RWTH AACHEN UNIVERSITY

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Written Examination „Fundamentals of Fluid Power“

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1. Exercise / 15 Points

1.1 Name 2 advantages and 2 disadvantages of hydraulic drives and controls. (2 points; 0.5/correct answer)

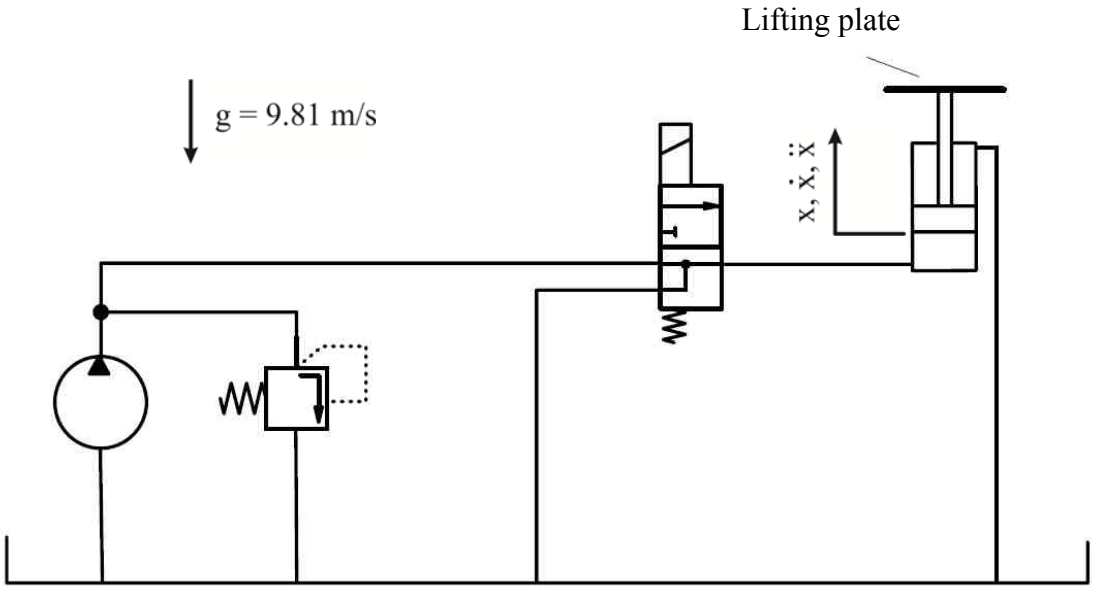
Advantage ☺	Disadvantage ☹

1.2 Name the primary and a secondary task of the hydraulic fluid in a hydraulic circuit. (1 point)

Primary: _____

Secondary: _____

1.3 The hydraulic circuit, shown below, is supposed to lift a weight of 6500 kg. The weight of the lifting plate, the piston and piston rod amounts to 850 kg.



Calculate the necessary cylinder diameter in mm, if the maximal system pressure is 200 bars. Neglect all losses. Mark your cylinder choice in the table below. (2 points)

Cylinder diameter d [mm]	Choice
50	☐
60	☐
70	☐
80	☐
100	☐
120	☐
160	☐

1.4 A lifting height of 1.5 m is needed, which shall be reached in T_{max} = 6 s by the chosen cylinder. The available pumps have a volumetric efficiency of 93% and are driven at 1500 rpm. Calculate the pump's necessary displacement volume and choose the best suited pump from the table below. (2 points)

