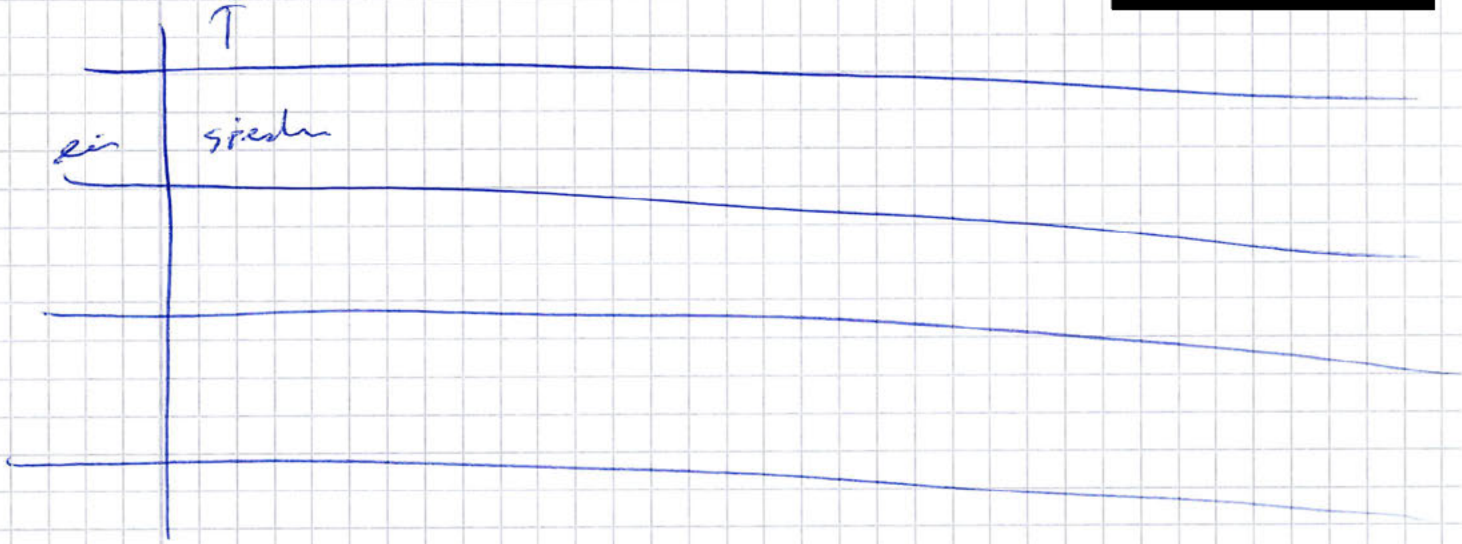
[redacted]

(1)



$m_{ein} = 0,3 \frac{kg}{s}$

$T_{ein} = 70°C$ $\Rightarrow$ siedendflüssig

$M_{ges,1} = 5755 kg$

$x_0 = 0,005$ $\quad T = 100°C$ immer

a) $\dot{Q}_{aus}$

$$0 = \dot{m}_{ein}\left((h_e - h_a) + \cancel{0} + \cancel{0}\right) + \dot{Q}_{aus} - \cancel{\dot{W}_{t,n}}^{\,0} \quad p\,dv$$

$$\dot{Q}_{aus} = m_{ein}(h_a - h_e) = \underline{\underline{37,8\,kW}}$$

TA2 $\quad h_e = h_f(70°C) = 292,98 \frac{kJ}{kg}$

$h_a(100°C) = h_f(100°C) = 419,04 \frac{kJ}{kg}$

Siedeflüssig

b)

[redacted]

1

d) halboffenes system

$$\Delta E = m_2 u_2 - m_1 u_1 = \Delta m_{12} \cdot h_{(12)} + Q \cancel{- W}^{0}$$

$$m_2 = (m_1 + m_{12}) \quad \boxed{m_1 = 5755 kg} \qquad Q = -35000 kJ$$

$$h_{12}(20°C) = h_f(20°C) = 83,96 \frac{kJ}{kg}$$

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

$$u_1(100°C) = 418,94 + 0,005(2506.5 - 418,94)$$
$$= 429,377 \frac{kJ}{kg}$$

$$\Delta m_{12}(u_2 - h_{12}) + m_1(u_2 - u_1) = Q$$

$$\Delta m_{12} = \frac{Q - m_1(u_2 - u_1)}{(u_2 - h_{12})}$$

$$\Delta m_{12} = \underline{\underline{3589,34 kg}}$$

e) $\Delta S = \cancel{\Delta S_{12}}$

$$\Delta S = (m_1 + m_{12}) s_2 - m_1 s_1$$

$$s_1(100°C) = 1,3069 \frac{kJ}{kg \cdot K}$$

$$s_2(70°C) = 0,9549 \frac{kJ}{kg \cdot K}$$

[redacted]

1

$$Tds = \frac{Q_{aus}}{\dot{m}}$$

$$\overline{T} = \frac{\int_e^a T\,ds}{(s_a - s_e)} = \frac{T_2 \cancel{Q_{aus}} - T_1}{\Rightarrow cv \ln\left(\frac{T_2}{T_1}\right)} =$$

~~Ideal~~
Ideal flüssigkeit

c) Entropie

$$0 = \dot{m}(s_e - s_a) + \frac{Q_{ab}}{\overline{T}_i} + S_{erz}$$

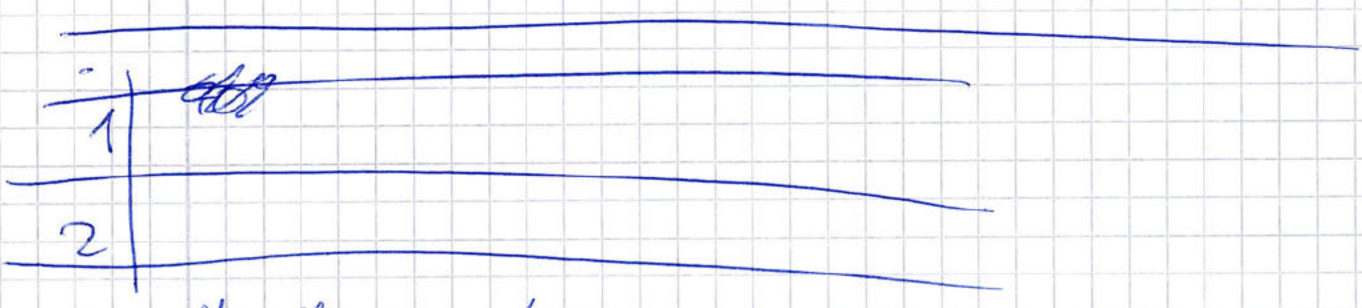
$\overline{T}_i \Rightarrow 100°C \Rightarrow 373{,}15 K$

$$S_{erz} = \dot{m}(s_a - s_e) = \frac{-65 kW}{373{,}15} = \underline{\underline{0{,}27 \frac{kJ}{}}}$$

TA2

$s_e = s_f(70°C) = 0{,}9549$

$s_a = s_f(100°C) = 1{,}3069$



halb offen system

(2)

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	T	p	h
1	$-30°$		
2		$p_2 = p_4$	
3		$p_3 = p_4$	
4		$p_4 = p_5$	
5	431,9 K	0,5 bar	
6		0,191 bar	

s1 s2 } $\eta_{vs} < 1$

} erwärmt

$\omega_{ut} = 200 \frac{m}{s}$ $\qquad$ $\omega_5 = 220 \frac{m}{s}$

$p_0 = (0{,}191 \text{bar})$ $\qquad$ $c_p = 1{,}006$

$\frac{\dot{m}_m}{\cancel{\dot{m}_{...}}} = 5{,}292 \text{ min}$

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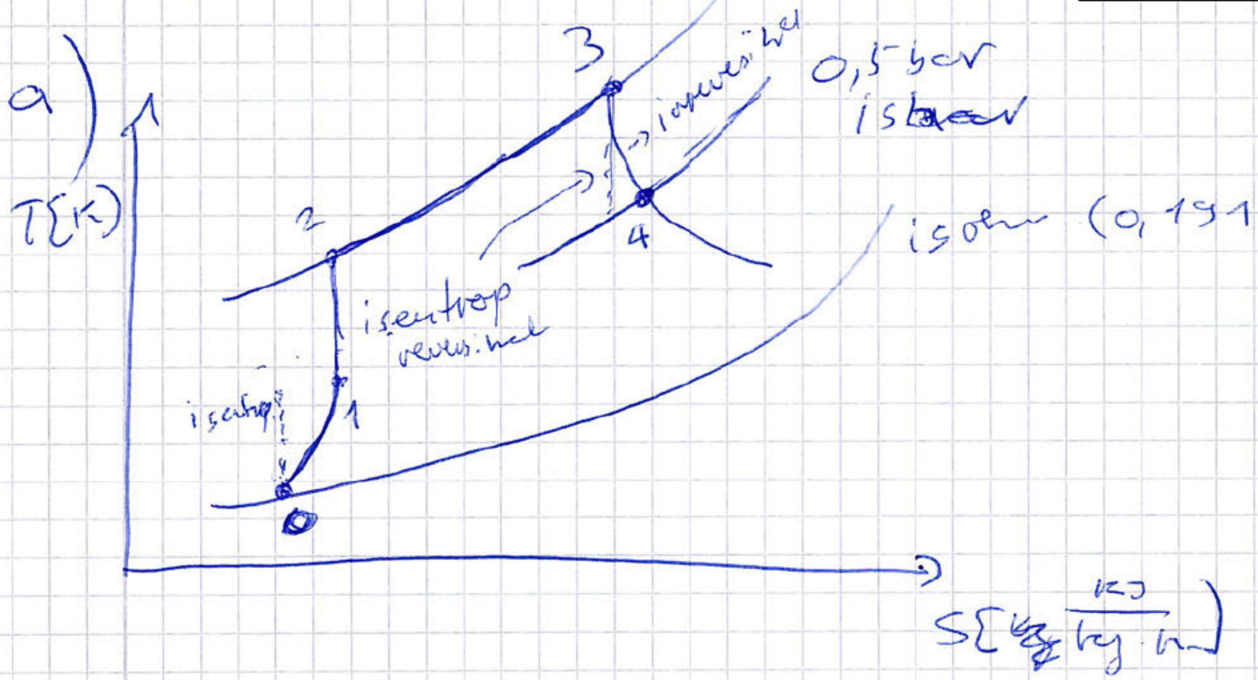
a)



b) $5 \rightarrow 6$

$$0 = \dot{m}_{ges}\left((h_5 - h_6) + \frac{(w_5^2 - w_6^2)}{2} + \cancel{\Delta e}\right) + \cancel{Q}$$

$$0 = m_g\left(c_p(T_5 - T_6) + \frac{w_5}{2} - \frac{w_6^2}{2}\right)$$

~~Ideal~~ Ideal gas

$$\frac{w_6^2}{2} = \cancel{0}$$

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

$$T_6 = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}} T_5 = \underline{\underline{328,07\,K}}$$

[redacted]

2

d)

$0 = \cancel{\dots}$

$0 = (\Delta e_{str}) + \cancel{\left(1 - \frac{T_0}{T_J}\right)\dot{Q}_J}^{0} - \dot{W}_{t,u} - e_{x\,verl}$

$e_{x\,verlust} = \Delta e_{str} - \cancel{W_{t,u}} - W_{t\,u}$

$= 100 \frac{kJ}{kg}$ ~~...~~

$\underline{\qquad}$ $-\dot{W}_T$

~~$W_{turb} = ...$~~

↳ gesamt arbeit Turbine an

Energie bilanz

$\frac{\dot{W}_{turbine}}{\dot{m}} = (h_3 - h_4) + \cancel{\dot{Q}}^{0}$ verachlässbar

$c_v(T_3 - T_4)$

[redacted]

$$w_c = \sqrt{2\dot{m}_g\left(c_p(T_5 - T_6) + \frac{w_5^2}{2}\right)}$$

$$\dot{m}_g = \cancel{\dots}$$

$$m_K + \dot{m}_M = \dot{m}_K(1 + 5{,}293)$$

$$0 = \dot{m}_K(h_2 - h_3) + m_K \cdot q_b$$

$$-q_b = c_p(T_2 - T_3)$$

$\rightarrow$ solve

T_2

Turbine $\Rightarrow$

$$0 = \dot{m}_K c_p (T_1 - T_2) + \cancel{\dot{Q}_{rel}}^{0} - W_t$$

rev

c) $\Delta e_{x,str} = e_{xstr_6} - e_{xr0}$

$$(h_6 - h_0) - T_0(s_6 - s_0) + p_0(v_6 - v_0)$$

$$= c_p(T_6 - T_0) - T_0\left(c_p\left(\frac{T_6}{T_1}\right) - R\ln\cancel{\left(\frac{p_6}{p_0}\right)}^{0}\right) + p_0(v_6 - v_0)$$

$-30°C$

$$v_0 = \frac{R \cdot T}{p_0} \qquad v_6 = \frac{R \cdot T}{p_0}$$

$$R = c_p\left(1 - \frac{1}{\kappa}\right)$$

$$c_v = \frac{c_p}{\kappa}$$

③

[redacted]

	T	V
1	500°C	3,14 L

$$p_{g,1} \cdot V_1 = m_g \cdot T_1 \cdot R$$

$$R = \frac{\bar{R}}{M_g} = 166{,}28 \frac{J}{kg}$$

$$p_{g,1} = p_0 + F/A \qquad A = \frac{\pi}{4} D^2 = 0{,}007$$

$$p_{g,1} = p_{innen} = p_0 + \frac{m_K \cdot 32 kg}{A}$$

$$= 1 bar + 0{,}448 = \underline{\underline{1{,}45 bar}}$$

$$\rightarrow m_g = \frac{p_{g,1} \cdot V_{g,1}}{T_1 \cdot R} \xrightarrow{0{,}00314} = 0{,}0035 kg = \underline{\underline{3{,}53 g}}$$

---

b) $T_{EW} = 0°C \qquad x \; \frac{m_{Eis}}{m_{EW}} 0{,}6$

$m_{Eis} = 0{,}6 \cdot 0{,}1 \, kg$

gesamt System

$\cancel{\frac{dE}{dt}}$ $\Delta E = Q - W_{Vu}$

$m_{eis}(u_2) + m_{EW}(u_2) + m$

$V_{1 EW} = V_{2 EW}$

geg 1bar

$\boxed{p_{2g} = 1 bar}$

↓

gleichgewicht

aussendruck

innendruck gleich

(3)

[redacted]

c) EW - System $\rightarrow$ inkompressibel

$\Delta E = Q_{zu} - \cancel{W}^{0}$

$m_{EW}(u_2) - m_{EW}(u_1) = Q_{zu}$

$u_1(x_1 = 0{,}6,\ 0°C) = u_f + 0{,}6(u_{fest} - u_f)$

u_f: $-333{,}458$; u_{fest}: $-0{,}045$

$= -132{,}73\ \frac{kJ}{kg}$

~~System~~ system gas

$\Delta E = Q_{ab} - W_V$

$c_v(T_2 - T_1) = m_g\, c_p(T_2 - T_1) - W_V$

W_V: $\int p\,dv$

$c_p = R + c_v$

d) $m_{EW}(u_2 - u_1) = Q_{zu}$, $Q_{zu} = +1{,}5\ kJ$

$u_1 = -\frac{Q_{zu}}{m_{EW}} + u_2$

$u_1 = -117{,}77$

~~Tripelpunkt~~ bei $0{,}003°$

$x_{Eis} = \frac{u_1 - u_{Flüssig}(0{,}003°C)}{u_{fest}(0{,}003°C) - u_{flüssig}(0{,}003°C)}$

$u_{Flüssig}(0{,}003°C)$: $-0{,}033\ kJ/kg$; $u_{fest}(0{,}003°C)$: $-333{,}442$

4

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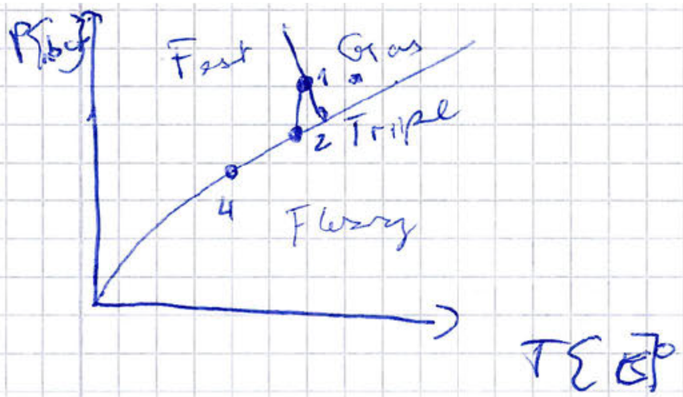

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$T_i = 10\,K$

$T = 4\,K$ verdampft

	T	p	
1	$p_1 = p_2$		flüssig
2			dampf
3	8bar		$s_2 = s_3$ } reversibel adiabat
4			$x_4 = 0$ ⇒ flüssig

$$0 = \dot m_R (h_2 - h_3) + \underset{-0{,}28\,kW}{\dot W_K} + \cancel{\dot Q}^0$$

$h_2(x_2 = 1,\ s_3)$

$h_3 = 264{,}15\ \frac{kJ}{kg}$

$h_4 = h_1 = (h_g\ 8bar)\ 93{,}42\ \frac{kJ}{kg}$

c) $$x_1 = \frac{h_1 - h_f(p_1)}{h_g - h_f}$$

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|W_t|} = \frac{\dot{Q}_K}{0{,}28K}$

~~$\dot{Q}_K$ ε_4~~

$\dot{Q}_K = \dot{m}_R(h_1 - h_2) - \cancel{W}^{0}$