[redacted]

1 a) Energiebilanz Wasser

$$\Rightarrow 0 = \dot{m}(h_{ein} - h_{aus}) + \dot{Q}_R - \dot{Q}_{aus}$$

$$h_{ein} = h_f(70°C) = 292{,}98 \frac{kJ}{kg} \quad (A-2)$$

$$h_{aus} = h_f(100°C) = 419{,}04 \frac{kJ}{kg} \quad (A-2)$$

$$\Rightarrow |\dot{Q}_{aus}| = \dot{m}(h_{ein} - h_{aus}) + \dot{Q}_R$$

$$= 62{,}13 \ kJ/s$$

$\Rightarrow$ da rausfliesst $\dot{Q}_{aus} = -62{,}13 \frac{kJ}{s} = -62{,}13 \ kW$

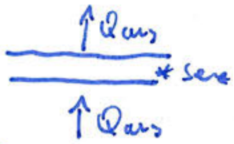
b) $$\bar{T}_{KF} = \frac{\int_e^a T\,ds}{s_a - s_e} \qquad \Rightarrow dH = T\,ds + V\cancel{dp} \text{ weil isobar}$$

$$= \frac{\int_e^a dH}{s_a - s_e} = \frac{h_a - h_e}{s_a - s_e} = \frac{\cancel{c_p}(T_a - T_e)}{\cancel{c_p}\ln\left(\frac{T_a}{T_e}\right) - \cancel{R\ln\left(\frac{p_a}{p_e}\right)}^{\to 0}}$$

$$= \frac{T_a - T_e}{\ln\left(\frac{T_a}{T_e}\right)} = 293{,}124 = \bar{T}_{KF}$$

c) $\dot{S}_{erz}$ aus Wärmeübertragung

Wand zwischen Reaktor & Kühlung



$$\Rightarrow \text{Entropiebilanz} \quad 0 = \sum \cancel{\dot{m}_i s_i}^{\to 0} + \frac{\dot{Q}_{aus}}{\bar{T}_R} - \frac{\dot{Q}_{aus}}{\bar{T}_{KF}} + \dot{S}_{erz}$$

$$\Rightarrow \dot{S}_{erz} = \frac{\dot{Q}_{aus}}{\bar{T}_{KF}} - \frac{\dot{Q}_{aus}}{\bar{T}_R} \qquad T_R: \text{isotherm da Nass-Dampf} = 373{,}15K$$

$$= 45{,}46 \frac{J}{sK} = 45{,}46 \frac{W}{K}$$

[redacted]

1 d) Zustand 1: 100°C

Zustand 2: 70°C $\Rightarrow \Delta m_{12}$ $T_{ein} = 20°C$

$Q_R = Q_{aus} = 35\,MJ$

Energiebilanz: $\Delta U = \Delta m_{12} h_{ein} + \cancel{Q_R - Q_{aus}} \cancel{- W}$

$\Delta U = m_2 \cdot u_2 - m_1 u_1$ $\Delta m_{12} = m_2 - m_1$

$u_2 = u_f(70°C) = 292{,}95 \frac{kJ}{kg}$

$u_1 = u(100°C, 0{,}005) = u_f(100°C) + 0{,}005(u_g(100°C) - u_f(100°C)) = 429{,}4 \frac{kJ}{kg}$

$h_{ein} = h_f(20°C) = 83{,}96 \frac{kJ}{kg}$

$m_1 = 5755\,kg$

$\Rightarrow m_2 = (m_1 + \Delta m)$

$\Rightarrow (m_1 + \Delta m) u_2 - m_1 u_1 = \Delta m\, h_{ein}$

$\Rightarrow m_1(u_2 - u_1) = \Delta m (h_{ein} - u_2)$

$\Rightarrow \Delta m = \frac{m_1(u_2 - u_1)}{h_{ein} - u_2} = 3757{,}45\,kg$

e) $\Delta S_{12} = m_2 s_2 - m_1 s_1$

$\Rightarrow m_2 = m_1 + \Delta m = 9512{,}45\,kg$

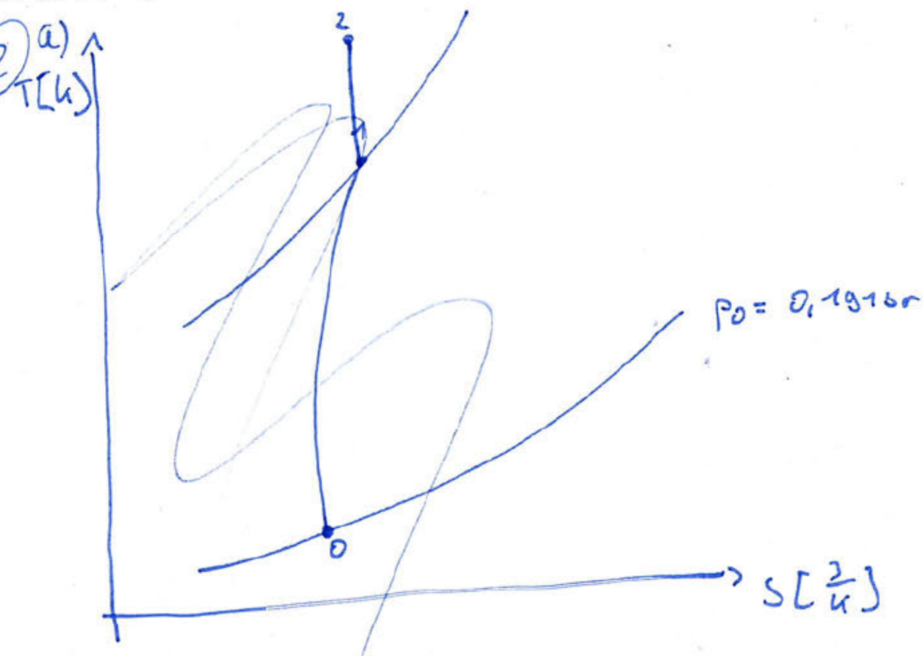
$s_2 = s_f(70°C) = 0{,}9549 \frac{kJ}{kgK}$

$s_1 = s_f(100°C) + 0{,}005(s_g(100°C) - s_f(100°C)) = 1{,}33714 \frac{kJ}{kgK}$

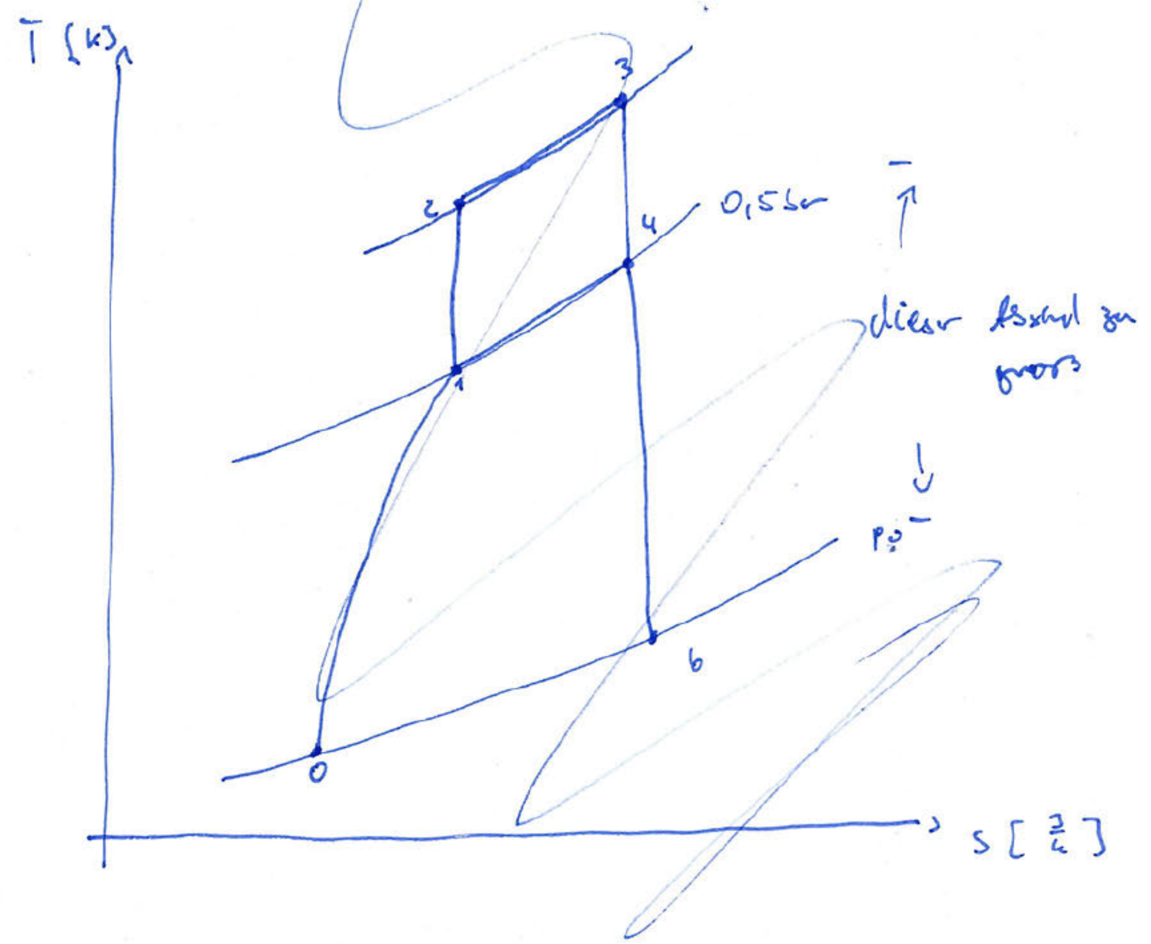
$\Rightarrow \Delta S_{12} = 1388{,}2 \frac{kJ}{K}$

[redacted]

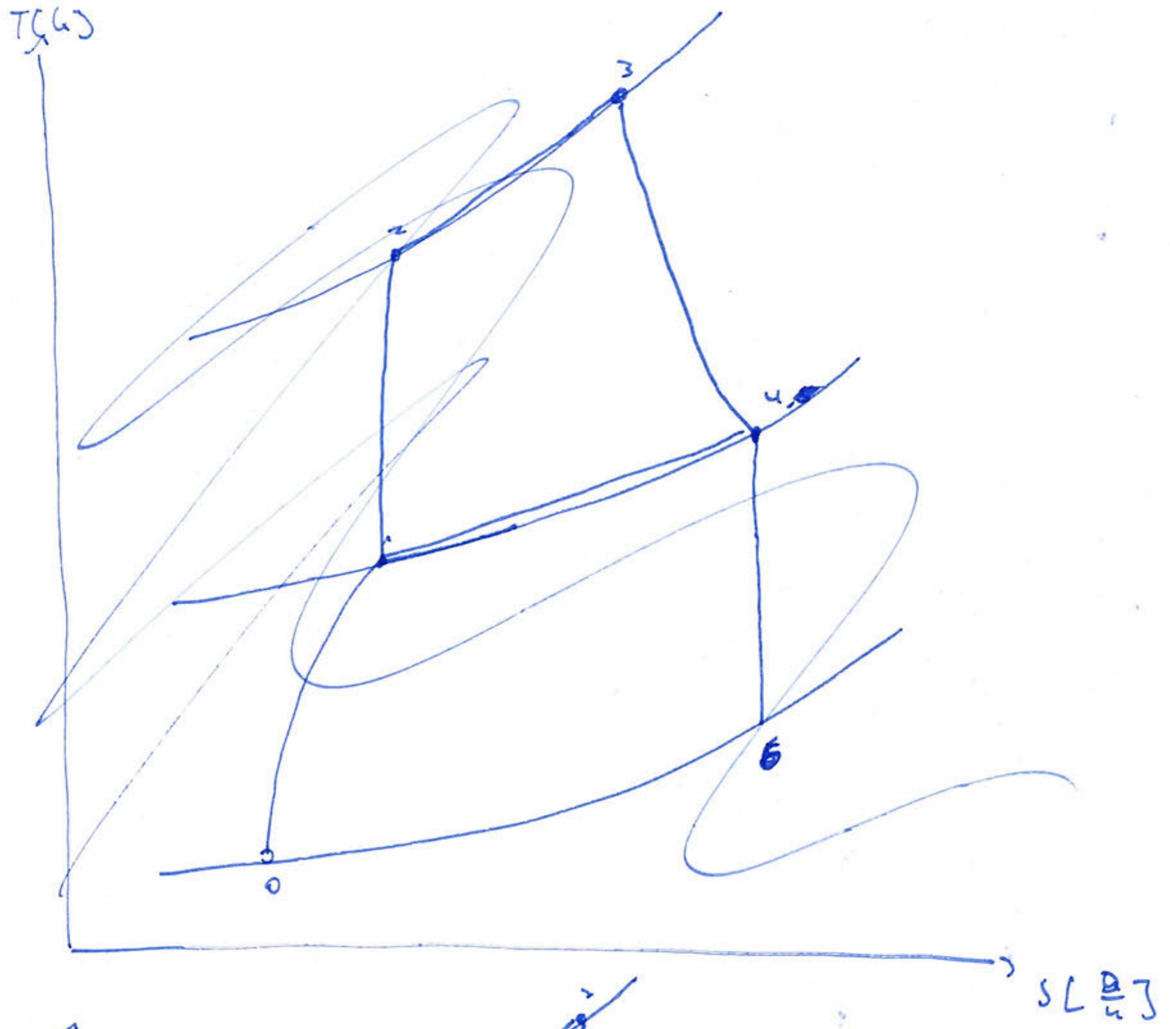
2 a)

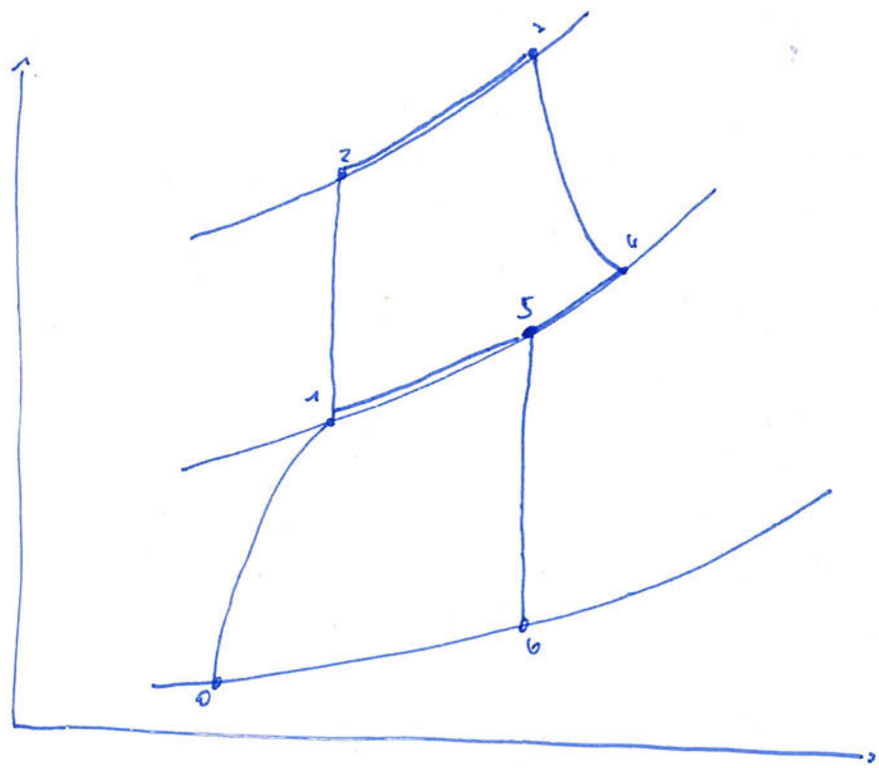


T[K]
2
1
0
$p_0 = 0{,}1916r$
$s[\frac{J}{K}]$



T [K]
3
2
4
0,5bar
1
dieser Abschnitt zu gross
p_0
6
0
$s[\frac{J}{K}]$


T[K]
3
2
4
5
0
s[kJ/K]


3
2
4
5
1
6
0

[redacted]

(2) b) $p_6 = 0{,}191\,\text{bar}$

$\cancel{pV = RT}$

=> Schubdüse : $\cancel{0 = \dot m(h_5 + \frac{1}{2}w_5^2 - h_6 - \frac{1}{2}w_6^2)} - w$

=> polytrope Gleichung $\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}}$ $n = k$

$$\Rightarrow T_6 = T_5 \left(\frac{p_6}{p_5}\right)^{\frac{0{,}4}{1{,}4}} = 328{,}14$$

=> Energiebilanz gesamte Turbine:

$$0 = \cancel{\dot m}(h_0 + \tfrac{1}{2}w_0^2 - h_6 - \tfrac{1}{2}w_6^2) + \underbrace{\dot Q_B}_{\dot q_B \cdot m_4} \quad | : \dot m \quad | + \tfrac{1}{2}w_6^2$$

$$\tfrac{1}{2}w_6^2 = c_p(T_0 - T_6) + \tfrac{1}{2}w_0^2 + q_B/6{,}2933$$ – siehe unten

$$\Rightarrow w_6 = \sqrt{2 \cdot \left(c_p(T_0 - T_6) + \tfrac{1}{2}w_0^2 + \tfrac{q_B}{6{,}2933}\right)}$$

~~= 1503 m/s~~ ~~=> falsch, ich achte 510 m/s~~

$= 498{,}866\ \frac{m}{s}$

c) $e_{x,str,6} - e_{x,str,0} = (h_6 - h_0 - T_0(s_6 - s_0) + k_6 - k_0)$

$$= \left(c_p(T_6 - T_0) - T_0\left(c_p \ln\left(\tfrac{T_6}{T_0}\right) - R \ln\left(\tfrac{p_6}{p_0}\right)\right) + \tfrac{1}{2}w_6^2 - \tfrac{1}{2}w_0^2\right)$$

$$= \cancel{122{,}2\ \tfrac{kJ}{kg}} = 116{,}6\ \frac{kJ}{kg}$$

d) Exergiebilanz

$0 = E_{x,str\,0-6} + E_{x,Q} - E_{x,verl}$

$E_{x,verl} = E_{x,str\,0-6} + E_{x,Q}$

$E_{x,Q} = \left(1 - \frac{T_0}{T}\right)\dot Q$ $\dot Q = 11{,}95\ \frac{kJ}{kg}$

$\dot m_M + \dot m_4 = m_{ges} = 6{,}293\ m_4$

$\frac{\dot m_M}{\dot m_4} = 5{,}293$

$\dot m_M = 5{,}293\ m_4$

$\dot q \cdot \dot m_4 = \dot q(m_4 + \cancel{\dot m_M}$

$\rightarrow \frac{\dot q\,m_4}{m_4 + m_M} = \dot q\left(\frac{\frac{m_4}{m_4}}{\frac{m_4}{m_4} + \frac{m_M}{m_4}}\right) \Rightarrow \dot q\,\frac{\dot m_4}{m_{ges}} = \dot q\,\frac{1}{6{,}293}$

$\frac{m_M}{m_4} = 5{,}2933$

[redacted]

2 d) $\dot{E}_{x,vel} = \dot{m}\, e_{x,str\,0-6} + \dot{m}_K q_B \quad | : \dot{m}$

$$e_{x,vel} = e_{x,str\,0-6} + \frac{q_B}{6{,}293}$$

$$= -116{,}6\,\frac{kJ}{kg} + \frac{1195\,\frac{kJ}{kg}}{6{,}293} = 73{,}3\,\frac{kJ}{kg} = e_{x,vel}$$

[redacted]

3 a) $PV = mRT$

$R = \frac{8314 \frac{J}{kmol \cdot K}}{50 \frac{kg}{kmol}} = 166{,}28 \frac{J}{kgK}$

$\cancel{PV} = RT$

Druck? Druck Eis:

$A = \pi \left(\frac{D}{2}\right)^2 = 7{,}854 \cdot 10^{-3} m^2$

$\Rightarrow p_{eis} = \frac{m_E g}{A} + p_0 = 143716{,}58 bar$

$= 1{,}44 bar$

$\Rightarrow$ Druck gas

$\Rightarrow p_g = p_{eis} + \frac{mg}{A} = 1{,}44 bar = p_{g1}$

$\Rightarrow m$: $PV = mRT$

$m = \frac{PV}{RT} = \frac{p_{g1} V_{g1}}{R T_{g1}} = 3{,}517 \cdot 10^{-3} kg = m_g$

b) $p_{g,2}$ sollte konstant bleiben, da sich p_0 nicht ändert und die Massen von oben ausserdem konstant bleiben

$p_{g,2} = 1{,}44 bar$

$T_{g,2}$: Das Wasser nimmt um zu schmelzen deutlich mehr Energie auf, als das Gas ~~kan~~ für einen grad temperatur unterschied abgibt, d.h. das gas nimmt deutlich den Temp. der Wasser ursprünglich ~~die~~ das gas gleicht sich deutlich an $\Rightarrow T_{g,2} \approx 0 = 0{,}003°C$

c) ~~$\Delta U_{12} = Q - W$~~

~~$m_g(u_2 - u_1) = Q_{12}$~~

~~$m_g(c_v(T_2 - T_1)) = Q_{12} =$~~

$W_{12} = \int_1^2 p\,dV = p(V_2 - V_1)$

$V_1 = 3{,}14 L$

$V_2 = \frac{mRT}{p} = 2{,}477 \cdot 10^{-3} m^3$

$\Delta U_{12} = Q - W$

$\Rightarrow W_{12} = -95{,}472$

$\Delta U_{12} + W = Q_{12} = 1017{,}65 \frac{kJ}{kg}$

$m(c_v(T_2 - T_1) + W = 1017{,}65 \frac{kJ}{kg} = |Q|$

aus sicht des gases

$Q = -1017{,}65$

~~$\Rightarrow$~~

[redacted]

d) $\Delta U = Q - \cancel{W}$ $\rightarrow W = 0$, da isochor

$m(u_2 - u_1) = Q$

$\cancel{u_2 = m}$

$\Rightarrow \frac{Q}{m} = \cancel{\phi}u_{fl}(0{,}003) + x_2(\cancel{\phi}_{fl} - \cancel{\phi}_{f}) - \underbrace{u_1}_{-200{,}1}$

$\Rightarrow \frac{Q}{m} - 200{,}1 - u_{fl}(0{,}003) = -x_2(\overset{u}{\cancel{\phi}_{fl}} - u_f)$

$\Rightarrow x_2 = \dfrac{\frac{Q}{m} - 200{,}1 - u_{fl}(0{,}003)}{-(u_{fl} - u_f(0{,}003))}$ $(0{,}003)$

$\Rightarrow u_{fl}(0{,}003) = -0{,}033$

$u_f(0{,}003) = -333{,}4427$

$\Rightarrow x_2 = 0{,}5696$ $\Rightarrow \underline{\underline{x_2 = 56{,}96\,\%}}$

$x_{Eis} = \frac{m_{Eis}}{m_{EW}} = 0{,}6$

$\Rightarrow$ ~~Eis~~ $60\,\%$ Eis

$\Rightarrow$ ~~ϕ_{Eis}~~

$\cancel{\phi}_{fl} - x_{Eis}(\cancel{\phi}_f - \cancel{\phi}_{Eis}) = \phi(x)$

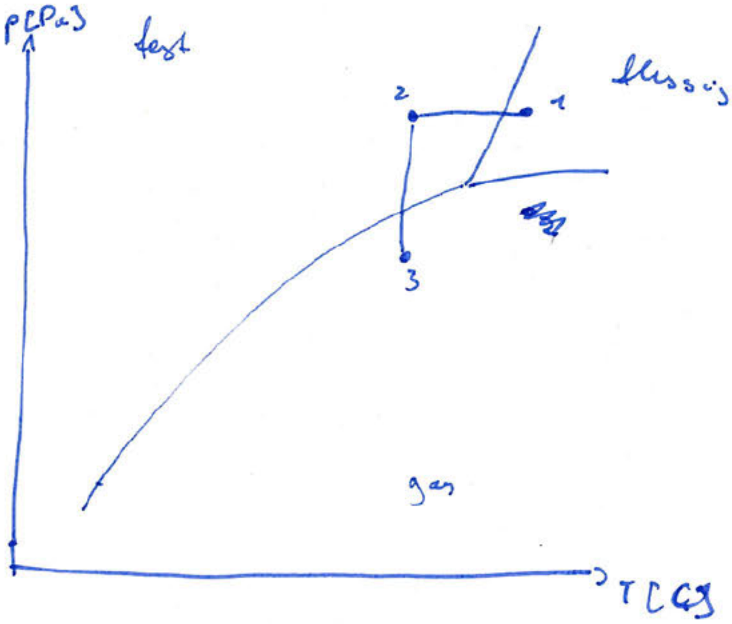
$\cancel{\phi}_{fl} - x_{Eis}(\cancel{\phi}_f - \cancel{\phi}_{Eis}) = \phi(x)$

$\Rightarrow u_1 = u_{fl}(0{,}0) - 0{,}6(u_f(0{,}0) - u_{fl}(0{,}0))$

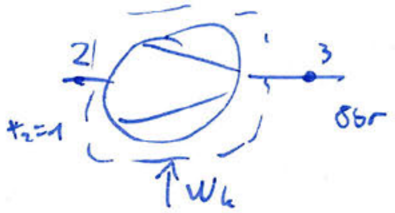
$= -200{,}1 \frac{kJ}{kg}$

[redacted]

(4) a)



b) Verdichter:



$$\Rightarrow \quad 0 = \dot{m}(h_2 - h_3) - W_k$$

$$\frac{W_k}{h_2 - h_3} = \dot{m}$$

$$h_2 = h_g(T_1 - 6K)$$

$$T_1 = -20°C = 253{,}15\,K$$

$$\Rightarrow T_2 = 247{,}15\,K \qquad (-26°C)$$

$$\Rightarrow h_2 = h_g(-26°C) = 231{,}62 \frac{kJ}{kg}$$

A 10

h_3? : isentrop: $s_3 = s_2 = s_g(-26°C) = 0{,}9390 \frac{kJ}{kgK}$

$\Rightarrow$ h_3 interpolieren

$$h_3 = h(40°C, 8bar) + \frac{h(50°C, 8bar) - h(40°C, 8bar)}{0{,}9711\frac{kJ}{kgK} - 0{,}9374\frac{kJ}{kgK}}\left(0{,}9390\frac{kJ}{kgK} - 0{,}9374\frac{kJ}{kgK}\right)$$

$$= 274{,}17 \frac{kJ}{kg}$$

$$\Rightarrow \dot{m} = \frac{-28\frac{kJ}{s}}{h_2 - h_3} = 6{,}58 \cdot 10^{-4} \frac{kg}{s} = 2{,}4 \frac{kg}{h}$$

[redacted]

c) x_1: $h_4 = h_f = h_f(8\,bar) = 93{,}42\ \frac{kJ}{kg}$

$\Rightarrow h_1 = h_f(1{,}0199\,bar) + x_1(h_g(1{,}0199\,bar) - h_f(1{,}0199\,bar))$

$\Rightarrow x_1 = \frac{h_1 - h_f}{h_g - h_f} = 0{,}3566 \;\hat{=}\; 35{,}66\,\% = x_1$

d) $\varepsilon_K = \frac{Q_{zu}}{W_t}$ $\qquad Q_{zu} = Q_K$

$\Rightarrow$

$\Rightarrow 0 = \dot{m}(h_1 - h_2) + Q_K$

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

$h_1 = h_f + 35{,}66\%(h_g - h_f) = 93{,}42\ \frac{kJ}{kg}$

$h_2 = 231{,}62\ \frac{kJ}{kg}$ $= 0{,}091\ \frac{kJ}{s} = 91\,W$

$\Rightarrow \varepsilon_K = \frac{Q_{zu}}{W_t} = \frac{91\,W}{28\,W} = 3{,}25$

e) die Temperatur ~~ist~~ würde sich $-26°C$ annehmen, ~~weil~~ da dies die Temperatur des Kühlmittels ist