Displacement volume V_1 [cm^3/rev]	**Choice**
20	☐
30	☐
40	☐
50	☐
70	☐

1.5 Calculate the actual system pressure and lifting time with the chosen components. (1 point)

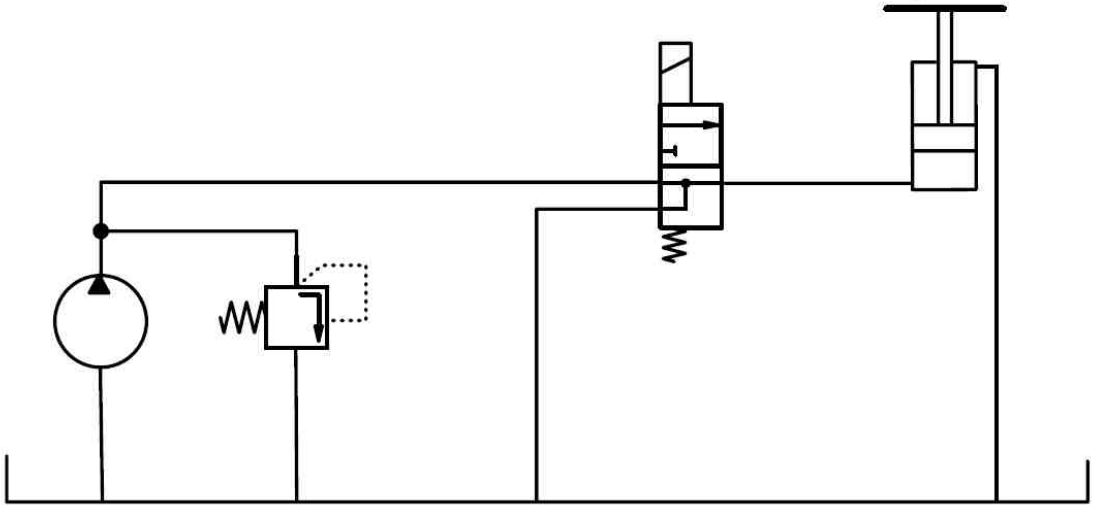
1.6 The oil contamination is measured after putting the system into service. A particle count according to ISO 4406 results in a purity level of 19/18/16. Fill in the particle sizes of the classification and the maximal count of particles in 1 ml oil for each class. Consider the following excerpt from the standard .(2 points; 1 point per correct column)

Ordinal number	Particle size	Particle count
19		
18		
16		

Particle-count per ml		Ordinal-number
from	to	
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

Level of purity according to ISO 4406:1999

1.7 In order to improve the purity level, filters are installed in the hydraulic circuit. Draw the position of three different filters into the following circuit. Name each filter and use the filter symbol. (2 points)



1.8 Derive the hydraulic inductance L_H of a symmetrical cylinder. Hint: $F = m \cdot \ddot{x}$
(3 points)

2. Exercise / 10 Points

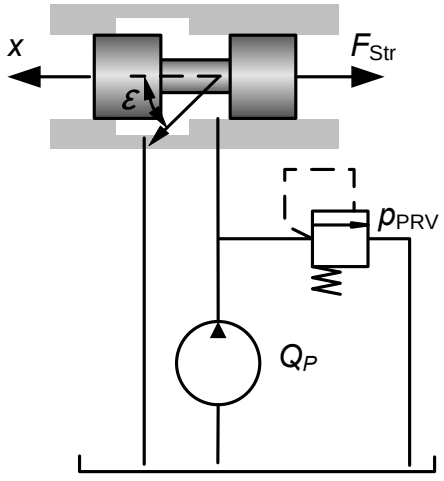
2.1 According to the function of hydraulic valves four types can be distinguished. Name all four types. (2 points)

1. _____
2. _____
3. _____
4. _____

2.2 Name all three types of mechanic-hydraulic converters which can be used to actuate hydraulic valves. (1.5 points)

1. _____
2. _____
3. _____

A simplified test bench for the measurement of a spool valve is given.



Data:		
	volume flow of the pump	$Q_P = 60\ l/min$
	pressure at pressure-relief-valve	$p_{PRV} = 210\ bar$
	density of the hydraulic oil	$\rho_{Oil} = 870\ kg/m^3$
	diameter of the spool	$d = 10\ mm$
	orifice coefficient	$\alpha_D = 0.6$

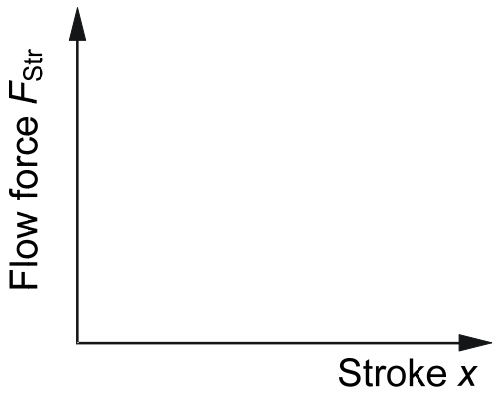
Calculate the opening stroke of the spool at the specified operating point. (1.5 points)
Assumption: pressure-relief-valve is closed

2.3 A flow force F_{Str} = 66.34 N has been measured. Calculate the flow angle ε at the specified operating point. (1.5 points)

