RWTH AACHEN UNIVERSITY

IFAS Institut für fluidtechnische Antriebe und Steuerungen

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Written Examination "Fundamentals of Fluid Powers"

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Exercise 1 / 15 Points

1.1 Name two benefits and two disadvantages of hydraulic drives and controls compared to mechanic or electric ones. Pay regard that all arguments differ from each other. (2 Points)

Benefits ☺	Disadvantages ☹

1.2 To which liquid group does HETG 32 belong? What does the number “32” stand for in the appellation? (2 Points)

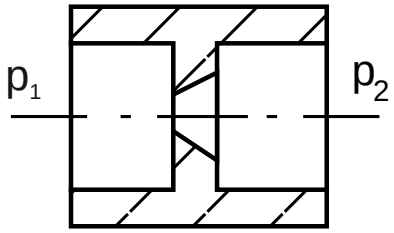
_____

_____

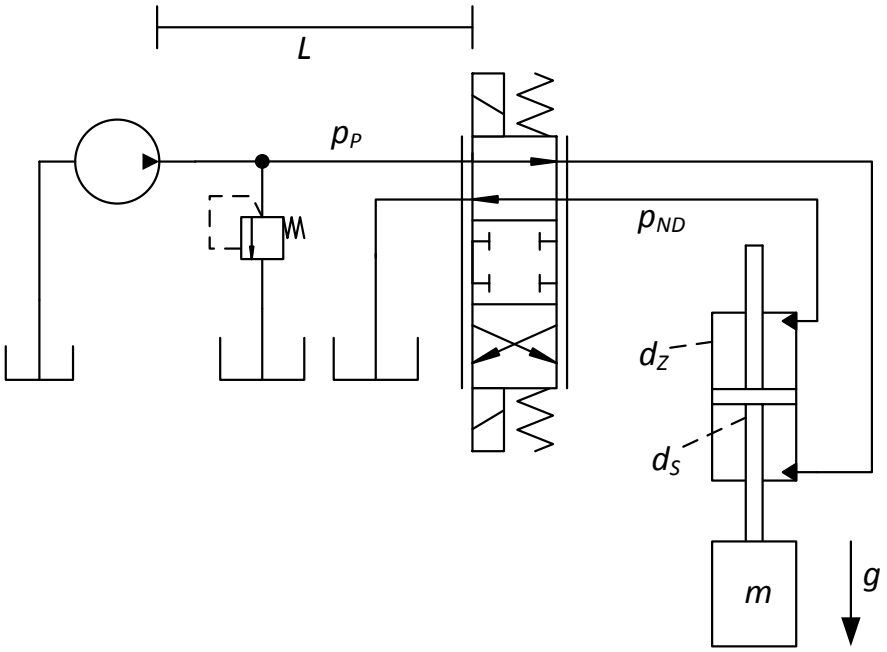
_____

1.3 A hydraulic cylinder shall achieve a force of 20 kN at a velocity of 1 m/s. Calculate the required operating pressure in bar for a flow rate of 30 l/min neglecting all losses. (1.5 Points)

1.4 Name the pictured hydraulic resistance and declare the corresponding flow law. (2 Points)



Given is the circuit of a hydrostatic linear actuator:



Given:	Diameter Piston Rod	d_{PR} = 25 mm
	Diameter Cylinder	d_C = 35 mm
	Gravitational acceleration	g = 9,81 m/s²
	Pressure of the Pump	p_P = 210 bar
	Pressure of the Return Pipe	P_{LP} = 5 bar

1.5 Calculate the mass m which can be lifted by the cylinder in the given operating point neglecting all losses. The valve is in the pictured position. Use SI-units in the solution. (2.5 Points)

1.6 The pipe L between the pump and the valve has a length of 6.7 m. What is the critical closing time t_{crit}? The mineral oil has an effective bulk modulus of 16 000 bar and a density of 890 kg/m³. Neglect all further pipes that lie between pump and valve. (2 Points)

1.7 The closing time t_{close} of the used valve is 18 ms. The oil flows through the pipe with a velocity v of 8 m/s. How big will the pressure surge be that strikes the valve? (3 Points)

(If you were not able to answer exercise1.6, calculate with a critical closing time t_{crit} of 12 ms and a sonic velocity of 1500 m/s.)

