Thermodynamik 1 HS23 [redacted]

① a) Energiebilanz Reaktor:

$$\cancel{\frac{dE}{dt}}^{\to 0,\text{stationär}} = \dot{m}\left(h_{ein} - h_{aus}\right) + \dot{Q} - \cancel{\dot{W}}^{\to 0}$$

$\dot{Q} = \dot{m}\left(h_{aus} - h_{ein}\right)$ $\qquad$ $\left.\begin{array}{l} h_{aus} = 419.04\,\frac{kJ}{kg} \\ h_{ein} = 292.98\,\frac{kJ}{kg} \end{array}\right\}$ TAB A-2

$= \cancel{a}$

b) $$\bar{T} = \frac{\int_1^2 T\,ds}{s_2 - s_1} = \frac{h_2 - h_1 + \cancel{V(p_2 - p_1)}^{\to 0}}{c \ln\left(\frac{T_2}{T_1}\right)} = \frac{c\left(T_2 - T_1\right)}{c \ln\left(\frac{T_2}{T_1}\right)} = \boxed{293.12\,K = \bar{T}}$$

c) $$\cancel{\frac{dS}{dt}}^{\to 0} = \cancel{\sum \dot{m}_i h_i}^{\to 0} + \frac{\dot{Q}}{\bar{T}} + \dot{S}_{erz}$$ Entropie- (Bilanz Wand)

$$\dot{S}_{erz} = -\frac{\dot{Q}}{\bar{T}} = \frac{65\,kW}{293.12\,K} = \boxed{0.2218\,\frac{kJ}{K \cdot s} = \dot{S}_{erz}}$$

d) $\cancel{E_1 = E_2}$ $\quad$ $m_{ges,1}$ $\quad$ $\frac{dE}{dt} = 0$

$$0 = m_{Ges,1}\left(h(70°C) - h(100°C)\right) + m_{12}\left(h(70°C) - h(20°C)\right)$$

$$m_{12} = -m_{Ges,1}\,\frac{h(70°C) - h(100°C)}{h(70°C) - h(20°C)} = -9755\,kg\,\frac{292.98\,\frac{kJ}{kg} - 419.04\,\frac{kJ}{kg}}{292.98\,\frac{kJ}{kg} - 83.96\,\frac{kJ}{kg}}$$

$$= \boxed{3470\,kg = \Delta m_{12}}$$

e) halboffenes System:

$\Delta S = m_2 s_2 - m_1 s_1$ $\qquad$ $s(70°C) = 0.9549$

$= \left(m_{ges,1} + \Delta m_{12}\right) s(70°C) - m_{ges,1}\, s(100°C)$ $\qquad$ $s(100°C) = 0.13069$

$$\boxed{\Delta S = 8056.8\,\frac{kJ}{K}}$$

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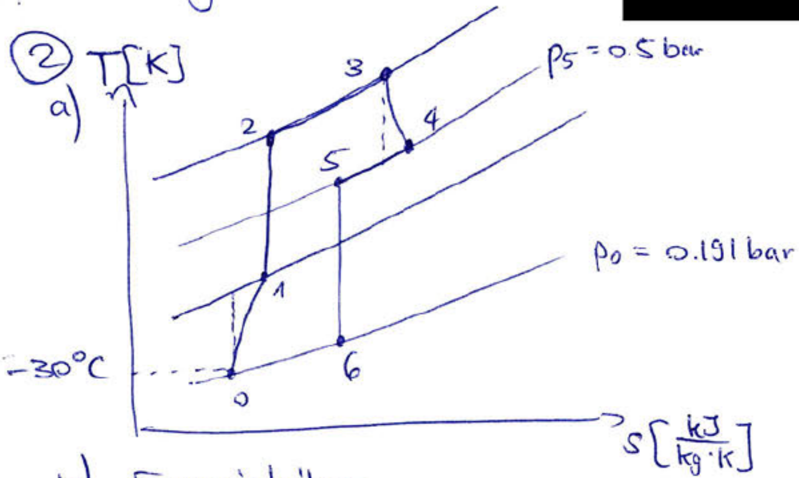
② a)



b) Energiebilanz um ganzes Triebwerk

$$\cancel{\frac{dE}{dt}}^{0} = \dot{m}\left(h_{ein} - h_{aus} + \frac{1}{2}w_0^2 - \frac{1}{2}w_6^2\right) \qquad h_{ein} - h_{aus} = c_p(T_0 - T_6)$$