Assumption: steady state flow

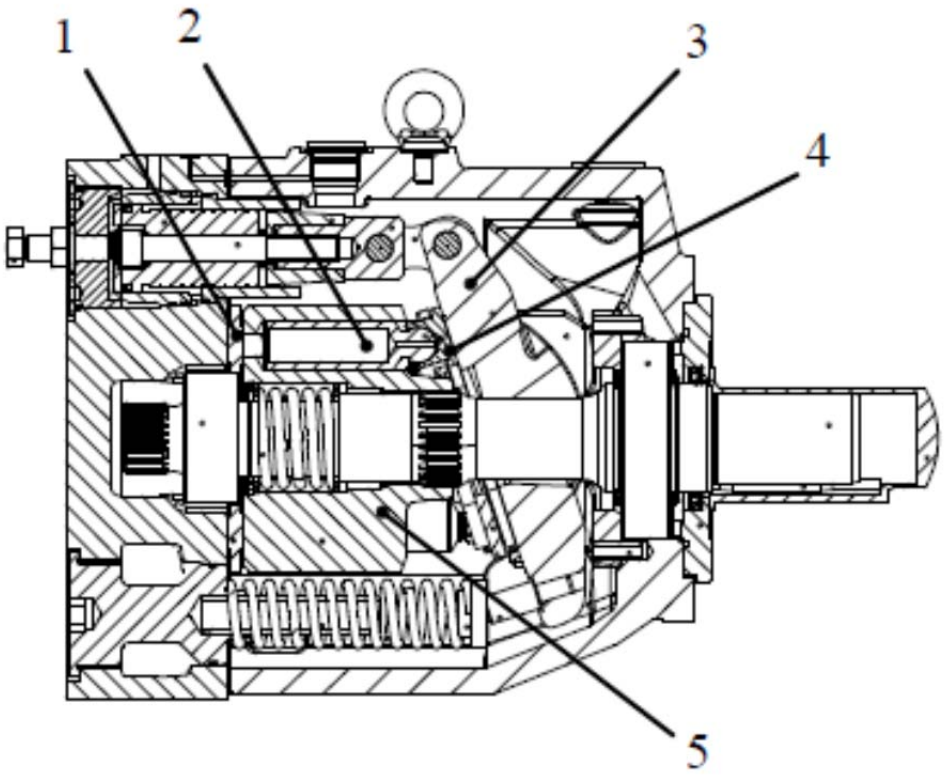
2.4 In which direction does the flow force generally act? (1 point)

2.5 Draw the qualitative course of the flow force in dependency spool's stroke. (1.5 points)



2.6 Show the range where a constant-pressure-system and where a constant-flow-system exists in the diagram. (1 point)

3. Exercise: Pumps and Motors / 10 Points



3.1 In the picture a hydraulic pump is given. Give the exact appellation of this pump design. (0.5 points)

_____

3.2 Name the marked elements 1 - 5. (2.5 points)

1._____

2._____

3._____

4._____

5._____

In the following a bent-axis unit is given with 9 pistons, a piston area of 2 cm^2 and a pitch circle D_k of 22.5 mm. The dead volume of one piston is 0.1 cm^3. The unit runs with a rotation speed of 5000 rpm at a pressure difference of 200 bars. The oil has a bulk modulus of 16000 bars and a swash plate angle of 18°.

3.3 Calculate the theoretical displacement volume of the pump. (1 point)

(If you could not solve 3.3, continue with a value of 30 cm^3)

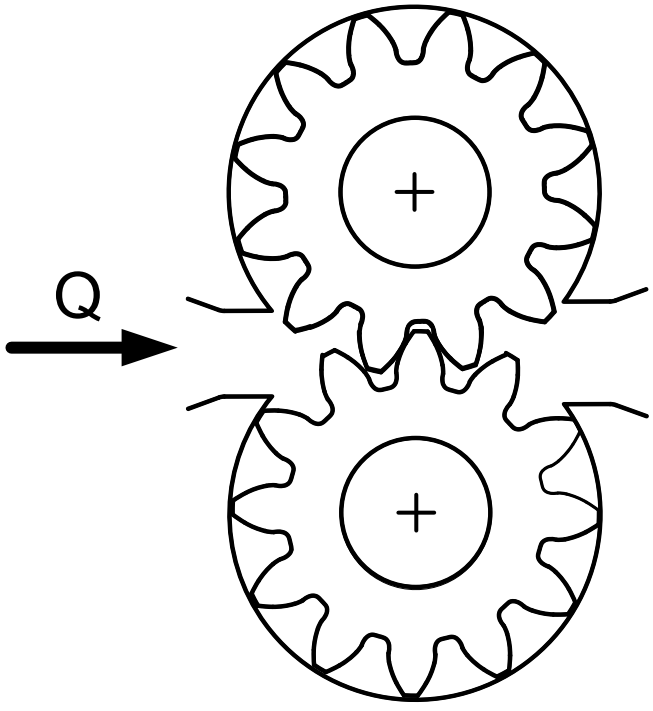
3.4 The valve plate of the pump is poorly designed and the pistons are connected to the high pressure port when in dead center position. How many percent of the theoretical volume flow rate are lost due to back-flowing oil? (2 points)