Exercise 2 / 10 Points

2.1 Draw the hydraulic symbol of a hand-operated spring returned 3/2-port proportional valve with all details (Switch position A: P is connected to A and T is closed; Switch position B: A is connected to T and P is closed). (1.5 Points)

2.2 Describe the functions of a pressure relief and a pressure reducing valve clearly. (1 Point)

_____

_____

_____

_____

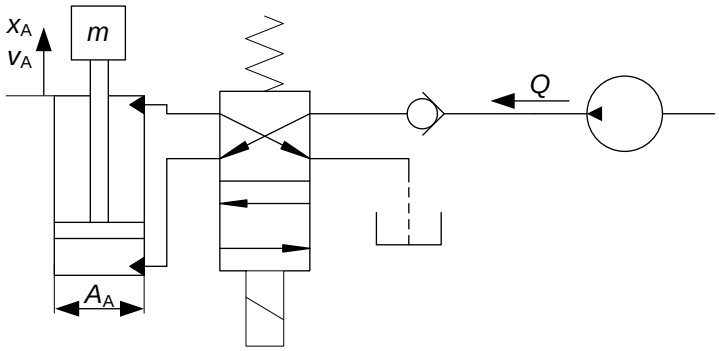
2.3 State two reasons that can lead to a breakdown of valves and recommend a different counteraction for each. (1 Point)

1. _____
   _____
2. _____
   _____

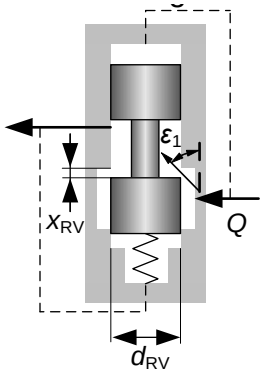
2.4 Enumerate three forces that can counteract the actuation of a control spool and indicate the conditional equation for each force. (1.5 Points)

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

A circuit of a freight elevator (A) is pictured below in extracts. You need to construct the check valve (RV) for the system. The 2/2-port valve pictured on the right hand side shall be used, which you still have in store.



Check valve



Given:	General	Hyd. output Pump	$P_h = 12$ kW
		Oil density	$\rho = 890$ kg/m^3
	Freight elevator	Velocity	$v_A = 0.1$ m/s
		Piston area	$A_A = 0.01$ m^2
	Check valve	Diameter	$d_{RV} = 10$ mm
		Max. stroke	$x_{RV,\,max} = 2$ mm
		Orifice coefficient	$\alpha_D = 0{,}6$
		Spring stiffness	$c_F = 2$ N/mm
		Inflow angle	$\epsilon_1 = 60°$

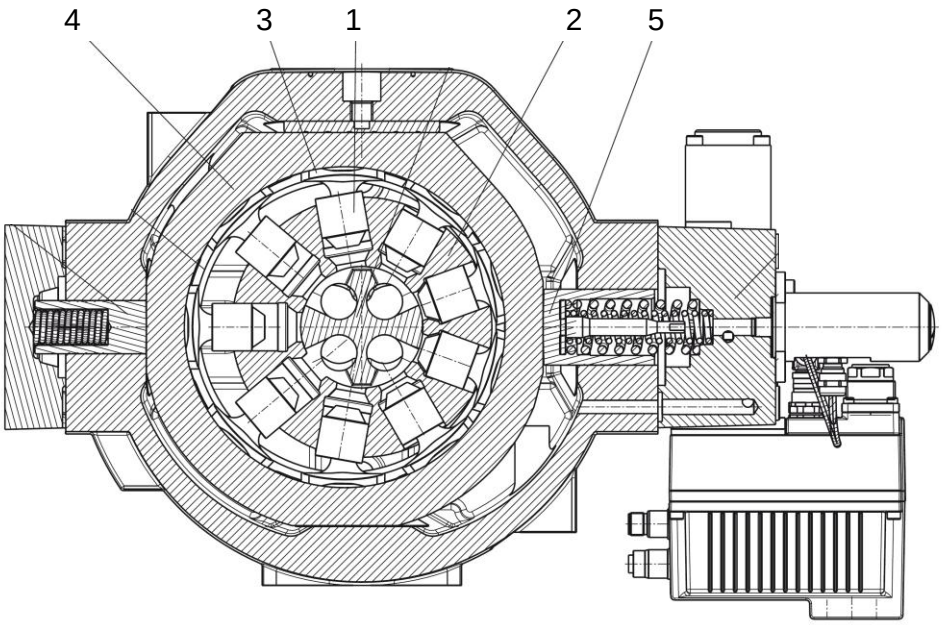
2.5 Check if the power loss of the check valve lies under 3 % of the pump's hydraulic output when it is fully opened. (2 Points)

