Name: Daniel Baxl

MET 330 Fluid Mechanics
Dr. Orlando Ayala
Summer 2023
Test 3

Take home – Due Sunday July 16th 2023 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.

3. There are 5 problems to solve, each worth (90/5) 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.

HONOR CODE

I pledge to follow the Honor Code and to obey all rules for taking exams and performing homework assignments as specified by the course instructor.

I understand that when asked to follow the Honor Code on exams or homework assignments I must follow the rules below.

1. When following the Honor Code a student must work entirely alone on exams.

2. When following the Honor Code a student may not share information about any aspect of the exam with other members of the class, other faculty members, or other people who has not already taken the exam this year, or its equivalent in future years.

3. When following the Honor Code a student must direct all questions concerning the exam or homework assignment to the course instructor or teaching assistant.

4. When following the Honor Code it is the student's responsibility to obtain clarification from the instructor if there are questions concerning the requirements of the Honor Code.

5. When following the Honor Code a student can only access websites related to ODU (such as Blackboard, etc.) while taking the test.

6. When following the Honor Code a student cannot access, neither ask for help, from websites such as coursehero, chegg, and any other similar website, while taking the test.

I understand that failure to follow this Honor Code imply that the professor will immediately report my case for academic dishonesty to the ODU Office of Student Conduct & Academic Integrity.

Student Name: David Baxter

Student Signature: David Baxter

Date: 7/16/23

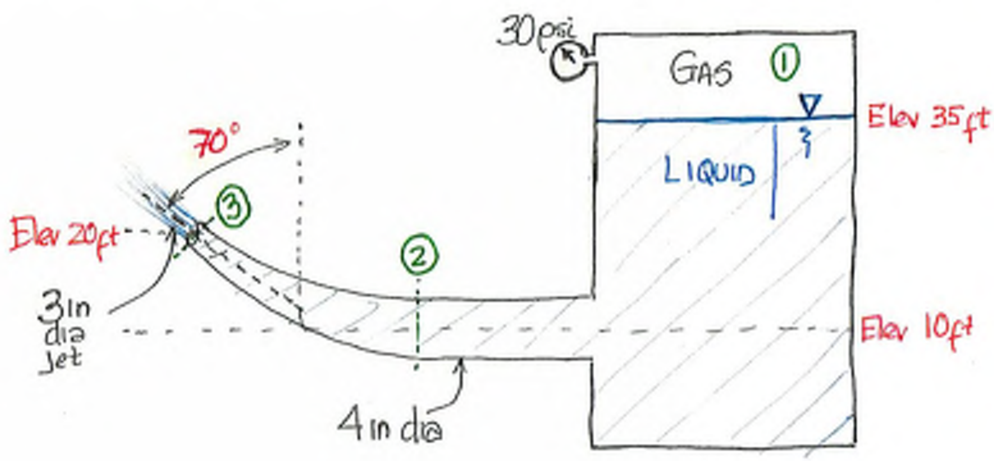
DIGIT	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
0	L_{bottom}=3ft L_{top}= 6ft	W=18ft Q=150ft³/s	Q=12000gpm D=24"	L_{curved}=10ft	D=600mm V=2.5m/s
2	L_{bottom}=3ft L_{top}= 3ft	W=18ft Q=350ft³/s	Q=12000gpm D=12"	L_{curved}=20ft	D=600mm V=1.0m/s
1	L_{bottom}=6ft L_{top}= 6ft	W=9ft Q=150ft³/s	Q=6000gpm D=24"	L_{curved}=30ft	D=300mm V=2.5m/s
4	L_{bottom}=3ft L_{top}= 6ft	W=9ft Q=350ft³/s	Q=6000gpm D=12"	L_{curved}=40ft	D=300mm V=1.0m/s
3	L_{bottom}=3ft L_{top}= 3ft	W=18ft Q=150ft³/s	Q=12000gpm D=24"	L_{curved}=50ft	D=600mm V=2.5m/s
6	L_{bottom}=6ft L_{top}= 6ft	W=18ft Q=350ft³/s	Q=12000gpm D=12"	L_{curved}=10ft	D=600mm V=1.0m/s
5	L_{bottom}=3ft L_{top}= 6ft	W=9ft Q=150ft³/s	Q=6000gpm D=24"	L_{curved}=20ft	D=300mm V=2.5m/s
8	L_{bottom}=3ft L_{top}= 3ft	W=9ft Q=350ft³/s	Q=6000gpm D=12"	L_{curved}=30ft	D=300mm V=1.0m/s
7	L_{bottom}=6ft L_{top}= 6ft	W=18ft Q=150ft³/s	Q=12000gpm D=24"	L_{curved}=40ft	D=600mm V=2.5m/s
9	L_{bottom}=3ft L_{top}= 6ft	W=18ft Q=350ft³/s	Q=12000gpm D=12"	L_{curved}=50ft	D=600mm V=1.0m/s

