Aufgabe 1

[redacted]

1

a) 1 HS am Reaktor

$$\cancel{\frac{dE}{dt}}^{0,\ \text{stationär}} = \sum_i \dot{m}\left[h_i + \cancel{ke_i}^{0} + \cancel{pe_i}^{0}\right] + \dot{Q}_{aus} - \cancel{\dot{W}}^{0}$$

$$\dot{Q}_{aus} = -\dot{m}_{ein}\, h_{ein} + \dot{m}_{aus}\cdot h_{aus}$$

Tab A-2: $h_{ein}(T_{ein} = 70°C) = 292.98\ \frac{kJ}{kg}$

$h_{aus}(T_{aus} = 100°C) = 419.04\ \frac{kJ}{kg}$

$$\dot{Q}_{aus} = -0.3\,\frac{kg}{s}\cdot 292.98\,\frac{kJ}{kg} + 0.3\,\frac{kJ}{s}\cdot 419.04\,\frac{kJ}{kg}$$

$$= 37.818\ \frac{kJ}{s} = \underline{\underline{37.818\ kW}}$$

b) $$\overline{T}_{KF} = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{T_a - T_e}{s_a - s_e}$$

c) $$\dot{S}_{erz} = \dot{m}\left[s_a - s_e\right] + \frac{\dot{Q}_R}{T_U}$$

~~ideale Flüssigkeit~~

TAB A-2: $s_a(T_a = 100°C) = 1.3069\ \frac{kJ}{kgK}$

$s_e(T_e = 70°C) = 0.9549\ \frac{kJ}{kgK}$

$$\rightarrow \dot{S}_{erz} = 0.3\,\frac{kg}{s}\left[1.3069 - 0.9549\right)\frac{kJ}{kgK} + \frac{100\ kW}{295\ K} = \underline{\underline{444.58\ \frac{W}{K}}}$$

d) $\frac{dE}{dt} = \sum_i \dot{m}_i \left[h_i + \cancel{ke_i + pe_i} \right]^0 + \sum_j \dot{Q}_j - \sum_k \cancel{\dot{W}_k}^0$