3.5 How large is approximately the kinematic flow pulsation of the pump? (1 point)

3.6 The unit is now used as a motor. Calculate the maximum power the idealized motor can deliver. Therefore, assume that the energy stored in the compressibility of the oil can completely be recovered. (1 point)

3.7 Is it possible that a real motor (see data given above) with an ideal valve plate design can deliver this power? Justify your answer shortly. (1 point)

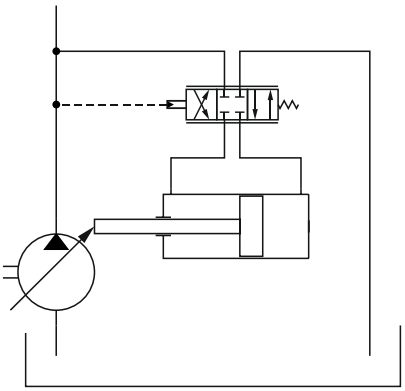
3.8 In the picture below, a motor is given. Draw in the direction of rotation and sketch the pressure profile over the displacement rooms of one gear for the ideal case. (1 point)



4. Exercise / 10 Points

Industrial presses are commonly driven hydraulically.

4.1 Which variable is controlled with the following circuit? How do you call the control? For what purpose is the control used? (1.5 Points)

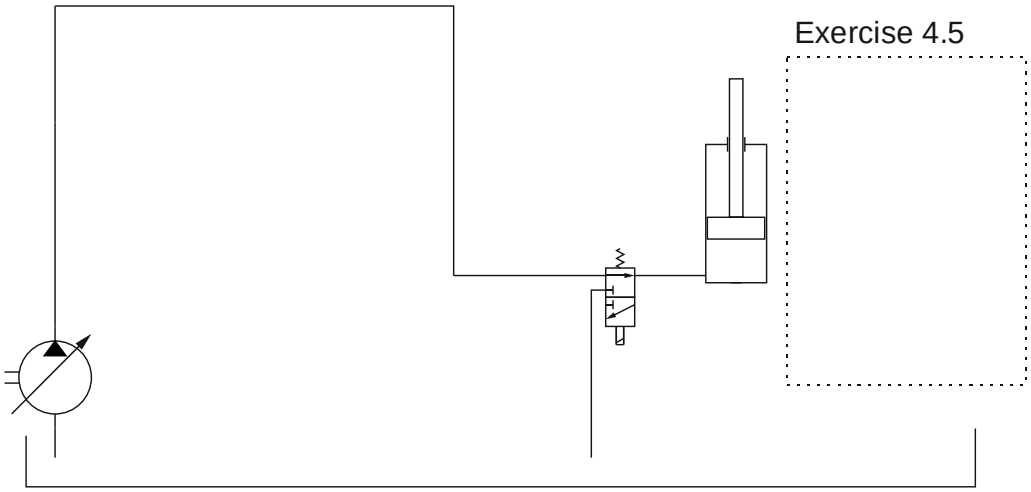


4.2 Why do you need flushing valves? Are they used in open or closed circuits? (1 Point)

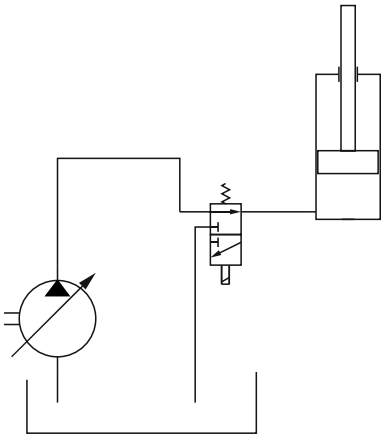
4.3 The velocity of the press cylinder shall be controlled during press process. Change the following circuit, so that the pump is volume flow controlled. (2 Points)

4.4 There are components necessary for a safe operation. Draw the component which is necessary to prevent overload. (0.5 Points)

