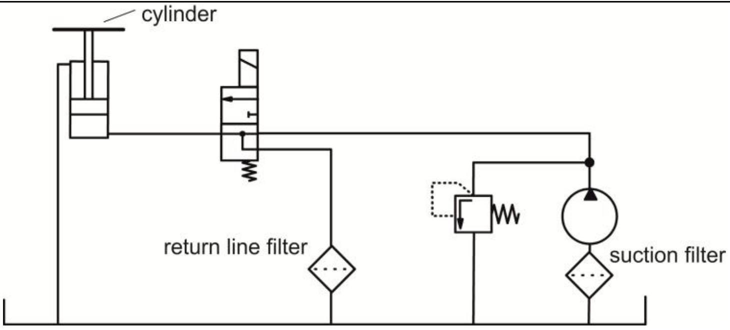
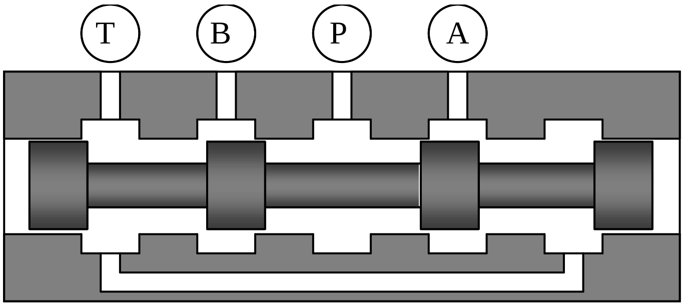
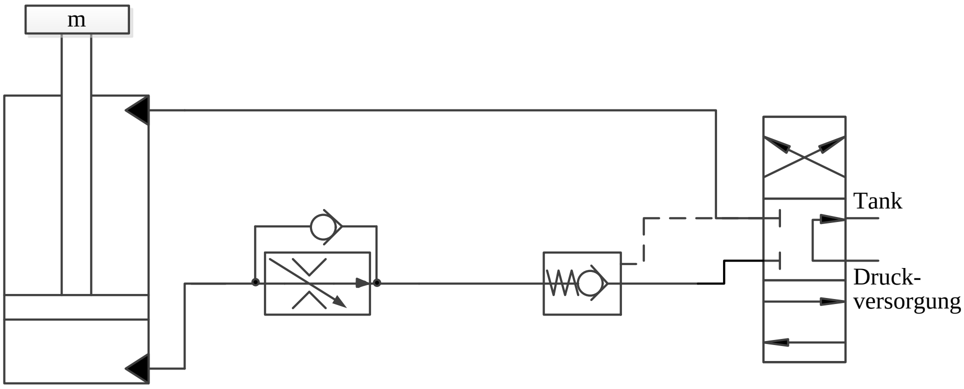
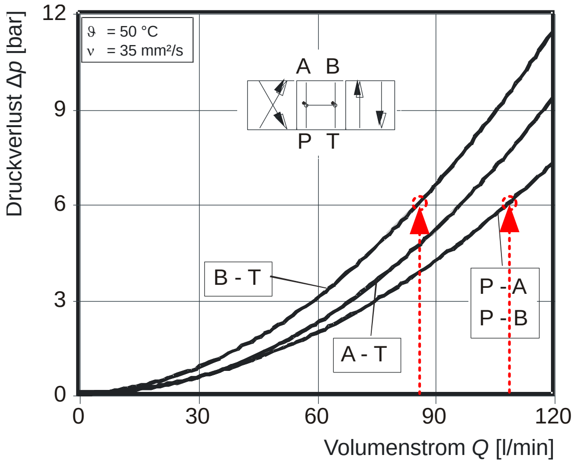
Sample Solution for Exercise: 1 Total Score: 15

