RWTH AACHEN UNIVERSITY

IFAS Institut für fluidtechnische Antriebe und Steuerungen

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Written Examination "Fundamentals of Fluid Powers"

February, 14th 2013

Exercise 1 / 15 Points

1.1 Name two benefits and two disadvantages of hydraulic drives and controls. (2 Points; 0.5 Points/answer)

Benefits ☺	Disadvantages ☹

1.2 Name three functions of the fluid in a hydraulic system. (1.5 Points)

_____

_____

_____

1.3 To which liquid group do HFD-liquids belong? (0.5 Points)

_____

1.4 The counting of particles in an oil sample of 17 ml result in the following disposition:

Size of Particles [µm]	>4 to ≤6	> 6 to ≤10	>10 to ≤14	>14 to ≤18	> 18
Quantity of Particles	12367	1178	461	109	8

Partikelanzahl pro ml		Ordnungs-zahl
von	bis	
2500000	-	> 28
1300000	2500000	28
640000	1300000	27
320000	640000	26
160000	320000	25
80000	160000	24
40000	80000	23
20000	40000	22
10000	20000	21
5000	10000	20
2500	5000	19
1300	2500	18
640	1300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2,5	5	9
1,3	2,5	8
0,64	1,3	7
0,32	0,64	6
0,16	0,32	5
0,08	0,16	4
0,04	0,08	3
0,02	0,04	2
0,01	0,02	1
0	0,01	0

Reinheitsgrade nach ISO 4406:1999

What is the sample's degree of contamination according to ISO 4406? (2.5 Points)

_____

_____

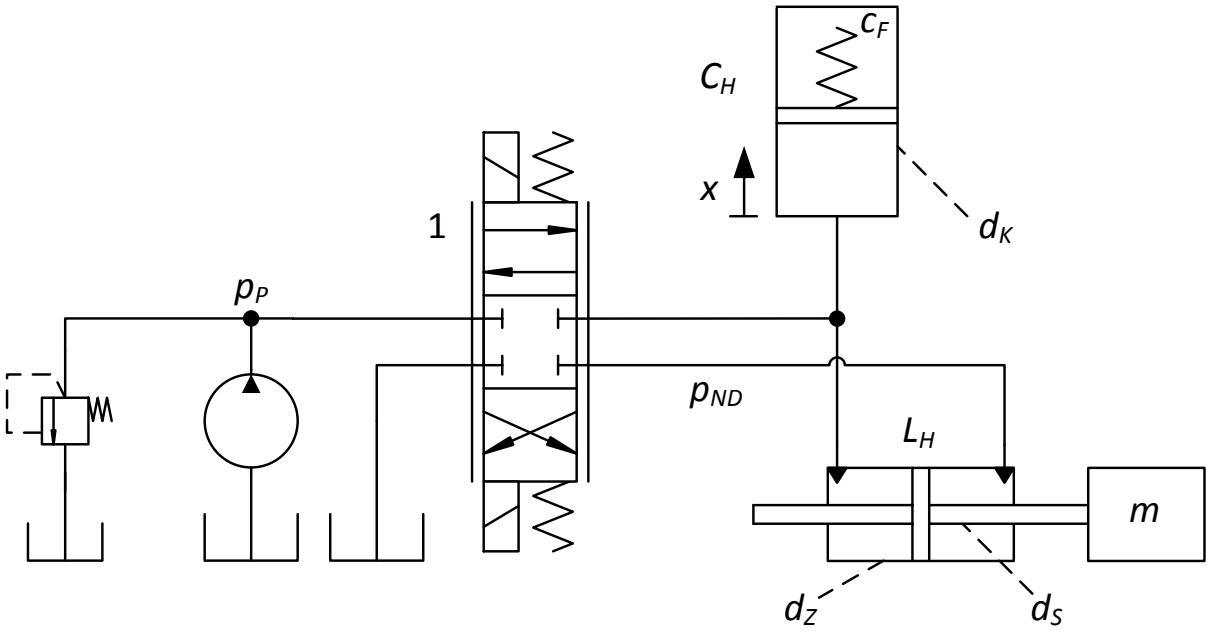
1.5 A hydraulic cylinder shall achieve a force of 15 kN at a maximum velocity of 1 m/s. Calculate the required flow rate in l/min if the operating pressure is 200 bar. All losses can be neglected. (1.5 Points)