4.5 A second press cylinder shall be driven by the same pump, when the first cylinder is not in operation. Draw the second, identical cylinder in the given field, and connect it to the circuit in a way that either the first one or the second one can be operated. Components may be integrated in the existing circuit. (1 Point)



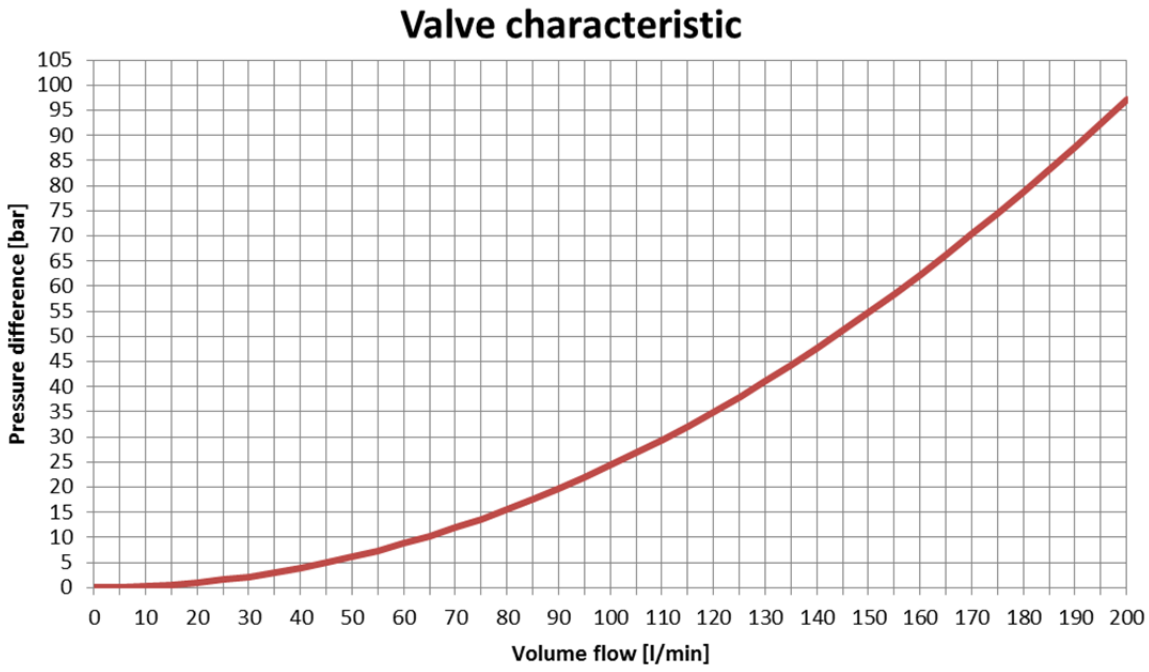
In the following, the circuit below is used.



4.6 Which power is needed for driving the pump, to enable the cylinder velocity at the stated cylinder pressure ($p_{\text{required, cylinder}}$)? State the procedure of estimating the input and output value for the valve calculation. (2 Points)

Given: $v_{\text{cylinder}} = 1$ m/s $p_{required,\ cylinder} = 160$ bar $A_{\text{cylinder}} = 2000$ mm²

$n_{\text{vol, Pump}} = 0.9$ $n_{\text{hm, Pump}} = 0.95$ $F_{Fritction,\ cylnder} = 1$ kN

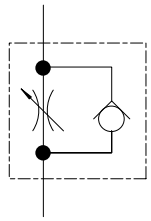
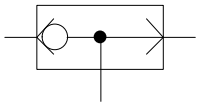
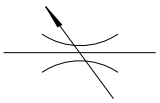
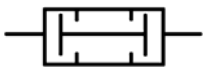


4.7 Calculate the efficiency of the cylinder considering the cylinder friction. (1 Point)

4.8 How does the volumetric efficiency change for a motor and a pump, when considering compression? Explain! (1 Point)

5. Exercise / 15 Points

5.1 Your task is to realize a pneumatic control. The cylinder movement needs to be activated from two signal transmitter at two different locations simultaneous. Which of the following elements do you use? Name the element. /1P

5.2 Name a benefit and a disadvantage each for the use of air instead of oil in technical practices in matters of the mentioned characteristics. /2P

	Benefit ☺	Disadvantage ☹
high compressibility		
low viscosity		

5.3 In a pneumatic system works a double acting cylinder. The piston moves only between the two end positions. The approach of intermediate positions is not required and should be preempted by the chosen valve. The task must be fulfilled with a single valve. Chose two appropriate valve types? /1P

