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Fall 2022
Test 1

Problem 1) For the manometer shown in the figure, the pressure difference between Point A and B was calculated and it was found to be 2.7177 psi.

Q_1) What would be the deflection in the manometer if instead of using oil with Sg = 0.90 you use gasoline?

Q_2) What is the minimum weight of the manometer so the gasoline does not go into the system?

Q_3) Using an excel spreadsheet, run the calculations again.

Q_4) Then determine the deflection for the case of using mercury as manometric fluid

Please, look at the results you got and make comments about them in the "analysis" section of your solution. Why do they make sense?

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Problem 1 page 2

Purpose:

1) The purpose of this problem is as follows.

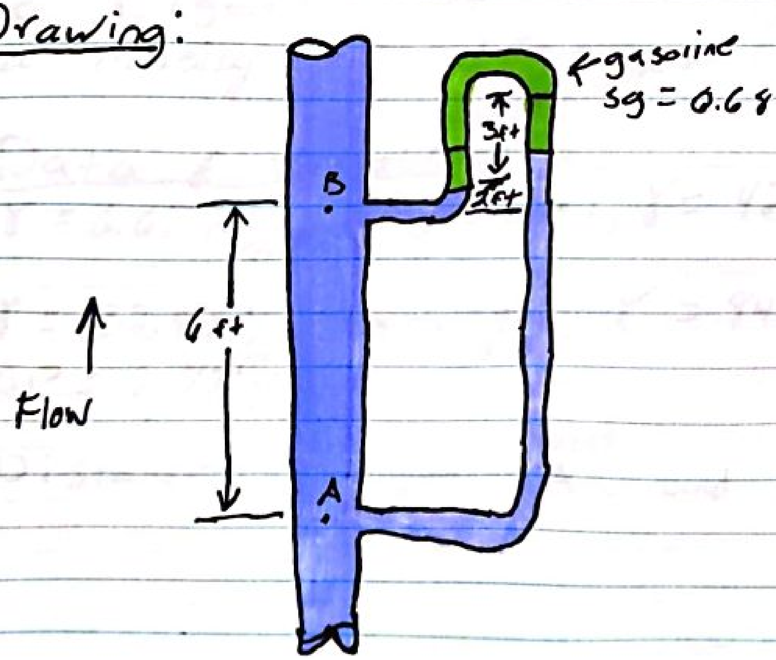
A.) Determine the deflection in the manometer if using gasoline as the manometric fluid.

B.) Determine the minimum height of the manometer so gasoline does not enter the system.

C.) Use excel to run the calculations again

D.) Determine the deflection in the manometer if using mercury

Drawing:



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<u>Problem 1</u> page 3

<u>Sources</u>: Robert L. Mott /
Joseph A. Untener
"Applied Fluid Mechanics", 7^{th} ed.
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<u>Design considerations</u>: Assumptions, Safety, Cost, etc.

- The $\Delta P = 2.72$ psi with oil Manometer uses the relationship $sg = 0.90$ between a change in pressure and a change in elevation. The manometer contains a liquid called gage fluid that does not mix with the fluid of the pressure to be measured. In this problem we will use gasoline as our gage fluid. gasoline has a $sg = 0.68$ and a γ (gama) of $6.67\ KN/m^3$ and a density of $680\ kg/m^3$ (Appendix B)

<u>Data & Variables</u>:

$\gamma = 6.67\ KN/m^3$ (gasoline), $\gamma = 42.40\ lb/ft^3$ (gasoline)

$\gamma = 132.8\ KN/m^3$ (mercury), $\gamma = 844.9\ lb/ft^3$ (mercury)

$\Delta P = 2.72\ psi$

Distance Between Point A and Point B = 6ft

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Problem 1 Page 4

Procedure: step 1) Match units
step 2) establish refferences
step 3) use Appendix B
step 4) use $\Delta p = \gamma h$
~~step 5) use~~ $E = \cancel{\frac{-\Delta p}{(\Delta V)/V}}$

This is for solving deflection we are not given the area, so deflection can't be solved

Calculations: $\Delta p = \gamma h$

$\Delta p = 2.72 psi$
$\cancel{\gamma = 8.99}$
$\gamma = 56.53$ (oil sg = 0.90)

$$\frac{2.72 \frac{lb}{in^2}}{\cancel{56.53 \frac{lb}{ft^3}}} = h$$

$4.67 \frac{lb}{in^3}$

$0.05 \cancel{ft} = h$ (oil, sg = 0.90)