1. On this problem you will compute the moment at the base of a vertical pole. The moment is due to a 80 mi/h wind. The pole is composed by two cylinders connected to each other end to end. The lowest cylinder is of 4 in nominal schedule 40 steel pipe with a length of L_{bottom}. The other cylinder is made of 3 ½ in nominal schedule 40 steel pipe with a length of L_{top}. The temperature of the air is 71 F. Use the table below to get the values for L_{bottom} and L_{top}. Use the 1st (from right to left) digit of your UIN to use the table.

2. On this problem you will compute the liquid height in an open channel with a slope of 0.001. The channel has a rectangular shape and it is made of cement. The width of the channel is W and water runs through it at a flow rate of Q. Is the flow supercritical or subcritical? Use the table below to get the values for W and Q. Use the 2nd (from right to left) digit of your UIN to use the table.

3. On this problem you will compute the reading of a mercury manometer when an orifice plate of β=0.5 is used to measure a water flow rate of Q running through a pipe with a diameter D nominal, schedule 40 pipe. Use the table below to get the values for Q and D. Use the 3rd (from right to left) digit of your UIN to use the table.

4. On this problem you will compute the force on the curved pipe section shown in the figure. The length of that section is L_{curved}. For the force you will provide its magnitude and direction. Neglect any energy losses. The specific weigth of the liquid is γ=55 lb/ft³. Use the table below to get the values for L_{curved}. Use the 4th (from right to left) digit of your UIN to use the table.

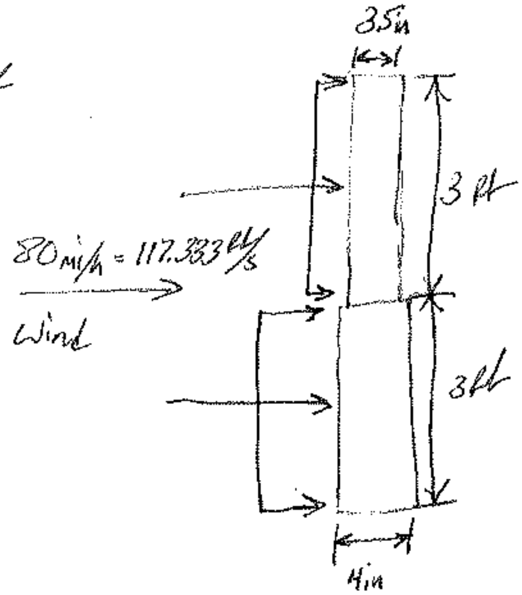


5. At the end of a steel pipe (E=2x10⁷ N/cm²) of internal diameter D, and thickness δ=10mm, there is a valve. The water velocity in the pipe is V. Calculate the pressure increment when the valve closes all of the sudden. Water compressibility module is E_o=2.03 x 10⁵ N/cm². Use the table below to get the values for D and V. Use the 5th (from right to left) digit of your UIN to use the table.

Q1)

Purpose

Compute the moment at the base of a vertical pole.



