YILDIZ TECHNICAL UNIVERSITY
MECHANICAL FACULTY / MECHATRONICS ENGINEERING DEPARTMENT

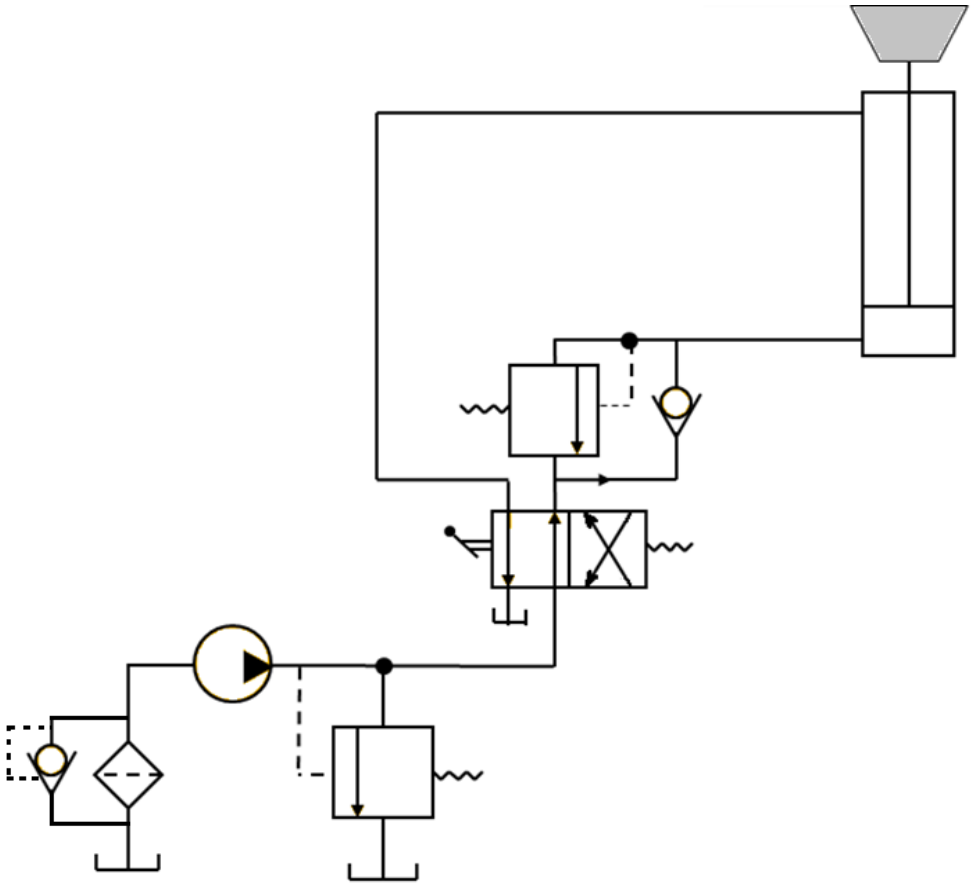
Student Name:	**Student number:**	**Signature:**
Course: MKT3842 Hydr.&Pneum.Systems GR2	**Date/Time:** 11.04.2019 / 17:00	**Duration:** 90 minutes
Exam Type: Midterm Exam	**Course Instructor:** Assoc.Prof. Cüneyt Yılmaz	

Question 1) [15 points] See the comparison table below, which is shuffled for (A) Electrical, (B) Hydraulic and (C) Pneumatic systems. Indicate which spec is for which system, by filling the blank cells with corresponding letters (A, B, C).

Energy storage	Limited (batteries)	A	Good (reservoir)	C	Limited (accumulator)	B
Distribution system	Limited, basically a local facility	B	Excellent, with minimal loss	A	Good, can be treated as a plant wide service	C
Energy cost	Highest	C	Medium	B	Lowest	A
Linear actuator	Short motion via solenoid. Otherwise via mechanical conversion	A	Cylinders. Very high force	B	Cylinders. Medium force	C
Controllable force	Controllable high force	B	Controllable medium force	C	Possible with solenoid and DC motors	A

Question 2) [15 points] A vertical hydraulic cylinder holds a heavy load. You want to manually rise and lower the load by a 4/2 valve. In case of a malfunctioning hydraulic pump, the load should not go down, unless the operator manually lowers it. So, complete the hydraulic circuit below for this safety purpose.

