RWTH AACHEN UNIVERSITY

IFAS Institut für fluidtechnische Antriebe und Steuerungen

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Written Examination „Fundamentals of Fluid Power“

August, 21st 2014

1. Exercise / 15 Points

1.1 Name one advantage and one disadvantage of hydraulic drives and controls. (1 point; 0.5/correct answer)

Advantage ☺	Disadvantage ☹

1.2 Name the primary and two secondary tasks of the hydraulic fluid in a hydraulic circuit. (1.5 points)

Primary: ____

Secondary: ____

Secondary: ____

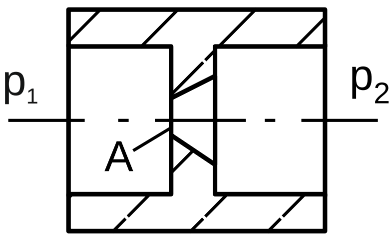
1.3 Name three different groups of hydraulic fluids. (1.5 Points)

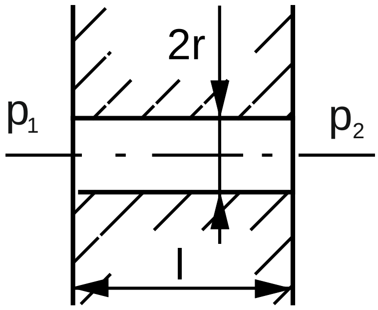
1. ____

2. ____

3. ____

1.4 Two hydraulic resistors are shown below. Name both resistors. (0.5 Points)





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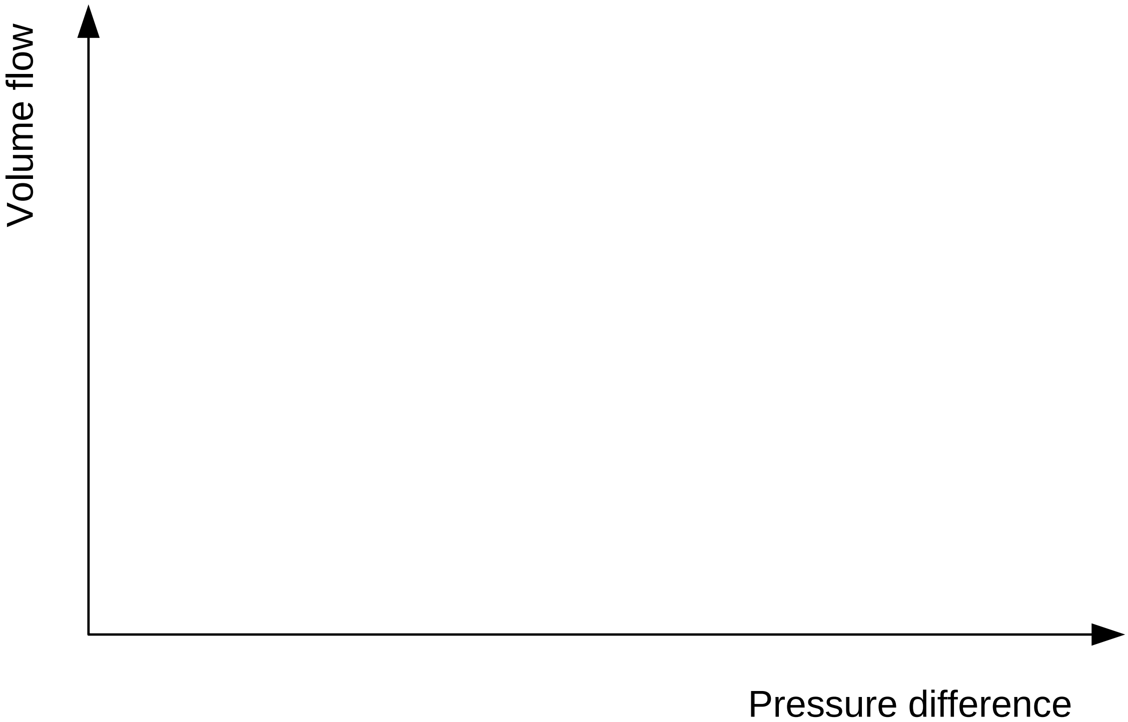
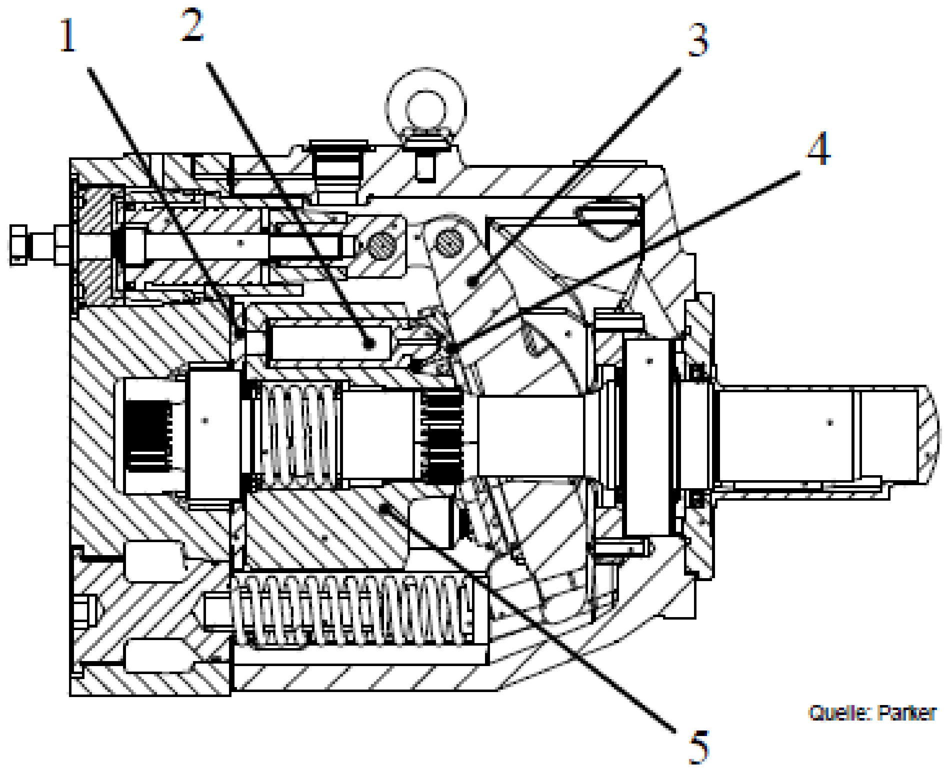
1.5 Plot the characteristic curve of both resistors into the graph shown below. Mark the curves clearly and state the corresponding flow law for each resistor. (2 Points)