1.6 Sketch the characteristic curve of a throttle and an orifice qualitatively into the diagram below. Name the characteristic curves and indicate the corresponding flow laws. (1.5 Points)

1.7 Which resistor is preferred in hydraulic circuits and why? (1 Point)

_____

1.8 Given is the hydraulic circuit of a hydrostatic linear actuator:



Given:	Diameter Piston Rod	d_S = 25 mm
	Diameter Cylinder	d_Z = 40 mm
	Mass	m = 200 kg
	Pressure of the Pump	p_P = 350 bar
	Pressure of the Return Pipe	p_{ND} = 5 bar

Calculate the force of the cylinder, neglecting all losses, in the given operating point. The valve is arranged in switching position 1. Give the solution in SI-units. (1.5 Points)

1.9 Deduce the formula of the spring piston accumulator's hydraulic capacity C_H in dependency of the pictured parameters. (3 Points)

Exercise 2 / 10 Points

2.1 Name the four groups in which valves can be divided due to their function and describe the function exactly in one sentence. (2 Points)

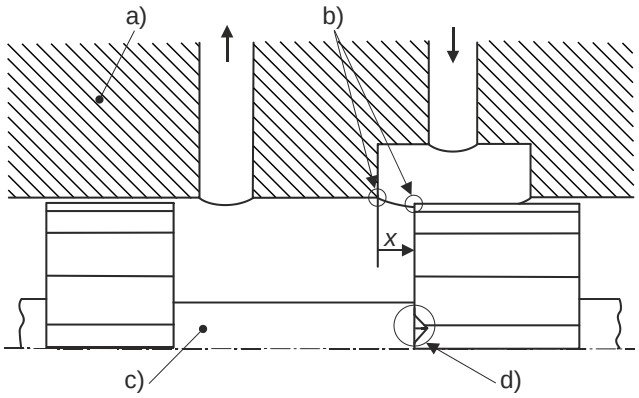
i. group:

ii. group:

iii. group:

iv. group:

2.2 Name the construction elements / function areas a) till d) explicitly. (1 Point)

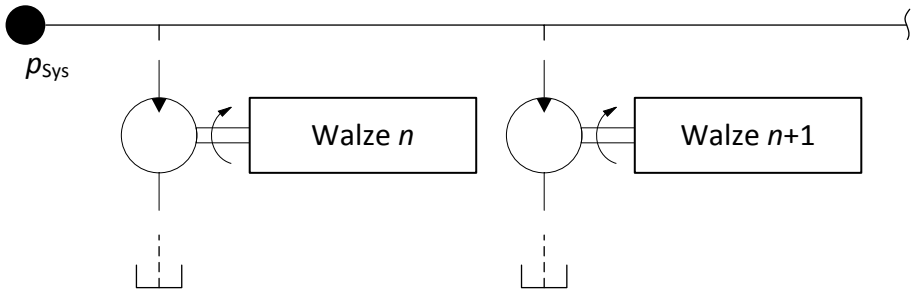


a)	b)
c)	d)

2.3 Name a benefit and a disadvantage for each listed field of operation. Keep in mind that all arguments differ from each other. (1.5 Points)

Field of Operation	Benefit	Disadvantage
Mechanic		
Electric		
Hydraulic		

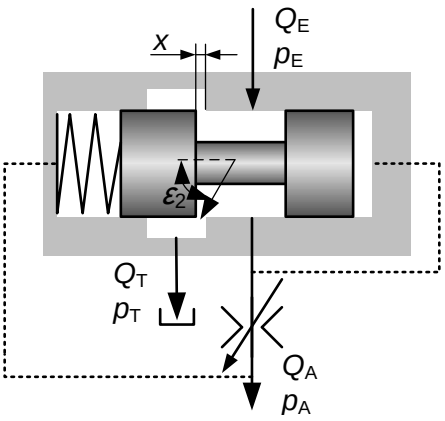
2.4 In a rolling mill different rolls shall be run using constant hydraulic motors supplied by a central pressure unit (p_{sys}) (cf. Fig.). The rotational speed shall be adjustable and kept constant once the desired speed is reached. The load on the rolls is constant, but deviations of the supply pressure (p_{Sys}) occur. Which kind of valve would you insert for this task (exact denomination) and would you attach it in front of or behind of the motors? Justify your decisions with one sentence each. (1 Point)



Kind of Valve: _____

Place of Attachment: _____

2.5 Calculate the flow rates Q_E and Q_A for the pictured valve. (1.5 Points)



Given:

$p_E = 220$ bar	$p_T = 20$ bar	$p_A = 180$ bar
$Q_T = 17.5$ l/min	$d_{DW} = 5$ mm	$d_{orifice} = 2$ mm
$\alpha_D = 0.7$	$\rho = 890$ kg/m³	$\varepsilon_1 = 90°$
$\varepsilon_2 = 60°$		

2.6 Define the opening width x of the pressure compensator. Act on the assumption that it is sharp-edged and without overlap. (1 Point)

2.7 What is the size of the stationary flow force on the pressure compensator? Draw its direction and justify this in one sentence. (If you were not able to solve subtask 2.6, consider x = 0.1 mm.) (1 Point)

2.8 Determine the required spring force so that the pressure compensator is in balance. (If you were not able to solve subtask 2.7, consider F_{Str} = 20 N.) (1 Point)

Exercise 3 / 10 Points

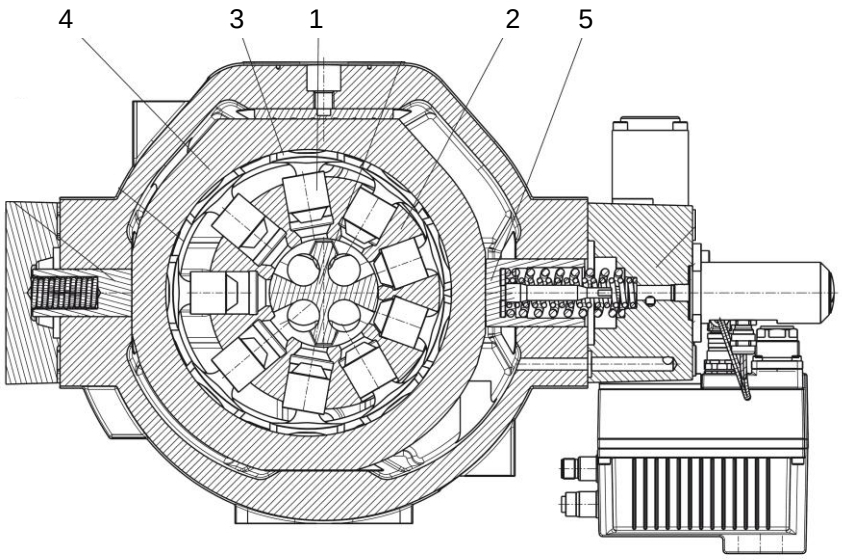


Fig. 3.1

3.1 In Fig. 3.1 a hydraulic pump is pictured. Give the complete appellation of this configuration. (0.5 Points)

_____

3.2 Name the marked construction elements 1 – 5. (2.5 Points)

1._____

2._____

3._____

4._____

5._____

3.3 Which two kinds of pulsation can occur in axial piston pumps? (Only the mentioning of both kinds of pulsation results in 0.5 Points).

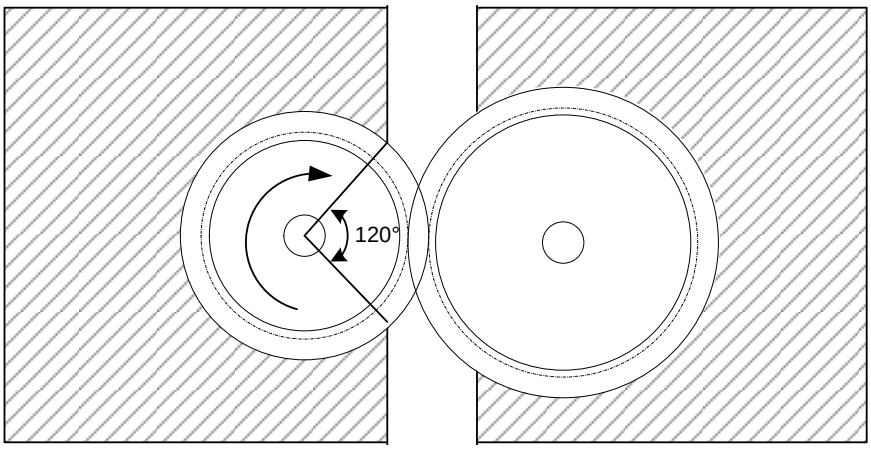
1._____

2._____

3.4 Which constructive feature at the control plate could you recommend against pulsation? (0.5 Points)

In the following the pump in Fig. 3.2 is given. The pressure in the pressure pipe is 100 bar higher than in the suction pipe. The width of the displacement elements is 2 mm, in the driving wheel exist 10 displacement elements and in the drifted wheel 20. The module of the displacement elements is m = 8 mm. The bulk-modulus of the oil is 16000 bar.

Pipe A



Pipe B

Fig. 3.2

3.5 Which kind of design is the pump in Fig. 3.2? (0.5 Points)

3.6 Calculate the theoretical displacement volume. (1 Point)

3.7 Draw in Fig. 3.2 the flow direction of the delivered flow rate and label it with the amount of the delivered flow rate per turn of the driving wheel. Label both pipes with their corresponding appellations. (If you were not able to solve task 3.6, indicate the flow rate in percent). (1 Point)

3.8 How much is the leakage flow rate of the right wheel that is flowing from the high pressure into the displacement rooms per minute if this wheel turns with a rotational speed of $n = 800\ \text{min}^{-1}$? (2 Points)

3.9 The pump should be redesigned as follows, cf. Fig. 3.3. Where do the pressure and suction pipes of the additional displacement unit need to be attached? Moreover draw in the place and the direction of all flow rates. About how many percent does the complete displacement volume of the unit change? (1.5 Points)

