) fordi ingen forsterkning mellom T_v og T_{potet}, blir stasjonært samme temp

i)



b)



Fag: ELE320, Reguleringsteknikk   Dato: 12. desember 2012
Kandidatnr: Sidenr:

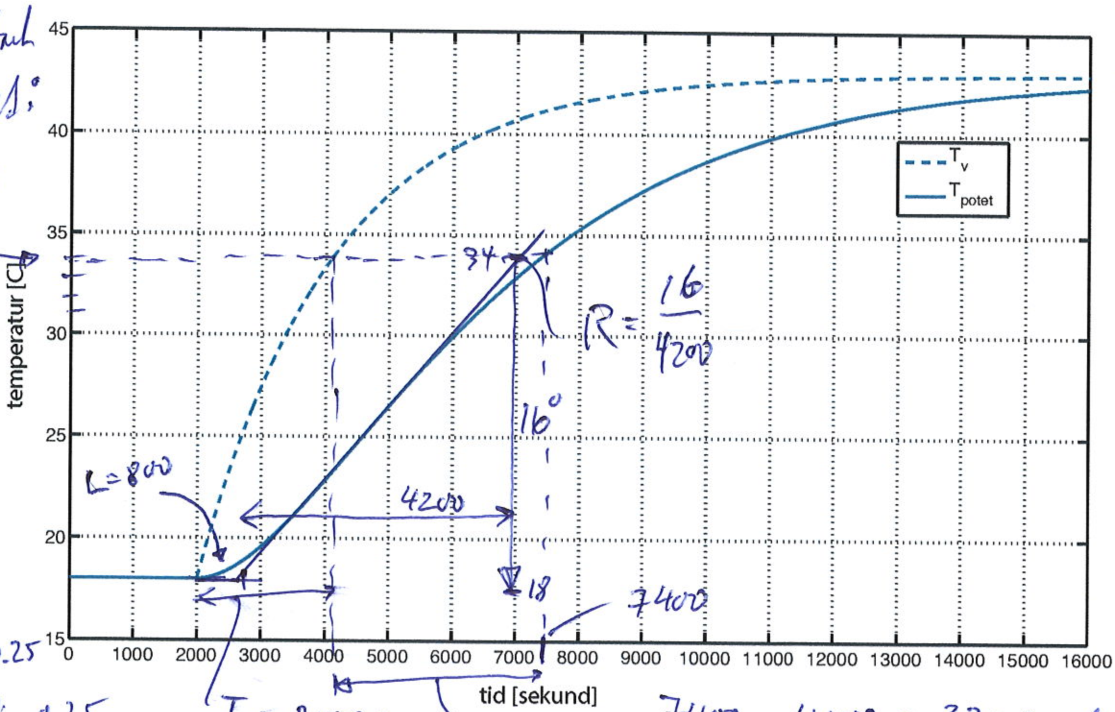
Tidskonstant avleses ved:

$18 + 25 \cdot 0.63$
$= 33.8^\circ$

Forsterkning

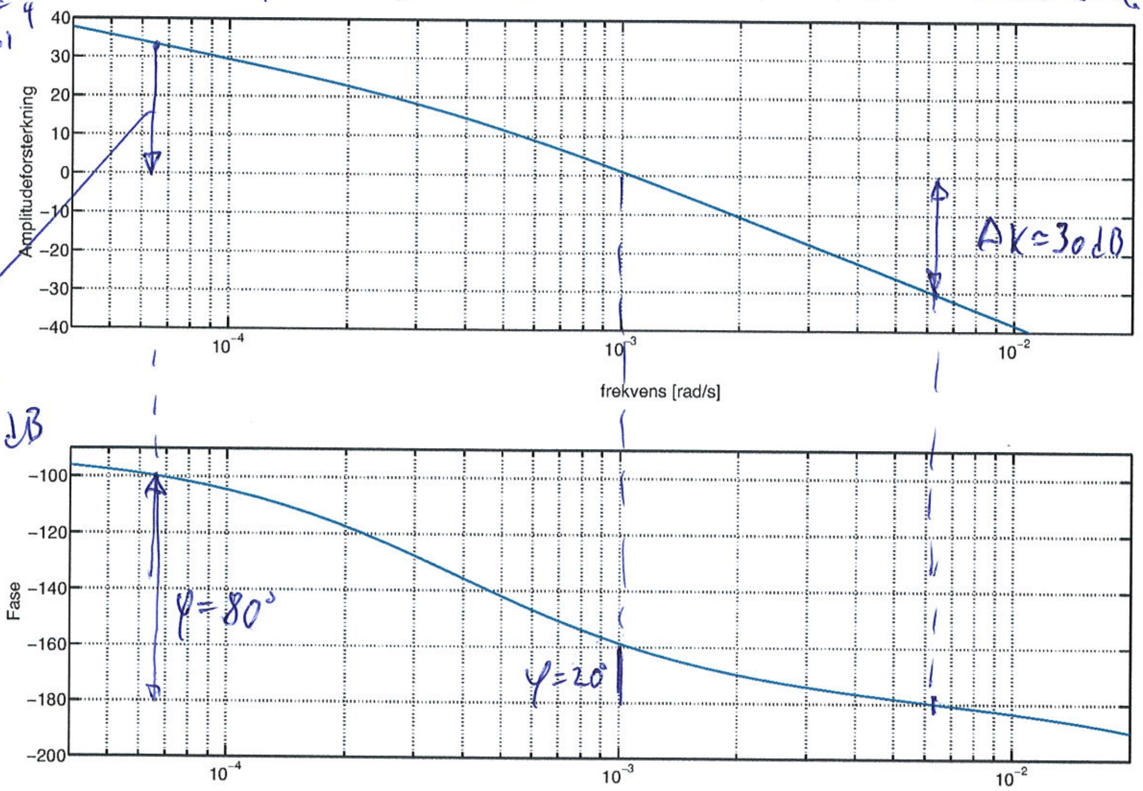
$K = \frac{\Delta y}{\Delta u}$
$= \frac{\Delta T_v}{\Delta P}$
$= \frac{25}{100} = 0.25$