1.6 A hydraulic pump is shown above. Please specify the pump exactly. (1 Point)

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1.7 Name the marked components 1 – 5. (2.5 Points)

1) ______________________________

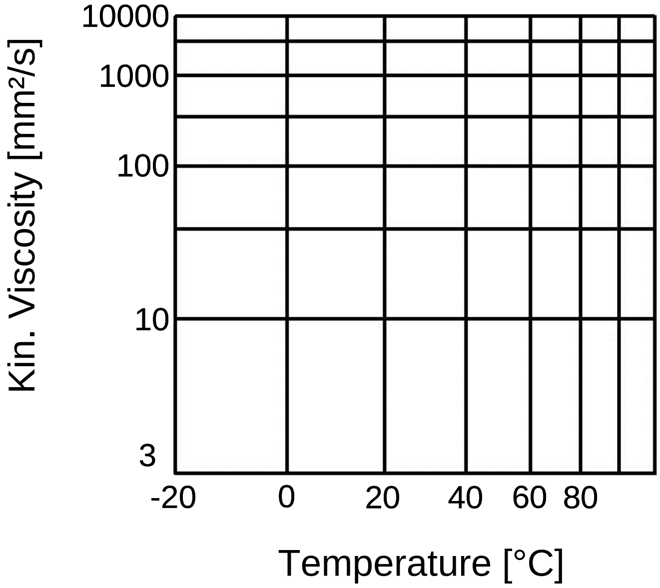
2) ______________________________

3) ______________________________

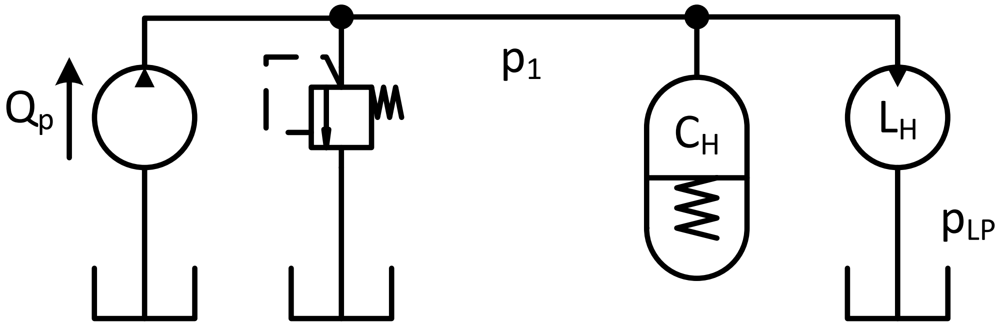
4) ______________________________

5) ______________________________

1.8 Plot the trend of the kinematic viscosity of HLP46 and HVLP10 qualitatively into the graph shown below. Mark the curves clearly. (1.5 Points)



1.9 The following hydraulic network is given. Compile the differential equation for the pressure p_1. A constant volume flow is provided by the pump and the pressure relief valve is closed. (3 Points)



1.10 What is the system's eigen angular frequency ω_0?

2. Exercise / 10 Points

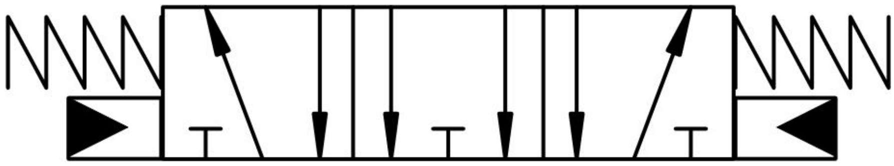
2.1 Name three frequently used electro-mechanical converters (electrical actuators for hydraulic valves). (1.5 Points)

1) ______________________________

2) ______________________________

3) ______________________________

2.2 Specify the complete name of the valve below. (1 Point)



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2.3 According to the shape of the blocking body of hydraulic seat valves three designs (function principles) can be distinguished. Name all three different design types. (1.5 Points)

1) ______________________________

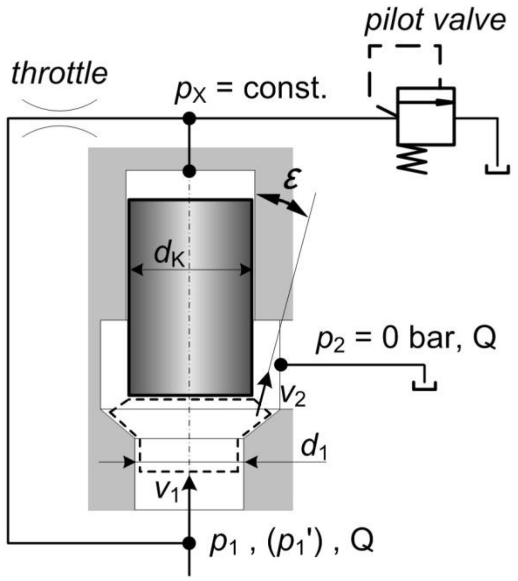
2) ______________________________

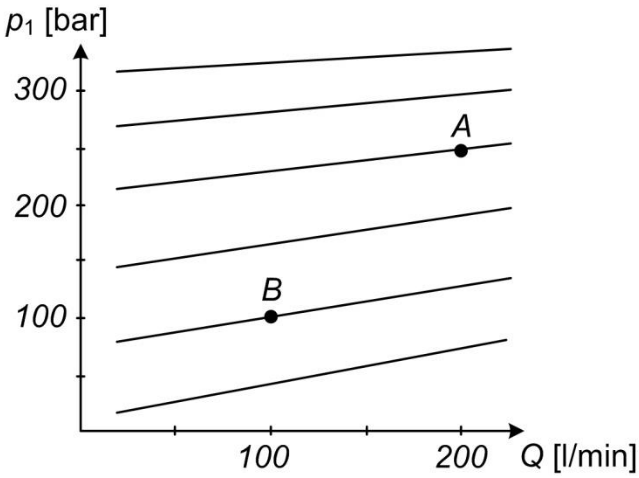
3) ______________________________

2.4 What is the major advantage of seat valves compared to spool valves? (0.5 Points)

In the picture a pilot operated pressure relief valve (PRV) and its characteristic behaviour depending on the pressure p_1 [bar] and the volume flow Q [l/min] is shown. The pilot pressure p_x can be adjusted by the pilot valve. v_1 is the velocity in the inlet and v_2 is the velocity in the smallest gap between the piston and the valve housing. Only pressure forces and flow forces act on the piston of the PRV – other influences are negligible.

Note: The following three exercises can be solved separately!





Data:	diameter of the piston	d_P = 16 mm
	diameter of the upstream	$d_1 \approx d_P$
	density of the hydraulic oil	$\rho_{Oil} = 870\ kg/m^3$
	viscosity of the hydraulic oil	$\nu = 68\ mm^2/s$
	orifice coefficient	$\alpha_D = 0.6$
	flow angle	$\varepsilon = 30°$

2.5 Calculate $\mathbf{v_2}$ in **operating point A** (see characteristic diagram of the valve). Note: Write down each step which is necessary to solve the exercise and specify the final result in the corresponding unit [m/s]. (1.5 points)

2.6 Calculate the flow force $\mathbf{F_{Str}}$ for **operating point B** (see characteristic diagram of the valve) and the dashed control area. Assume that $\mathbf{v_2}$ now is **90 m/s.** Note: Write down each step which is necessary to solve the exercise and specify the final result in the corresponding unit [N]. (2.0 points)

2.7 Calculate the pressure p_1‘ for the **operating point A**. p_1‘ is the pressure which would occur if there was no flow force. You can assume a constant pilot pressure p_x. You can also assume that normally the acting flow force would be $\mathbf{F_{Str} = 338\ N}$ for the operating point A in the event that you wouldn’t neglect it. Note: Write down each step which is necessary to solve the exercise and specify the final result in the corresponding unit [bar] (2.0 points)

3. Exercise / 10 Points

3.1 Name three designs of hydraulic displacement units with continuous displacement. (1.5 Points)

1) ______________________________

2) ______________________________

3) ______________________________

3.2 Pumps exhibit the phenomenon of flow ripple. Name the two types of flow ripple and explain the underlying cause **briefly**. (2 Points)

1) ______________________________

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2) ______________________________

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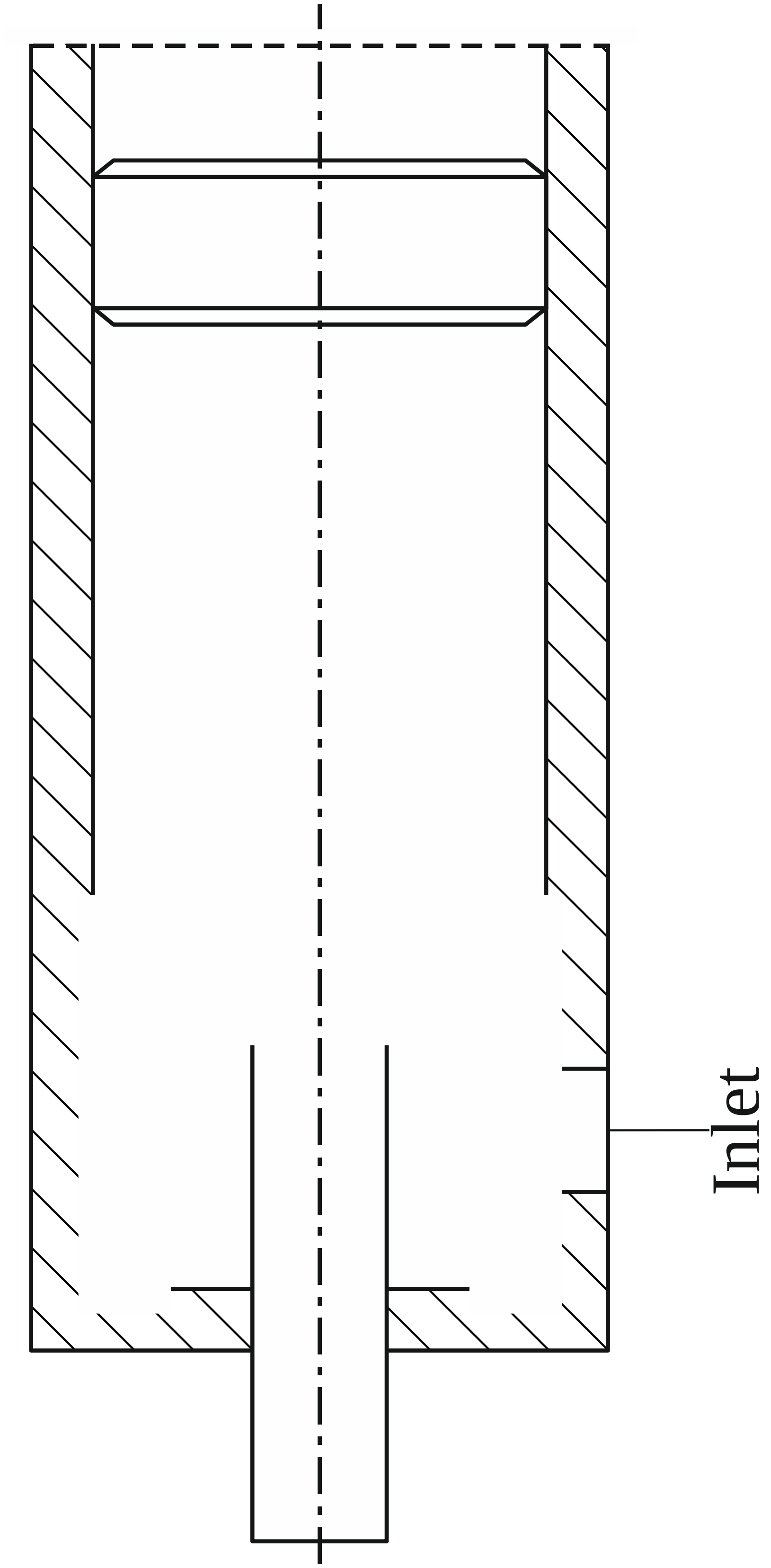
3.3 Complete the sketch of an end of stroke damper for a double acting cylinder. The retraction of the cylinder must remain unaffected. (2 Points)



3.4 Typically a pump has to be protected against pressure overload. Name the one pump which does not require such a safeguard. (0.5 Points)

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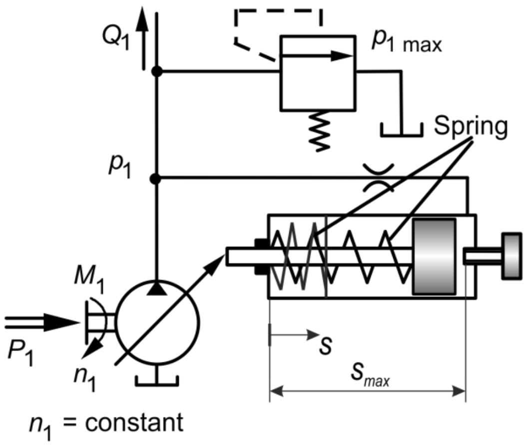
3.5 Summer has finally arrived and you would like to operate a fan with a hydrostatic transmission. In order to turn the fan at the desired angular velocity a flow rate of 84.84 l/min is required. The pump rotates with 2000 rpm. Calculate the necessary displacement volume of the pump. Assume that the volumetric efficiency is negligible. (1 Point)

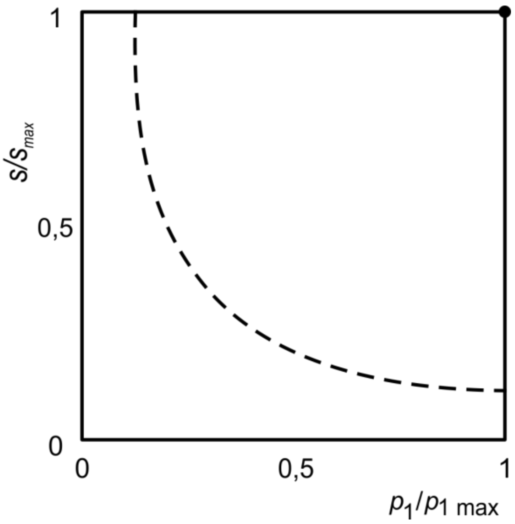
3.6 Since you can and you always wanted to know, calculate the ratio of compression work to usable work for the afore mentioned pump. In order to calculate the ratio, derive the required term first. (3 Points)

Given:	Equivalent bulk modulus	E'_{Fl}= 16.000 bar
	Load pressure of the pump	Δp = 50 bar
	Dead volume of a single piston	V_{tot} = 0.88 cm³
	Spring Stiffness	$c = \frac{dF}{dx}$
	Compression work	$W_K = \frac{c \cdot dx^2}{2}$

4. Exercise / 10 Points

4.1 Name of the hydraulic circuit shown below. (1 point)





Note: The characteristic on the right shows the spring position depending on the pressure.

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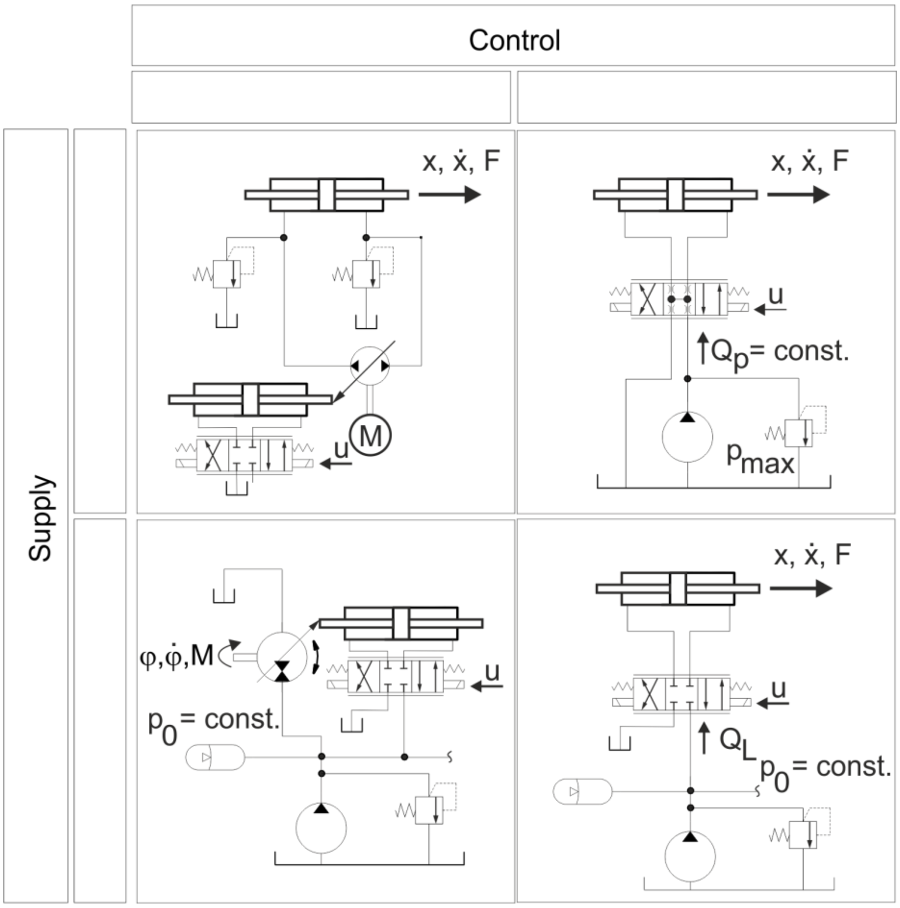
4.2 How does the orifice act? For what purpose is it needed? (1 Point)

Note: The explanation of the orifice formula is **not** asked for here!

4.3 Fill in the boxes with the right controls and supplies! (1 point)

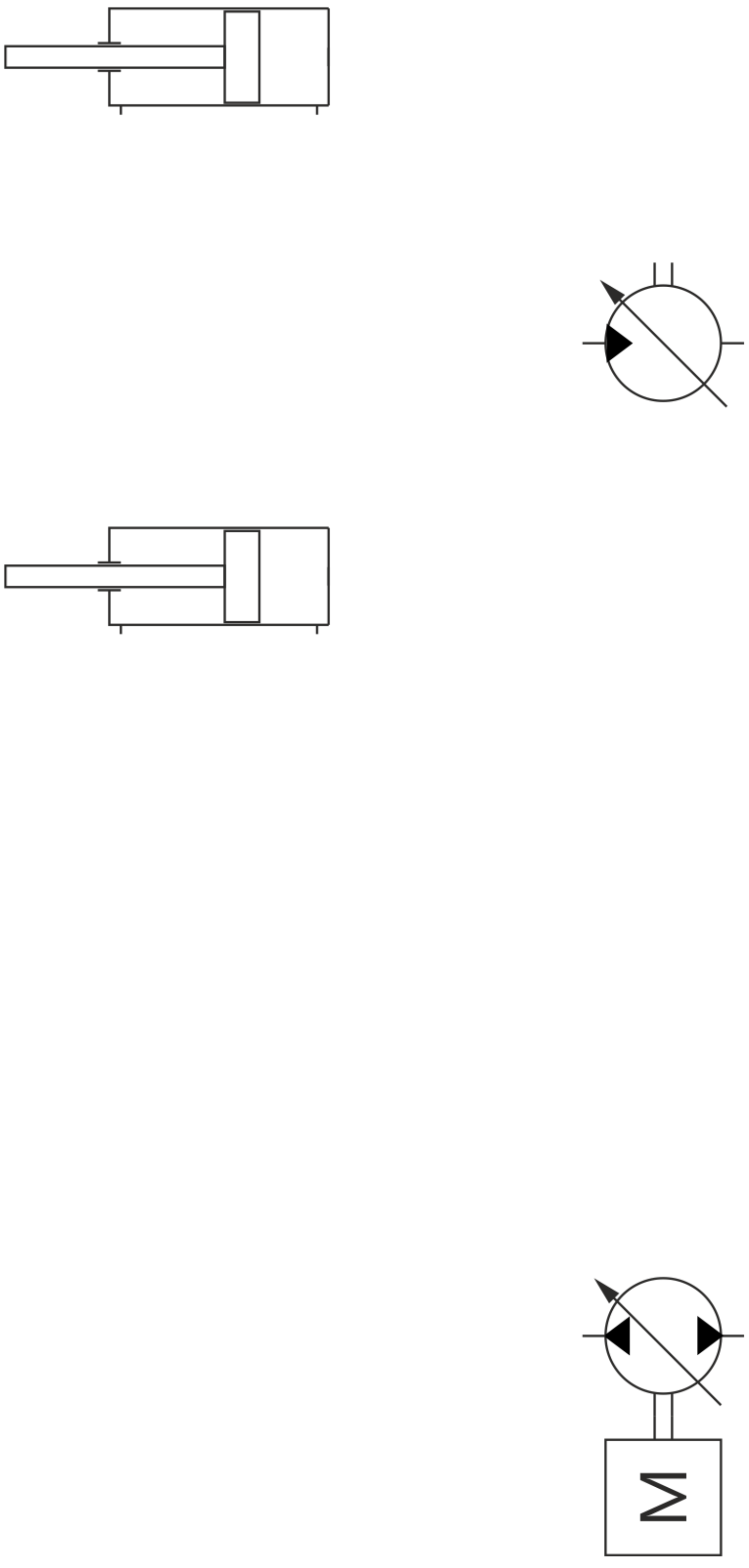


In mobile machinery hydraulics are commonly used. The work hydraulics and the rotational drive of an excavator are examined in the following. As an example two cylinders are considered for the work hydraulics and a motor for the rotational drive. The hydraulic system is driven by a constant pressure system with an open circuit pump.

4.4 Complete the circuit of the work hydraulics and the rotational drive, ensuring the following: (4 points)

1. Both cylinders can be driven independently from each other and from the motor. The cylinders can be controlled smoothly.
2. The motor can be driven independently from the cylinders and can be controlled smoothly.
3. The system is secured against over load, but only where necessary.
4. Components for long life and reliable operation are integrated in the secondary circuit.