Answer 2)



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Question 3) [15 points] Consider using an 12 liter accumulator precharged of 100 bar to do a delay operation in a hydraulic circuit. The flow rate in the flow restriction valve was adjusted as 120 Liters/min. If a 2 second delay needed, determine the threshold pressure to beat the spring force of the accumulator just after this delay.

Answer 3) According to Boyle's Law:

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

where

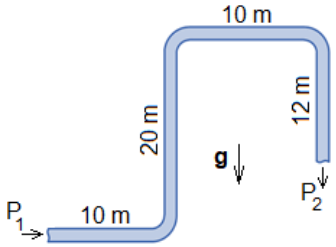
$V_1 = 12\ liters$ is the size of the accumulator, and $V_2 = V_1 - 120\,\frac{Liters}{\min} \cdot \frac{2\ sec}{60} = 12 - 4 = 8\ Liters$

$$100 \cdot 12 = P_2 \cdot 8$$

$$1200 = P_2 \cdot 8$$

$$P_2 = \frac{1200}{8} \quad \rightarrow \quad \boldsymbol{P_2 = 150\ bar}$$

Question 4) [15 points]
Consider the pipe line given in the figure. The diameter is 102.3 mm , pipe length is 52 m, fittings are 3 x 90° long radius (R/D = 4) welded elbows, fluid velocity is 180 m/min, fluid density is 1000 kg/m^3, friction factor is 0.018. Calculate the pressure loss?



Fitting	Types	$(L/D)_{eq}$
90° Elbow Curved, Threaded	Standard Radius (R/D = 1)	30
	Long Radius (R/D = 1.5)	16
	Standard Radius (R/D = 1)	20
90° Elbow Curved, Flanged/Welded	Long Radius (R/D = 2)	17
	Long Radius (R/D = 4)	14
	Long Radius (R/D = 6)	12
90° Elbow Mitered	1 weld (90°)	60
	2 welds (45°)	15
	3 welds (30°)	8

Hint: Friction related loss: $\Delta P = \mu \cdot \frac{L}{D} \cdot KineticEnergy$

Answer 4)

From the table , the equivalent L/D value for the 90° elbow is 14. The equivalent L is $L_{eq} = 14 \times 102.3\ mm = 1.432\ m$ for one fitting. For whole length:

$$L_{all} = 52 + 3 \cdot 1.432 = 54.296\ m$$

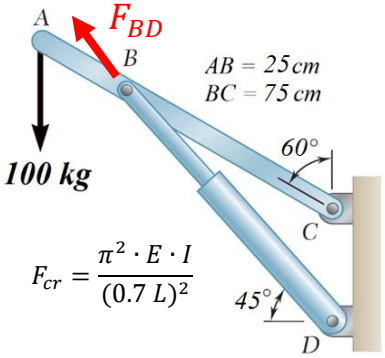
So, the pressure loss is calculated as:

$$\Delta P = \mu \cdot \frac{L_{all}}{D} \cdot \frac{\rho \cdot V^2}{2} + \rho \cdot g \cdot h = 0.018 \cdot \frac{56.296}{0.1023} \cdot \frac{1000 \cdot \left(\frac{180}{60}\frac{m}{s}\right)^2}{2} + 1000 \cdot 9.81 \cdot (20 - 12)$$

$$\boldsymbol{\Delta P = 123054\ Pa}$$

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Question 5) In a hydraulic lifting mechanism shown in the figure, a hydraulic cylinder with 4 cm inner radius was selected. To hold the load at the shown position:



a) **[10 points]** Determine the required pressure applied to the cylinder (neglect the mechanism weight, the pressure losses to the reservoir side, and the effect of the pump suction port level).

b) **[5 points]** Calculate the minimum radius of the cylinder rod (maximum allowable normal stress: $\sigma_{all} = 50\ MPa$).

c) **[5 points]** Calculate the cylinder wall thickness assuming the thin wall approach in the calculation ($\sigma_{all} = 50\ MPa$).

d) **[5 points]** Calculate the maximum stroke of the cylinder (E=100 GPa) at the given position.