2.6 How far do you need to pre-tension the spring for the valve to opens at a pressure difference of 1 bar? (0.5 Points)

2.7 Check if the valve fully opens under the described circumstances. Take into consideration the flow force. Friction can be neglected. (2.5 Points)

(If you did not calculate the spring's pre-tension, use a pre-tension of 4 mm.)

Exercise 3 / 10 Points



3.1 In the picture you see a hydraulic pump. Give the complete appellation of this pump configuration. (0.5 Points)

_____

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

1. _____

2. _____

3. _____

4. _____

5. _____

3.3 At piston pumps it is differentiated between kinetically caused and compression caused flow pulsation. Explain briefly both kinds of pulsation. (1 Point)

Kinetic Pulsation: _____

_____

Compression Pulsation: _____

_____

In the following a double-stroke vane pump is given. The 6 vanes have a width of 4 mm, a depth of 40 mm and a length – measured from the rotor – 1 mm to 7 mm over the stroke. The housing at its smallest point has a diameter of 38 mm.

3.4 Calculate approximately the theoretical displacement volume of the unit. (2 Points)

3.5 Name two possibilities/effects to accomplish sealing between vane and the stroke ring at the unit. (1 Point)

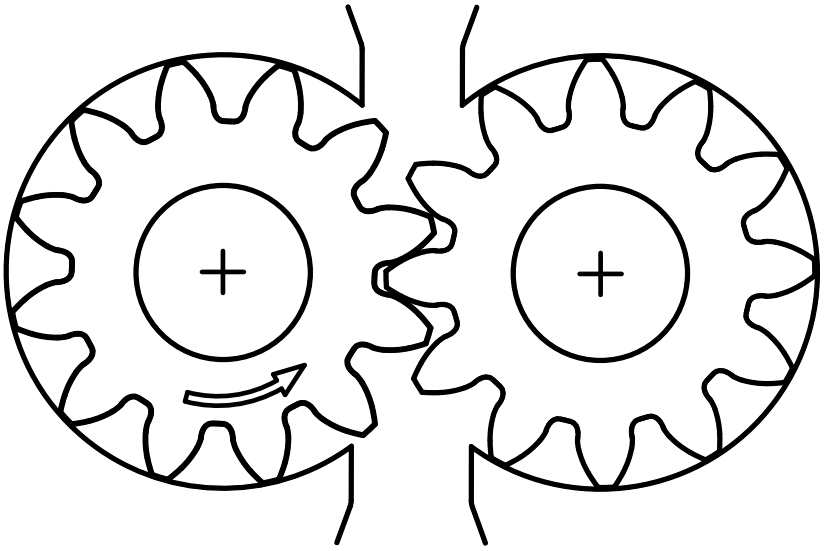
1. _____

2. _____

3.6 The unit should be run with a constant rotational speed. Does it make sense to use this unit in a direct load controlled system? Justify your answer! (1 Point)

3.7 Given is the gear motor pictured in the following. Label the connections of the motor. Draw in additionally on the left hand side the ideal and on the right hand side the real pressure distribution over the single displacement rooms. Mark additionally the point which is mostly endangered for solid-state contact. (2 Points)