<table>
<tr><th>Subtask</th><th>Th</th><th>Points</th></tr>
<tr><td>1.1</td><td>Bernoulli: $\rho \cdot g \cdot h - \frac{\rho}{2} \cdot v^2 = \left(\xi_T + \lambda \cdot \frac{l}{d} + \xi_V \right) \cdot \frac{\rho}{2} \cdot v^2$ 0.5 P
$v = \sqrt{\frac{2 \cdot \rho \cdot g \cdot h}{\rho \cdot \left(1 + \xi_T + \lambda \cdot \frac{l}{d} + \xi_V \right)}} = \sqrt{\frac{2 \cdot 9.81 \cdot 10}{1 + 0.3 + 0.03 \cdot 20/0.05 + 3}}\, m/s$ 1 P
$v = \sqrt{12.04}\, m/s = 3.47\, m/s$ 0.5 P</td><td>2.0</td></tr>
<tr><td>1.2</td><td>$\mathrm{Re} = \frac{v \cdot D_H \cdot \rho}{\eta} = \frac{3.47 \cdot 0.05}{50 \cdot 10^{-6}} = 3471 \geq 2300 \Rightarrow turbulent$</td><td>2.0</td></tr>
<tr><td>1.3</td><td>$Q_{\max} = v \cdot \frac{\pi}{4} \cdot d^2 = 3.47 \cdot \frac{\pi}{4} \cdot 0.05^2 = 6.81 \cdot 10^{-3}\, m^3/s = 409\, l/\mathrm{min}$</td><td>0.5</td></tr>
<tr><td>1.4</td><td>$\dot{Q}_0 = \frac{A}{l \cdot \rho} \cdot \rho \cdot g \cdot h = \frac{\pi \cdot d^2 \cdot g \cdot h}{4 \cdot l} = \frac{\pi \cdot 0.05^2 \cdot 9.81 \cdot 10}{4 \cdot 20}\, m^3/s^2$ 1 P
$\dot{Q}_0 = 9.631 \cdot 10^{-3}\, m^3/s^2$ 1 P</td><td>2.0</td></tr>
<tr><td>1.5</td><td>$T = \frac{Q_{\max}}{\dot{Q}_0} = \frac{6.81 \cdot 10^{-3}}{9.631 \cdot 10^{-3}}\, s = 0.707 s$</td><td>1.0</td></tr>
<tr><td>1.6</td><td><table><tr><td>>4 µ</td><td>max. 80000</td></tr><tr><td>>6 µ</td><td>max. 5000</td></tr><tr><td>>14 µ</td><td>max. 320</td></tr></table></td><td>1.5</td></tr>
<tr><td>1.7</td><td>

1 Point per filter</td><td>2.0</td></tr>
<tr><td>1.8</td><td>HEES = synthetic ester</td><td>1.0</td></tr>
<tr><td>1.9</td><td>viscosity (without further specification) 0.5 P
viscosity group, nominal viscosity, viscosity at 40 °C or similar +0.5 P</td><td>1.0</td></tr>
<tr><td>1.10</td><td>HLP 46 has the lowest VI (Blackline 46) 0.5 P
Justification: highest V_{40}, lowest V_{100} +1.5 P</td><td>2.0</td></tr>
<tr><td></td><td>Summe:</td><td>15</td></tr>
</table>

Sample Solution for Exercise: 2 Total Score: 10

Subtask	Ro	Points
2.1	 Denomination: hydraulically actuated, spring-centred 4/3- port valve Functionality: A connected element can be moved arbitrarily in the middle position because ports A and B are connected with port T	2.0
2.2	 Denomination: Flow control valve with by-pass (check valve); unlockable check valve	2.0
2.3	$x_{\mathrm{F}} = \frac{\Delta p \cdot A}{c_{\mathrm{F}}} = \frac{\Delta p \cdot \pi \cdot d^2}{c_{\mathrm{F}}\;4} = 18.76\,\mathrm{mm}$	1,0
2.4	$\Delta p = \left(\frac{Q}{\alpha_D\;A}\right)^2 \frac{\rho}{2} = \left(\frac{220\,\mathrm{l}}{0{,}7\;\pi\;0.007\,\mathrm{m} \cdot 0.001\,\mathrm{m\;min}}\right)^2 \frac{890\,\mathrm{kg}}{2\,\mathrm{m}^3} = 252.47\,\mathrm{bar}$ $p_0 = p_{\mathrm{T}} + \Delta p = 257.47\,\mathrm{bar}$	0.5
2.5	constant pressure system: $F_{\mathrm{Str}} = 2 \cdot \alpha_{\mathrm{D}}^2 \frac{\cos \varepsilon_1}{\sin \varepsilon_1} d \cdot \pi \cdot x \cdot \Delta p = 198.04\,\mathrm{N}$ alternative: $F_{\mathrm{Str}} = \frac{\rho\,Q^2}{d\;\pi\;x} \frac{\cos \varepsilon_1}{\sin \varepsilon_1} = 198.04\,\mathrm{N}$ $x = x_0 + \frac{F_{\mathrm{Str}}}{c_{\mathrm{F}}} = 1\,\mathrm{mm} + 4.95\,\mathrm{mm} = 5.95\,\mathrm{mm}$	1.5

2.6	increase of the inflow angle ε_1 deviation of the flow (increase of the outflow angle $90° \le \varepsilon_2 \le 180°$) decrease of the flow cross section area $A = d \cdot \pi \cdot x$	1.0
2.7	$Q_{Ein} = v \cdot A = v \cdot \frac{\pi}{4} d^2_{Kolben} = 109.93 \frac{l}{min}$ $Q_{out} = v \cdot A = v \cdot \frac{\pi}{4} (d^2_{Piston} - d^2_{Rod}) = 84.45 \frac{l}{min}$ The pressure loss amounts ca. 6 bar for both directions (from diagram). $P = \Delta p \, (Q_{in} + Q_{out}) = 1943.8 \, W$ 	2.0
	Summation:	10

Sample Solution for Exercise: 3 Total Score: 10

Subtask	Sk	Points
3.1	vane pump	0.5
3.2	1. vane, 2. valve plate, 3. rotor, 4. stator ring, 5. housing	2.5
3.3	(see table below)	1.5

	wobble plate	**swash plate**	**bent axis**
variability	very bad	good	bad
rotating mass	small	big	big
imbalance	yes	no	no
run through shaft	yes	yes	no
motor mode	bad	bad	good

3.4 (Points: 1)

Because in the calculation of efficiency factors of pumps the compression work is considered as a loss of the pump. Therefore motors normally reach higher efficiency factors.

3.5 (Points: 1)

$$V = z \cdot A_P \cdot d_P \cdot \tan(\alpha) = 3 \cdot 6cm^2 \cdot 10cm \cdot \tan(15°) = 48.23cm^3$$

$$Q = V \cdot n = 48.23cm^3 \cdot 1500rpm = 72.346\frac{l}{\min}$$

3.6 (Points: 0.5)

$$\delta' = 1 - \cos\left(\frac{90°}{z}\right) = 0.13397 \Rightarrow 13.397\%$$

3.7 (Points: 3)

$$\left[\sum \frac{dV_P}{d\varphi}\right]_{\max} = \frac{h_{\max}}{2} \cdot A_P \left[\sin\left(\frac{\pi}{2}\right) + \sin\left(\frac{\pi}{2} + \frac{2\cdot\pi}{z}\right) + \sin\left(\frac{\pi}{2} + \frac{4\cdot\pi}{z}\right)\right]$$

$$= \frac{h_{\max}}{2} \cdot A_p [1 - 0{,}5 - 0{,}5] = \frac{h_{\max}}{2} \cdot A_P$$

$$\left[\sum \frac{dV_P}{d\varphi}\right]_{\min} = \frac{h_{\max}}{2} \cdot A_P \left[\sin(\pi) + \sin\left(\pi + \frac{2\cdot\pi}{z}\right) + \sin\left(\pi + \frac{4\cdot\pi}{z}\right)\right]$$