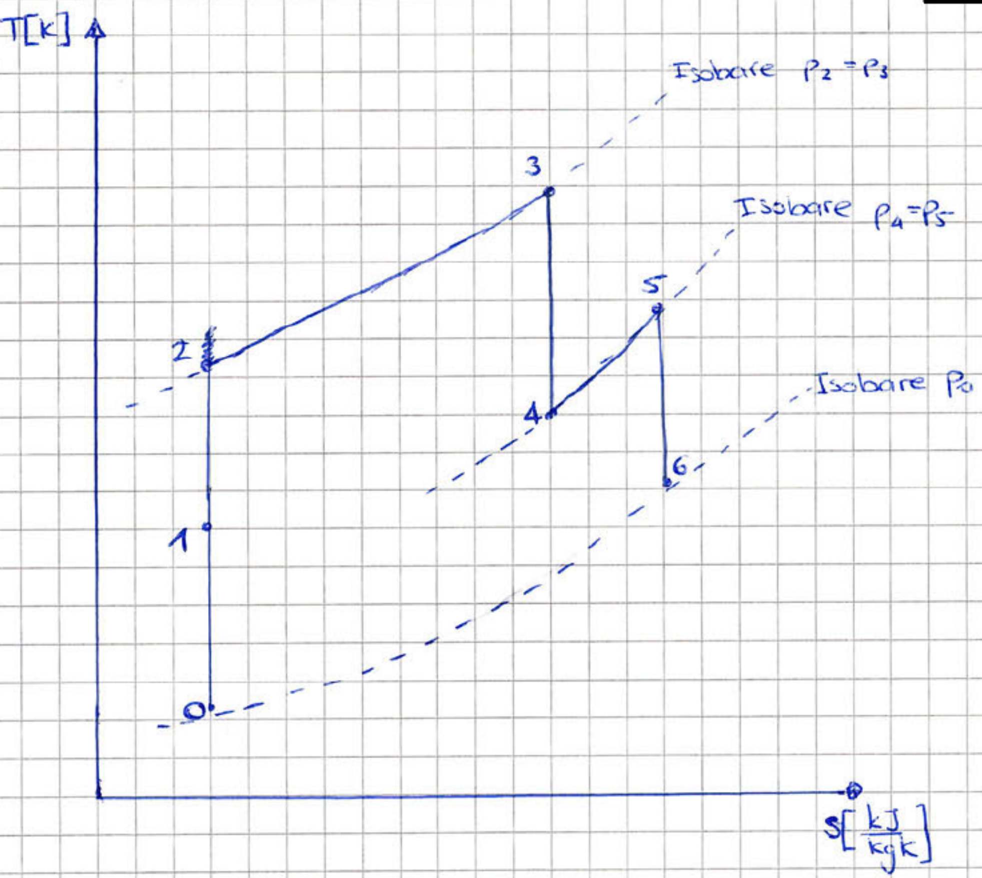
e

e) $\Delta S = S_2 - S_1 = m(s_2 - s_1) = \sum_j \frac{Q_j}{T_j} + S_{erz}$

$-S_{erz} = \sum_i \dot{m}_i s_i + \sum_j \frac{\dot{Q}_j}{T_j}$

Aufgabe 2

a)



b) Prozessschritt 5-6 isentrop:

$$T_6 = T_5 \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} = 431{,}9\,K \left(\frac{0.191 \cdot 10^5\,Pa}{0.5 \cdot 10^5\,Pa}\right)^{\frac{0.4}{1.4}} = \underline{\underline{328{,}07\,K}}$$

Energiebilanz an Schubdüse:

$$0 = \dot{m}\left[h_e - h_a + \frac{w_e^2 - w_a^2}{2}\right] + \underbrace{\cancel{\dot{Q}}}_{0,\ \text{adiabat}} - \underbrace{\cancel{\dot{W}}}_{0}$$

$$\cancel{h_e - h_a = h_6 - h_5 \underset{\text{ideales Gas}}{=} c_{p,Luft}^{ig}(T_6 - T_5) = 1.006\,\frac{kJ}{kgK}(328{,}07 - 431{,}9)\,K}$$

$$h_5 - h_6 \underset{\text{ideales Gas}}{=} c_{p,Luft}^{ig}(T_5 - T_6) = 1.006\,\frac{kJ}{kgK}(431.9\,K - 328.07\,K) = \underline{104{,}45\,\frac{kJ}{kg}}$$

$$\rightarrow \quad 0 = h_5 - h_6 + \frac{w_5^2 - w_6^2}{2}$$

$$-(h_5 - h_6) = \frac{w_5^2 - w_6^2}{2} \rightarrow -2(h_5 - h_6) = w_5^2 - w_6^2$$

$$w_6 = \sqrt{w_5^2 + 2(h_5 - h_6)} = \sqrt{\left(220\,\frac{m}{s}\right)^2 + 2\,(104.45)\,\frac{kJ}{kg}} = \underline{\underline{507{,}25\,\frac{m}{s}}}$$

c) $\Delta e_{x,str} = e_{x,str,6} - e_{x,str,0}$

$$= h_6 - h_0 - T_0(s_6 - s_0) + ke_6 - (\cancel{h_0} - \cancel{h_0} - T_0(\cancel{s_0 - s_0}) + ke_0)$$

$$h_6 - h_0 = \int_{T_0}^{T_6} c_{p_{Luft}}^{ig}(T)\, dT = c_{p_{Luft}}^{ig}(T_6 - T_0)$$

$$= 1.006 \frac{kJ}{kgK}(328.07\,K - 243.15\,K) = \underline{85{,}43} \frac{kJ}{kg}$$

Aus TAB A-22: $s^\circ(T_6) = \frac{(1{,}79783 - 1{,}78249)\frac{kJ}{kgK}}{(330-325)K}(328{,}07-325)K + 1{,}78249\frac{kJ}{kgK}$

$$s^\circ(T_6) = \underline{1.7919} \frac{kJ}{kgK}$$

$$s^\circ(T_0) = \frac{(1.51917 - 1.47824)\frac{kJ}{kgK}}{(250-240)K}(243{,}15 - 240)K + 1.47824\frac{kJ}{kgK}$$

$$s^\circ(T_0) = \underline{1{,}4911} \frac{kJ}{kgK}$$

$\rightarrow \Delta e_{x,str} = h_6 - h_0 - T_0(s_6 - s_0) + ke_6 + ke_0$

$ke_6 = \frac{1}{2}w_6^2 \qquad ke_0 = \frac{1}{2}w_{Luft}^2 = 20000 \frac{m^2}{s^2}$

$= 128651.28 \frac{m^2}{s^2}$

$\rightarrow \Delta e_{x,str} = 85{,}43\frac{kJ}{kg} - 243.15\,K\left(1.7919\frac{kJ}{kgK} - 1{,}4911\frac{kJ}{kgK}\right) + (1288651{,}28 - 20000)\frac{m^2}{s^2}$

$$\underline{\underline{\Delta e_{x,str} = 1280.94 \frac{kJ}{kg}}}$$

d) $\dot{E}_{x,verl} = T_0 \dot{S}_{erz}$

$e_{x,verl} = T_0 \frac{\dot{S}_{erz}}{\dot{m}_{ges}} = T_0[s_a - s_e] = T_0[s_6 - s_0] = 243.15\,K\left(s_6^\circ(T_6) - s_0^\circ(T_0) - R\ln\left(\frac{p_6}{p_0}\right)\right)$

$$= 243{,}15\,K\left(1{,}7919\frac{kJ}{kgK} - 1.4911\frac{kJ}{kgK} - \underbrace{R\ln(1)}_{0}\right)$$

$$e_{x,verl} = \underline{\underline{73.14}} \frac{kJ}{kg}$$

[redacted]

Aufgabe 3

a) $pV = mRT$

$$R = \frac{\bar{R}}{M} = \frac{8314 \frac{J}{kmol\,K}}{50 \frac{kg}{kmol}} = 166.28 \frac{J}{kg\,K}$$

b)

c) 1. HS

$$\Delta U = \cancel{\dot{m}\left[h + ke + pe\right]}^{0} + Q - \cancel{W}^{0}$$

$$Q_{12} = \Delta U = (U_2 - U_1) \cdot m_g$$

$$Q_{12} = c_v^{pg}\left(T_{2g} - T_{1g}\right) = 0.633 \frac{kJ}{kg\,K}\left(0.003°C - 500°C\right) \cdot 0.0036\,kg$$

$$Q_{12} = \cancel{2846}\ \underline{\underline{-1139{,}39\ J}}$$

d) $\cancel{x_{Eis,2} = \frac{m_{Eis}}{m_{Eis} + m_{Wasser}} = \frac{0{,}6\, m_{EW}}{m_{EW}}}$

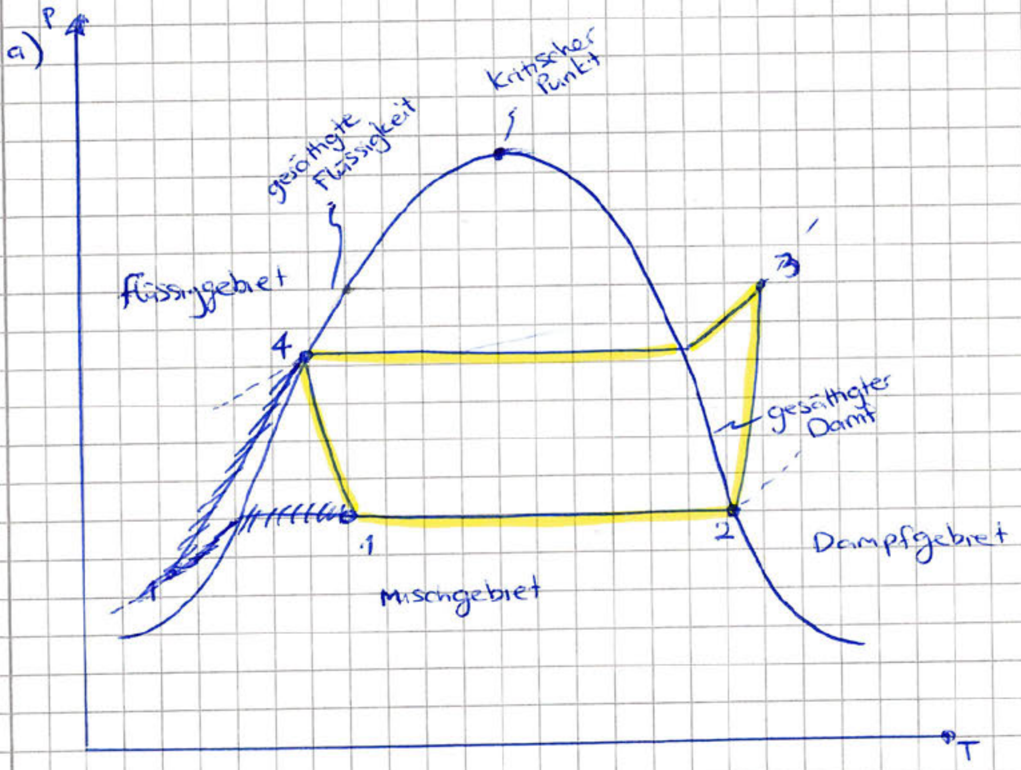
$$x_{Eis_2} = \frac{m_{Eis,2}}{m_{EW_2}} = \frac{u - u_f}{u_g - u_f}$$