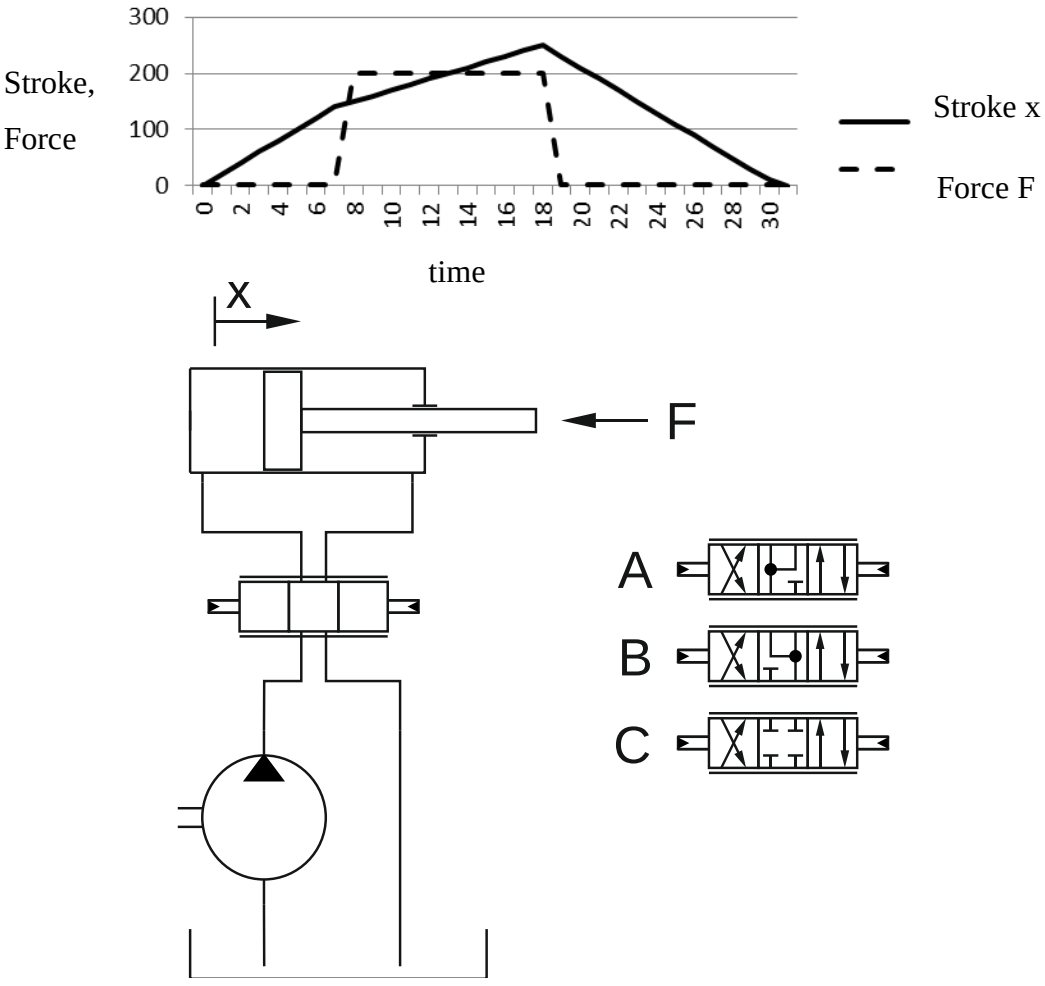
Ideal *Real*



Exercise 4 / 10 Points

4.1 Why are orifices preferred over throttles in controls? (1 Point)

4.2 At the development of an industrial press the following schematic process of force and way/velocity is demanded. Which of the suggested valves (right) is most suitable to match the requirements? Justify your answer and name the benefits of the valve! (1.5 Points)