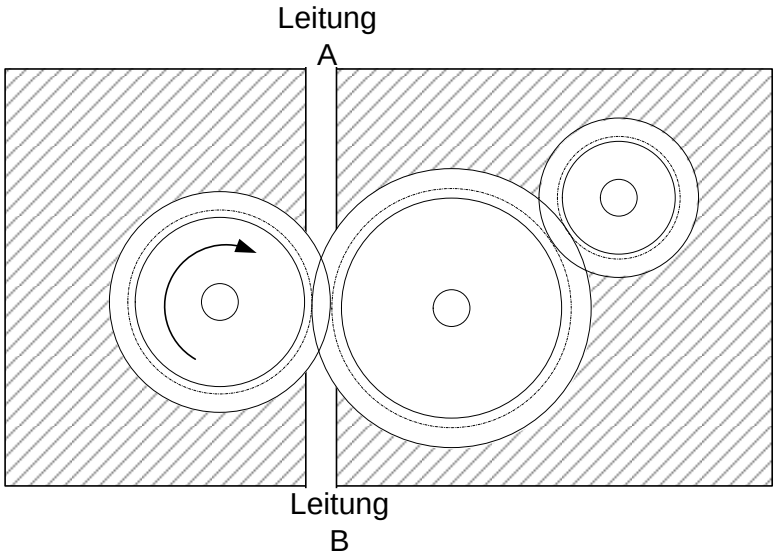


Fig. 3.3

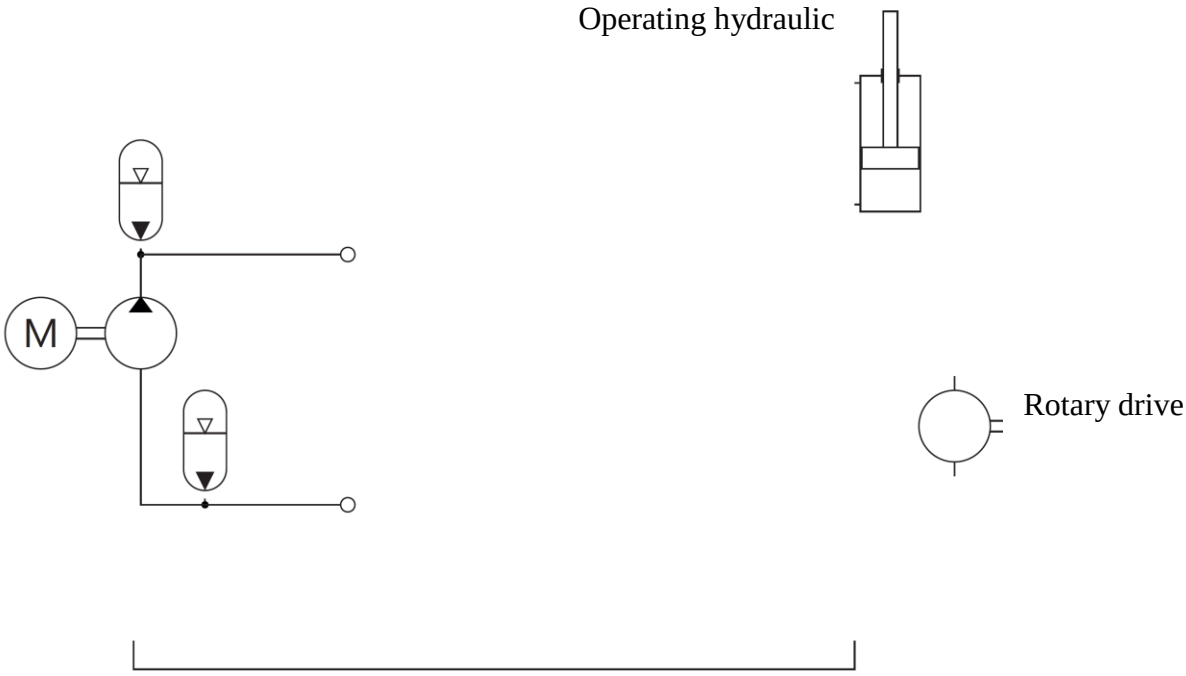
Exercise 4 / 10 Points

For construction machines it is increasingly paid attention to energy efficiency to improve the economic efficiency. In this exercise an excavator is considered exemplary whereat in a hydraulic circuit the rotary drive and the cylinders (in this case just one) of the operation hydraulics (excavator's boom and bucket) are powered. One approach to increase the energy efficiency is to avoid throttle losses as far as possible and to use a constant pressure system. Thereby the reclamation of energy at the traction drive is possible.

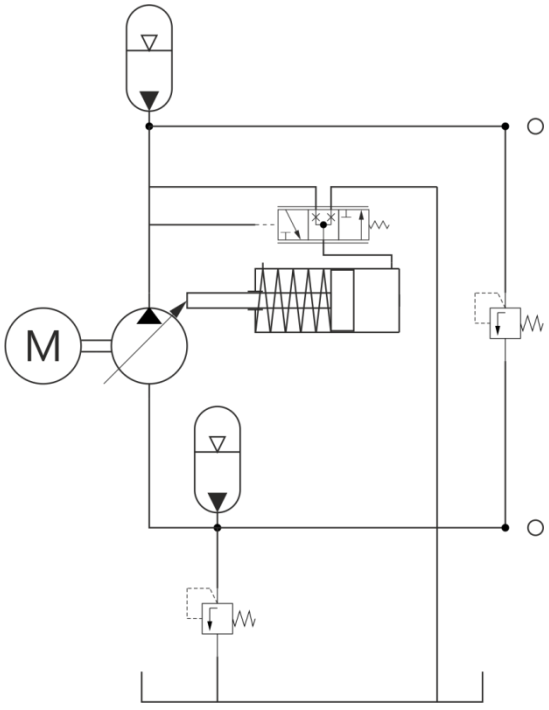
4.1 Name, where it is requested, the required specification of the five main characteristics which are necessary for the system and give a considerably reason for the necessity of the specification. (3 Points)