[redacted]

4

Aufgabe 4

a)



b) $T_1 = T_i - 6\,K$

$T_i = -10\,°C = 263{,}15\,K$

$T_1 = 257.15\,K = -16\,°C$

Aus TAB A-10 : $h_1(T=-16\,°C) = h_f(T=-16\,°C) = 29.30\,\frac{kJ}{kg}$

$h_4 = h_1 = 29.30\,\frac{kJ}{kg}$ (Drossel isenthalp)

$p_3 = p_4 = 8$ bar

$x_4 = 0 \longrightarrow$ aus TAB A-11 $h_4 = h_g(p_4 = 8\,bar) = 264.15\,\frac{kJ}{kg}$

$\left(\longrightarrow \frac{p_1}{p_4} = \left(\frac{T_1}{T_4}\right)^{\frac{n}{n-1}}\right)$

1. HS am Verdichter

$$\underbrace{\cancel{\frac{dE}{dt}}}_{0,\ \text{stationär}} = \dot m \left[h_2 - h_3\right] + \underbrace{\cancel{\dot Q}}_{0,\ \text{adiabat}} - \dot W_K$$

$$\dot W_K = \dot m \left[h_2 - h_3\right] \longrightarrow \dot m_{R134a} = \frac{\dot W_K}{h_2 - h_3}$$

c) $x_1 = \frac{h_1 - h_{1f}}{h_{1g} - h_{1f}}$

Drossel isenthalp $\longrightarrow$ $h_4 = h_1 = 264.15 \frac{kJ}{kg}$

$h_1 f(T_1 = -16°) \overset{\text{TAB A-10}}{=} 29.30 \frac{kJ}{kg}$

$h_1 g(T_1 = -16°) \overset{\text{TAB A-10}}{=} 237.74 \frac{kJ}{kg}$

$\rightarrow x_1 = \frac{264.15 \frac{kJ}{kg} - 29.30 \frac{kJ}{kg}}{237.74 \frac{kJ}{kg} - 29.30 \frac{kJ}{kg}} = 1.127$?

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{\dot{W}_t} = \frac{|\dot{Q}_{zu}|}{|\dot{Q}_{ab}| - |\dot{Q}_{zu}|}$

1. HS am Verdampfer

$0 = \dot{m}[h_1 - h_2] + \dot{Q}_K$

$\rightarrow \dot{Q}_K = \dot{m}(h_2 - h_1) = \dot{m}_{R134a}[h_2 - h_1]$

$h_2 = h_f \overset{\text{TAB-A-10 @ } T_2 = -22°C}{=} 21.77 \frac{kJ}{kg}$

$h_1 = 29.30 \frac{kJ}{kg}$

$\rightarrow \dot{Q}_K = 4 \frac{kg \cdot h}{h \cdot 3600 s}\left(21.77 \frac{kJ}{kg} - 29.30 \frac{kJ}{kg}\right) = -8.367 \frac{J}{kgs}$

$\rightarrow \varepsilon_K = \frac{|\dot{Q}_{zu}|}{|\dot{W}_t|} = \frac{0.00837 \frac{kJ}{kgs}}{0.028 \frac{kJ}{kgs}} = \underline{\underline{0.299}}$

e)