$\boxed{h = 0.58 in}$ oil, sg=0.90

$\Delta p = \gamma h$

$$\frac{2.72 \frac{lb}{in^2}}{3.5 \frac{lb}{in^3}} = h$$

$$\gamma = \frac{42.40 \frac{lb}{ft^3}}{12}$$ (gasoline)

$\gamma = 3.5 \frac{lb}{in^3}$

Q1) $\boxed{h = 0.78 in}$ gasoline

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$\Delta p = \gamma h$

$$\frac{2.72 \frac{lb}{in^2}}{70.4 \frac{lb}{in^3}} = h$$

$\gamma = 844.9 \frac{lb}{ft^3}$ (mercury)

$$\frac{}{12}$$

$\gamma = 70.41 \frac{lb}{in^3}$

Q4 $\boxed{h = 0.04 in}$ mercury

Q2) There is 2 ft of manometer tube and we require a minimum of 0.79 in before the gasoline will mix with the fluid being measured.

Q3) Excel

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Problem 1, Page 6

Summary: This problem looked at the nature of differnt manometric fluids and how the specific weight of the manometric fluids allowed for changes in height / deflection.

Materials: 1) Heavy oil, 2) Manometer, 3) Gasoline, 4) Mercury, Fluid being measured

Analysis: In this problem we discovered the deflection for Gasoline to be h = 0.78in and the deflection for mercury to be 0.04in. This makes sense, mercury has a higher γ which means it has a higher shear stress, the higher shear stress results in less deformation over the same pressure relative to gasoline.

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Problem 2) Page 1

The system shown in the figure was designed to handle a total of 30 gpm of coolant. The owners of the company realized that the coolant needed for Machines #1 and #2 are different to what they had estimated initially. Instead of 20 gpm and 10 gpm, they actually need 30 gpm for each machine exactly. Thus, they need a new pump to deliver the new total flow rate of coolant. The coolant has a specific gravity of 0.92 and a dynamic viscosity of 3.6×10^{-5} $\frac{lb \cdot s}{ft^2}$. The filter has a resistance coefficient (K) of 1.85 on the velocity head in the section line. You are hired to redesign for now only the pumped system, but we do not know what the best pipe size would be for this new flow rate. Here is what you need to do:

a.) pick a commercial steel pipe schedule 40 that will give a mean flow velocity of about 3 m/s with the new total flow rate. (do not forget there are two machines in the upper system and 1 pipe in the pumped system)

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Problem 2) Page 2

b.) With the selected pipe, compute the pump head and the power delivered by the pump to the coolant. Also, compute the pressure at the inlet of the pump.

c.) using an excel spreadsheet, run the calculations again.

d.) using an excel spreadsheet, run the calculations again using different steel pipe schedule 40 sizes, pick two pipe sizes smaller than the one you selected on part a, and two pipe sizes larger than the one you selected on part a. Keep in mind that the fluid velocity will change for every pipe size while the flow rate is the same for all cases.

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Problem 2) Page 3

e.) For each of the pipe sizes, estimate the cost of installation using the pipe cost list below and consider than labor, transportaion, and pump costs amount for about 40 % of the pipe cost. Inclde a 15% extra for unforseen costs. Make a table of the installation cost in excel.

Pipe nominal size (in)	Cost per c ft
1/2	$12.95
3/4	$17.95
1	$23.95
1 1/4	$28.95
1 1/2	$33.95
2	$46.95
2 1/2	$71.95
3	$92.95

f.) For each of the pipe sizes, estimate the cost to maintain the system operating for 2 years knowing that the electricity cost is about $730 per kW constantly used during those 2 years. Make a table of the operation costs in excel.

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Problem 2) Page 4

g.) Add both costs (operational and Installation) and plot on the same graph the cost of installation, the cost of operation, and total cost as a function of nomical pipe diameter.

h.) Please, look at the results you got and make comments about them in the "analysis" section of your solution. Why do they make sense? What do you think is the best pipe size to use in this system?

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Problem 2) Page 5

Purpose: The purpose of this problem is to redesign the pipe size to accomidate ~~match~~ the new flow rate. once the new pipe is determined, the purpose is to determine the cost impacts.

a.) Determine pipe size

b.) Compute pump head, Power delivered, and pressure at pump inlet

c.) use excel to run calculations again

d.) use excel to run calculations for different pipe sizes
- pick two smaller sizes
- pick two larger sizes

e.) estimate cost of each pipe size.

f.) estimate cost to maintain the system for 2 years

g.) Plot operational and Installation cost on the same graph

h.) make comments about the results in the analysis section

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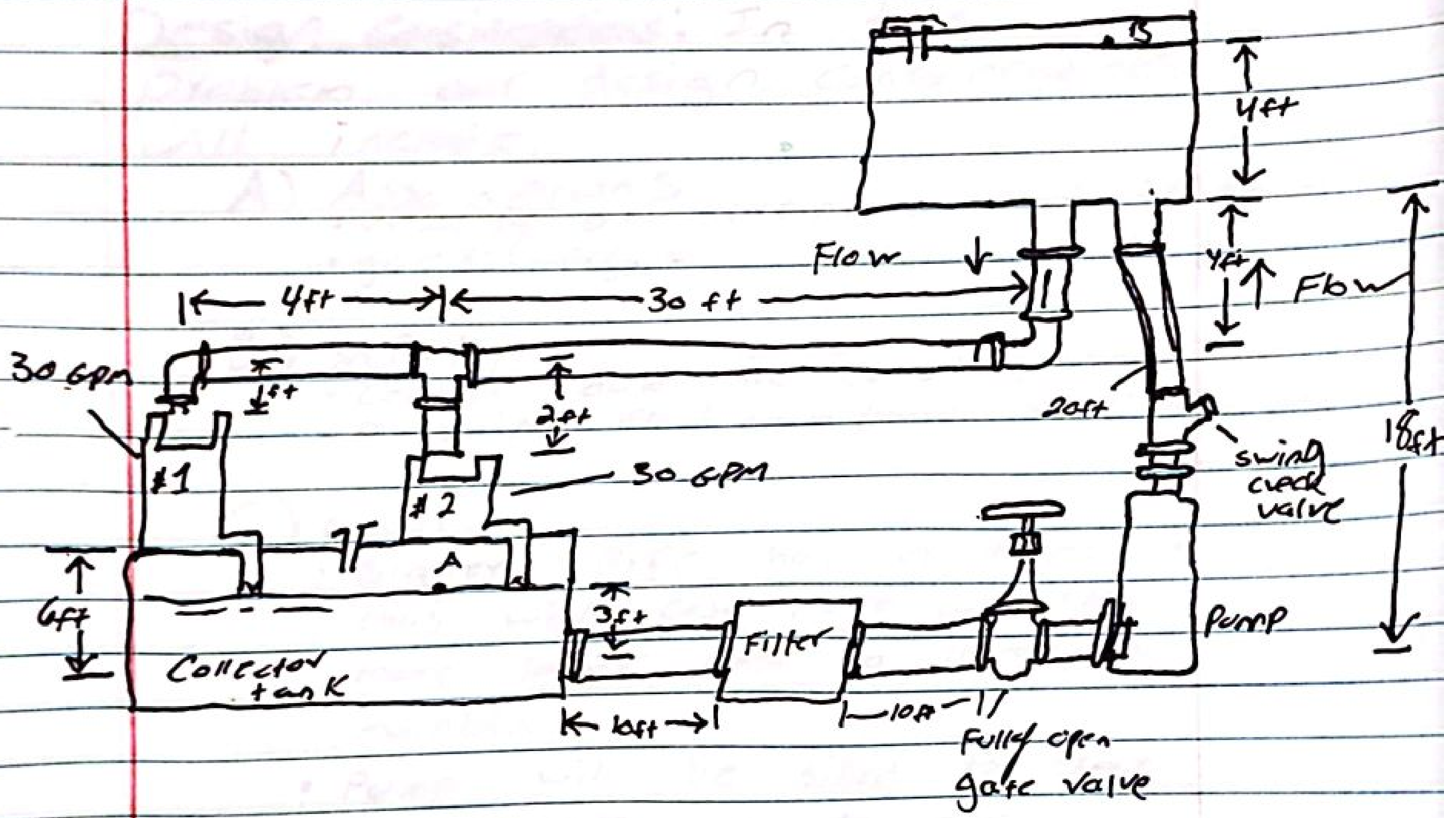
Problem 21 Page 6

Drawing:



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Problem 2 page 7

Sources: Robert L. Mott |
Joseph A. Untener
"Applied Fluid Mechanics". 7th Ed.
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Design Considerations: In this problem our design considerations will include,

A) Assumptions
- velocity at surface of fluid is zero
- $g_c = 32.2\,ft/sec^2$

B) Safety
- Coolant could be caustic, wear PPE
- pressurized fluid could cause injury, wear PPE

C) Cost
- Bigger pipe has more material, thus will cost more and require more labor cost to install and maintain
- Pump will be sized to exact requirements as to not oversize the pump and thus save money

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Problem 2 Page 8

Data and Variables:

~~f~~ $f_{pipe} =$

$Q = 60$ GPM

$S_g = 0.92$

dynamic viscosity $= 3.6 \times 10^{-5} \frac{lb \cdot s}{ft^2}$

$K_{filter} = 1.85$

$V = 3 m/s$

Procedure: Step 1) Match Units
Step 2) Establish refferences
Step 3) Use Appendix F
Step 4) Use $Q = VA$
Step 5) Use Bernoulis / General Energy Equation

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

Calculations:

$Q = VA$ (pipe diameter) $A = \frac{1}{4}\pi d^2$

$$\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g} + h_A - h_L = \frac{P_B}{\gamma} + Z_B + \frac{V_B^2}{2g}$$

(Pump head press.) $\cancel{\Delta P = \frac{P_B - P_A}{\gamma}}$ $\cancel{P = \gamma h}$ (Pump head press.) $= \frac{P_B - P_A}{\gamma}$

(Power delivered) $h_A = \frac{P_B - P_A}{\gamma} + (Z_B - Z_A) + \frac{V_B^2 - V_A^2}{2g} + h_L$

(Inlet Pressure) suction $\cancel{P = \gamma h}$ $P = \gamma h_{L\,Inlet}$

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Problem 2) page 9

$Q = VA$

$60 \frac{Gal}{min} = 3 \frac{m}{s} \cdot A$

$60 \frac{Gal}{min} = 0.23 \frac{m^3}{min}$

$\downarrow$

$0.23 \frac{m^3}{min}$

$\downarrow$

$0.0038 \frac{m^3}{s} = 3 \frac{m}{s} \cdot A$

$\frac{0.0038 \frac{m^3}{s}}{3 \, m/s} = A$

$A = 0.0013 m^2$

$\downarrow$

$\boxed{A = 2.02 in^2}$

$A = \frac{1}{4} \pi d^2$

$2.02 in^2 = \frac{1}{4} \pi d^2$

$\sqrt{\frac{2.02 in^2}{\frac{1}{4} \pi}} = d$

$\sqrt{\frac{2.02 in^2}{0.785}} = d$

$\sqrt{2.57} = d$

Commercial steel pipe schedule 40
1 1/2 NPS
1.610 ID

$\boxed{d = 1.60 in}$

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Problem 2 page 10

$$\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g} + h_A - h_L = \frac{P_B}{\gamma} + Z_B + \frac{V_B^2}{2g}$$

The value of the following terms are zero:

$\Delta p = 0$

$\Delta V = 0$

Pump head press. $= \cancel{\gamma h}$

$$= \frac{P_B - P_A}{\gamma}$$

$$= 14.7\frac{lb}{in^2} - 14.7\frac{lb}{in^2}$$

$$= \frac{0}{\gamma}$$

$$= 0 / 29.62\frac{ft}{s^2}$$

$\gamma = sg \cdot g_c$

$\gamma = 0.92 \cdot 32.2\ ft/s^2$

$\gamma = 29.62\ \frac{ft}{s^2}$

$$\boxed{\text{Pump head Press.} = 0}$$

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Problem 2 Page 11

$$h_A = \frac{P_B - \cancel{P_A}^{0}}{\cancel{\gamma}} + (Z_B - Z_A) + \frac{V_B^2 - \cancel{V_A^2}^{0}}{\cancel{2}} + h_L$$

$$\boxed{h_A = Z_B - Z_A + h_L}$$

$$h_L = f\frac{L}{D}\cdot\frac{v^2}{2g} + 2K_{elbow}\cdot\frac{V^2}{2g} + K_{\substack{swing\\check\\valve}}\cdot\frac{v^2}{2g} +$$

$$K_{Tee}\cdot\frac{V^2}{2g} + K_{Filter}\cdot\frac{v^2}{2g} + K_{\substack{gate\\valve\\open}}\cdot\frac{v^2}{2g}$$

$f\frac{L}{D} = 0.020\ \frac{L}{D} = 0.020\ \frac{\quad}{1.60}$ $D = 1.60\ in$

$K_{elbow} = \frac{30}{D} = \frac{30}{1.60\ in} = 18.75\ in$

$K_{\substack{swing\\check\\valve}} = \frac{100}{D} = \frac{100}{1.60\ in} = 98.4\ in$

$K_{Tee} = \frac{20}{D} = \frac{20}{1.60\ in} = 12.5\ in$

$K_{Filter} = 1.85 \rightarrow \frac{1.85 \cdot 1.60\ in}{0.020} = 148\ in$

$K_{\substack{gate\\valve\\open}} = \frac{8}{D} = \frac{8}{1.60\ in} = 5\ in$

Density $\rho =$ $slugs/ft^3$

Dynamic viscosity $\eta = 3.6 \times 10^{-5}\ lb.s/ft^2$

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Problem 2 Page 12

$$h_L = f \frac{L}{D} \cdot \frac{v^2}{2g} \qquad v = \frac{3m}{s} \rightarrow \cancel{0.27\frac{in}{s}}$$

$$0.82 \frac{in}{s}$$

$$= 0.020 \left(\frac{\quad in}{1.60 in}\right) \frac{v^2}{2g}$$

$$h_L = 0.020 \left(\frac{972 in}{1.60 in}\right) \frac{\left(\cancel{0.87}\,0.82 \frac{in}{s}\right)^2}{2g}$$

$L = 10ft + 1ft + 2ft + 4ft + 30ft + 4ft + 20ft + 10ft$

$L = 81ft \cdot 12$

$L = 972 in$

$$h_L = 0.020 \cdot 607.5 in \frac{0.67 in^2}{2 \cdot 32.2 \frac{ft}{s^2}}$$

$$h_L = 12.15 \cdot \frac{0.67 in^2}{2 \cdot 2.68 \frac{in}{s^2}}$$

$$= 12.15 \cdot \frac{0.67 in^2}{5.36 \frac{in}{s^2}} \qquad \frac{v^2}{2g} = \cancel{0.125}\ 0.125$$

$$h_L = \underset{f \frac{L}{D} \cdot \frac{v^2}{2g}}{1.52 in} + (2)\, 18.75 in \cdot \frac{v^2}{2g}$$

$$h_L = 1.52 in + 4.69 in$$

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Problem 2 Page 13

$h_L = 1.52\,in + 4.69\,in + K_{\substack{swing\\check\\valve}} \cdot \frac{v^2}{2g}$

$98.4\,in \cdot 0.125$

$h_L = 1.52\,in + 4.69\,in + 12.3\,in + K_{Tee} \cdot \frac{v^2}{2g}$

$h_L = 18.51 + 12.5\,in \cdot 0.125$

$h_L = 18.51\,in + 1.56\,in + K_{Filter} \cdot \frac{v^2}{2g}$

$h_L = 20.07\,in + 148\,in \cdot 0.125$

$h_L = 20.07\,in + 18.5\,in + K_{\substack{gate\\valve\\open}} \cdot \frac{v^2}{2g}$

$h_L = 38.57\,in + 5\,in \cdot 0.125$

$h_L = 38.57\,in + 0.625\,in$

$\boxed{h_L = 39.20\,in}$

$h_A = Z_B - Z_A + 39.20\,in$

$h_A = 264\,in - 36\,in + 39.20\,in$

$\boxed{h_A = 267.2\ lb \cdot in}$

CamScanner

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Problem 2 Page 14

$P = \gamma h$ $\gamma = 29.62\ ft/s^2$ $\frac{v^2}{2g} = 0.125$

Pressure at Pump Inlet

$$h_{L_{Inlet}} = f\frac{L}{D}\cdot\frac{v^2}{2g} + K_{Filter}\cdot\frac{v^2}{2g} + K_{\substack{gate\\valve\\open}}\cdot\frac{v^2}{2g}$$

$$h_L = 0.020\left(\frac{240\ in}{1.60\ in}\right)0.125\ in$$

$$h_{L_{Inlet}} = 0.020\cdot 150\ in\cdot 0.125\ in$$

$$h_{L_{Inlet}} = 3.75\ in + 148\ in + 5\ in$$

$$h_{L_{Inlet}} = 156.75\ in\cdot lb \rightarrow h_{L_{Inlet}} = 13.06\ ft$$

$\gamma = 29.62\ ft/s^2$

$$P_{Inlet} = \gamma h_{L_{Inlet}}$$

$$P = 29.62\frac{ft}{s^2}\cdot 13.06\ ft$$

$$\boxed{P_{Inlet} = 386.84\ \frac{ft^2\cdot lb}{s^2}}$$

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Problem 2 Page 15

Summary: This problem redesigned a system to adjust for a higher flow rate. We solved for the required pipe diameter and then solved for all the energy losses to determine pump attributes. The pricing was applied and graphed.

Materials:
- Schedule 40 commercial Steel 1 1/2 NPS
- 2 elbows
- 1 Tee
- 1 Filter
- 2 Tanks
- 2 Machines
- 1 Pump

Analysis: In this problem we discovered the cost relationship with system design. We found how flow rate requirements drive the system along with velocity requirements.