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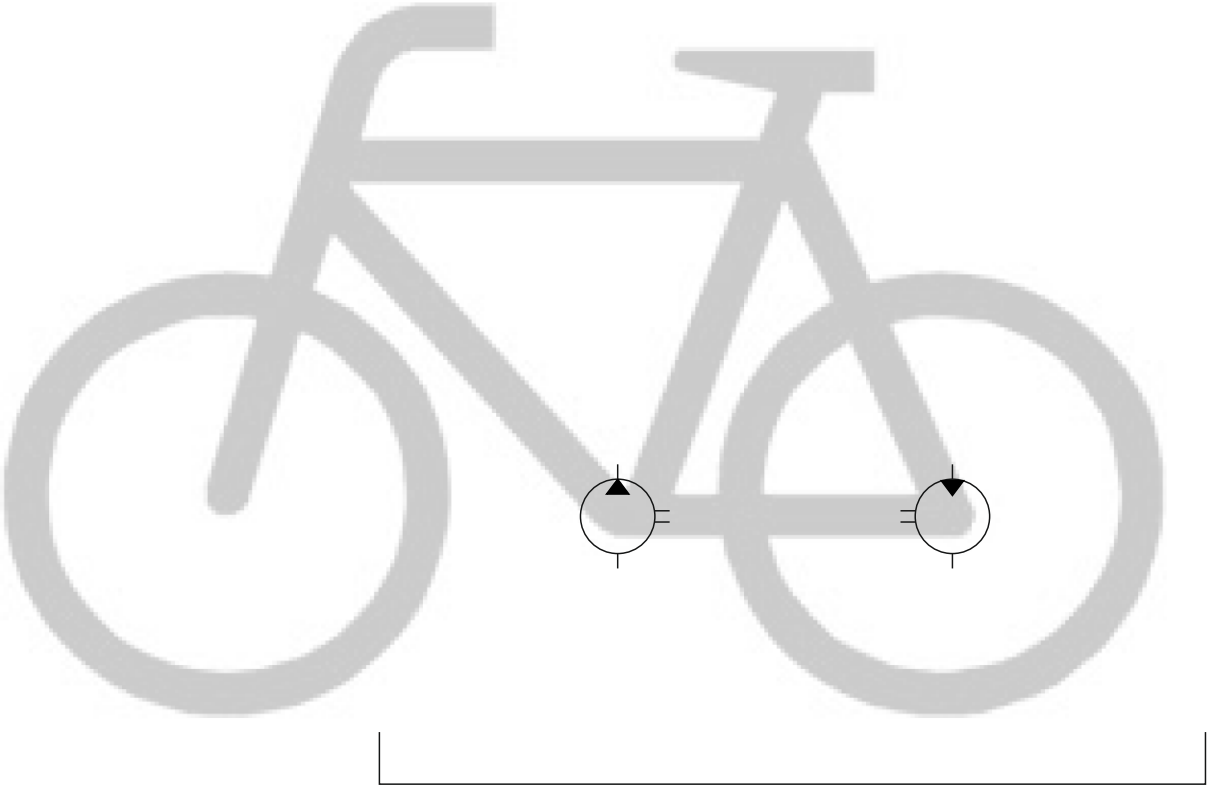
_____

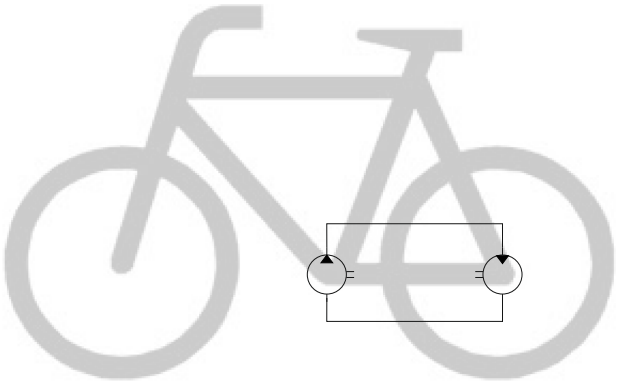
4.3 In the following, a bike should be considered at which a hydrostatic transmission is used for the power transfer. Therefore a pump is installed at the pedals and a hydromotor at the rear wheel (cf.: sketch). An accumulating system should be integrated which absorbs energy during the braking to use it later for driving. Complete the circuit with pipes and further components in a way that it fulfills the following requirements: (3 Points)

a. The translation from the pedal movement to the driving speed should be adjustable.
b. A free-wheel shall be possible (driving without pedal movement).
c. The system for the accumulation of energy shall be displacement-controlled.
d. The driving operation should be independent from the accumulator load.
e. A safe and permanent operation should be possible even in a dusty environment.



The same bike is now considered in a simplified version (cf.: sketch). For the start-up at an inclination the following data is given.