Main Characteristic	Specification	Reason
Circuit System		
Arrangement	xxx	xxx
Adjustment		
Power Output		
Power Transmission	xxx	xxx

4.2 Complete the circuit corresponding to the requirements. And add the construction elements for a safe and permanent operation. (3 Points (1 Point for each control and 0.5 Points each for a safe and permanent operation))



4.3 Which benefit would the pressure supply unit pictured at the bottom have compared to the pressure supply unit from exercise 0? (1 Point)



4.4 For the drive of the excavator with 4 wheels and one motor per wheel a primary control is used while the motors are parallel interconnected. Calculate the swash plate angle of the pump to reach a velocity of 15km/h at an ascending slope of 10°. Rolling friction and wind resistance can be neglected. (2 Points)

Given: $m_B = 24$ t $g = 9{,}81$ m/s² $R_{wheel} = 1$ m

$N_{pump} = 1500$ U/min $V_{pump} = 750$ cm³ $V_{motor} = 500$ cm³

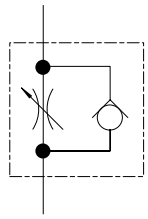
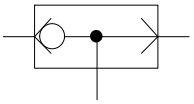
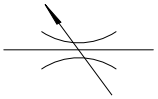
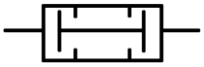
$\eta_{hmMotor} = 95$ % $\eta_{volMotor} = 90$ % $i = n_{Motor}/n_{wheel} = 4$

$\eta_{volPump} = \eta_{hmPump} = f(\text{pivoting angle}) \approx \alpha$

4.5 Calculate the pressure in the case mentioned above? (1 Point)

Exercise 5 / 15 Points

5.1 You need to construct a pneumatic control. It is necessary that the cylinder movement can be released from two signalers at two different places. Which one is the element you need to build in additionally? (1 Point)

5.2 Name the three construction forms of pneumatic limited semi-rotary drives. (1,5 Points)

5.3 Name three types of piston seals. (1,5 Points)

5.4 At which pre-pressure does the same mass flow flow through an ideal nozzle with the tightest diameter of 3 mm and an ideal nozzle with the tightest diameter of 6 mm and a pre-pressure of 3 bar_{abs}? The pressure behind the nozzle in both cases amounts 1 bar_{abs} each. (1 Point)

Fig. 5.1 shows schematically a symmetrical constructed pressure intensifier. It transforms the supply pressure p_{Vers} onto a higher pressure level p_{HD} by connecting the chambers 1 till 4 in a way that always two chambers intensify the volume of a third chamber.

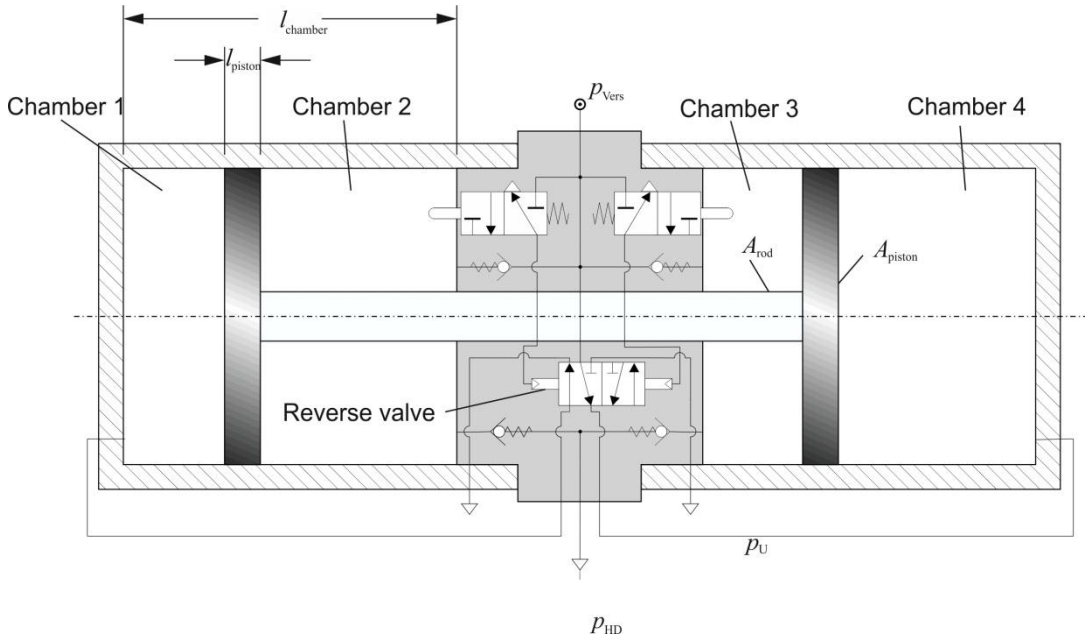


Fig. 5.1: Pressure Intensifier

Given are the following hints and characteristics:

P_{con} = 6 bar	p_U = 1 bar	A_{rod} = 80 mm²
L_{piston} = 10 mm	T_U = 293,15 K	T_{con} = 293,15 K
A_{piston} = 2400 mm²	$L_{chamber}$ = 100 mm	

All pressures are indicated and need to be indicated as absolute pressures. The cross-section areas are full sections.

5.5 Name two more possibilities next to the use of a pressure intensifier to increase the power of a cylinder drive. (1 Point)

5.6 Give the specific appellation of the reverse valve in Fig. 5.1 an. (1,5 Points)

5.7 Allocate the chamber pressures p_U, p_{con} und p_{HD} to the chambers 1 to 4 for the actual valve position. (2 Points)

Chamber	1	2	3	4
Pressure				

5.8 Calculate the theoretical maximum achievable pressure p_{HD}. Friction can be neglected. (2 Points)

5.9 Calculate the mass flow rate relation of $\dot{m}_{HD}/\dot{m}_{Vers}$, that appears during operation. Dead volumes and friction can be neglected. (2 Points)

5.10 Calculate the temperature T_{HD} of the compressed air at the high pressure connection. Consider a polytropic change of state with n = 1,2. Consider p_{HD} = 10 bar for the high pressure. (1,5 Points)

6th Exercise / 10 Points

For the automized opening of beer bottles you develop a portable system which is run by a valve driven cylinder activated by a compressed air bottle. The bottle opener is released by a hand-operated 4/2-port valve. Due to a copious field test you could gain the awareness that the cylinder needs to provide a force of 20 Nin the direction of moving out to open the bottle. The cylinder stroke amounts 30 mm to achieve an adaption to different bottle neck geometries. To avoid a damage of the bottles the cylinder shall move in and out with a constant velocity. The cylinder velocity shall amount 10 mm/s. If the valve is unactuated the cylinder is moved in.

