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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Summer 2024
Test 2

Take home – Due Sunday June 30th 2024 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.
3. There are 2 problems to solve, each worth (90/2) 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 CANVAS. You must submit only one file and it has to be a pdf file. For the ePortfolio you are also supposed to upload this artifact to your Google drive. When you are done solving the test, please go ahead and upload it now before you forget.
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 it is ODU related.

Problem 1 Given: (pipe lengths $L_A = 10m, L_B = 9m, L_C = 10m$) (Elevations $Z_1 = 4m, Z_2 = 3m$)

Pipe diameter = $\frac{3}{4}$ in = 0.01905 m

Solution:

what I know

- Filled system with water
- Minor losses
- Friction factor is 0.02
- minor loss K for half open gate valve is 5

Step 1 Cross sectional Area

$A = \pi \left(\frac{D}{2}\right)^2 \Rightarrow \pi \left(\frac{0.01905}{2}\right)^2 = 2.85E^{-4}\ m^2$

Step 2 Energy between points 1 and 2

use Bernoulli equation

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

* Note given: $P_1 = P_2$ assume atmospheric pressure at both sides $V_1 = V_2$

$Z_1 - Z_2 = h_f + h_m \Rightarrow 4 - 3 = h_f + h_m \Rightarrow 1 = h_f + h_m$

Step 3: Headloss

$h_f = f \frac{L}{D} \frac{V^2}{2g}$

Total pipe length $\Rightarrow L = L_A + L_B + L_C = 10 + 9 + 10 = 29m$

* Frictional Headloss

$h_f = 0.02 \times \frac{29}{0.01905} \times \frac{V^2}{2 \times 9.81}$

Minor Head loss

$h_m = K \frac{V^2}{2g} \Rightarrow 5 \times \frac{V^2}{2 \times 9.81}$

Total Head Loss

$1=(0.02\times\frac{29}{0.01905}+5)\times\frac{V^2}{2\times9.81} \Rightarrow 1=30.44+5\times\frac{V^2}{19.62} \Rightarrow 1=35.44\left(\frac{V^2}{19.62}\right)$

$\Rightarrow V^2=\frac{1\times19.62}{35.44}=0.5536 \Rightarrow \sqrt{0.5536} \Rightarrow V=0.744\ m/s$

Step 4: Flow rate

$Q=A\times V \Rightarrow 2.85\times10^{-4}\times0.744=2.1204\times10^{-4}\ m^3/s \Rightarrow \boxed{0.212\ L/s}$

Step 5: check velocity criteria

V = 0.744 m/s

we know the velocity criterion $V<3m/s$ so this is satisfied

Step 6: the pressure at Exit of the tee

$\frac{P_1}{\rho g}+Z_1+\frac{V_1^2}{2g}=\frac{P_3}{\rho g}+Z_3+\frac{V_3^2}{2g}$ $+h_{f}+h_m$

we know $h_f+h_m=1m$

Subsitute into Bernoli equation

$\frac{P_1}{\rho g}+4=\frac{P_3}{\rho g}+0+1 \Rightarrow \frac{P_1}{\rho g}+4=\frac{P_3}{\rho g}+1 \Rightarrow \frac{P_3}{\rho g}=\frac{P_1}{\rho g}+3$