$\frac{1}{k_v A_v} = \frac{1}{40 \cdot 0.1} = \frac{1}{4} = 0.25$



43°C
ΔT=25°C
18°C

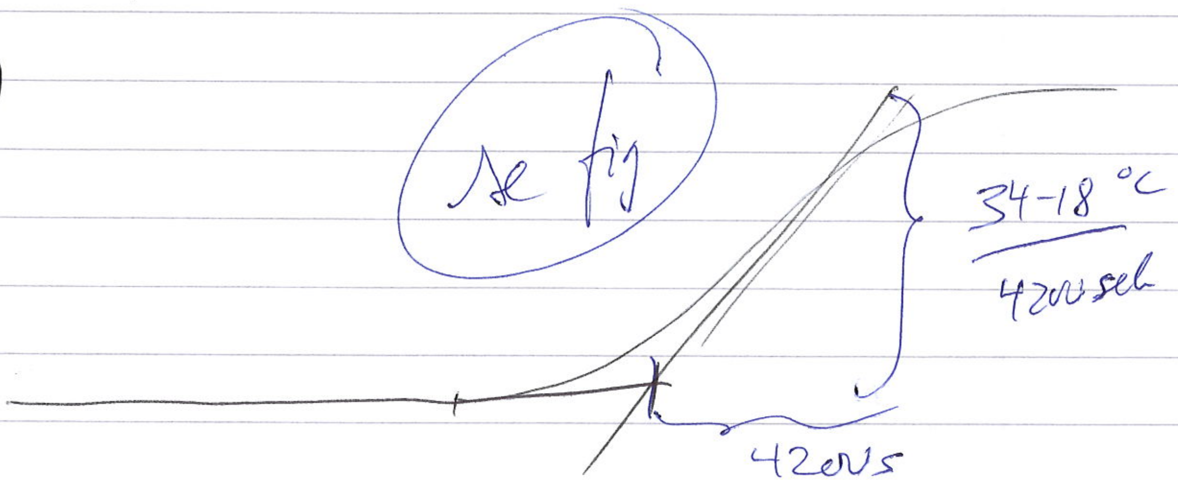
$T_1 = 2100$ s
$7400 - 4100 = 3300$ sek $= T_2$



trekkes ved 32 dB

2 Reglering

a)



$L \approx 800$

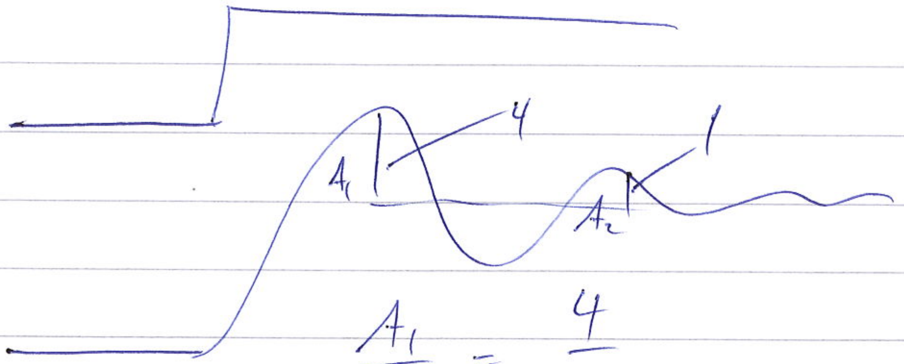
$$R = \frac{16\,°C}{4200} \approx 3{,}80 \cdot 10^{-3}$$

$$K_p = \frac{0.9 \cdot V}{L \cdot R} = \frac{0.9 \cdot 10V}{800 \cdot 3{,}80 \cdot 10^{-3}} =$$

$$\approx \underline{\underline{2{,}96}}$$

$$T_i = 3.3 \cdot L \approx \underline{\underline{3 \cdot 800}} = \underline{\underline{2400}}$$

b)



$$\frac{A_1}{A_2} = \frac{4}{1}$$

c) $$H_r(s) = \frac{K_p(T_i s + 1)}{T_i s}$$

$$= \frac{3.8 \cdot 10^{-3}(2400 \cdot s + 1)}{2400 s}$$

$$H_0(s) = H_p(s) \cdot H_m(s) \cdot H_r(s)$$

$$= \frac{0.25}{(2100 s + 1)(2900 s + 1)} \cdot \frac{1}{10 s + 1} \cdot \frac{3.8 \cdot 10^{-3}(2400 s + 1)}{2400 s}$$

$$M(s) = \frac{H_0(s)}{1 + H_0(s)} = \frac{\frac{t}{n}}{1 + \frac{t}{n}} = \frac{t}{n + t}$$

$$= \frac{0.25 \cdot 3.8 \cdot 10^{-3}(2400 s + 1)}{0.25 \cdot 3.8 \cdot 10^{-3}(2400 s + 1) + (2100 s + 1)(2900 s + 1)(10 s + 1) 2400 s}$$

d) $y_r(s) = \frac{20}{s}$

$$y(s) = M(s) \cdot y_r(s)$$

$$\lim_{t \to \infty} y(t) = \lim_{s \to 0} s \cdot y(s)$$

$$= \lim_{s \to 0} s \cdot M(s) \cdot y_r(s)$$

$$= \lim_{s \to 0} \cancel{s} \cdot M(s) \cdot \frac{20}{\cancel{s}}$$

$$= M(0) \cdot 20$$

$$M(0) = \frac{0.25 \cdot 3.8 \cdot 10^{-3}}{0.25 \cdot 3.8 \cdot 10^{-3} + 0} = 1$$

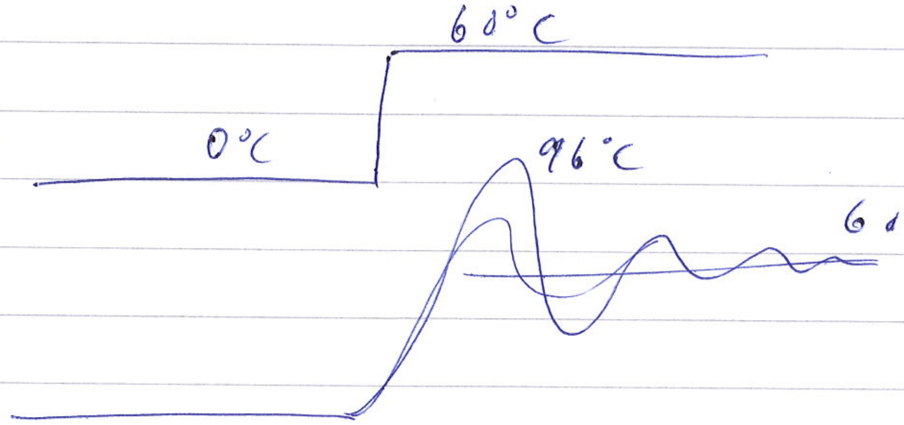
$$= 1 \cdot 20$$

$$= \underline{\underline{20}}$$

Siden $\lim_{t \to \infty} y(t) = 20$ og $y_r(t) = 20$

$\Rightarrow \underline{\underline{e(t) = 0}}$ stasjonært.

f) 20° fasemargin gir $\delta = 0.6$



$\delta = 0.6 \Rightarrow T_{max} = 96°C$ $(60 + 60 \times 0.6)$

e) $\varphi = 20°$ og $\Delta K = 30$ dB

g) reduser K_p, øk T_i

h) For å få til $\zeta \geq 1$ (kritisk/overdempet respons) må fasemargin være minst 80° slik at $\delta = 0$.

På denne måten blir ikke potetene eksponert for $T > 60°C$

Må redusere forsterkningen slik at vi får $\varphi = 80°$, dvs med 32 dB

$20 \log(x) = -32\,\text{dB} \Rightarrow x = 0.025$

Ny K_p = Gammel $K_p \cdot 0.025 = 29.6 \cdot 0.025 = \underline{0.74}$

Ny $\Delta K = 30 + 32 = 62$ dB