Given:	Rotational speed wheel	$n = 0$ U/min
	Torque at the wheel	$M = 78$ Nm
	Pressure leakage coefficient	$k_p = 0{,}001$ (l/min)/bar
	Rotational speed - leakage coefficient	$k_n = 0{,}001$ (l/min)/(U/min)
	Motor leakage	$Q_{Leck,\,Motor} = k_p\, p + k_n\, n$
	Hydro-mechanic efficiency factor motor	$\eta_{hm,\,Motor} = 0.9$
	Volumetric efficiency factor pump	$\eta_{vol,\,Pump} = 0.9$
	Hydro-mechanic efficiency factor pump	$\eta_{hm,\,Pump} = 0.9$
	Displacement volume motor	$V_{Motor} = 25\ cm^3$
	Displacement volume pump	$V_{Pump} = 50\ cm^3$



4.4 What is the pedal rotational speed when the bike starts to move? (1.5 Points)

4.5 The same bike now is considered in action. How big is the torque at the wheel at a velocity of 30 km/h (this corresponds to a wheel rotational speed of 104 rpm) if the pedal is actuated with 40 Nm. What is the power provided by the driver? (2 Points)

4.6 How do the efficiency factors (volumetric and hydro-mechanic) change at strongly decreasing temperatures? Explain your answer! (1 Point)

Exercise 5 / 15 Points

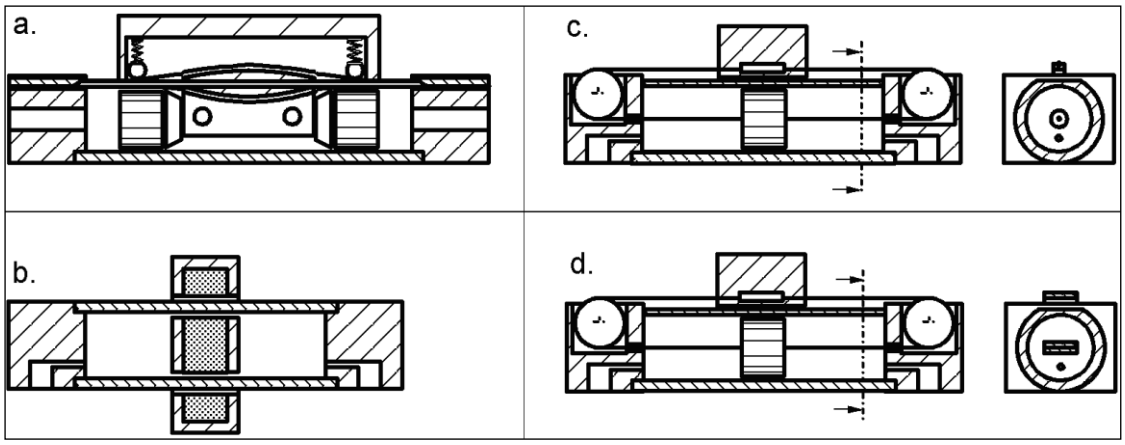
5.1 In pneumatic constructions so called service units are used. Of which three components do these consist? (1,5 Points)

_____

_____

_____

5.2 Double acting cylinders without a piston rod can be divided into different designs. Name the different designs for the pictured cylinders. (2 Points)