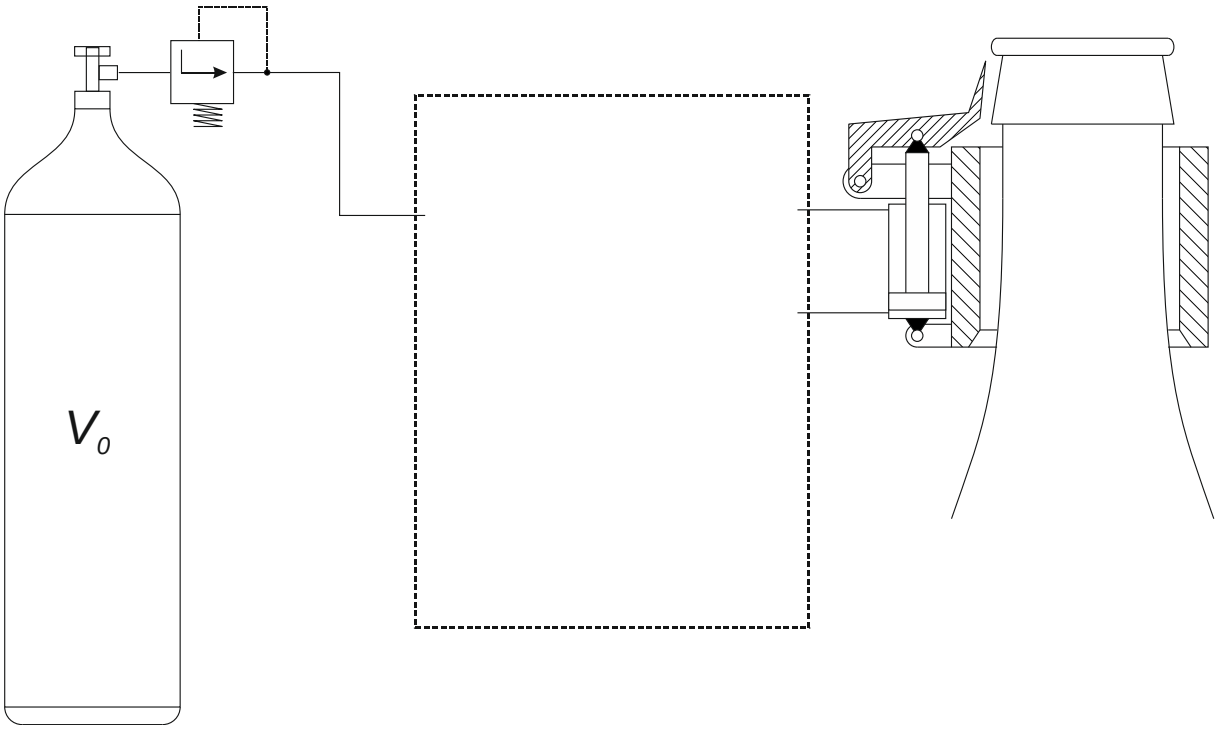
Advise:

- The critical pressure ratio *b* of all resistors amounts 0,4.
- Take all cylinders as frictionless.
- Neglect dead volumes of hoses and pipes.
- Neglect mass and weight forces.
- All valves and pipes are thermally isolated.

Resistors:	
Critical Pressure Ratio	b = 0,4
Cylinder:	
Max. Force	F = 20 N
Stroke	x = 30 mm
Desired Speed	v = 10 mm/s
Nitrogen Bottle:	
Injection Pressure (at T_U)	p_0 = 50 bar
Volume	V_0 = 0,5 l

Environment:	
Environmental Pressure	p_U = 1 bar
Environmental Temperature	T_U = 293,15 K

Constants (Technical State at Standard Conditions):	
Gas Constant for Air	R_0 = 288 Nm/kgK
Standard Temperature	T_0 = 293,15 K
Standard Pressure	p_0 = 1 bar



6.1 The cylinder velocity shall be kept constantly in both movement directions. Electric energy is not available. Complete the circuit above to achieve the required characteristics. Integrate moreover the hand-operated 4/2-port valve. (1,5 Points)

6.2 The smallest available cylinder exhibits a piston area of 50 mm² and a rod area of 25 mm². Which minimum operating pressure do you need to achieve the requirements? (1,5 Points)

6.3 You would like to operate with the bottle opener until the pressure of the compressed air bottle underruns 10 bar. Which minimal sonic conductance *C* (in Nl/(min bar)) does your pressure reducing valve need to exhibit at minimum require in its fully opened state? Act on the assumption that the hand-operated valve constitutes a negligible resistor. Consider a required operating pressure of the cylinder of 6 bar. (2,5 Points)

Advice: Act on the assumption that everywhere environmental temperature is given.

6.4 You can use the bottle opener until the nitrogen bottle pressure underruns 10 bar. How many bottles can you open with the installation during one evening? (1,5 Points)

Advices:

- The evening is long – Act on a slow change in state inside of the nitrogen bottle.
- Consider the required operating pressure of the cylinder with 6 bar.

6.5 You take a pneumatic cylinder which you use as a hand pump to run the equipment. For this you remove the pressure bottle, the pressure reducing valve and all components you drew in in exercise 6.1 and then you connect the pump cylinder directly at the piston-sided cylinder chamber of the operating cylinder. The pump cylinder exhibits a displacement volume of 10 cm^3. Which maximum pressure can occur at the stroke end of the operating cylinder? (1 Point)

6.6 Which mechanic energy needs to be dedicated at the pump cylinder at minimum? Consider the pump cylinder as frictionless. (2 Points)