$$0 = c_p(T_0 - T_6) + \frac{1}{2}w_0^2 - \frac{1}{2}w_6^2$$

Energiebilanz um Schubdüse

$$0 = c_p(T_5 - T_6) + \frac{1}{2}w_5^2 \; m - \frac{1}{2}w_6^2$$

$$c_p(T_0 - T_6) + \frac{1}{2}w_0^2 = c_p(T_5 - T_6) + \frac{1}{2}w_5^2$$

T

c) $$\Delta e_{x,str} = \left(h_6 - h_0 - T_0(s_6 - s_0) + \frac{1}{2}w_6^2 - \frac{1}{2}w_0^2\right) \qquad T_6 = 340K \quad w_6 = 510\,\frac{m}{s}$$

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

$$\boxed{\Delta e_{x,str} = 165.47\,kJ/kg}$$

d) $$\cancel{\frac{dE_x}{dt}} = \cancel{\dot{E}_{x,str}}$$

$$\cancel{\frac{de_x}{dt}} = \cancel{e_{x,str}}$$

$$\Delta e_{x,str} = e_{x,q} - e_{x,verl}$$

$$= \left(1 - \frac{T_0}{T}\right)\dot{q} - e_{x,verl}$$

$$e_{x,verl} = \left(1 - \frac{T_0}{T}\right)\dot{q} - \Delta e_{x,str}$$

$$\boxed{e_{x,verl} = 804.1\,\frac{kJ}{kg}}$$

Thermodynamik 1 HS23 [redacted]

a) $p_{G,1} = p_0 + \frac{m_K g}{A} + \frac{m_{EW} g}{A}$ $\quad A = \pi \left(\frac{D}{2}\right)^2 = 0.007854 m^2$

$= 10^5 Pa + \frac{32 kg \cdot 9.81 N/m}{0.007854 m^2} + \frac{0.1 kg \cdot 9.81 N/m}{0.007854 m^2}$

$\boxed{p_{G1} = 140.1 kPa} = \cancel{1.401 \, bar = p_{G1}}$

$pv = RT$ $\quad R = \frac{\bar{R}}{M} = \frac{8.314 \frac{kJ}{kmol \cdot K}}{50 \, kg/kmol} = 0.16628 \frac{kJ}{kg \cdot K}$

$v_{G,1} = \frac{R T_{G,1}}{p_{G1}}$

$= \frac{0.16628 \cdot 773.15}{140.1} = 0.9176 \, m^3/kg$

$m = \frac{V_{G1}}{v_{G1}} = \frac{0.00314 m^3}{0.9176 m^3/kg} = 0.003422 kg = \boxed{3.422 g = m_{G,1}}$

b) $p_{G,2} = p_{G1} = 140.1 kPa$ (Masse von EW, Kolben und patm verändern sich nicht)

Thermodynamisches GGW: $T_{G,2} = T_{EW,2}$

$p_{EW,2} = p_0 + \frac{m_K g}{A} = 139.97 kPa = 1.3997 \, bar$

Interpolieren mit Tab. 1: ~~0.0024~~ $T_{EW,2} = 0.003 + \frac{0.003}{-0.4 \, bar}(0.3997 \, bar)$

$\Rightarrow \boxed{T_{G,2} = 0°C}$ $\quad = 0°C$

c) $\Delta U_{G,12} = Q - \cancel{W}^{\to 0}$

$m_G(u_2 - u_1) = Q$

$m_G c_v^{PG}(T_2 - T_1) = 0.003422 kg \cdot 0.633 \frac{kJ}{kg \cdot K}(-500 K) = -1.083 kJ = Q$

$\cancel{Q_{12} = -1.083 kJ}$

$\Rightarrow \boxed{Q_{12} = 1.083 kJ}$

d) $\Delta U_{W,12} = Q - \cancel{W}^{\to 0}$

$m_{EW}(u_2 - u_1) = Q$

$u_2 = \frac{Q}{m_{EW}} + u_1$

$= -189.27 \frac{kJ}{kg}$

$u_1 = u_f(0°C) + x(u_{fest}(0°C) - u_f(0°C))$

$= -0.045 + 0.6(-333.458 + 0.045)$

$= -200.1 \frac{kJ}{kg}$

$u_2 = u_{f1} + x_2(u_{fest} - u_{f1})$

$x_2 = \frac{u_2 - u_{f1}}{u_{fest} - u_{f1}} = \frac{-200.1 + 0.045}{-333.458 + 0.045} = \boxed{0.6000216 = x_{Eis,2}} \Rightarrow \boxed{x_{Eis,2} = 0.600}$