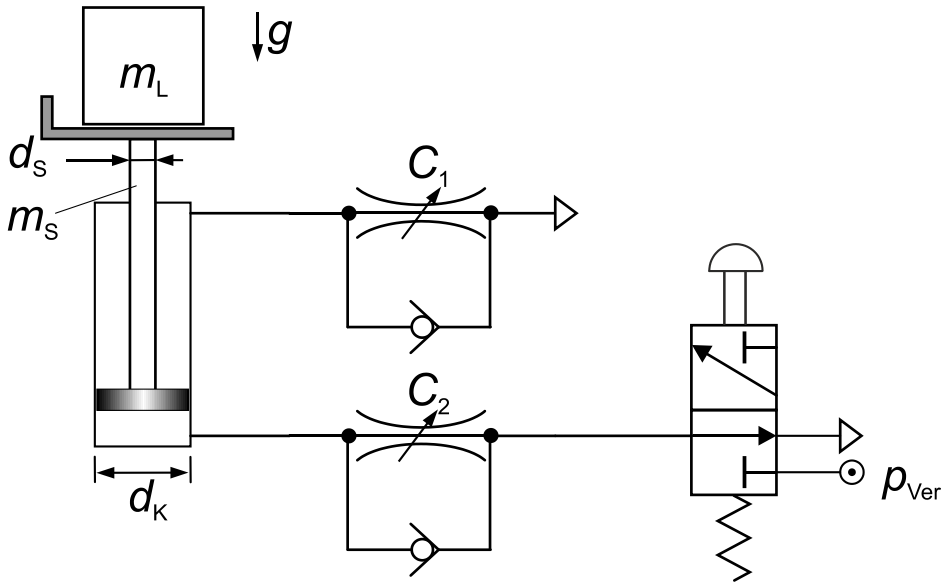
a: _____ c: _____

b: _____ d: _____

5.3 Name a benefit and a disadvantage each for the use of air instead of oil in technical practices in matters of the mentioned characteristics. (3 Points)

	Benefit ☺	Disadvantage ☹
Maintenance of the Pressure Medium		
Low Viscosity		
Low Operating Pressure		

In a production hall boxes are loaded onto a pneumatic elevating mechanism corresponding to the following circuit diagram. As soon as a box with the mass m_L stands on the platform the stroke process is provoked manually and the box is lifted a stroke h. The retraction of the platform is realized by the dead weight of the platform m_S.



Gegeben:	d_K = 90 mm	d_S = 25 mm	b = 0,528
	p_{Ver} = 6 bar_{abs}	p_U = 1 bar_{abs}	Stroke h = 1000 mm
	m_L = 150 kg	m_S = 20 kg	$R_{N2} = 296{,}8 \frac{J}{kg\,K}$
	T = 293,15 K	$g = 9{,}81 \frac{m}{s^2}$	

Advice: The system is isothermal and frictionless. Pipe volumes can be neglected. Mass inertia shall be neglected. All pressures are indicated and need to be indicated as absolute pressures.

5.4 Calculate the pressure that occurs through extension of the cylinder at the rod-sided chamber. Does a load-independent velocity for small changes in load mass occur? Justify your answer! (2,5 Points)

5.5 The cylinder needs to retract by its dead weight m_S (without load) in t = 5 s to stick to the predetermined tact time. Calculate the sonic conductance C_2 in Nl/(s bar). Neglect the accelerating phase (3 Points)

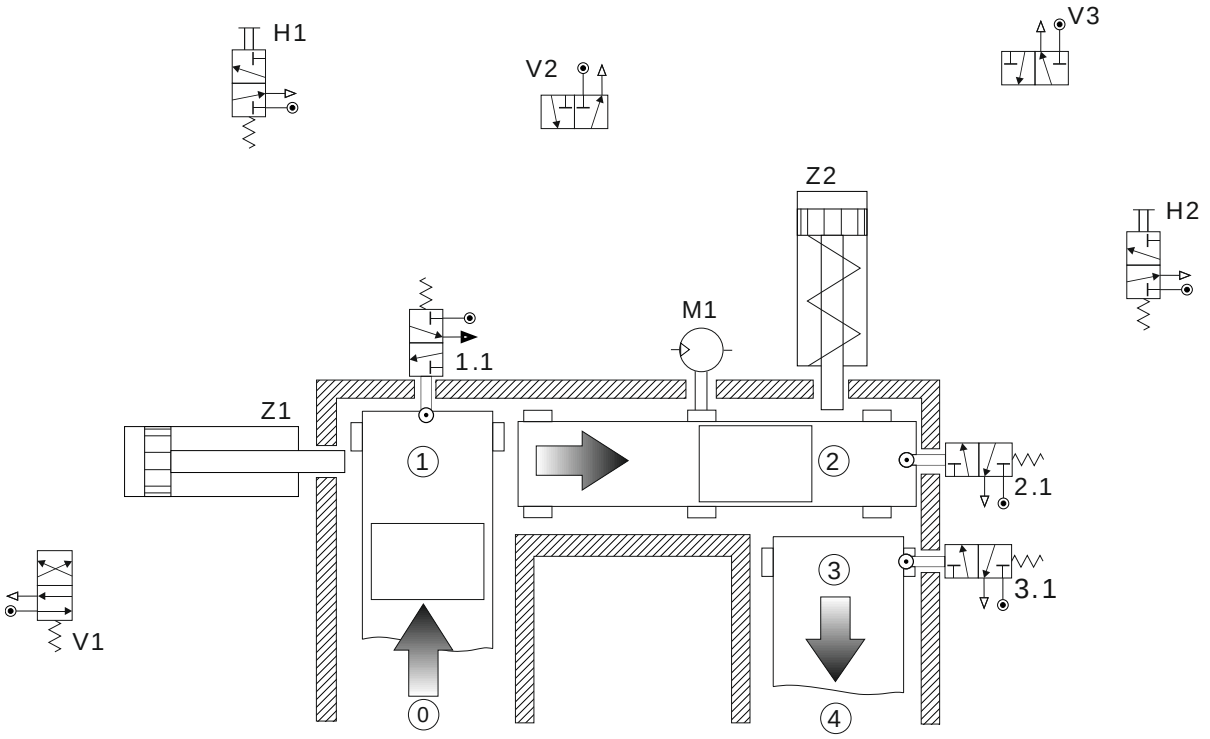
To keep up the operation in case of emergency it is possible to actuate the drive alternatively by a nitrogen bottle with a pressure reducing regulator, so it yields $p_{Ver,\,air} = p_{Ver,\,N2} = p_{Ver}$.

5.6 How does the extension velocity change qualitatively? Justify you answer **briefly**! (1 Point)

5.7 Until which pressure does a nitrogen bottle with a volume of $V_{N2} = 20\,l$ need to be filled to perform 20 stroke processes safely? (2 Points)

6th Exercise / 10 Points

A partly automized picking process of a mail order company for the processing of orders is pictured in the sketch at the bottom. Empty boxes are lead to a loading station (1) by a conveyor belt (0). After the boxes are loaded with goods a worker actuates manual actuation H1. A cylinder shifts the box onto a further conveyor belt which transports the box to the next workspace (2). Here another manual loading takes place. Once this is completed the local operator actuates switch H2 whereupon a cylinder Z2 shifts the box in position (3). The box leaves the sketched process part throughout a third conveyor belt (4).



Consider the following advices:

a. All push-buttons, valves and cylinders are pictured in the construction sketch in an unactuated state.
b. Bilateral pressure-operated pulse valves remain in their particular switching position.
c. The return springs of the valves are not able to move the boxes.
d. The strokes of the cylinders as well as the measurements of the boxes are chosen in a way that a box can only actuate one push-down button at maximum at any moment.
e. Fill in your answers <u>in the answer sheet</u> after the assignment of tasks! Further answer sheets are available from the supervisor as required.

The process shall be realized with an absolute pneumatic circuit. The valves pictured in the sketch shall therefore be connected wisely and if necessary completed by required components. Act according to the following processes and requirements:

6.1 When the box reaches workspace (1) and the operator confirms the end of the loading process with the hand switch H1 the cylinder Z1 shall move out with the help of valve V1. As soon as the box leaves the workspace (1) the cylinder Z1 shall move in again. (2 Points)

6.2 The extending movement of cylinder Z1 shall occur damped to avoid a damage of the goods. (1,5 Points)

6.3 When the box is positioned at workspace (1) the second conveyor belt shall start to transport the box to workspace (2). Make sure it is only conveyed as long as workspace (2) is free. (1.5 Points)

6.4 A delay that begins with the actuation of the push-down of button 2.1 shall be added to avoid an early actuation of hand switch H2. Just at the end of the delay and the actuation of the hand switch H2, cylinder Z2 can move out. Integrate valve V3 into the timing chain. (3,5 Points)

6.5 As soon as the box reaches position (3) the cylinder Z2 is moved in. To reduce the tact time, this process shall elapse as fast as possible. Provide an adequate measure. (1,5 Points)

Lösung: