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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Spring 2022
Test 3

Take home – Due Sunday April 10th 2022 before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)
2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments, the other eighty (90) points will come from the problem solutions. I will not grade neither give you points for the technical writing, if you still want to present your test following the technical writing, you can follow the attached rubric.
3. There are 2 problems, but you are supposed to solve only one. It is your choice. If you solve both, I will grade only one and give you extra 10 points towards the 2nd test for the second problem you solve (if correctly solved). You need to tell me which problem you want me to grade towards this third test. The problem you pick to be graded is worth all 90 points.
4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.
5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.
6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit your solution as a pdf file and the excel spreadsheet. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive.
7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.
8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

IX. PROHIBITED CONDUCT

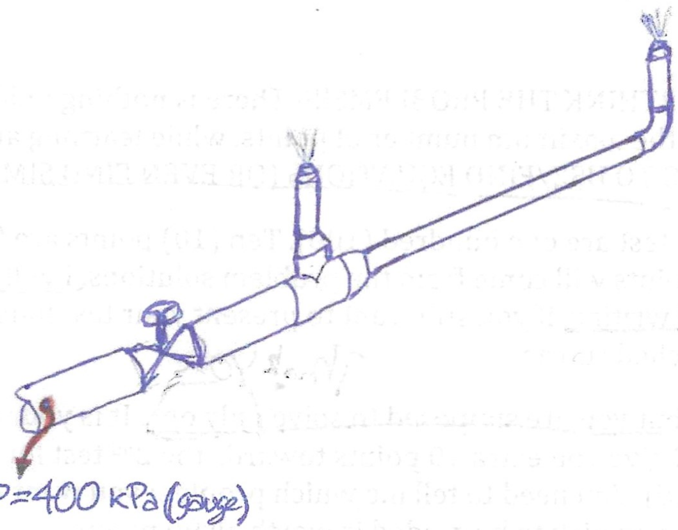
A. Academic Integrity violations, including:

1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

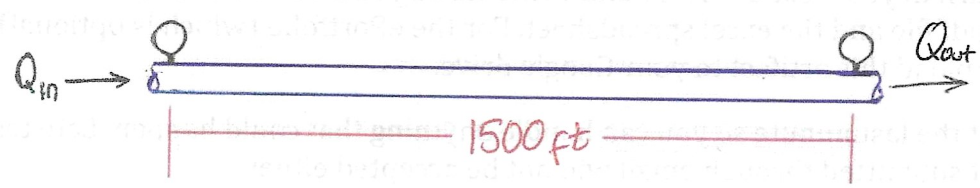
1) The system sketched in the figure is an automatic sprinfler system for a narrow plot of lawn. Water is supply by a main that guarantees a constant pressure of 400 kPa (gauge). The sprinkler pipeline is made of schedule-40 steel pipe. For a wide-open ball valve, determine the flow rate delivered to each sprinkler head. Do not neglect minor losses. The characteristic of the system is as follows:

a. From point where pressure is 400 kPa to the T-joint: 1 ½ inches nominal pipe of 6.5 m.
b. From T_joint to 1st sprinkler head: 1 inch nominal pipe of 0.3 m.
c. From T_joint to 2nd sprinkler head: 1 inch nominal pipe of 8.3 m.
d. K of the sprinkler head is 50.

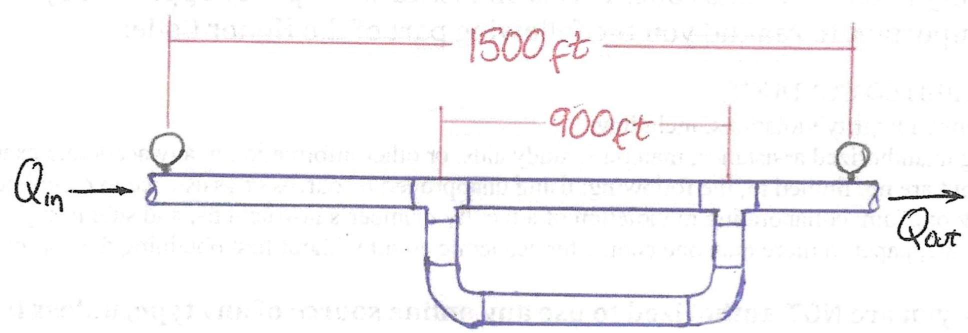


Are the flows through each sprinkler the same? If not, what would you do to make them the same? How does the fluid velocity compare to the critical velocity (3 m/s)? If it is too far off, what would you do?

2) A horizontally laid 2 inches standard steel tubing is 1500 ft long and has water passing through it at a 65 gpm flow rate. Determine the corresponding pressure drop

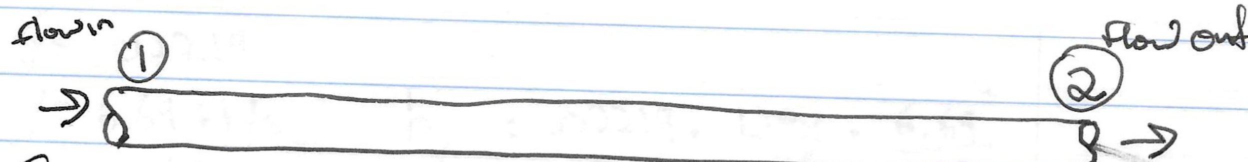


The pipe is modified by adding a loop made of 1 ½ inches standard steel tubing that is only 900 ft long. What is the expected increase in flow rate through the system for the same pressure as in the original pipe (the one you calculated)? Consider all minor losses.



Problem 2 Part 1

$Q = 65$ gallon/min 2" Ø pipe, 1500' Long



Series problem * no elivation change, Pump or additional K values

$$\cancel{h_A} + \frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_1} = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2} + \cancel{h_R} + h_L$$

* Since flow ① = flow ②, V on both sides Cancels

Class I problem, determin energy losse, Pressure drop

$$\frac{P_1 - P_2}{\gamma} = hL_{1-2} \therefore \Delta P = h_{L_{1-2}}(\gamma)$$

So, $Q = 65$ gal/min, or $.1448 \, ft^3/s$ (google conversion)
2" dia or $.1\overline{66}$

$Q = VA \therefore .1448 = \pi\left(\frac{.166}{2}\right)^2 \cdot V \therefore U = 6.69 \, ft/s$

$N_R = \frac{VD}{\nu} = \frac{6.69 \cdot .166}{1.21 \times 10^{-5}}$ * assume 60° for ν

$N_R = \boxed{91780.17}$

$\varepsilon = 1.5 \times 10^{-4}$

$$f = \frac{.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{N_R^{.9}}\right)\right]^2}$$

$$\frac{.25}{\left[\log\left(\frac{1}{3.7\left(\frac{.166}{1.5 \times 10^{-4}}\right)} + \frac{5.74}{91780.17^{.9}}\right)\right]^2}$$

$= .02219$

For $h_{L_{1-2}}$, $h_L = f \frac{L}{D} \frac{V^2}{2g}$

$f = .02219$

$V = 6.69$ ft/s

$L = 1500'$ ft

$D = .166$ ft

$h_{L_{1-2}} = .02219 \cdot \frac{1500}{.166} \cdot \frac{6.69^2}{2 \cdot 32.2}$

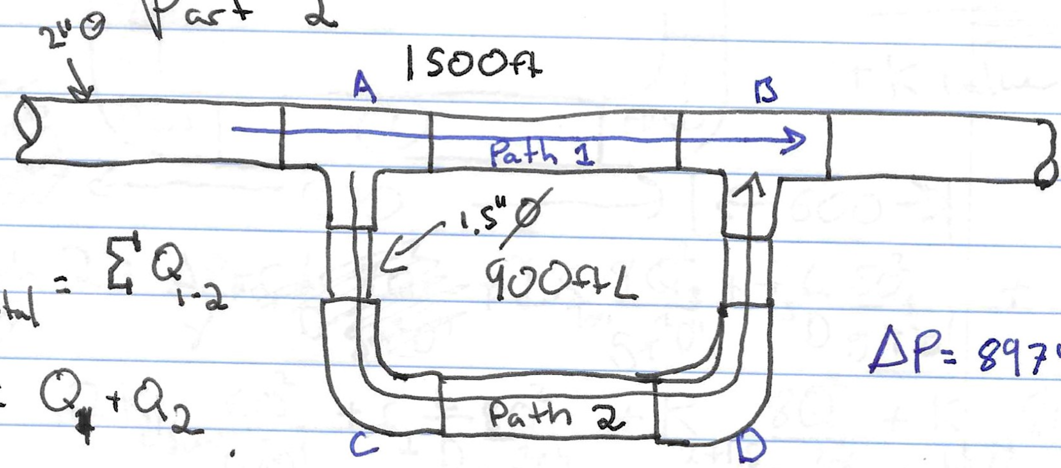
$= 139.35$

from earlier, $\Delta P = h_{L_{1-2}} \cdot \gamma$

$\gamma = 64.4$

$\Delta P = 139.35 \cdot 64.4 = 8974.13728$

Part 2



$Q_{total} = \sum_1^1 Q_{1-2}$

$Q = Q_1 + Q_2$

$\Delta P = 8974.13728$

from part 1, $\Delta P = h_{L_{1-2}} \cdot \gamma$

so:

Path 1, $L = 1500'$: $\Delta P = \left(f \frac{L}{D} \frac{V^2}{2g} + K_A \frac{V_{AB}^2}{2g} + K_B \frac{V_{AB}^2}{2g} \right) \gamma$

The same, so just 2x

Path 2, $L = 900'$: $\Delta P = \left(f \frac{L}{D} \frac{V^2}{2g} + 2 \cdot K_A \frac{V_{AB}^2}{2g} + 2 K_C \frac{V_{CD}^2}{2g} \right) \gamma$

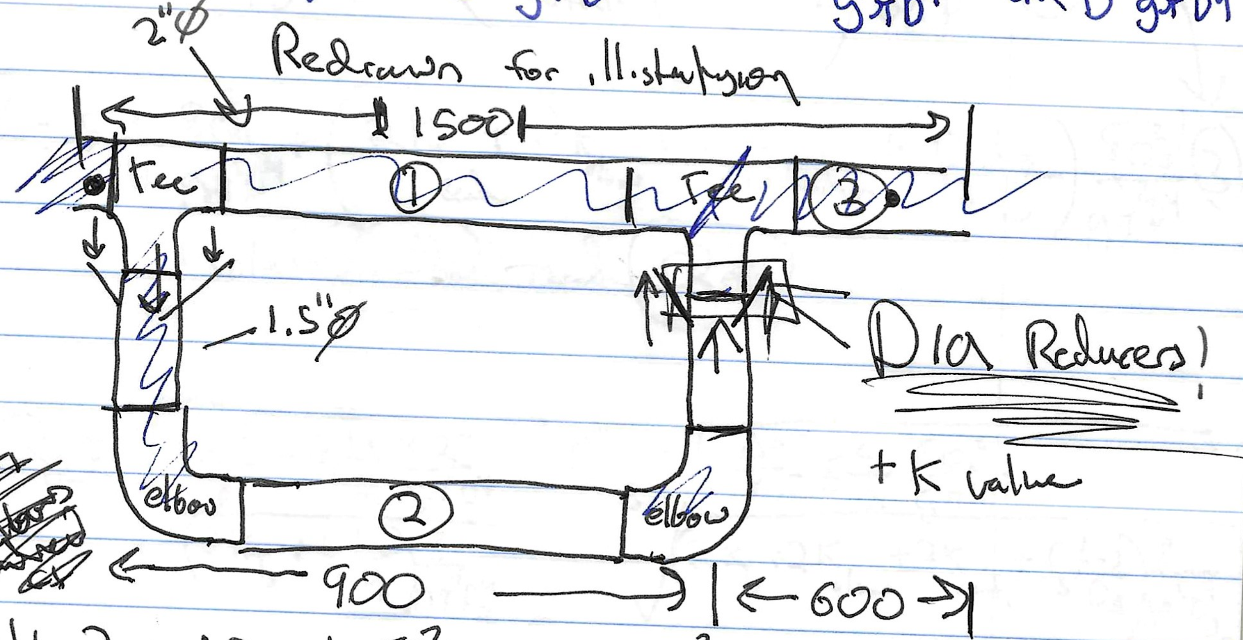
Plug in equation

$$\frac{V^2}{2g} = \frac{8Q^2}{g\pi^2 D^4}$$

Path 1 $f = .02219$

$$\text{Path 1} = \frac{\Delta P}{\gamma} = f\frac{L}{D}\frac{8Q_1^2}{g\pi^2D^4} + K_A \cdot 2 \cdot \frac{8Q_1^2}{g\pi^2D^4} + f_{end}\frac{L}{D}\frac{8Q_3^2}{g\pi^2D^4}$$

Redrawn for illustration



$$\text{Path 2} = \frac{\Delta P}{\gamma} = + 2K_{Tee}\frac{8Q_1^2}{g\pi^2D^4} + f_3\frac{L}{D}\frac{8Q_3^2}{g\pi^2D^4} +$$

Too many Pipe length frictions

$$2K_{elbow}\frac{8Q^2}{g\pi^2D^4} + f_2\frac{L}{D}\frac{8Q^2}{g\pi^2D^4} + K_{2\to1.5}\frac{8Q^2}{g\pi^2D^4} + K_{1.5\to2}\frac{8Q^2}{g\pi^2D^4}$$

$D_1 = .166'$ $D_2 = .125'$ $L3 = 600$ $L1 = 900$ $L_2 = 900$

$\nu = 1.21\times10^{-5}$ $\gamma = 64.4$, $\Delta P = 8974.13728$

$K_{Tee} = 20 ft$ → K_{Tee} 60 ft ↓ K_{elbow} 30 ft Table 10.4

Assume 60

$K_{contract} \frac{.166}{.125} = 1.328 = .42$ $K_{enlargement}$ .42

$$* \quad \boxed{Q_1 = Q_2 + Q_3} \quad *$$

Total flow → Q_1

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D^4} + \left(2K_{Tstraight} + f_2 \frac{L_2}{D_2}\right) \frac{8Q_2^2}{g\pi^2 D^4} \quad (2)$$

$$\frac{\Delta P}{\gamma} = f_1 \frac{L}{D} \frac{8Q_1^2}{g\pi^2 D^4} + \left(2K_{T\,Bend} + 2K_{elbow} + 2K_{contraction} + f_3 \frac{L_3}{D}\right) \frac{8Q_3^2}{g\pi^2 D^4} \quad (3)$$

Isolate Q_3 and Q_2

$$Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma} - f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D^4}}{\left(2K_{T_s} + f_2 \frac{L_2}{D_2}\right) \frac{8}{g\pi^2 D_2^4}}} \qquad Q_3 = \sqrt{\frac{\frac{\Delta P}{\gamma} - f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D^4}}{\left(2K_{T_B} + 2K_{elbow} + 2K_{cont.} + f_3 \frac{L_3}{D_3}\right) \frac{8}{g\pi^2 D_2^4}}}$$

* Move to excell for itteration

$$f = \frac{.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{R_N^{.9}}\right)\right]^2} \qquad N_R = \frac{V \cdot D}{\nu} = 4 \cdot Q/\pi/\nu/D_1$$

~~* Realized the diameter [illegible] was not the D of the pipe. Excel adjusted accordingly~~

They're the same

Brains fried after hours

$$\boxed{Q_1 = .1192,\ Q_2 = .0673,\ Q_3 = .0519} \quad \text{All } ft^3/s$$