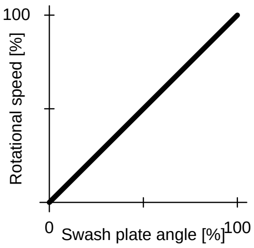
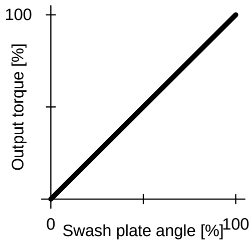
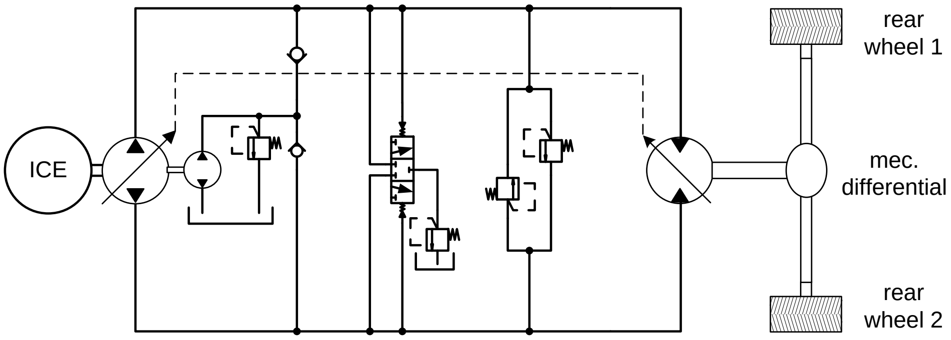
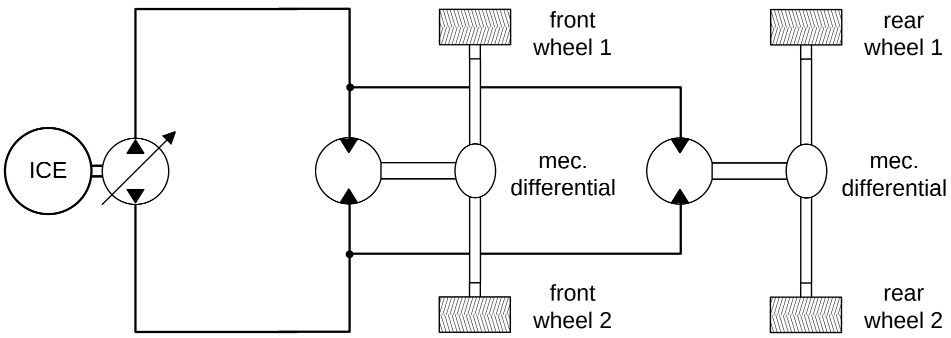
$$= \frac{h_{\max}}{2} \cdot A_P [0 - 0.866 + 0.866] = \frac{h_{\max}}{2} \cdot A_P \cdot 0.866$$

$$\left[\sum \frac{dV_K}{d\varphi}\right]_{avg} = h_{\max} \cdot A_P \frac{z}{2\pi}$$

$$\delta = \frac{\frac{h_{\max}}{2} \cdot A_P \cdot (1 - 0.866)}{h_{\max} \cdot A_P \frac{3}{2\pi}} \cdot 100\% = 14.03\%$$

Summation: 10

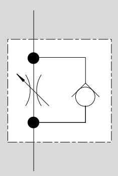
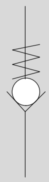
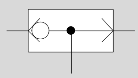
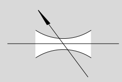
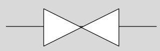
Sample Solution for Exercise: 4 Total Score: 10

<table>
<tr><th>Subtask</th><th>Va</th><th>Points</th></tr>
<tr><td>4.1</td><td>
<table>
<tr><td>adjustment</td><td>primary adjustment</td><td>secundary adjustment</td></tr>
<tr><td>impressing</td><td>impressing of flow rate</td><td>impressing of pressure</td></tr>
<tr><td>output control</td><td>torque-controlled</td><td>rotational speed-controlled</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
</table>
</td><td>2.5</td></tr>
<tr><td>4.2</td><td>
</td><td>2.5</td></tr>
<tr><td>4.3</td><td>

T-pieces → hydraulic differential
2 constant motors</td><td>1</td></tr>
<tr><td>4.4</td><td>$$P_{hydr} = \frac{P_{out}}{\eta_{hm} \cdot \eta_{vol}} = \frac{M_{out} \cdot n_{out} \cdot 2 \cdot \pi}{\eta_{hm} \cdot \eta_{vol}} = Q_{requ} \cdot \Delta p$$
$$Q_{requ} = \frac{800\,Nm \cdot 1200 rpm \cdot 2 \cdot \pi}{0.98 \cdot 0.93 \cdot 33\,MPa} = 200.55 \frac{l}{\min}$$</td><td>1</td></tr>
</table>