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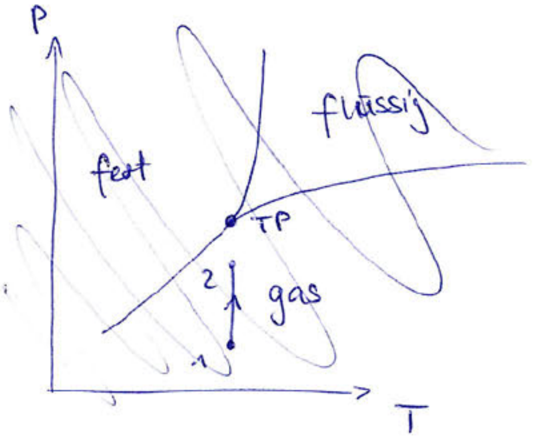
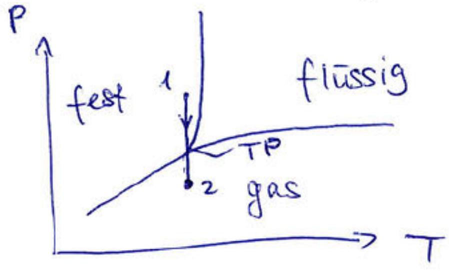
4 a)



a)



	Temp.	Druck
1		
2		
3		8 bar
4		8 bar

b) noch machen!

c) Annahme: $T_2 = -22°C$, $\dot{m} = 4 \frac{kg}{h}$

TAB A-10: $p_2 = 1.2192$ bar $= p_1$

$s_4 = s_1$ (adiabat) $\quad s_4 = 0.3459 \frac{kJ}{kg \cdot K}$ TAB A-11

$$s_1 = s_f(1.2192 \text{ bar}) + x\left(s_g(1.2192 \text{ bar}) - s_f(1.2192 \text{ bar})\right)$$

$$x = \frac{s_1 - s_f}{s_g - s_f} = \boxed{0.303 = x_1}$$

Interpolation mit TAB A-11:

$$s_f = 0.0879 + \frac{0.1055 - 0.0879}{1.4 - 1.2}(1.2192 - 1.2)$$
$$= 0.08959$$

$$s_g = 0.9354 + \frac{0.9322 - 0.9354}{1.4 - 1.2}(1.2192 - 1.2)$$
$$= 0.9348$$

b) Energiebilanz um Verdichter:

$$\frac{dE}{dt} = \dot{m}(h_2 - h_3) + \dot{W}$$

$$\dot{m} = \frac{+\dot{W}_K}{h_2 - h_3}$$

$T_i = -20°C$

$\Rightarrow T_2 = -26°C$

$h_2 = 231.62°C$ TAB A-10

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

$|\dot{Q}_{zu}| = |\dot{Q}_K|$

Energiebilanz ~~Kondensator~~ Verdampfer

$\cancel{\frac{dE}{dt}}^{\to 0,\text{ stationär}} = \dot{m}(h_1 - h_2) + \dot{Q}_K - \cancel{\dot{W}}^{\to 0}$

$h_1 = h_4$ (isenthalpe Drossel)

$= 93.42 \frac{kJ}{kg}$ TAB A-11

$h_2 = 239.08 \frac{kJ}{kg}$ TAB A-10

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

$= 4kg/h \left(239.08 \frac{kJ}{kg} - 93.42 \frac{kJ}{kg}\right)$

$= 562.64 \frac{kJ}{h}$

$= 0.156 \frac{kJ}{s} = 156W$

$\Rightarrow \varepsilon_K = \frac{\dot{Q}_K}{\dot{W}_K} = \frac{156W}{28W} = \boxed{5.57 = \varepsilon_K}$

e) Temperatur würde weiter sinken, aber immer langsamer, da c_p immer grösser wird.