2/2-way valve	3/2-way valve	5/2-way valve	4/2-way valve	4/3-way valve

5.4 Pneumatic switching valves can be activated by direct current (DC) or alternating current (AC) solenoids. Each of these has individual benefits and disadvantages. Name a benefit and disadvantage for each type. /2P

DC solenoids:

benefit	disadvantage

AC solenoids:

benefit	disadvantage

5.5 In your application the high acceleration at the start of the cylinder movement is critical for your goods. Which type of flow control do you use to minimize the load on the goods? Evaluate your answer briefly. /1P

Supply Air Flow Control	Exhaust Air Flow Control

_____

_____

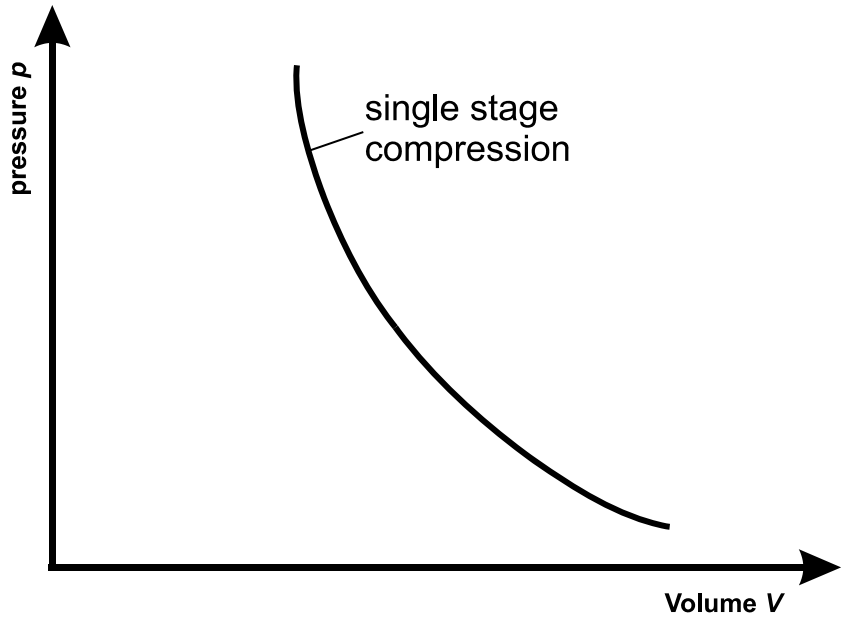
For the following exercise these characteristics and hints are given:

- All pressures are given as absolute pressures and need to be shown as such
- Pressure ratio $\varepsilon_1 = 2.5$
- Ambient pressure $p_u = 1$ bar
- Ambient temperature $T_u = 20$ °C
- Maximum permissible temperature $T_{max} = 120$ °C
- Temperature drop by cooling $\Delta T = -90$ K
- Gas constant $R = 287$ Nm/kg K
- Polytropic exponent $n = 1.4$
- Volumeflow of the compressor $Q_N = 1000$ Nl/min

5.6 Your task is to construct the second compressor stage of a two stage compressor with intermediate cooling. The pressure ratio of the second stage has to be chosen so that the maximum permissible temperature T_{max} is not exceeded. The air is sucked in from the environment and is compressed in the first compressor stage with a pressure ratio ε_1. The cooler in between the stages reduces the temperature by ΔT. Determine the highest allowable pressure ratio ε_2 of the second compressor stage and the achievable outlet pressure of the compressor. /3P

5.7 How much power is required for the compression process of the first compressor stage? Use the information from task 5.6 /2P

5.8 The following image shows the process of a single stage compression. Add the process of a second stage compression with intermediate cooling. Denote the saved energy in comparison to the single stage compression. /2P



5.9 How would the ideal process look like? Add the ideal process to the image above. Mark the ideal process and name the change of state. /1P

6. Exercise / 10 Points

Figure 6.1 shows an automatic loading process. A box is placed on scales during the loading. The weight of the box is measured by the spring stroke. When the final weight is reached, the hatch closes and the box is pushed onto the conveyor belt and is carried away. By placing a new box on the scales, the process will restart. An emergency switch guarantees a safe stop of the loading process in a case of an emergency.

The process shall be realized using only pneumatic components. The depicted valves in the scheme shall be connected reasonably. If necessary, further pneumatic components can be added.

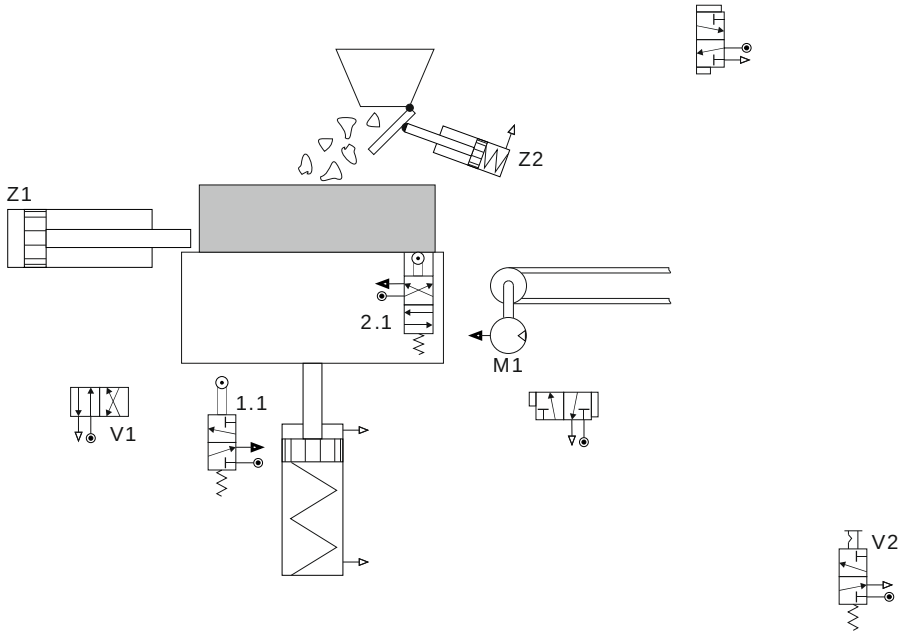


Figure 6.1: Scheme of an automatic loading

Hints:

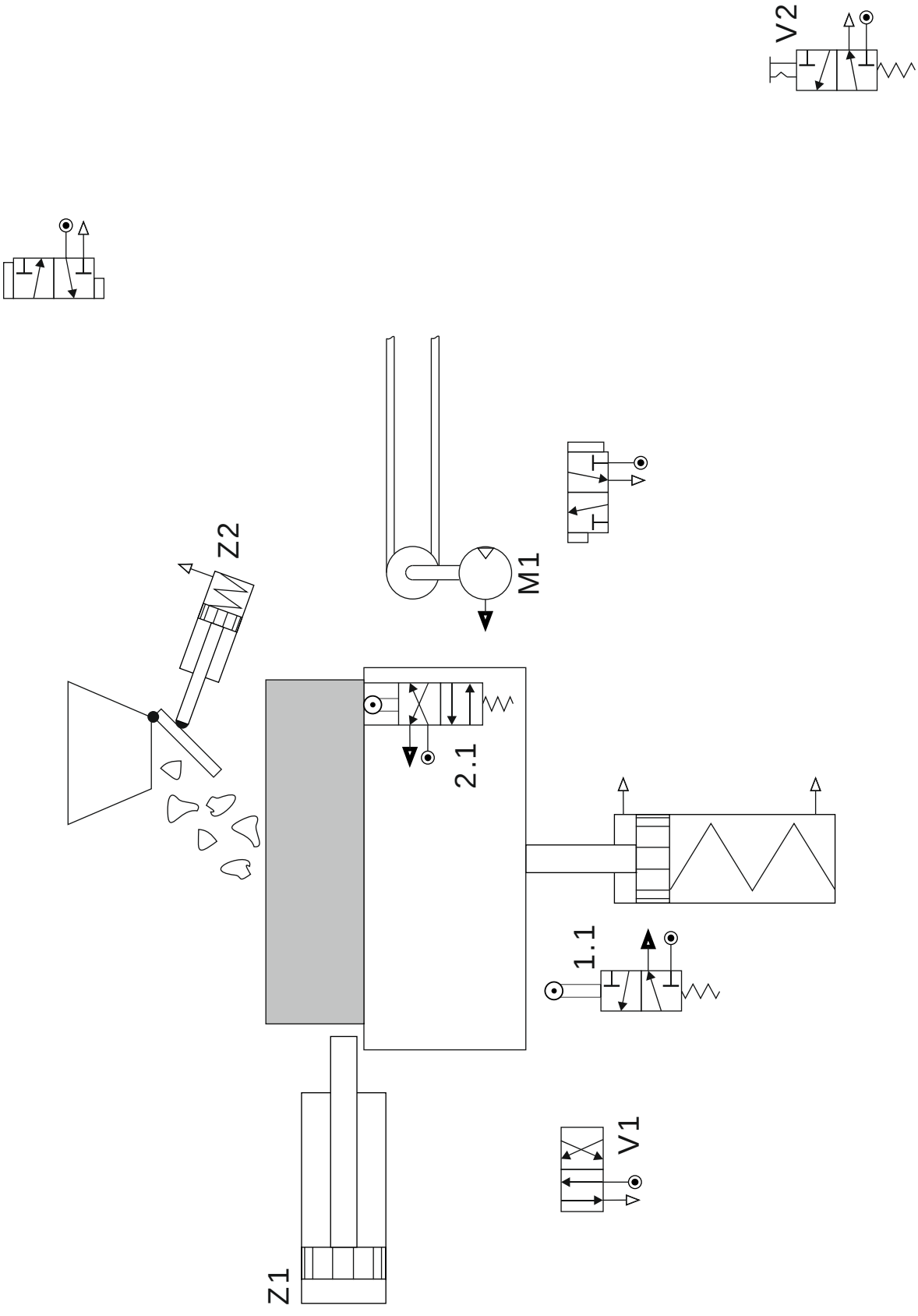
a) All push buttons, valves and cylinders in Figure **6.1** are shown in the state of loading.

b) Pulse valves with identical actuation area rest in their actual position, if pressurized bilateral.

c) All pressure sources have the same supply pressure. Consider the given actuation area differences of some valves.

d) Insert your solution on the answer sheet at the next page of the exercise.
<u>Don't</u> use Figure 6.1 !

Answer sheet A6.1-5:



Please realize the following operations and requirements in the pneumatic diagram:

6.1 When the box on the scales reaches the final weight, the hatch shall close with the help of cylinder Z2 and the conveyor belt M1 shall start moving. The spring force of cylinder Z2 is strong enough to close the hatch. (2 Points)

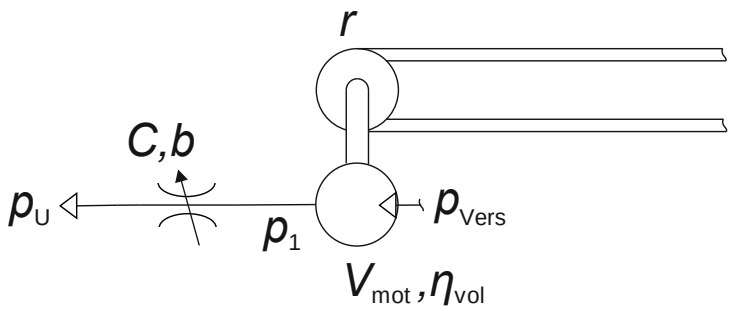
6.2 Simultaneously with the operation in 6.1, cylinder Z1 shall push the box onto the conveyor belt with a constant, load independent velocity. (1.5 Points)

6.3 As soon as the box has left the scales, cylinder Z1 shall retract quickly. By placing a new box on the scales, cylinder Z2 opens the hatch again. (1 Point)

6.4 When the pressure in cylinder Z2 has reached a defined pressure level during the hatch opening, the conveyor belt M1 will stop. (1 Point)

6.5 The activation of the emergency button V2 stops the conveyor belt M1 and closes the hatch Z2. Ensure that this operation is always performable and has a higher priority compared to contradicting operations. (2 Points)

In the future, the conveyor belt shall move with constant, load independent velocity. Therefore, you add a throttle at the motor exhaust connection. You know the following data V_{mot}, η_{vol} and r of the motor. The manufacturer provides you with the data C und b of the throttle.



Gegeben: $V_{mot} = 4$ l/U $\eta_{vol} = 75$ % $r = 0.2$ m

$p_{Vers} = 6$ bar$_{abs}$ $p_U = 1$ bar$_{abs}$ $T_0 = 293.15$ K

$R_0 = 288$ Nm/kgK $C = 2.17$ Nl/sbar $b = 0{,}45$

Hints: The System is isothermal. All pipe volumes and mass inertias can be neglected. All given pressures are absolute values and shall be given as absolute values by you.

6.6 At which pressure p_1 does the belt start to move with a constant velocity? (0.5 Points)

6.7 Is it possible to guarantee a conveyor belt velocity of at least 0.5 m/s under regard of an exhaust air pressure of $p_1 = 3$ bar and the given throttle data? Justify your Answer! (2 Points)