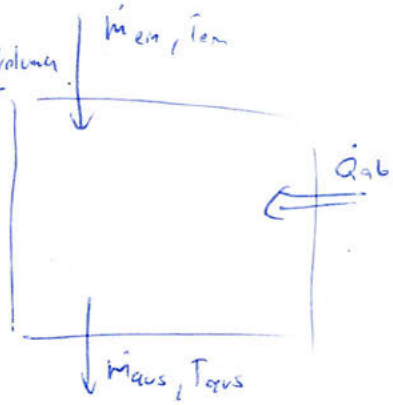
Aufgabe 1)

a) $\frac{dE}{dt} = \dot{m}_{ein}\left(h_{ein} - h_{aus} + (k_e + p_e)\right) + \dot{Q}_{ab} - P_v$

(0, stationär; kein Einfluss; keine Leistung erbracht)



$\Rightarrow \dot{Q}_{ab} = \dot{m}_{ein}\left(h_{aus} - h_{ein}\right)$

$h_{ein} = h(70°C, x=0) = h_f(70°C) = 292.98\ \frac{kJ}{kg}$

$h_{aus} = h(100°C, x=0) = h_f(100°C) = 419.04\ \frac{kJ}{kg}$

$\Rightarrow \dot{Q}_{ab} = 0.3\frac{kg}{s} \cdot \left(419.04\frac{kJ}{kg} - 292.98\frac{kJ}{kg}\right) = 37.818\ kW$

$\dot{Q}_{ab} = \dot{Q}_R - \dot{Q}_{aus} \Rightarrow \dot{Q}_{aus} = \underline{62.182\ kW}$

b) $\overline{T}_{KF} = \frac{\int_1^2 T \cdot ds}{s_2 - s_4}$

$\frac{dS}{dt} = \dot{m}\left(s_4 - s_2\right) + \frac{\dot{Q}_{zu}}{\overline{T}} + S_{irr}$

$\dot{q}_{zu} = (s_2 - s_1) \cdot \overline{T} \Rightarrow \overline{T} = \frac{\dot{q}_{zu}}{(s_2 - s_1)}$

$\dot{q}_{zu} = \frac{\dot{Q}_{aus}}{\dot{m}}$

b) $\bar{T} = \dfrac{\int_e^a T\,ds}{s_a - s_e}$

Wärmeübertrager isolier

$\dfrac{dS}{dt} = \dot{m}(s_e - s_a) + \dfrac{\dot{Q}_{zu}}{\bar{T}} + \dot{S}_{irr}$

$\dfrac{dE}{dt} = \dot{m}(h_e - h_a) + \dot{Q}_{zu} - \dot{W}_v$

$\dot{m} = \dfrac{\dot{Q}_{zu}}{h_a - h_e}$

$h_a - h_e = \Delta h = c_p^{pg}(T_a - T_e)$

c) mit $\bar{T}_{KF} = 295\,K$, $\dot{Q}_{zu} = 65\,kW$

$\dfrac{dS}{dt} = \dot{m}(s_e - s_a) + \dfrac{\dot{Q}_{zu}}{\bar{T}} + \dot{S}_{irr}$

$\dot{S}_{irr} = \dot{m}(s_a - s_e) - \dfrac{\dot{Q}_{zu}}{\bar{T}}$

$\dot{S}_{irr} = \dot{Q}_{zu}\left(\dfrac{s_a - s_e}{h_a - h_e} - \dfrac{1}{\bar{T}}\right)$

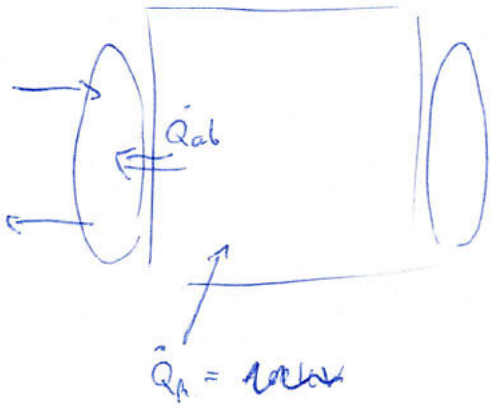
$= \dot{Q}_{zu}\left(\dfrac{\ln\left(\frac{T_a}{T_e}\right)}{(T_2 - T_1)} - \dfrac{1}{\bar{T}}\right) = 1.411\,9\ \dfrac{kJ}{kgK}$