Assuming P_1 is atmospheric pressure it will be 0

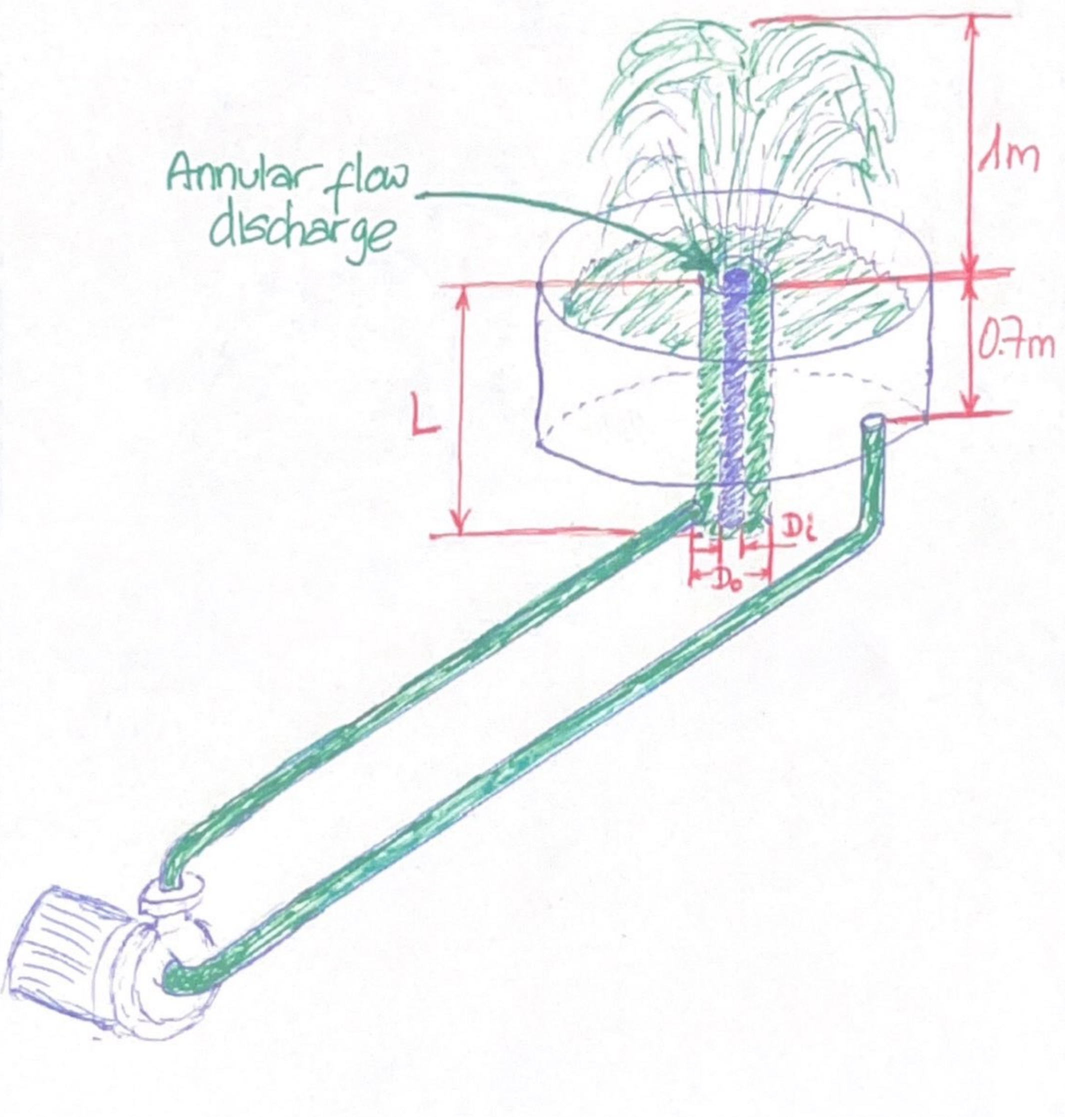
$P_1=0pa$

$\frac{0}{\rho g}+4=\frac{P_3}{\rho g}+1 \Rightarrow 4=\frac{P_3}{\rho g}+1 \Rightarrow \frac{P_3}{\rho g}=3 \Rightarrow P_3=3\rho g$

$\Rightarrow P_3=3\times1000\ kg/m^3\times9.81m/s^2=\boxed{29430pa}$

2. You are in charge of designing a new decorative water fountain at ODU. It consists of a water reservoir and piping to and from a pump as shown in the figure (please be aware that this is just a scketch, no real dimensions were intended). You are asked to used only PVC pipes (see Table G3). The outlet line from the pump is 18 m and the inlet line to the pump is 20 m. The outlet line leads to the bottom of an annular flow line. The expansion there has a loss of K=2 based on the kinetic energy before the expansion. The annular flow passage has a length L = 1.80 m and is bounded by D_o=10 cm and D_i=7cm (use hydraulic radius for the energy loss calculations of such annular flow passage. Check Chapter 9 and lecture notes). It is also made of PVC. There is negligible loss at the exit of the annulus, which is exposed to the atmosphere. Consider all other minor losses following what is on the sketch. What is the pump power required for the flow configuration shown? If the pump-motor combination has an efficiency of 92%, determine the electrical power requirements.

HINTS: (1) The flow rate should be enough so the water reaches 1 m as sketched. (2) Use the velocity criteria discussed in class to select the PVC pipe diameters.



Problem 2 Given: PVC pipes.

$L_{out} = 18m$, $L_{in} = 20m$ Annular flow passage

$L = 1.80m$, $D_o = 10cm = 0.10m$ $D_i = 7cm = 0.07m$

loss coefficient for expansion $K = 2$

Pump efficiency 42%, Required height of water jet 1m

Solution: Flow rate step 1

★ need to determine the velocity of the water jet that will achieve a height of 1m

$h = \frac{V^2}{2g}$

$V = \sqrt{2gh} \Rightarrow \sqrt{2 \times 9.81 \times 1} \Rightarrow \sqrt{19.62} = 4.429\ m/s$

we need Angular flow passage cross sectional area for Q

Step 2: Cross sectional Area

$A = \pi\left(\frac{D_o^2 - D_i^2}{4}\right) = \pi\left(\frac{0.10^2 - 0.07^2}{4}\right) = 0.004005\ m^2$

Step 3: Flow rate

$Q = A \times V \Rightarrow 0.00405 \times 4.43 = \boxed{0.0177\ m^3/s}$

step 4: Head loss

$h_f = f\frac{L}{D}\frac{V^2}{2g}$, ★ $D_h = 0.05m$

- Input pipe

$h_f = 0.02 \times \frac{20}{D_h} \times \frac{4.43^2}{2 \times 9.81} \Rightarrow 0.02 \times \frac{20}{0.05} \times \frac{4.43^2}{2 \times 9.81} = 8m$

- output pipe

$h_{fout} = 0.02 \times \frac{18}{D_{out}} \times \frac{4.43^2}{2 \times 9.81} \Rightarrow 0.02 \times \frac{18}{0.05} \times \frac{4.43^2}{2 \times 9.81} = 7.2m$

Minor head loss for expansion

$h_m = K\frac{V^2}{2g} \Rightarrow 2 \times \frac{4.43^2}{2 \times 9.81} \Rightarrow 2m$

total headloss

$h_{total} = h_{fL} + h_{fcat} + h_m \Rightarrow 8 + 7.2 + 2 = 17.2m$

Step 5: total Dynamic Head (TDH

$TDH = h_{static} + h_{total} \Rightarrow 1 + 17.2 = 18.2m$

Step 6: Determine the pump power

$P = \rho g Q \cdot TDH \Rightarrow 1000 \times 9.81 \times 0.0177 \times 18.2 \Rightarrow 3162.6W$

Step 7: the Electrical power requirements

$P_{elec} = \frac{P}{Efficiency} \Rightarrow \frac{3162.6}{0.92} \Rightarrow 3437.6W$