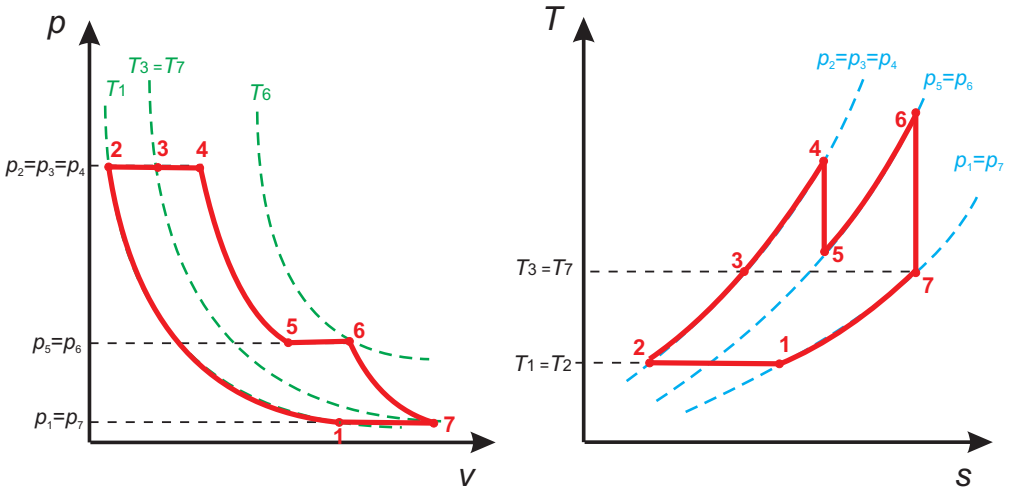
Musterlösung Aufgabe 1: «ideales Gas»

I. TEILAUFGABE A) ⇒ 7 PUNKTE



II. TEILAUFGABE B) 4 PUNKTE

2→4 isobare ZÄ $\Rightarrow p_2 = p_3 = p_4 = 12.25 \cdot 1.5 = 18.375\ bar$

7→1 isobare ZÄ $\Rightarrow p_7 = p_1 = 1.5\ bar$

5→6 isobare ZÄ $\Rightarrow p_5 = p_6$

$\frac{p_4}{p_5} = \frac{p_6}{p_7} \Rightarrow p_5^2 = p_4 \cdot p_7 \Rightarrow p_5 = \sqrt{p_4 \cdot p_7} = \sqrt{p_4 \cdot p_7} = \sqrt{18.375 \cdot 1.5} = 5.25\ bar$

4→5 reversibel adiabate ZÄ:

$$T_5 = T_4 \cdot (\frac{p_4}{p_5})^{\frac{1-\kappa}{\kappa}} = (600 + 273.15) \cdot (\frac{18.375}{5.25})^{\frac{1-1.4}{1.4}} = 610.44\ K$$

$$T_6 = T_7 \cdot (\frac{p_7}{p_6})^{\frac{1-\kappa}{\kappa}} = (430 + 273.15) \cdot (\frac{1.5}{5.25})^{\frac{1-1.4}{1.4}} = 1005.76\ K$$

III. TEILAUFGABE C) ⇒ 4 PUNKTE

$$q_{12} = -w_{t,12} = -\int v dp = -\int \frac{R \cdot T}{p} dp = -R \cdot T_1 \cdot \ln(\frac{p_2}{p_1}) = -287 \cdot 293.15 \cdot \ln(12.25) = -210.8\ \frac{kJ}{kg}$$

$$q_{34} = c_p \cdot (T_4 - T_3) = 1004.5 \frac{kJ}{kgK} \cdot (600 - 430) K = 170.765\ \frac{kJ}{kg}$$

$$q_{56} = c_p \cdot (T_6 - T_5) = 1004.5 \frac{kJ}{kgK} \cdot (1005.76 - 610.44) K = 397.106\ \frac{kJ}{kg}$$

IV. TEILAUFGABE D) $\Rightarrow$ 3 PUNKTE

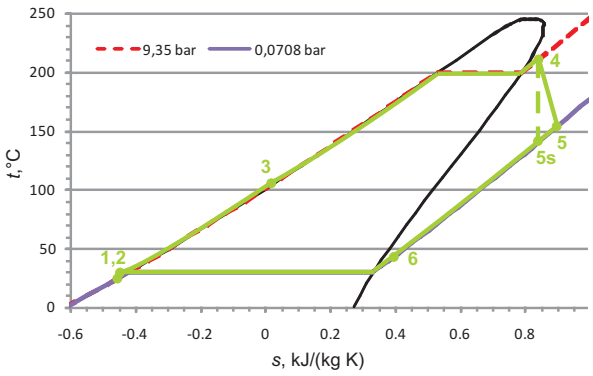
$$P_{45} = \dot{m} \cdot w_{t,45}$$
$$\dot{m} = \frac{\dot{V}_1}{v_1} = \frac{\dot{V}_1 \cdot p_1}{R \cdot T_1} = \frac{4750 \cdot 1.5 \cdot 10^5}{3600 \cdot 287 \cdot 293.15} = 2.35 \ \frac{kg}{s}$$
$$w_{t,45} = c_p \cdot (T_5 - T_4) = 1004.5 \cdot (610.44 - 873.15) = -263.895 \ \frac{kJ}{kg}$$
$$P_{45} = 2.35 \frac{kg}{s} \cdot (-263.895 \frac{kJ}{kg}) = -620.786 \ kW$$
$$w_{t,67} = c_p \cdot (T_7 - T_6) = 1004.5 \cdot (703.15 - 1005.76) = -303.975 \ \frac{kJ}{kg}$$
$$P_{67} = 2.35 \frac{kg}{s} \cdot (-303.975 \frac{kJ}{kg}) = -715.071 \ kW$$

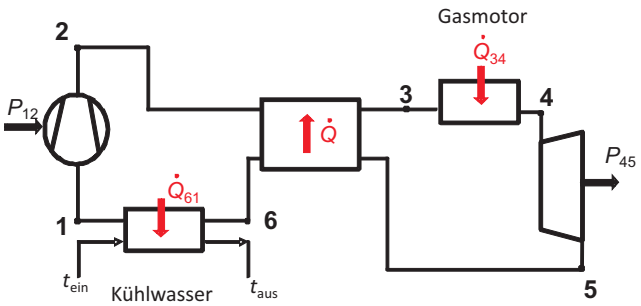
V. TEILAUFGABE E) $\Rightarrow$ 1 PUNKTE

$$\eta_{th} = \frac{Nutzen}{Aufwand} = \frac{|w_{t,12} + w_{t,45} + w_{t,67}|}{q_{34} + q_{56}} = \frac{|210.8 - 263.895 - 303.975|}{170.765 + 397.106} = 62.88 \ \%$$

Musterlösung Aufgabe 2: «Kreisprozess»

I. TEILAUFGABE A) ⇒ 5 PUNKTE





II. TEILAUFGABE B) 6 PUNKTE

$p_1 = p(30°C) = 0.0708\ bar,\ t_1 = 30 - 5 = 25\ °C \quad \Rightarrow h_1 = h(25°C) - 150.61\ \frac{kJ}{kg},$

$s_1 = -0.44922 \frac{kJ}{kg \cdot K} = s_{2s}\ \frac{kJ}{kg \cdot K}$

Interpolation bei $p = 9.35bar$:

$$h_{2s} = -159.33 + \frac{-140.30 + 159.33}{-0.41899 + 0.48284} \cdot (-0.44922 + 0.48284) = -149.3098\ \frac{kJ}{kg}$$

$$\eta_{s,P} = \frac{w_{ts,12}}{w_{t,12}} \Rightarrow w_{t,12} = \frac{w_{ts,12}}{\eta_{s,P}} = \frac{h_{2s} - h_1}{\eta_{s,P}} = \frac{-149.3098\ \frac{kJ}{kg} - (-150.61\ \frac{kJ}{kg})}{0.7} = 1.857\ \frac{kJ}{kg}$$

$p_4 = p_2 = 9.35\ bar,\ t_4 = t(9.35bar) + 10°C = 200 + 10 = 210\ °C$

$\Rightarrow h_4 = h(9.35bar, 210°C) = 372.16\ \frac{kJ}{kg},\ s_4 = 0.84011 = s_{5s}\ \frac{kJ}{kg \cdot K}$

Interpolation:

$$h_{5s} = 258.87 + \frac{267.84 - 258.87}{0.84111 - 0.81926} \cdot (0.84011 - 0.81926) = 267.43\ \frac{kJ}{kg}$$

$$\eta_{s,T} = \frac{w_{t,45}}{w_{ts,45}} \Rightarrow w_{t,45} = w_{ts,45} \cdot \eta_{s,P} = (h_{5s} - h_4) \cdot \eta_{s,T} = (267.43\ \frac{kJ}{kg} - 372.16\ \frac{kJ}{kg}) \cdot 0.9 = -94.26\ \frac{kJ}{kg}$$

III. TEILAUFGABE C) $\Rightarrow$ 5 PUNKTE

$P_{Nutz} = 30\ kW$

$\dot{m}_{HMDS} = \frac{P_{Nutz}}{|w_{t,12} + w_{t,45}|} = \frac{30}{|1.857 + (-94.26)|} = 0.3247\ \frac{kg}{s}$

$h_3 = h(109.46^{o}C,\ 9.35\ bar) = 19.907\ \frac{kJ}{kg}$

$\dot{Q}_{34} = \dot{m}_{HMDS} \cdot (h_4 - h_3) = 0.3247\ \frac{kg}{s} \cdot (372.16 - 19.907) \frac{kJ}{kg} = 114.38\ kW$

IV. TEILAUFGABE D) $\Rightarrow$ 2 PUNKTE

$\eta_{ex} = \frac{P_{Nutz}}{\dot{E_{zu}}} = \frac{P_{Nutz}}{(1 - \frac{T_a}{T_m}) \cdot \dot{Q}_{zu}}$

$s_3 = s(109.46^{o}C, 9.35bar) = 0,52513 \frac{kJ}{kg \cdot K}$

$T_m = \frac{\Delta h_{34}}{\Delta s_{34}} = \frac{372.16 - 19.907}{0.84011 - 0.04941} = 445.5\ K$

$\eta_{ex} = \frac{30\ kW}{(1 - \frac{283.15}{445.5}) \cdot 114.38\ kW} = 71.97\ \%$

V. TEILAUFGABE E) $\Rightarrow$ 3 PUNKTE

$\dot{Q}_w = \dot{Q}_{ab}$

$\dot{m}_{KW} \cdot c_{p,Wasser} \cdot \Delta T_{ein,aus} = \dot{Q}_{ab}$

$\dot{m}_{KW} = \frac{\dot{Q}_{ab}}{c_{p,Wasser} \cdot \Delta T_{ein,aus}} = \frac{\dot{Q}_{zu} - P_{Nutz}}{c_{p,Wasser} \cdot \Delta T_{ein,aus}} = \frac{(114.38 - 30)\ kW}{4.19\ \frac{kJ}{kgK} \cdot (20 - 15) K} = 4.028\ \frac{kg}{s}$

Musterlösung Aufgabe 3:

I. TEILAUFGABE A) ⇒ 3 PUNKTE

$m = 10\ kg,\ p_u = 1,0142\ bar,\ t_u = 20°C,\ m_L = 0,409\ kg$

$$V = m_L \cdot v = m_L \cdot \frac{R_L \cdot T}{p} = 0,409\ kg \cdot \frac{0,287\ kJ/(kgK) \cdot 293,15\ K}{1,0142 \cdot 10^5\ N/m^2} = 0,33929\ m^3 = \pi \cdot \frac{D^2}{4} \cdot H$$

$$\Rightarrow D = \sqrt{\frac{4 \cdot V}{\pi \cdot H}} = 0,6\ m$$

II. TEILAUFGABE B) ⇒ 3 PUNKTE

$p_i = p_s(100°C) = 1,0142\ bar = p_u$

$$F_i = p_i \cdot A = 1,0142 \cdot 10^5 \frac{N}{m^2} \cdot 10^{-4} m^2 = 10,142\ N = F_a$$

$\Sigma F = 0,\ F_g = (m_T + m_W) \cdot g$

$m_T = 10\ kg, \quad m_W = m_{flW} + m_{WD} = V_{fl} \cdot \rho' + (V_{ges} - V_{fl}) \cdot \rho''$

$$V_{fl} = \frac{\pi}{4} \cdot D^2 \cdot h = \frac{\pi}{4} \cdot 0,6^2 \cdot 0,05 m^3 = 0,014137\ m^3$$

$$m_W = [0,014137 \cdot 958,35 + (0,33929 - 0,014137) \cdot 0,5982] kg = 13,7429\ kg$$

$$F_g = (10 + 13,7429) kg \cdot 9,81 \frac{m}{s^2} = 232,917\ N$$

III. TEILAUFGABE C) ⇒ 2 PUNKTE

$$\frac{F_{max}}{A} = \frac{9,404 N}{1 cm^2} = \Delta p = p_u - p_i \quad \rightarrow p_i = p_u - \frac{F_{max}}{A}$$

$$p_i = 1,0142\ bar - \frac{9,404\ N}{10^{-4} m^2} = 0,0738\ bar = p_s(T_2) \quad \Rightarrow T_2 = 40°C$$

IV. TEILAUFGABE D) ⇒ 2 PUNKTE