Note: Draw all activation means including the electric interface.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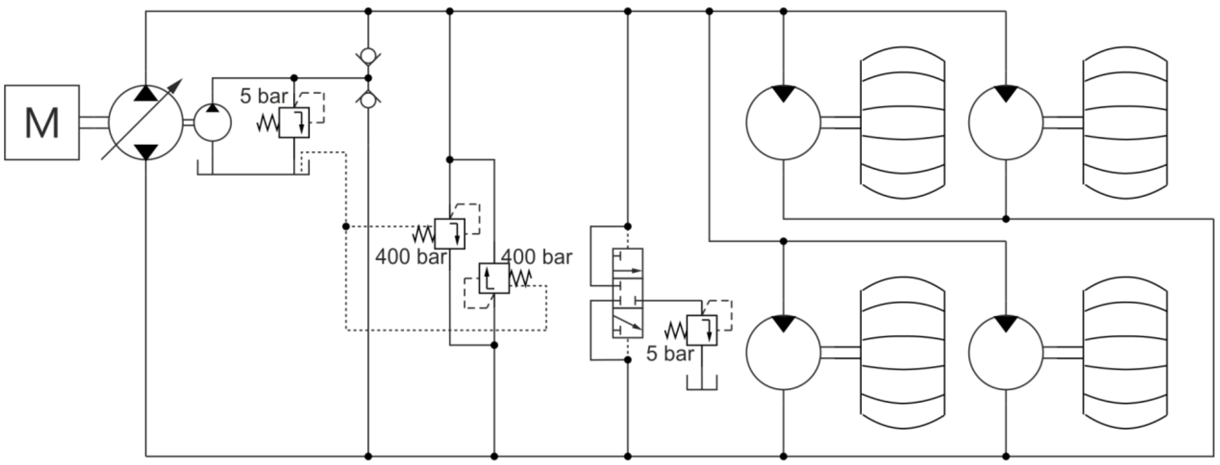
Opposed to exercise 4.3 now the traction drive with closed loop control, as shown in the figure, is examined. Solve the following exercises using these assumptions:

1. No additional pressure drop is considered at the PRVs after opening.
2. Any pressure drop over other valves is neglected.
3. During startup the rotational speed of the wheels is exactly 0 rpm.
4. The leakage of each single motor Q_{Leakage} depends on the highest acting pressure p_{HP} as this formula shows: $Q_{\text{Leakage}} = k_{\text{Leakage}}\, p_{\text{HP}}$



Given:	Startup torque of each single motor	$M_{\text{Startup}}=2{,}5\ kNm$
	Number of driven wheels	$Z_{\text{Wheels}}=4$
	Hydromechanic efficiency of motor	$\eta_{\text{hm, Motor}} = 0.9$
	Hydromechanic efficiency of pump	$\eta_{hm,\ Pump} = 0.95$
	Volumetric efficiency of pump	$\eta_{vol,\ Pump} = 0.95$
	Factor for leakage at motor	$k_{\text{Leakage}} = 0.05$ l/(min bar)
	Motor displacement	$V_{\text{Motor}} = 500$ cm³
	Rotational speed of pump	$n_{\text{Pump}} = 1500$ rpm
	Maximum displacement of pump	$V_{\text{Pump}} = 500$ cm³

4.5 At first the startup procedure is considered. What swash plate angle is needed in order to start moving the excavator? What power is required at the pump? (2 points)

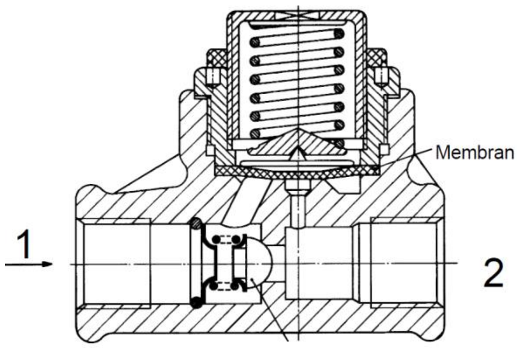
4.6 After starting, the excavator suddenly needs to perform an emergency break. How large is the maximal breaking torque at **each** single wheel, which can be applied by the motor? (1 point)

5. Exercise / 15 Points

5.1 Valves can be designed as seat or spool valves. Name 1 advantage and 1 disadvantage for each. (2 Points)

	Seat valve	**Spool valve**
advantage		
disadvantage		

5.2 Draw the equivalent circuit diagram of the depicted valve and label the primary (1) and secondary (2) valve port in your drawing. **Briefly** describe the function of the valve. (2 Points)



Function: ____

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5.3 Adjustable throttle check valves are often installed in close proximity to pneumatic drives. What are these valves often used for in this context? (1 Point)

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5.4 Name 4 general advantages of pneumatic drives. (2 Points)

