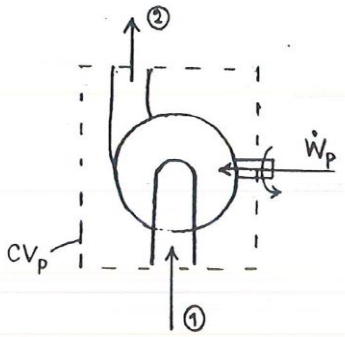
Aufgabe 1 (10 Punkte):

1) a)



[E]: $\frac{dE_P}{dt} = 0 = \dot{m}_P(h_1 - h_2) + \dot{W}_P$

$\dot{W}_P = \dot{m}_P(h_2 - h_1)$

Method (1): $h(T,P) \simeq h_f(P) + u_f(T) - u_f(T_{sat}@P)$

$\dot{W}_P = \dot{m}_P\left[h_f(P_2) + u_f(T_2) - u_f(T_{sat}@P_2) - (h_f(P_1) + u_f(T_1) - u_f(T_{sat}@P_1))\right]$

isothermal

$= 20\frac{kg}{s}[762.81 - 761.68 - 417.46 + 417.36]\frac{kJ}{kg}$

$\boxed{\dot{W}_P = 21\ kW}$

Method (2): $h(T,P) \simeq h_f(T) + v_f(T)[P - P_{sat}(T)]$

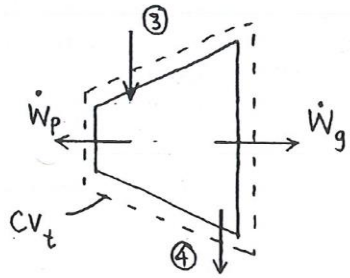
$\dot{W}_P = \dot{m}_P\{h_f(T_2) + v_f(T_2)[P_2 - P_{sat}(T_2)] - h_f(T_1) - v_f(T_1)[P_1 - P_{sat}(T_1)]\}$

$= \dot{m}_P \cdot v_f(T_2)[P_2 - P_1]$

$= 20\frac{kg}{s} \times 1.002\times10^{-3}\frac{m^3}{kg} \times (1000 - 100)\ kPa$

$\boxed{\dot{W}_P = 18\ kW}$

b)



[E]: $\frac{dE_t}{dt} = 0 = \dot{m}_t(h_3 - h_4) - \dot{W}_P - \dot{W}_g$

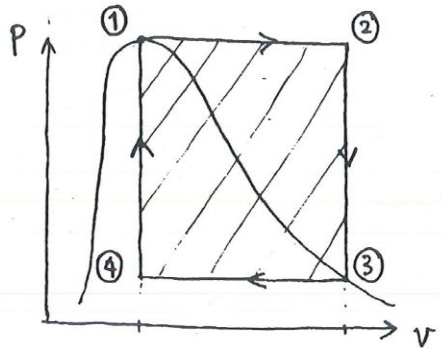
$\dot{W}_g = \dot{m}_t c_p(T_3 - T_4) - \dot{W}_P$

$= 0.1\frac{kg}{s} \times \frac{5}{2} \times \frac{8.314\ kJ}{4\ kg\cdot K}(700 - 87.5)\ K - \dot{W}_P$

$\boxed{\begin{array}{rl} \dot{W}_g = & 298\ kW \quad \text{method (1)} \\ & \text{OR} \\ = & 300\ kW \quad \text{method (2)} \end{array}}$

Aufgabe 2 (25 Punkte):

2)



a) $m = \frac{\forall_1}{v_1} = \frac{0.3155\ m^3}{3.155 \times 10^{-3}\ m^3/kg} = \boxed{100\ kg}$

b) $W_{net} = \oint P\, d\forall$ = area shaded

$= (P_1 - P_3)(\forall_2 - \forall_1)$,

$= (22.09 - 1.4) \times 10^3\ kPa \times (44.64 - 1) \times 0.3155\ m^3$

where $v_3 = v_2 = 44.64 \times 3.155 \times 10^{-3}\ \frac{m^3}{kg}$

$= 0.1408\ \frac{m^3}{kg}$

$\Rightarrow P_3 = 1.4\ MPa$

$\boxed{W_{net} = 285 \times 10^3\ kJ}$

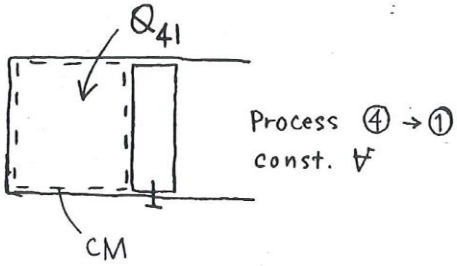
c) $x_4 = \frac{3.155 \times 10^{-3} - 1.149 \times 10^{-3}}{0.14084 - 1.149 \times 10^{-3}} = \boxed{0.0144}$

d) $u_4 = x_4 u_{fg} + u_f = 854.0\ \frac{kJ}{kg}$

$[E]_{41}$: $U_1 - U_4 = Q_{41}$

$Q_{41} = m(u_1 - u_4)$

$= 100\ kg\,(2029.6 - 854.0)\frac{kJ}{kg}$



$\boxed{Q_{41} = 118 \times 10^3\ kJ}$

Aufgabe 3 (20 Punkte):

Zustand 1:

$s_1 = (1\text{-}x_1)\ s_1' + x_1\ s_1'' = 2.8168$ kJ/kgK

Zustand 2:

$s_2 = s_1 = 2.8168$ kJ/kgK

$p_2 = 20 \times 100$ kPa $= 2$ MPa → $s_2' = 2.4474$ kJ/kgK, $s_2'' = 6.3409$ kJ/kgK

➔ Nassdampf

Zustand 3:

$p_3 = p_2$, $s_3 = s_2 + \Delta s = 5.8168$ kJ/kgK

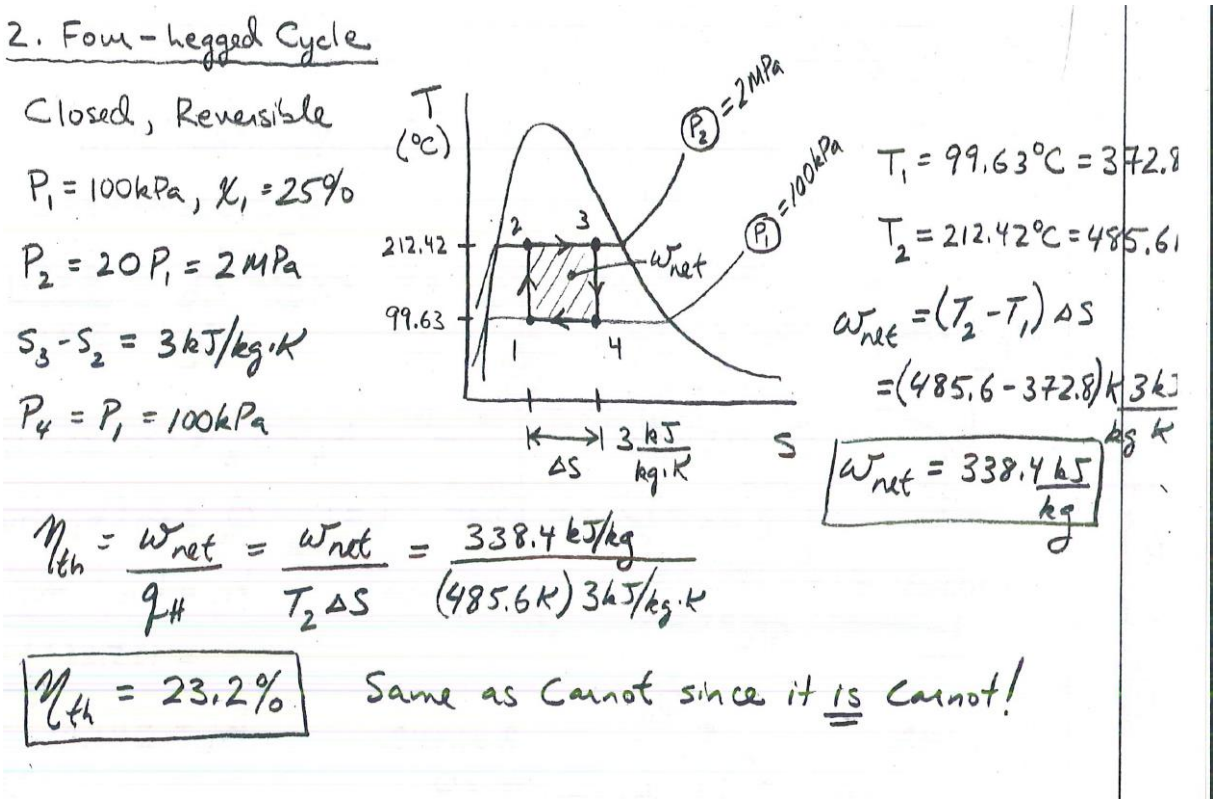
$p_3 = 2$ MPa → $s_3' = 2.4474$ kJ/kgK, $s_3'' = 6.3409$ kJ/kgK

➔ Nassdampf

Zustand 4:

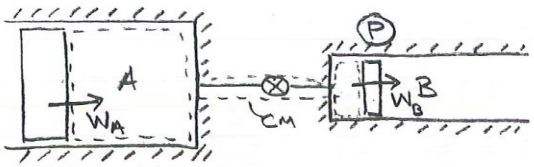
$s_4 = s_3$, $p_4 = p_1 = 100$ kPa → $s_4' = 1.3026$ kJ/kgK, $s_4'' = 7.3594$ kJ/kgK

➔ Nassdampf



Aufgabe 4 (35 Punkte):

1. Exhaust Process



$1 \to 2$: V_A = constant, isentropic
P_B = constant

$2 \to 3$: V_A decreases
$P_A = P_B$ = constant

$V_{A1} = 0.6\,l$ $P_{A1} = 500\,kPa$ $V_{B1} = 0$
$V_{A2} = V_{A1}$ $T_{A1} = 1200\,K$ $P_B = 100\,kPa$
$V_{A3} = V_{A1}/10$

$c_p = 1.142\,kJ/kg.K$
$c_v = 0.855\,kJ/kg.K$ $\Big\}\ k = 1.336$
$R = 0.287\,kJ/kg.K$

T_{A2} $\quad T_{A2} = T_{A1}\left(\frac{P_{A2}}{P_{A1}}\right)^{\frac{k-1}{k}}$

$= 1200K\left(\frac{100}{500}\right)^{\frac{.336}{1.336}}$

$\boxed{T_{A2} = 801\,K}$

m_{A2}/m_{A1} $\quad \frac{P_{A2}}{P_{A1}} = \left(\frac{v_{A1}}{v_{A2}}\right)^k = \left(\frac{V_{A1}}{V_{A2}}\frac{m_{A2}}{m_{A1}}\right)^k = \left(\frac{m_{A2}}{m_{A1}}\right)^k \Rightarrow \frac{m_{A2}}{m_{A1}} = \left(\frac{P_{A2}}{P_{A1}}\right)^{1/k} = \left(\frac{100}{500}\right)^{1/1.336}$

$\boxed{\frac{m_{A2}}{m_{A1}} = 30\%}$

T_{B2} $\quad$ [E]: $\Delta U = 0 - W_{B12} = -P_B(V_{B2} - 0)$

$m_{A2}u_{A2} + m_{B2}u_{B2} - m_{A1}u_{A1} + m_{B2}P_B v_{B2} = 0$

[M]: $m_{B2} = m_{A1} - m_{A2}$

$m_{A2}(u_{A2} - u_{B2} - RT_{B2}) + m_{A1}(u_{B2} - u_{A1} + RT_{B2}) = 0$

$m_{A2}\left[c_v(T_{A2} - T_{B2}) - RT_{B2}\right] + m_{A1}\left[c_v(T_{B2} - T_{A1}) + RT_{B2}\right] = 0$

$m_{A2}c_vT_{A2} - m_{A2}\underbrace{(c_v + R)}_{c_p}T_{B2} - m_{A1}c_vT_{A1} + m_{A1}\underbrace{(c_v + R)}_{c_p}T_{B2} = 0$

$T_{B2} = \frac{m_{A1}c_vT_{A1} - m_{A2}c_vT_{A2}}{m_{A1}c_p - m_{A2}c_p} = \frac{1}{k}\left\{\frac{T_{A1} - (m_{A2}/m_{A1})T_{A2}}{1 - (m_{A2}/m_{A1})}\right\}$

$T_{B2} = \frac{1}{1.336}\left\{\frac{1200K - 0.3(801K)}{1 - 0.3}\right\} = \boxed{1026\,K}$

m_{A3}/m_{A1} $\quad \frac{m_{A3}}{m_{A1}} = \frac{P_{A3}V_{A3}}{RT_{A3}}\frac{RT_{A1}}{P_{A1}V_{A1}} = \frac{P_{A3}}{P_{A1}}\frac{T_{A1}}{T_{A3}}\frac{V_{A3}}{V_{A1}} = \left(\frac{100}{500}\right)\left(\frac{1200}{801}\right)\frac{1}{10}$

$\boxed{\frac{m_{A3}}{m_{A1}} = 3\%}$

P_s $\quad$ [S]: $\Delta S = 0 - 0 + P_s$

$P_s = S_3 - S_1 = m_{A3}s_{A3} + m_{B3}s_{B3} - m_{A1}s_{A1} - \underbrace{m_{B1}s_{B1}}_{0}$

[M]: $m_{B3} = m_{A1} - m_{A3}$

$$P_S = m_{A3}s_{A3} + m_{A1}s_{B3} - m_{A3}s_{B3} - m_{A1}s_{A1}$$

$$= m_{A3}(s_{A3} - s_{B3}) + m_{A1}(s_{B3} - s_{A1})$$

$$= m_{A3}\left\{ c_p \ln\frac{T_{A3}}{T_{B3}} - R\ln\frac{P_{A3}}{P_{B3}} \right\} + m_{A1}\left\{ c_p \ln\frac{T_{B3}}{T_{A1}} - R\ln\frac{P_{B3}}{P_{A1}} \right\}$$

Need T_{B3} [E]: $\Delta U = W_{A23} - W_{B23} = -P_{A23}(V_{A3} - V_{A2}) - P_{B23}(V_{B3} - V_{B2})$

$$m_{A3}u_{A3} + m_{B3}u_{B3} - m_{A2}u_{A2} - m_{B2}u_{B2} + m_{A3}RT_{A3} - m_{A2}RT_{A2} + m_{B3}RT_{B3} - m_{B2}RT_{B2} = 0$$

$$m_{A3}u_{A3} + (m_{A1} - m_{A3})u_{B3} - m_{A2}u_{A2} - (m_{A1} - m_{A2})u_{B2} + m_{A3}RT_{A3} - m_{A2}RT_{A2} + (m_{A1} - m_{A3})RT_{B3} - (m_{A1} - m_{A2})RT_{B2} = 0$$

$$m_{A3}(u_{A3} - u_{B3} + RT_{A3} - RT_{B3}) + m_{A1}(u_{B3} - u_{B2} + RT_{B3} - RT_{B2}) + m_{A2}(u_{B2} - u_{A2} - RT_{A2} + RT_{B2}) = 0$$

$$m_{A3}\left[c_v(T_{A3} - T_{B3}) + R(T_{A3} - T_{B3})\right] + m_{A1}\left[c_v(T_{B3} - T_{B2}) + R(T_{B3} - T_{B2})\right] + m_{A2}\left[c_v(T_{B2} - T_{A2}) + R(T_{B2} - T_{A2})\right] = 0$$

$$m_{A3}c_p(T_{A3} - T_{B3}) + m_{A1}c_p(T_{B3} - T_{B2}) + m_{A2}c_p(T_{B2} - T_{A2}) = 0$$

$$T_{B3} = \frac{m_{A1}c_pT_{B2} + m_{A2}c_p(T_{A2} - T_{B2}) - m_{A3}c_pT_{A3}}{m_{A1}c_p - m_{A3}c_p}$$

$$= \frac{T_{B2} + (m_{A2}/m_{A1})(T_{A2} - T_{B2}) - (m_{A3}/m_{A1})T_{A3}}{1 - (m_{A3}/m_{A1})}$$

$$= \frac{1026\text{K} + 0.3(801 - 1026)\text{K} - (0.03)\,801\text{K}}{1 - 0.03} = \boxed{963\text{K}}$$

$$m_{A1} = \frac{P_{A1}V_{A1}}{RT_{A1}} = \frac{(500\text{kPa})(0.6\times10^{-3}\text{m}^3)}{(.287\text{kJ/kg·K})(1200\text{K})} = \boxed{0.871\text{g}} \Rightarrow m_{A3} = \boxed{0.0261\text{g}}$$

$$P_S = .0261\times10^{-3}\text{kg}\left\{1.142\frac{\text{kJ}}{\text{kg·K}}\ln\frac{801}{963}\right\} + 0.871\times10^{-3}\text{kg}\left\{1.142\frac{\text{kJ}}{\text{kg·K}}\ln\frac{963}{1200} - .287\frac{\text{kJ}}{\text{kg·K}}\ln\frac{100}{500}\right\}$$

$$= -.00549\frac{\text{J}}{\text{K}} + 0.18347\frac{\text{J}}{\text{K}} = \boxed{0.178\ \text{J/K}}$$