Answer 5)

a) $\sum M_C = 0 \quad \rightarrow \quad 100 \cdot (25+75) \cdot \cos 30° + F_{BD_x} \cdot 75 \cdot \sin 30° - F_{BD_y} \cdot 75 \cdot \cos 30° = 0$

$F_{BD_x} = F_{BD} \cdot \cos 45°$ and $F_{BD_y} = F_{BD} \cdot \sin 45° \quad \rightarrow$

$$100 \cdot (25+75) \cdot \cos 30° + F_{BD} \cdot \cos 45° \cdot 75 \cdot \sin 30° - F_{BD} \cdot \sin 45° \cdot 75 \cdot \cos 30° = 0$$

$$F_{BD} = \frac{100 \cdot (25+75) \cdot \cos 30°}{\sin 45° \cdot 75 \cdot \cos 30° - \cos 45° \cdot 75 \cdot \sin 30°} = 446.14\ kg = 446.14\ \cdot 9.81\ N = 4376.65\ N$$

$$F_{BD} = P \cdot \pi\ \cdot R^2$$

where P is the required pressure to hold the load.

$$P = \frac{F_{BD}}{\pi\ \cdot R^2} = \frac{4376.65}{\pi\ \cdot 0.04^2} \quad \rightarrow \quad \boldsymbol{P = 870707.5\ Pa}$$

b) Cylinder rod radius (r):

$$\sigma_{all} \geq \frac{F_{BD}}{\pi\ \cdot r^2} \quad \rightarrow \quad r \geq \sqrt{\frac{F_{BD}}{\pi \cdot \sigma_{all}}} \quad \rightarrow \quad r \geq \sqrt{\frac{4376.65}{\pi \cdot 50 \cdot 10^6}} \quad \rightarrow \quad r \geq 0.00528\ m\ ,\ \ Let\ \boldsymbol{r = 6\ mm}$$

c) Cylinder wall thickness (t):

$$t \geq \frac{P \cdot\ R_i}{\sigma_{all}} = \frac{870707.5\ \cdot 0.04}{50 \cdot 10^6} = 0.0007\ m\ , \quad Let\ \ \boldsymbol{t = 1\ mm}$$

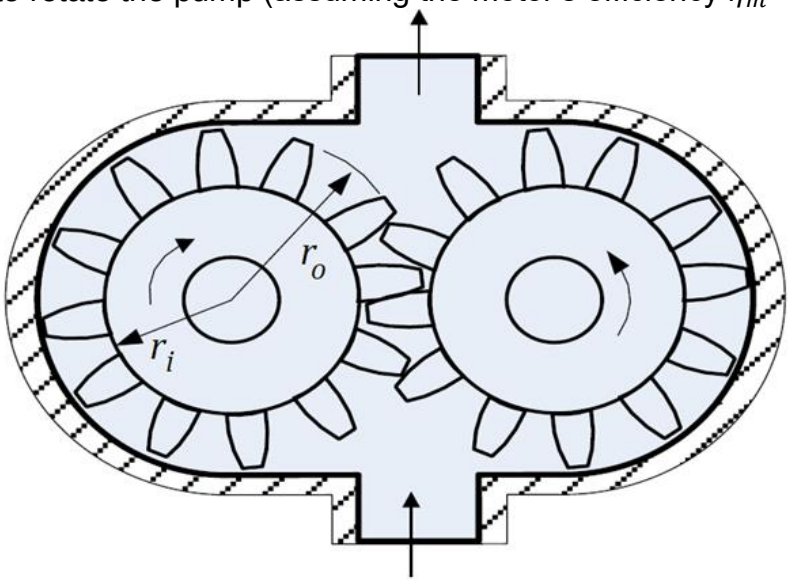
d) Cylinder stroke (L):