4.5	$V_{Pump_1} = \frac{Q_{requ}}{n_{out} \cdot \eta_{vol}} = \frac{200.55 \frac{l}{\min}}{2100\, rpm \cdot 0.94} = 101.6\, cm^3$ [151.97cm³]	1
4.6	$\eta_{hm2} = \eta_{hm1} \cdot \left(e^{\alpha 2} - 1\right) = 97\% \cdot \left(e^{0.6} - 1\right) = 79.75\%$ $M_{Pump2} = \frac{\Delta p \cdot V_{Pump2}}{2 \cdot \pi \cdot \eta_{hm2}} = \frac{33 MPa \cdot 101.6\, cm^3 \cdot 0.6}{2 \cdot \pi \cdot 79.75\%} = 401.47\ Nm$ $P_{in} = M_{Pume2} \cdot n_{in} \cdot 2 \cdot \pi = 401.47 Nm \cdot 2100 \frac{U}{\min} \cdot 2 \cdot \pi = 88.29 kW$ M_{pump2} = [600.5 Nm/ 296.36 Nm] P_{an} = [132.06 kW/ 65.18 kW]	2
	Summation:	10

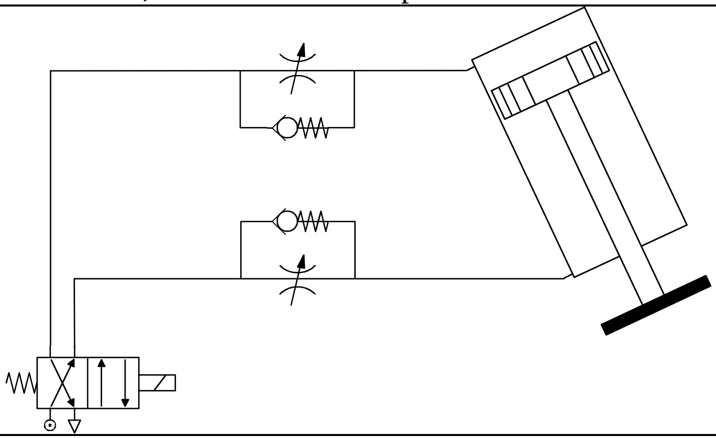
Sample Solution for Exercise: 5 Total Score: 15

<table>
<tr><td>Subtask</td><td>vG</td><td>Points</td></tr>
<tr><td>5.1</td><td>single acting cylinder</td><td>∑=0,5</td></tr>
<tr><td>5.2</td><td>
<table>
<tr><td></td><td>Benefit</td><td>Disadvantage</td></tr>
<tr><td>low operating pressure</td><td>pressure resistance of the construction elements is unproblematic, use of hose pipes is possible</td><td>lower forces and torques than in hydraulics</td></tr>
<tr><td>low viscosity</td><td>low flow losses, high operating velocity</td><td>High leakage losses, low damping</td></tr>
<tr><td>high comressibility</td><td>energy accumulation, elastic drive behaviour</td><td>low static and dynamic stiffness in open control chains</td></tr>
</table>
</td><td>∑=3</td></tr>
<tr><td>5.3</td><td>
<table>
<tr><td>Rotary Motor</td><td>Use of Expansion Work Possible Due to Principle</td><td>Use of Expansion Work Not Possible Due to Principle</td></tr>
<tr><td>Vane Motor</td><td>x</td><td></td></tr>
<tr><td>Geared Motor</td><td></td><td>x</td></tr>
<tr><td>Turbines</td><td>x</td><td></td></tr>
<tr><td>Piston Motors</td><td>x</td><td></td></tr>
</table>
</td><td>∑=2</td></tr>
<tr><td>5.4</td><td>
<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>one way flow control valve</td><td>non-return valve with spring</td><td>shuttle valve</td><td>adjustable throttle</td><td>shut-off valve</td></tr>
</table>
</td><td>∑=2,5</td></tr>
</table>

5.5	slow lowering → isothermal change of state load per wheel: $F_{Fahrzeug} = \frac{m_{PKW} \cdot g}{4} = 4905N$ balance of forces at air spring: $F_{vehicle} + p_U \cdot A_D - p_F \cdot (A_D - A_K) - A_K \cdot p_{oil} = 0$ $\Leftrightarrow p_F = \frac{F_{vehicle} + p_U \cdot A_D - A_K \cdot p_{oil}}{A_D - A_K} = 22{,}08bar$ calculation of the volume V_1 after compression of volume V_0 $V_0 = A_F \cdot l - A_D \cdot x_0 - (l - x_0) \cdot A_K = 1746{,}8cm^3$ ideal gas: $pV = mRT$ with m, T =const: $p_0 V_0 = p_1 V_1 \Leftrightarrow V_1 = \frac{p_{F0}}{p_F} V_0 = 1582{,}20cm^3$ calculation of the compression travel s $s = \frac{V_0 - V_1}{A_D - A_K} = 8{,}7cm$	∑=3
5.6	abrupt change of state → adiabatic, isenstropic → $n = 1{,}4$ increase of temperature after isentropic relation and $T_{F,unloaded} = T_U$: $\frac{p_{F,unloaded}}{p_F} = \left(\frac{T_{F,unloaded}}{T_F}\right)^{\frac{n}{n-1}} \Leftrightarrow T_F = \frac{T_{F,unloaded}}{\left(\frac{p_{F,unloaded}}{p_F}\right)^{\frac{n-1}{n}}} = 312{,}45K$ specific work that is stored in the spring $w = \frac{R}{n-1}(T_F - T_{F,unloaded}) = \frac{288 \frac{Nm}{KgK}}{1{,}4-1}(312{,}45K - 293{,}15K) = 13896 \frac{J}{Kg}$ ai r mass in the spring $m_{Feder} = \frac{p_{F,unloaded} \cdot V_{F,unloaded}}{R \cdot T_{F,unloaded}} = \frac{24bar \cdot 1700cm^3}{288 \frac{Nm}{KgK} \cdot 293{,}15K} = 48{,}33g$ energy that is stored in the spring $E = w \cdot m_{spring} = 671{,}53J$	∑=2

5.7	calculation of the volume that needs to be displaced: $V_{leak} = (A_D - A_K) \cdot (l - (x_0 + s)) = 1885mm^2 \cdot (250mm - 50mm - 20mm)$ $= 339{,}3cm^2$ mass in the volume that needs to be displaced: $m_{Leck} = \frac{p_F \cdot V_{Leck}}{R \cdot T_F} = \frac{24bar \cdot 339{,}3cm^3}{288\frac{Nm}{KgK} \cdot 300K} = 9{,}425g$ Because it is deaerated from p_F over the gap to the environment in every case critical flow can be considered (b<<0,528). $\dot{m}^* = C \cdot p_F \cdot \rho_0 \sqrt{\frac{T_0}{T_F}} = 0{,}5\frac{Nl}{\min \cdot bar} \cdot 24bar \cdot 1{,}1845\frac{kg}{m^3} \cdot \sqrt{\frac{293{,}15K}{300K}} = 0{,}234\frac{g}{s}$ The time T for the displacement of the volume occurs to: $T = \frac{m_{leak}}{\dot{m}^*} = \frac{9{,}425g}{0{,}234\frac{g}{s}} = 40{,}28s$	∑=2
	Summation:	15

Sample Solution for Exercise: 6 Total Score: 10

Subtask	Ev	Points
6.1	electrically actuated , spring return 4/2-port switching valve	0,5
6.2	For an exhaust air flow control in a wide area the velocity is independent of the load; so in this case independent of the mass of the different boxes.	0,5
6.2		1,0
6.3	$\sum F = 0 = F_R - p_A \cdot A_K + p_B \cdot (A_K - A_S) + p_U \cdot A_S$	0,5
	$\Rightarrow F_R = p_A \cdot \frac{\pi}{4} D^2 - p_B \cdot \frac{\pi}{4}(D^2 - d^2) - p_U \cdot \frac{\pi}{4} d^2$	
	$\Rightarrow F_R = \frac{\pi}{4} \cdot \left[6 \cdot 32^2 - 5{,}5 \cdot (32^2 - 12^2) - 1 \cdot 12^2\right] \cdot bar \cdot mm^2 = 91{,}1N$	0,5+0,5
6.4	$\dot{m}^* = \rho_B \cdot Q_B = \frac{p_B}{R_L \cdot T_B} \cdot \frac{\pi}{4}(D^2 - d^2) \cdot v$	0,5
	$\Rightarrow \dot{m}^* = \rho_B \cdot Q_B = \frac{5{,}5bar}{288Nm/(kgK) \cdot 300K} \cdot \frac{\pi}{4}(32^2 - 12^2)mm^2 \cdot 1m/s$	
	$\Rightarrow \dot{m}^* = 4.399g/s$	0,5
	The throttle in the exhausting pipe is floated supercritically (exhaust flow control). Therefore yields:	
	$\dot{m}^* = C \cdot p_B \cdot \rho_0 \cdot \sqrt{\frac{T_0}{T_B}}$	0,5
	$\Rightarrow C = \frac{\dot{m}^*}{p_B \cdot \rho_o} \sqrt{\frac{T_B}{T_0}} = \frac{4{,}399g/s}{5{,}5bar \cdot 1{,}184kg/m^3} \sqrt{\frac{300K}{293{,}15K}} = 40{,}93l/(\min \cdot bar)$	0,5
	$C = \frac{\alpha_D \cdot A_2 \cdot \Psi_{\max} \sqrt{2 \cdot R_{L,0} \cdot T_o}}{p_0}$	0,5
	$\Rightarrow A_2 = \frac{C \cdot p_0}{\alpha_D \cdot \Psi_{\max} \sqrt{2 \cdot R_{L,0} \cdot T_o}} = \frac{40{,}93l/(\min \cdot bar) \cdot 1bar}{0{,}7 \cdot 0{,}484 \sqrt{2 \cdot 288Nm/(kgK) \cdot 293{,}15K}}$	
	$A_2 = 4{,}89mm^2$	0,5
6.5	1st law for a closed system: $Q_{12} + W_{12} = U_2 - U_1 + E_{a2} - E_{a1}$	

	$Q_{12}=0$, because of an adiabatic change of state $E_{a2}-E_{a1}=0$ (assignment of tasks)	
	$W_{12}=\frac{m_{Kiste}}{2}v^2$	0,5
	$U_2-U_1=m\cdot c_v\cdot(T_2-T_1)$	0,5
	From the ideal gas equation yields $m=\frac{p_0\cdot V}{R_L\cdot T_0}$	0,5
	$\Rightarrow \frac{m_{Kiste}}{2}v^2=\frac{p_0\cdot V}{R_L\cdot T_0}\cdot\frac{R}{\kappa-1}\cdot(T_2-T_0)=\frac{p_0\cdot V}{\kappa-1}\cdot\frac{(T_2-T_0)}{T_0}$	0,5
	$\Rightarrow T_2=\left(\frac{m_{Kiste}}{2}\frac{\kappa-1}{p_0\cdot V}v^2+1\right)\cdot T_0$	
	$\Rightarrow T_2=\left(\frac{50kg}{2}\frac{4}{\pi}\frac{1{,}4-1}{1bar\cdot 100^3mm^3}1m^2/s^2+1\right)\cdot 293{,}15K=330{,}47K$	0,5
6.6	isentropic change of state	
	$\Rightarrow x_2=x_1\cdot\left(\frac{T_1}{T_2}\right)^{\frac{1}{\kappa-1}}$ page 24	0,5
	$\Rightarrow x_2=100mm\cdot\left(\frac{293{,}15K}{330{,}47K}\right)^{\frac{1}{0{,}4}}=74{,}11mm$	
	The absorber moves 25,89 mm.	0,5
	(for T_2=327 K: $\Rightarrow$ $x_2=76{,}1mm$ $\Rightarrow$ absorber movement 23,9 mm.)	
	Summation:	10