Design Considerations

- Incompressible fluids
- Isothermal process
- Steady state

Data and Variables

80 mi/h wind = 117.333 ft/s

lower cylinder = 4in sch 40 = 4.5in OD

$L_{Bottom} = 3ft$

Upper cylinder = 3.5 sch 40 = 4in O.D

$L_{Top} = 6ft$

$T_{air} = 71°F$

$\rho = 2.32 \times 10^{-3} \frac{slugs}{ft^3}$

$V = 1.64 \times 10^{-4}$

- First we find the Reynolds number for both sections

$$Re_{Top} = \frac{117.333(\frac{4}{12})}{1.64 \times 10^{-4}} = 238482 \qquad Re_{Bottom} = \frac{117.333(\frac{4.5}{12})}{1.64 \times 10^{-4}} = 268292$$

- Use chart and Reynolds number to find drag coefficient

$C_{D_{Top}} = 1.1 \qquad C_{D_{Bottom}} = 1.0$

$A_{Top} = \frac{4}{12} \times 3 = 1ft^2$

$A_{Bottom} = \frac{4.5}{12} \times 3 = 1.125 ft^2$

- Now we use the drag force equation to determine forces acting on the sections of the pole

$$F_D = C_D\left(\frac{\rho V^2}{2}\right)A$$

$$F_{Top} = 1.1\left(\frac{(2.32 \times 10^{-3} \frac{slugs}{ft^3})(117.333 \frac{ft}{s})^2}{2}\right)(1ft^2) = 17.57 lbf$$

$$F_{Bottom} = 1.0\left(\frac{(2.32 \times 10^{-3})(117.333)^2}{2}\right)(1.125) = 17.97 lbf$$

$$F = 17.57 + 17.97 = 35.54 lbf$$

• Now we use the force and apply it to the moment

$$M = \frac{1}{2} F_D \left(L_{Bottom} + \frac{L_{Top}}{2} \right) + \left(\frac{L_{Bottom}}{2} \right)$$

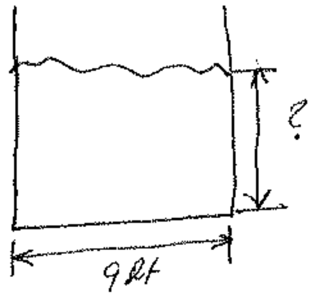
$$= \frac{1}{2}(35.54)\left(3 + \frac{3}{2}\right) + \left(\frac{3}{2}\right)$$

$$= 81.47 \text{ lb-ft}$$

(Q2)

Purpose

Compute the liquid height in an open channel.



Design considerations

- Incompressible fluid
- Isothermal process
- Steady state

Data and variables

Slope = 0.001

W = 9 ft

Q = 350 ft³/s

n = 0.017

- Use open channel flow rate equation

$$Q = \frac{1.49}{n} A S^{\frac{1}{2}} R^{\frac{2}{3}}$$

- rearrange to put all known values on the same side

$$AR^{2/3} = \frac{nQ}{1.49 S^{1/2}}$$

$$= \frac{0.017 (350 \text{ ft}^3/s)}{1.49 (0.001)^{1/2}}$$

$$= 126.28$$

- obtain equations for area and hydralic radius

$$A = 9h$$

$$WP = 9 + 2h$$

$$R = A/WP = \frac{9h}{9+2h}$$

$$126.28 = 2h \left(\frac{9h}{9+2h} \right)^{2/3}$$

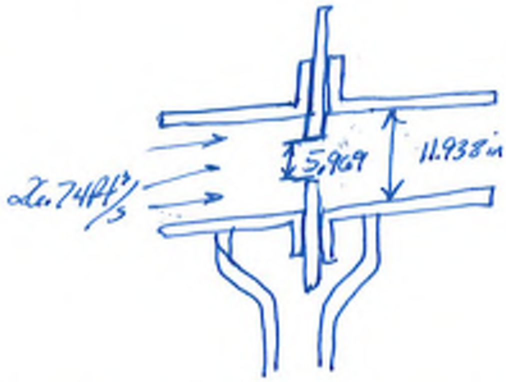
	A	B	C
1	h (ft)	LHS	%diff
2	5	63.20	-49.95%
3	6	85.13	-32.58%
4	7	109.06	-13.64%
5	7.6775	126.28	0.00%
6	8	134.74	6.70%
7	9	162.00	28.29%
8	10	190.70	51.01%
9	11	220.71	74.78%

h = 7.6775 ft

3)

Purpose

Compute the reading of a mercury manometer.