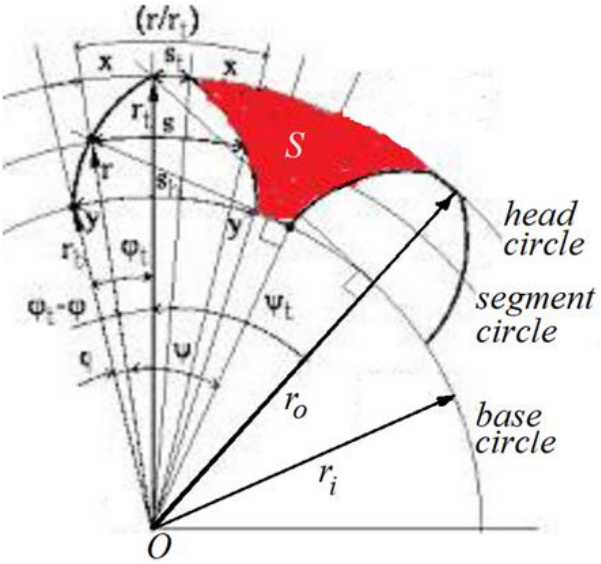
$$F_{cr} = F_{BD} = \frac{\pi^2 \cdot E \cdot I}{(0.7\,L)^2} \quad \rightarrow \quad L = \sqrt{\frac{\pi^2 \cdot E \cdot I}{F_{BD} \cdot (0.7)^2}} = \sqrt{\frac{\pi^2 \cdot E \cdot \frac{1}{4} \cdot \pi \cdot r^4}{F_{BD} \cdot (0.7)^2}}$$

$$L = \sqrt{\frac{\pi^2 \cdot 100 \cdot 10^9 \cdot \frac{1}{4} \cdot \pi \cdot (0.006)^4}{4376.65 \cdot (0.7)^2}} \quad \rightarrow \quad \boldsymbol{L = 0.68\ m}$$

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Question 6) **[15 points]** Consider a hydraulic gear pump with gear tooth top radius $r_o = 15\,mm$, deep radius $r_i = 10\,mm$, number of teeth $Z = 12$, gear thickness $h = 9\,mm$, efficiency $\eta = 88\%$. If the system needs $40\,bar$ and $3\,liters/min$ flow rate, then determine the specs of the electric motor to rotate the pump (assuming the motor's efficiency $\eta_m = 90\%$).





Hint: Assume the area of one gap of the gear (S) the same as the area of one tooth. $1\,bar = 100\,kPa$

Answer 6)

$$S = \pi \cdot \frac{r_o^2 - r_i^2}{2 \cdot Z} = \pi \cdot \frac{15^2 - 10^2}{2 \cdot 12} = 16.36\,mm^2$$

$$Q = 3 \cdot 10^6\,mm^3/min$$

$$n = \frac{Q}{2 \cdot Z \cdot S \cdot h \cdot \eta} = \frac{3 \cdot 10^6}{2 \cdot 12 \cdot 16.36 \cdot 9 \cdot 0.88}\ [rpm]$$

$$n = 965\,rpm$$

Let $\boldsymbol{n = 1000\,rpm}$

$$Power\ of\ the\ pump\ [kW] = Pressue\ [kPa] x\ Flow\ Rate\ \left[\frac{m^3}{sec}\right] = (40 \cdot 10^2\ [kPa]) x \left(\frac{3 \cdot 10^{-3}}{60}\left[\frac{m^3}{sec}\right]\right)$$

$$Power\ of\ the\ pump = 0.2\,kW = 200\,W$$

$$Minimum\ power\ of\ the\ motor\ required = Power\ of\ the \frac{pump}{\eta} = \frac{200}{0.9} = 222.2\,W$$

From the market, a motor with a higher power, e.g. $\boldsymbol{230\,W}$, may be picked, because the calculated power would not be be a nominal power of a pump in the market.

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