$m = \dfrac{\dot{Q}_{zu}}{h_a - h_e}$

$\Delta s = c_p \ln\left(\dfrac{T_2}{T_1}\right) - R \ln\left(\dfrac{p_2}{p_1}\right)$

[redacted]

d)



1 -> 2) $\dot{Q}_{ab} = \dot{Q}_A = 35\,MJ$

$$\frac{dE}{dt} = \dot{m}\left(h_{e,\text{wasser}} - h_{a,\text{wasser}}\right) + \dot{Q}_{a,A} - \cancel{\dot{W}_v}^{\,0}$$

$$\Rightarrow \Delta E = \Delta m_{12}\left(h_{e,kg} - h_{a,kg}\right) + Q_{A,12}$$

$$\Rightarrow \Delta E = \Delta U = m_{\text{wasser}}\, u_2 - u_1$$

$u_1 = m_{gas,1} \cdot u_f(100°C) = m \cdot 419.95 \frac{kJ}{kg}$

$u_2 - m_{gas,1} \cdot u_f(70°C) = m \cdot 292.95 \frac{kJ}{kg}$

$\Delta U =$

$u_1 = m_{gas} \cdot u_1 \Rightarrow u_1 = u_f(100°C) + \left(u_g(100°C) - u_f(100°C)\right) \cdot 0.005$

$= 429.3728 \frac{kJ}{kg}$

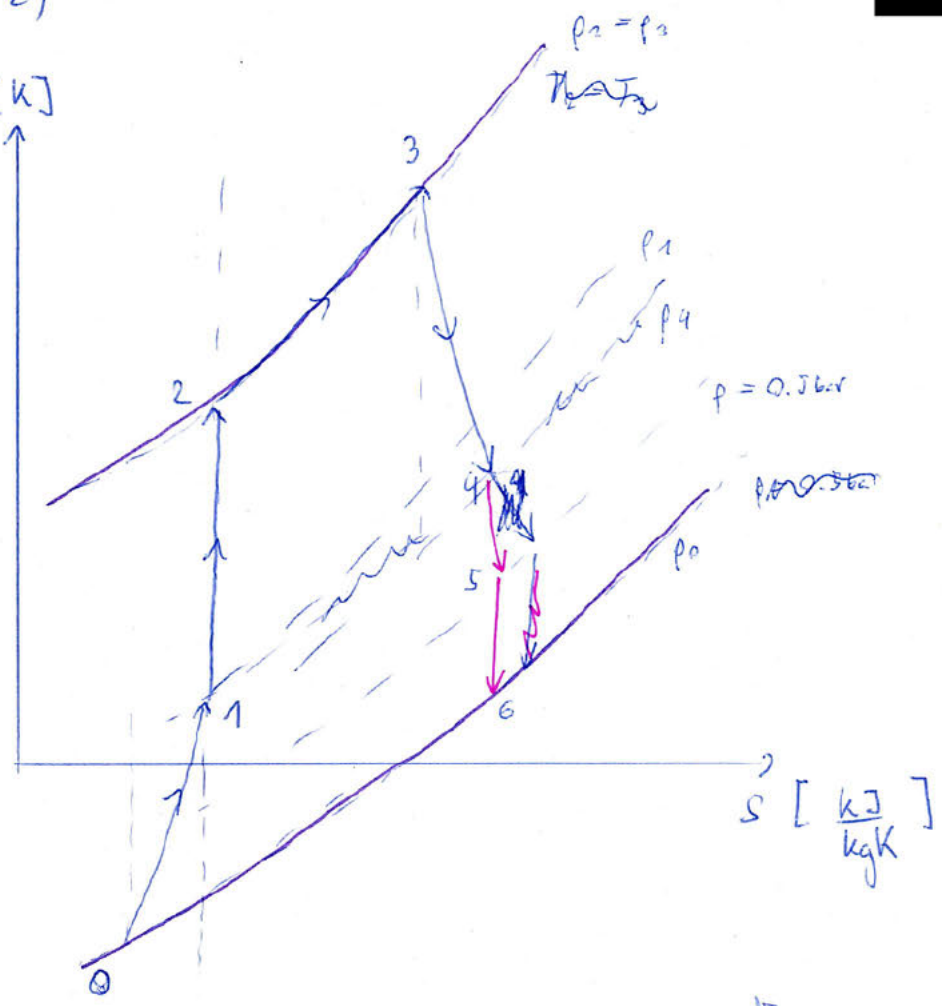
$\rightarrow \Delta U = -785.14\,MJ$

$$\Rightarrow \Delta m_{12} = \frac{\Delta U - Q_{A,12}}{\left(h_{e,gas} - h_{a,gas}\right)}$$

Kühlmittel: $c_p^{Ay} = konst$ $\quad \frac{dE}{dt}^{\nearrow 0} = \dot{m}(\Delta h) + \dot{Q}_{zu}$

Aufgabe 2)

a)



b) Schubdüse: $w_5 = 220 \frac{m}{s}$ $p_5 = 0.56 bar$ $T_5 = 431 K$

$$\frac{dE}{dt}^{\nearrow 0} = \dot{m}_5 \cdot \left(h_5 - h_6 + \frac{(w_e^2 - w_a^2)}{2} \right) + \dot{Q}_{zu}^{\nearrow 0} - P_v^{\nearrow 0}$$

reversible & adiabate Schubdüse → isentrop mit $n = 1.4$

$$\Delta h = c_p^{15} (T_5 - T_6) \quad \Rightarrow \quad \Delta h = 104.448 \frac{kJ}{kg}$$

$$T_6 = T_5 \left(\frac{p_6}{p_5} \right)^{\frac{n-1}{n}} = 328.07 K$$

$\left(\dot{m}_5 = \dot{m}_M + \dot{m}_{K,5} \qquad \dot{m}_{K,5} = \dot{m}_{K,1} \Rightarrow \dot{m} = \right)$

$$\Rightarrow w_a = \sqrt{w_e^2 + \Delta h \cdot 2} = 498.89 \frac{m}{s}$$

c) $\dot{e}_{x,str,0} = \frac{w_0^2}{2}$ da T_0, p_0 Bezugspunkt für Exergie $\Rightarrow e_{x,str,0} = 20 \frac{kJ}{kg}$

$\dot{e}_{x,str,6} = h_6 - h_0 - T_0 (s_6 - s_0) + \frac{w_6^2}{2}$

$c_p^{pg}(T_6 - T_0) - T_0 \cdot \left(c_p^{pg} \ln\left(\frac{T_6}{T_0}\right) - R \ln\left(\frac{p_6}{p_0}\right)^{0} \right) + \frac{w_6^2}{2}$

$= 85.429 \frac{kJ}{kg} - 73.27 \frac{kJ}{kg} + 124.448 \frac{kJ}{kg} = 136.605 \frac{kJ}{kg}$

$\Rightarrow \Delta e_{x,str} = \underline{\underline{116.60 \frac{kJ}{kg}}}$

d) $\frac{dE_x}{dt}^{0} = \dot{E}_{x,str} + \dot{E}_{x,Q}^{\neq 0} - \left[\dot{W}_n - p_0 \frac{dV(t)}{dt}^{0} \right] - \dot{E}_{x,verl}$

$: \dot{m}$

$\Rightarrow e_{x,verl} = e_{x,str} + e_{x,Q}$

$q = 1195 \frac{kJ}{kg}$

$e_{x,Q} = \frac{\dot{E}_{x,Q}}{\dot{m}} = \frac{1}{\dot{m}_K} \left(1 - \frac{T_0}{T}\right) \cdot \dot{Q} = \left(1 - \frac{T_0}{T}\right) q \cdot y$ $\quad T = 1298\,K$

$e_{x,verl} = 116.60 \frac{kJ}{kg} + 969.58 \cdot \frac{1}{6.293} \frac{kJ}{kg}$

$= \underline{\underline{270.67 \frac{kJ}{kg}}}$

$y \cdot \dot{m}_{ges} = \dot{m}_K$

$\dot{m}_{ges} = \dot{m}_K + 5.293 \cdot \dot{m}_K$

$\dot{m}_K = \frac{1}{6.293} \cdot \dot{m}_{ges}$

Aufgabe 3)

a) c_v^{ps} $\quad \mu_g \quad \Rightarrow \quad p_1 = \dfrac{m_1 \cdot R_1 \cdot T_1}{V_1}$

$R = \dfrac{\bar{R}}{\mu_g} = 166{,}28 \dfrac{J}{kgK} \qquad m_1 = \dfrac{p_1 \cdot V_1}{R_1 \cdot T_1}$

$A_2 = \pi \cdot r^2 = \pi \cdot \dfrac{D^2}{4} = \dfrac{\pi}{400}\,in$

$p = \dfrac{m_{EW} \cdot g}{A_2} + \dfrac{32\,kg}{A_2} \cdot g + p_{am} = 140\,kPa = 1{,}4\,bar$

$m_1 = 3{,}4217\,g$

b) $\dfrac{dE}{dt} = \dot{W}(\dots) + \dot{Q}_{12} - \dot{W}_v$ | für gas

$\Rightarrow \Delta E = \Delta U = -W_v$

$\dfrac{dE}{dt} = \dot{m}_2$

$p_{g,2} = p_{EW,2}$ $\qquad \Delta U_{EW} = cit$

b) $p = konst \Rightarrow T_{g,2} = T_{g,1}\left(\frac{V_{2,g}}{V_{1,g}}\right)$

$V_{2,g} = -\frac{W_V}{p} + V_1$

$\frac{dE}{dt} = \dot{m}(\ldots)^{0} + \dot{Q}_{zu} - W_V$

$\Delta u_{EW} \cdot m_{EW} = Q_{zu} - W^{0}$ & $\Delta u_g \cdot m_g = \dot{q}_{zu} - W_V$

$\Rightarrow W_V =$

c) $T_{3,2} = 0.005°C$

$\frac{dE}{dt} = \dot{m}(\ldots)^{0} + \dot{Q}_{zu} - \dot{W}_V$

$dE = m_g \cdot \Delta u_{gas} = m_g \cdot c_v (T_2 - T_1) =$

$\dot{W}_V \Rightarrow p\,konst \Rightarrow \frac{T_2}{T_1} = \frac{V_2}{V_1} \Rightarrow V_2 = 1.109L$

$W_V = (V_2 - V_1) \cdot p = -284.28\,J$

$\Rightarrow Q_{zu} = -1082.96\,kJ \mp 284.28 = -1367.24\,J$

$\Rightarrow |Q_{ab}| = 1367.24\,J$

d) $p = p_{s,1} = 1{,}4\ \text{bar}$ $\quad Q = 15000\,\text{J}$

$$\frac{dE}{dt} = \dot{W}(\ldots) + \dot{Q}_{zu} - \dot{W}_v$$

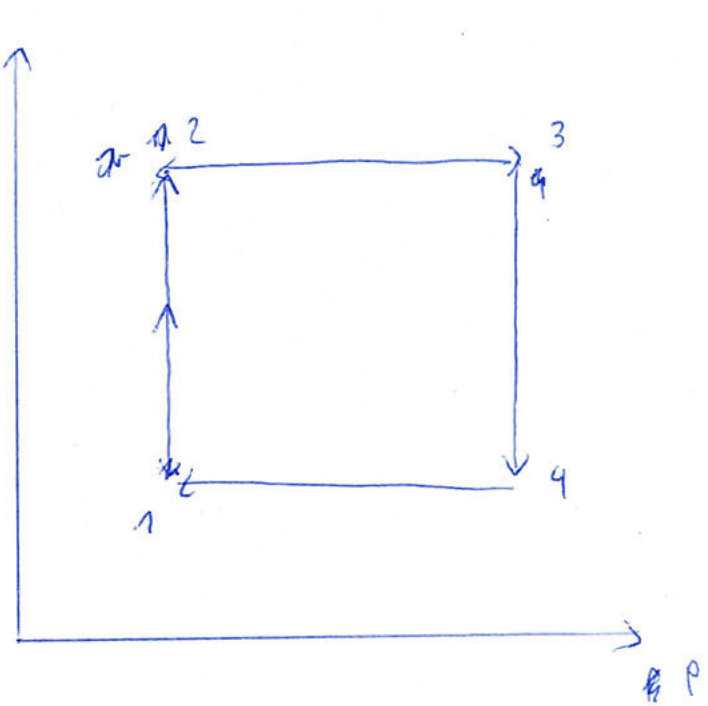
$$\Delta E = |Q_{zu}|$$

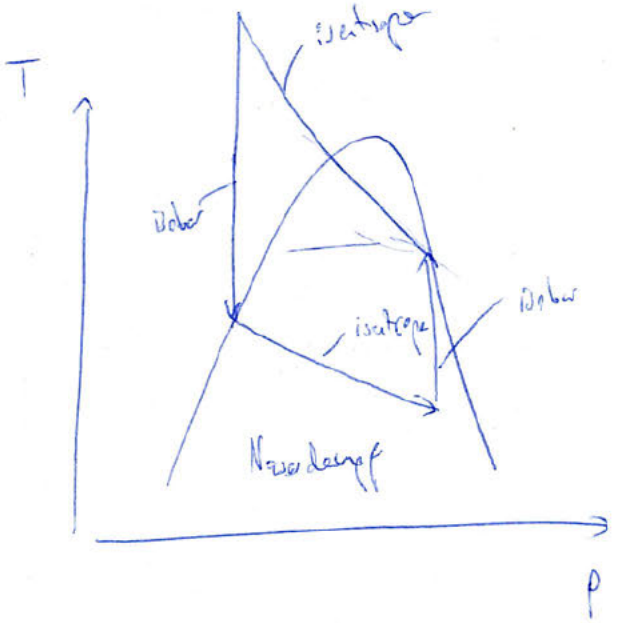
$$\Delta u \cdot m_L = |Q_{zu}| \Rightarrow \frac{15000\,\text{J}}{\text{kg}} = \Delta u$$

$$\Rightarrow x_{Flüssig} = \frac{\Delta u - u_{fest}(1{,}4\,\text{bar})}{u_{fl}(1{,}4\,\text{bar}) - u_{fest}(1{,}4\,\text{bar})} = 0{,}04 \Rightarrow x_{eis} = 0{,}9550 = 1 - x_{flüssig}$$

Aufgabe 4)

a)





b) $\frac{dE}{dt} = \dot{m}(h_2 - h_3) + \dot{Q}_{zu} - \dot{W}_K$

$h_2 = h_{gk}(s_2 = s_3)$

$h_3 = h(s_3 \rightarrow s_2, 8\,bar)$ $\quad \dot{W}_K = -28\,W$

~~4)~~

c) $x_1 = \dfrac{s_2 - s_f}{s_g - s_f}$

d) $\varepsilon_K = \dfrac{\dot{Q}_{zu}}{\dot{W}_t} = \dfrac{\dot{Q}_K}{\dot{W}_t} = \dfrac{\dot{Q}_K}{28\,W}$

$Q_K \Rightarrow$

$\cancel{\dfrac{dE}{dt}}^{\,0} = \dot{m}(h_1 - h_2) + \dot{Q}_{zu} - \cancel{\dot{W}_v}^{\,0}$

$\dot{Q}_{zu} = \dot{m}(h_2 - h_1)$

$\Rightarrow \varepsilon_K = \dfrac{\dot{m}(h_2 - h_1)}{28\,W}$

e)