Design Consideration

- Incompressible fluid
- Isothermal process
- Steady state

Data and variables

Orific. plate $\beta = 0.5$

$Q = 12000 gpm = 26.74 ft^3/s$

$D = 12''$ $ID = 11.938 in$

$A = 0.7771 ft^2$

Water

$\gamma = 62.3 lb/f$

$\nu = 1.05 \times 10^{-5}$

mercury

$\gamma = 844.9 lb/ft^3$

- first I need to find diameter of orifice by using given $\frac{d}{D}$ ratio

$$0.5 = \frac{d}{D}$$

$$d = 0.5D$$

$$= 0.5(11.938)$$

$$= 5.969 in$$

- Information need to solve the problem

$A_{pipe} = 0.7771 ft^2$

$A_{orific} = \frac{\pi D^2}{4} = \frac{\pi\left(\frac{5.969}{12}\right)^2}{4} = 0.1943 ft^2$

$\frac{d}{D} = 0.5$

$R_e = \frac{VD}{\nu} = \frac{(34.41)\left(\frac{11.938}{12}\right)}{1.05 \times 10^{-5}} = 3260210.95$

$V = \frac{Q}{A} = \frac{26.74 ft^3/s}{0.7771 ft^2} = 34.41 ft/s$

- now I use the chart to find C

$C = 0.605$

- now that all the neccessary information has been found I take the orifice plate flow meter equation and rearrange it so that all known variables are on one side.

$$h = \frac{\left(\frac{Q}{A_1 \times C}\right)^2 \times \left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$$

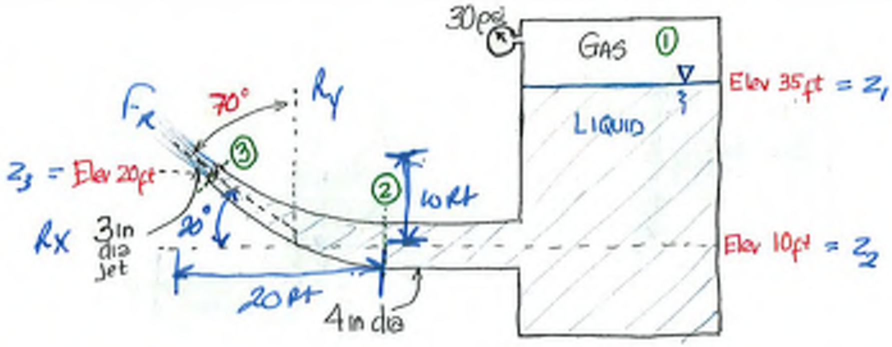
$$= \frac{\left(\frac{26.74}{0.7771 \times 0.605}\right)^2 \times \left(\left(\frac{0.7771}{0.1943}\right)^2 - 1\right)}{2(32.2)\left(\frac{844.9}{62.3} - 1\right)}$$

$$= 59.96 ft$$

4)

Purpose

Compute force on curved pipe section shown in figure



Design considerations

- Incompressible fluid
- Isothermal process
- Steady state
- neglect any energy losses

Data and variables

$L_{curved} = 20\,ft$

$\gamma_{liquid} = 55\,lb/ft^3$

$30_{psi} = 4320\,lb/ft^2$

Density $= 0.0033\,slugs/ft^3$

$A_3 = \frac{\pi D^2}{4}$

$= \frac{\pi\left(\frac{3}{12}\right)^2}{4}$

$= 0.0491\,ft^2$

$A_2 = \frac{\pi\left(\frac{4}{12}\right)^2}{4}$

$= 0.0873\,ft^2$

- First we start with Bernoullis equation to find the velocity at V_3

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g}^{0} + z_1 = \frac{P_3}{\gamma}^{0} + \frac{V_3^2}{2g} + z_3 + h_L^{0}$$

$$\frac{P_1}{\gamma} + z_1 = \frac{V_3^2}{2g} + z_3$$

$$V_3 = \sqrt{2g\left(\frac{P_1}{\gamma} + z_1 - z_3\right)}$$

$$= \sqrt{2(32.2)\left(\frac{4320}{55} + 35 - 20\right)}$$

$$= 73.35\,ft/s$$

- now we use continuity equation to find V_2

$$A_3V_3 = A_2V_2$$

$$V_2 = \frac{A_3V_3}{A_2}$$

$$= \frac{0.0491\,ft^2(73.35\,ft/s)}{0.0873\,ft^2}$$

$$= 41.25\,ft/s$$

- now we reapply Bernoullis equation to find P_2

$$\frac{P_3}{\gamma}^{0} + z_3 + \frac{V_3^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L^{0}$$

$$P_2 = \left(\left(\frac{V_3^2 - V_2^2}{2g}\right) + (z_3 - z_2)\right)\gamma$$

$$= \left(\left(\frac{(73.35)^2 - (41.25)^2}{2(32.2)}\right) + (20 - 10)\right)(55)$$

$$= 3691.71\,lb/ft^2 = 25.64\,psi$$

• next we find the Pressure at exit

$$P_3 = P_2 + \frac{\gamma(V_1^2 - V_2^2)}{2g}$$

$$= 3691.71\ \text{lb/ft}^2 + \frac{0.0662\ \text{lb/ft}^3\left(41.25\ \text{ft}^2/\text{s}^2 - 7.335\ \text{ft}^2/\text{s}^2\right)}{2\left(32.2\ \text{ft}/\text{s}^2\right)}$$

$$= 3685.64\ \text{lb/ft}^2$$

• now we use force equations for x and y direction

• for the x direction

$$F_x = \rho Q(V_{3x} - V_{2x})$$

$Q = AV$
$= 0.0491 \times 73.35$
$= 3.6015$

$$R_x - P_2A_2 + P_3A_3\cos 20° = \rho Q(-V_3\cos 20° - (-V_2))$$

$$R_x = P_2A_2 - P_3A_3\cos 20° - \rho QV_3\cos 20° + \rho QV_2$$

$$= (3691.71\ \text{lb/ft}^2)(0.0873\ \text{ft}^2) - (3685.64\ \text{lb/ft}^2)(0.0491\ \text{ft}^2)\cos 20° - (0.0033\ \text{slugs/ft}^3)(3.6015\ \text{ft}^3/\text{s})\cos 20° + (0.0033\ \text{slugs/ft}^3)(3.6015\ \text{ft}^3/\text{s})(41.25\ \text{ft/s})$$

$$= 152.71\ \text{lbf}$$

• For force in the y direction

$$F_y = \rho Q(V_{3y} - V_{2y})$$

$$R_y - P_2A_2\sin 20° = \rho Q(V_2\sin 20° - 0)$$

$$R_y = P_2A_2\sin 20 + \rho QV_2\sin 20$$

$$= (3691.71\ \text{lb/ft}^2)(0.0873\ \text{ft}^2)\sin 20 + (0.0033\ \text{slugs/ft}^3)(3.6015\ \text{ft}^3/\text{s})(41.25\ \text{ft/s})\sin 20$$

$$= 110.72\ \text{lbf}$$

• $F_r = \sqrt{R_x^2 + R_y^2}$

$$= \sqrt{152.71^2 + 110.72^2}$$

$$= 188.62\ \text{lbf}$$

(Q5)

Purpose

Calculate the pressure increment When the valve closes suddenly

Design Considerations

- Incompressible fluid
- Isothermic process
- Steady state

Data and Variables

steel pipe $E = 2\times10^7\ N/cm^2$

$ID = 300mm = 3cm$

thickness $\delta = 10mm = .1cm$

$V = 1m/s = 100cm/s$

Water compressibility module

$E_0 = 2.03\times10^5\ N/cm^2$

Water density at 25°C

$997\ kN/m^3 = 0.997\ N/cm^3$

- first we find C using equation

$$C = \frac{\sqrt{\frac{E_0}{\rho}}}{\sqrt{1+\frac{E_0 D}{E\delta}}}$$

$$= \frac{\sqrt{\frac{2.03\times10^5\ N/cm^2}{0.997\ N/cm^3}}}{\sqrt{1+\frac{(2.03\times10^5\ N/cm^2)(3cm)}{(2\times10^7\ N/cm^2)(.1cm)}}}$$

$$= 395.07\ N/cm^2$$

- now find ΔP using equation

$$\Delta P = \rho C V$$

$$= 0.997\ N/cm^3 (395.07\ N/cm^2)(100\ cm/s)$$

$$= 39,387.48\ N/cm^2$$

$$\approx 39.4\ Mpa$$