1) ____

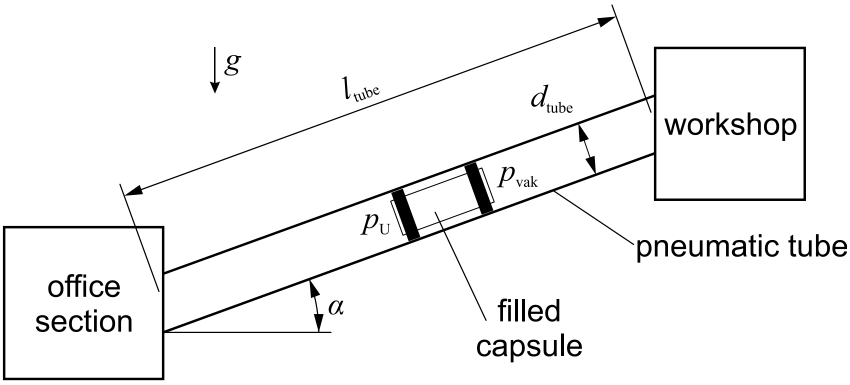
2) ____

3) ____

4) ____

Your task is to connect the IFAS office section with the workshop using a pneumatic capsule transportation system to speed up the exchange of drawings and small parcels. The goods are placed into a capsule. Afterwards the filled capsule with the mass $m_{capsule}$ is placed into the pneumatic tube in the office section and is accelerated by the reduced pressure p_{vak} in front of the capsule.

capsule
(Source: Aerocom)



Provided:	$m_{capsule}$ = 2 kg	g = 9.81 m/s²	d_{tube} = 60 mm
	$F_{f,const}$ = 10 N	p_U = 1 bar	l_{tube} = 200 m
	$k_{friction} = 0.4\,\frac{Ns}{m}$	$R_0 = 288\,\frac{Nm}{kg\,K}$	$T_U = T_0$ = 293.15 K
	α = 20°		

All pressures are given as absolute pressures and need to be declared as such!

5.5 How far must the pressure p_{vak} decrease in front of the capsule so that the filled capsule climbs the incline of α = 20° at constant velocity of $v_{capsule}$ = 8 m/s? (2 Points)

Hint: The friction force of the capsule in the pneumatic tube can be approximated by the following equation:

$F_{friction} = F_{f,const} + k_{friction} \cdot v_{capsule}$

5.6 The vacuum pump sucks with a constant standard volume flow rate of $Q_{0,\,vac}$ = 100 Nl/min (Standard l/min). How long does it take to achieve a pressure of p_{vac} = 0.8 bar in the pneumatic tube? Hint: The pneumatic tube is leakage free and the capsule movement does not start before the pressure decrease is completed. The process is considered to take place very slowly. (2 Points)

5.7 A small hole causes air from the outside to leak into the evacuated pneumatic tube with p_{vac} = 0.8 bar. The hole with sharp edges (α_D = 0.65) has a diameter of d_{hole} = 1 mm. Determine the mass flow into the pneumatic tube. (2 Points)

5.8 Despite the hole in the pneumatic tube, as described in exercise 5.7, the capsule is supposed to move with a velocity of $v_{capsule}$ = 8 m/s. Assume a leakage mass flow rate of 1 g/s through the hole. Determine the necessary standard volume flow rate $Q_{0,transport}$ of the vacuum pump in Nl/min (Standard l/min). (2 Points)

6. Exercise / 10 Points

You have changed the tires of your car and only the inflation of the tires is still to do. Since the car is not able to move without air in the tires, you have bought a small mobile compressor. Following data is given with the compressor:

Given:	Performance	P = 1.1 kW
	Average intake flow	Q = 180 Nl/min (Standard l/min)
	Maximum pressure	p_{rel} = 8 bar_{rel}
	Polytropic exponent	n = 1.15

Hint: The ambient condition corresponds to the technical standard condition.

6.1 Which compressor designs are suitable for the given operating range? Specify two compressor designs and an example for each design. (2 Points)

	Compressor design:	Example:
1.		
2.		

6.2 Which flow rate can the compressor deliver at 8 bar_{rel} gauge pressure, if you assume a total efficiency of 25 %? (1 Point)

6.3 Directly after inflation, the tire pressure is 2.2 bar_{rel}. The tire volume measures 35 l. How much time does the inflation take under polytropic conditions with n=1.15? Assuming a constant back-pressure about 2.2 bar_{rel}: Which technical performance is needed for the compression process? (3.5 Points)

Hints: Assume a steady intake flow of 180 Nl/min (Standard l/min). The tire volume stays constant. Indicate all pressures as absolute values.

6.4 After inflating the tires, the pressure drops due to the cooling of the compressed air. Up to which pressure must the tire be inflated to achieve a gauge pressure of 2.2 bar_{rel} after cooling back down to ambient temperature? (2.5 Points)

Hint: Indicate all pressures as absolute values. The gas temperature at the required pressure is unknown. For the polytropic inflation assume an exponent of $n=1.15$.

6.5 How can the efficiency of the compressor be increased? Which additional component is necessary? (1 Point)

Measure:

Component: