Test 1

Part A and Part B

My work on the problems

Name: ____.

MET 330 Fluid Mechanics
Dr. Orlando Ayala
Fall 2024
Test 1

Take home – Due Wednesday September 25th, 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, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. For the technical writing I will follow the attached rubric.

3. There are 2 main different parts, each one is worth 80/2 points.

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call 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 the test solution in only one file, and it has to be a pdf file. You must also submit the excel spreadsheet. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

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.

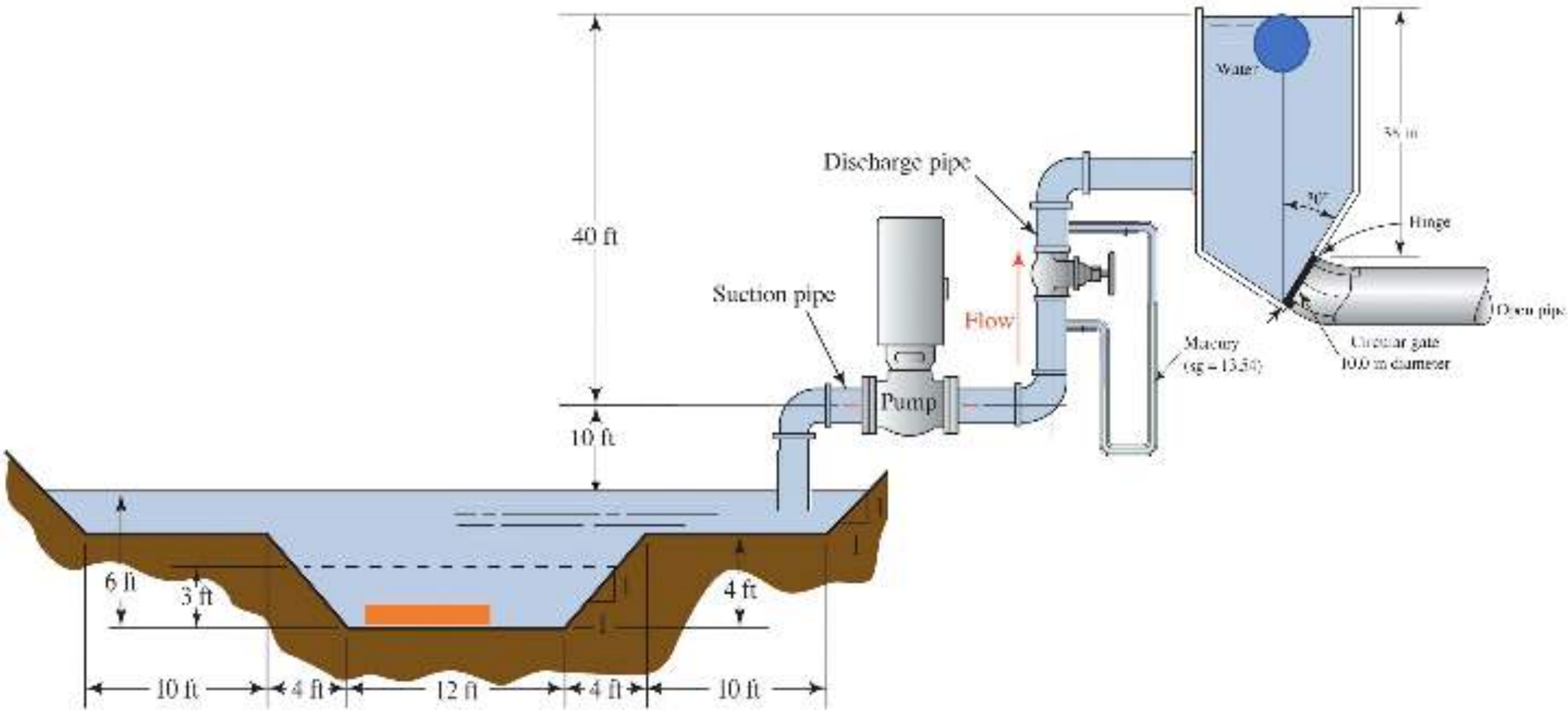
A company has hired you to design a system that delivers 60°F water from a large, open channel to another elevated one, as shown in the accompanying figure (NOTE: THE FIGURE IS NOT TO SCALE). The system must deliver 3.387 ft^3/s of water from the lower channel to the upper channel. The total length of the suction pipe is 11 feet, and the discharge pipe length is 2500 feet. For this task, you will focus on designing specific portions of the system.

a. To prevent spillage in the elevated channel, your client proposes the system shown in the figure. A circular gate seals the pipe to stop the flow, and when the water level reaches 38 inches, a fully submerged spherical buoy opens the gate.

- How large should the buoy be to perform this function? Ignore the weight of the circular gate and the buoy.
- Is the buoy stable while pulling the gate open? Why?
- You are required to perform all calculations by hand but must also create an Excel spreadsheet to automatically run the calculations. Ensure that the Excel results match your hand calculations. NOTE: When using trigonometric functions in Excel, be sure to use radians for angles.
- The company also wonders whether the 30^o degree angle of the circular gate was an appropriate decision. Find the best angle which will allow the use of a smaller buoy. To facilitate the answer of this equation, use the spreadsheet, with it run the calculations for different angles and make a table with the different angles and the corresponding buoy diameter. Finally, plot buoy size (diameter) vs. the angle of the gate. Would the stability change because of a smaller (or larger) buoy? Why?
- Review your results and provide comments in the "analysis" section of your solution. Why do the results make sense?

b. The company needs to monitor valve performance, and they propose using an on-site U-tube manometer (shown in the figure) to measure the pressure difference across the valve. The valve's pressure difference at a flow rate of 3.387 ft^3/s is 3.393 psi. The distance between the two taps where the manometer is connected is 20 inches.

- What will the U-tube manometer reading (i.e., deflection) be?
- What would be the pressure difference between the two taps if there is no flow?
- You are required to perform all calculations by hand but must also create an Excel spreadsheet to automatically run the calculations. Ensure that the Excel results match your hand calculations.
- Use the spreadsheet, with it run the calculations for different valve pressure difference and make a table with the different valve pressure differences and the corresponding mercury deflection. Finally, plot mercury deflection vs. valve pressure difference.
- Review your results and provide comments in the "analysis" section of your solution. Why do the results make sense?


Water
Hinge
Circular gate
Discharge pipe
Suction pipe
Flow
Pump
40 ft
10 ft
6 ft
3 ft
4 ft
10 ft
4 ft
12 ft
4 ft
10 ft

Problem solution rubric

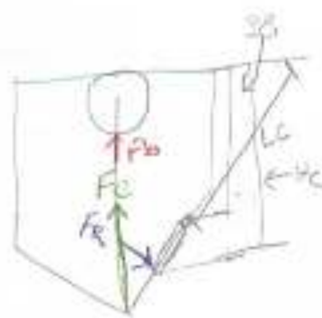
	Exceeds Standard 4 10 points	Meets Standard 3 7 points	Approaches Standard 2 4 points	Needs Attention 1 0 points
1. Purpose **5%**	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	The purpose of the section to be answered is partially identified, and is stated in a somewhat unclear manner.	The purpose of the section to be answered is erroneous or irrelevant.
2. Drawings & Diagrams **10%**	Clear and accurate diagrams are included and make the section easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
3. Sources **5%**	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	A few background sources are used and cited correctly, but some are not reputable sources.	Background sources are cited incorrectly.
4. Design considerations (assumptions, safety, cost, etc) **10%**	Design is carried out with applicable assumptions and full attention to safety and cost, etc.	Design is generally carried out with assumptions and attention to safety, cost, etc.	Design is carried out with some assumptions and some attention to safety, cost, etc.	Assumptions, safety and cost were ignored in the design.
5. Data and variables **5%**	All data and variables are clearly described with all relevant details.	All data and variables are clearly described with most relevant details.	Most data and variables are clearly described with most relevant details.	Data and variables are not described OR the majority lack sufficient detail.
6. Procedure **25%**	Procedure is described in clear steps. The step description is in a complete and easy to understand short paragraph.	Procedure is described in clear steps but the step description is not in a complete short paragraph.	Procedure is described in clear steps. The step description is in a complete short paragraph but it is difficult to understand.	Procedure is not described in clear steps at all.
7. Calculations **20%**	All calculations are shown and the results are correct and labeled appropriately. The units of all values are shown.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
8. Summary **5%**	Summary describes the design, the relevant information and some future implications.	Summary describes the design and some relevant information.	Summary describes the design.	No summary is written.
9. Materials **5%**	All materials used in the design are clearly and accurately described.	Almost all materials used in the design are clearly and accurately described.	Most of the materials used in the design are clearly and accurately described.	Many materials are described inaccurately OR are not described at all.
10. Analysis **10%**	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation.	The design is discussed and analyzed. No argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is not discussed and analyzed.

Spencer Reed
MET 330
Test 1

Part A:

Purpose: Determine how large the buoy needs to be to open the circular gate and determine if the buoy is stable.

Diagram:



Sources: Applied Fluid Mechanics 8th edition; Mott and Utner
Pierson Online

Design Considerations:

H_2O and Mercury do not mix
Water Temp. is 60°F
Static Fluid

Given Data:

$h = 38ft$ $T_w = 60°F$ $d_g = 10in$ $\gamma_w = 62.41\ lb/ft^3$ Table A-2

Materials:

H_2O
Cable
Buoy

$h_c = 38 + y \rightarrow 38 + \frac{9}{2}\cos 30° \rightarrow 38\ \frac{1}{2}\cos 30° = 42.33in$

$L_c = \frac{h_c}{\cos 30} \rightarrow \frac{42.33}{\cos 30} = 48.88in$

$F_R = \gamma_w h_c A \rightarrow 62.4\,lb/ft^3 \times 42.33in \times A$ Find A

$A = \frac{\pi d^2}{4} \rightarrow \frac{\pi 10^2}{4} = 78.54in^2$

$F_R = 62.4\,lb/ft^3 \times \frac{42.33\,in \times 78.54\,in}{1728\,in^3/ft^3} = 120.1\,lb$

Now I need the moment of inertia on the hinge

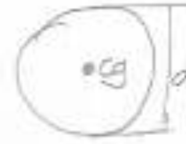
$I_c = \frac{\pi d^4}{64} \rightarrow \frac{\pi 10^4}{64} = 490.87in^4$

$L_p - L_c = \frac{I_c}{L_c A} \rightarrow \frac{490.87in^4}{48.88in^2 \cdot 78.54in^2} = 0.13in$

$\Sigma M_H = F_R(5in + (L_p - L_c)) - F_c \times 5in = 0$

$F_c = \frac{120.6\,lb \times 5.13in}{5in} = 123.74\,lb$

Now that we know the forces on the cable and the forces on the gate we need to find the force on the buoy and its size



Buoy is stable as it's a solid body that is fully submerged

$d_B = \left(\frac{6V_B}{\pi}\right)^{1/3}$ ∴ Find

$F_c = F_b = \gamma_w V_B$

$V_B = \frac{123.74\,lb}{62.4\,lb/ft^3} = 1.98ft^3$

$d_B = \left(\frac{6(1.98ft^3)}{\pi}\right)^{1/3} = 1.55ft$

$F_B = \gamma_w \times V_B \rightarrow 62.4\,lb/ft^3 \times 1.98ft^3 = 123.55\,lb$

Find CB location

$y_{cb} = \frac{1}{2}d_B \rightarrow \frac{1}{2}\,1.55ft = 0.775$

$h_c = 42.33in$

$L_c = 48.88in$

$A = 78.54in^2$

$F_R = 120.1\,lb$

$I_c = 490.87in^4$

$L_p - L_c = 0.13in$

$F_c = 123.74\,lb$

$V_B = 1.98ft^3$

$d_B = 1.55ft$

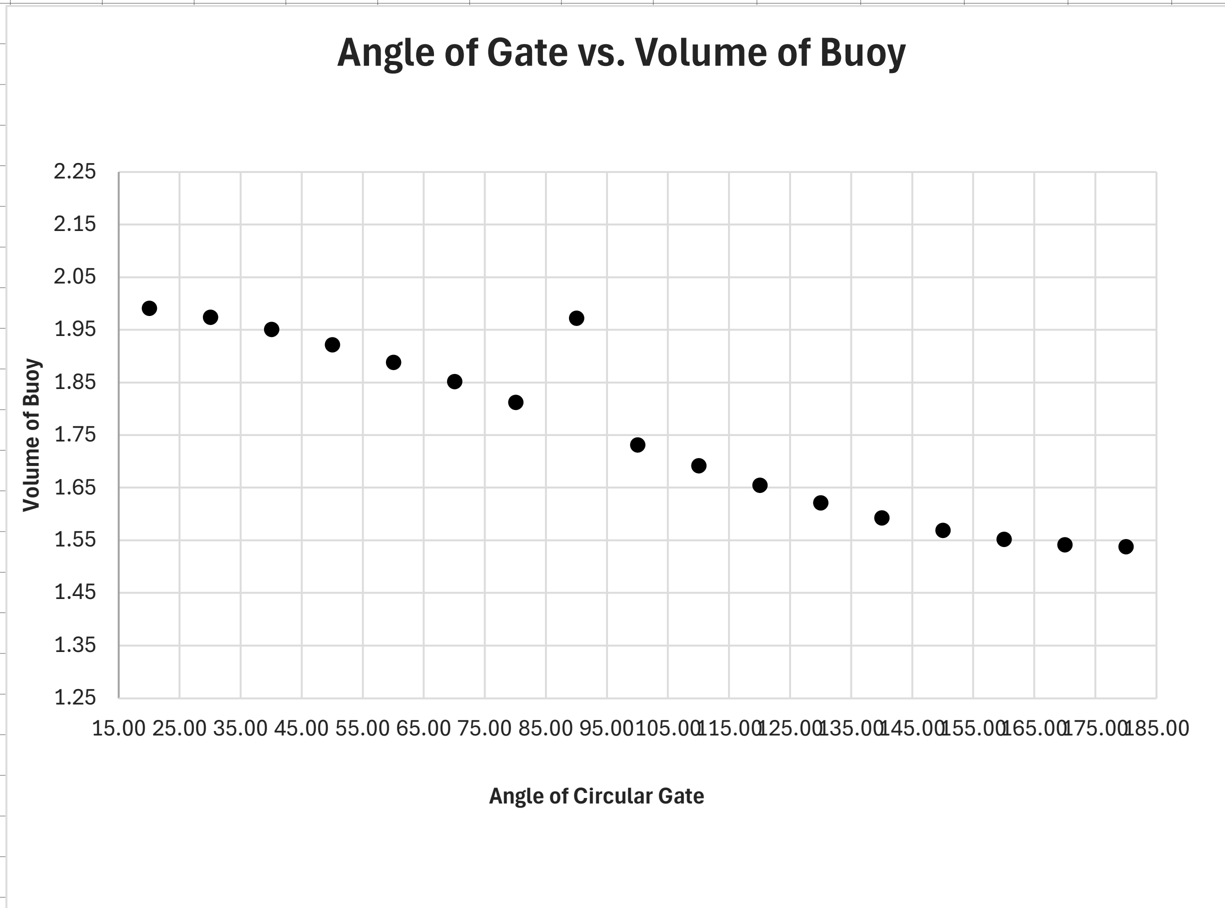
$F_B = 123.55\,lb$

$y_{cb} = 0.775ft$

$y_{cb} = y_{cg}$

Spencer Reed						
MET 330				**Given:**		
Test 1				pi =	3.141593	
				h =	38.00	in
				Angle =	30.00	deg
hc =	42.33	in		dg =	10.00	in
Lc =	48.88	in		rg =	5.00	in
Fr =	120.06	lb		cos30 =	0.87	
A =	78.54	in		Tw =	60.00	F
Igate =	490.87	in		dgate =	10.00	in
Lp - Lc =	0.13	in		yw =	62.40	ft^3
EMH =	123.20	lb				
Vd =	1.97	ft^3				
dbuoy =	1.56	ft^3				
ycb =	0.78	ft				
cgbuoy =	0.78	ft				

	20 Deg.	**30 Deg.**	**40 Deg.**	**50 Deg.**	**60 Deg.**	**70 Deg.**	**80 Deg.**	**90 Deg.**	**100 Deg.**	**110 Deg.**	**120 Deg.**	**130 Deg.**	**140 Deg.**	**150 Deg.**	**160 Deg.**	**170 Deg.**	**180 Deg.**
pi =	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142	3.142
h =	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00
Angle =	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00	130.00	140.00	150.00	160.00	170.00	180.00
dg =	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
rg =	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
cosX =	0.94	0.87	0.77	0.64	0.50	0.34	0.17	0.00	-0.17	-0.34	-0.50	-0.64	-0.77	-0.87	-0.94	-0.98	-1.00
Tw =	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
dgate =	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
yw =	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40	62.40
									Calculated								
hc =	42.70	42.33	41.83	41.21	40.50	39.71	38.87	38.00	37.13	36.29	35.50	34.79	34.17	33.67	33.30	33.08	33.00
Lc =	45.44	48.88	54.61	64.12	81.00	116.10	223.83	0	-213.83	-106.10	-71.00	-54.12	-44.61	-38.88	-35.44	-33.59	-33.00
Fr =	121.10	120.06	118.64	116.89	114.86	112.62	110.24	107.77	105.31	102.92	100.68	98.66	96.91	95.49	94.45	93.81	93.59
A =	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54	78.54
Igate =	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87	490.87
Lp - Lc =	0.14	0.13	0.11	0.10	0.08	0.05	0.03	62.50	-0.03	-0.06	-0.09	-0.12	-0.14	-0.16	-0.18	-0.19	-0.19
EMH =	124.28	123.20	121.74	119.95	117.87	115.56	113.11	123.08	108.04	105.59	103.28	101.20	99.40	97.94	96.87	96.21	95.99
Vd =	1.99	1.97	1.95	1.92	1.89	1.85	1.81	1.97	1.73	1.69	1.66	1.62	1.59	1.57	1.55	1.54	1.54
dbuoy =	1.56	1.56	1.55	1.54	1.53	1.52	1.51	1.56	1.49	1.48	1.47	1.46	1.45	1.44	1.44	1.43	1.43
ycb =	0.78	0.78	0.78	0.77	0.77	0.76	0.76	0.78	0.74	0.74	0.73	0.73	0.72	0.72	0.72	0.72	0.72
cgbuoy =	0.78	0.78	0.78	0.77	0.77	0.76	0.76	0.78	0.74	0.74	0.73	0.73	0.72	0.72	0.72	0.72	0.72


Angle of Gate vs. Volume of Buoy
Volume of Buoy
2.25
2.15
2.05
1.95
1.85
1.75
1.65
1.55
1.45
1.35
1.25
15.00 25.00 35.00 45.00 55.00 65.00 75.00 85.00 95.00 105.00 115.00 125.00 135.00 145.00 155.00 165.00 175.00 185.00
Angle of Circular Gate

Part A Analysis

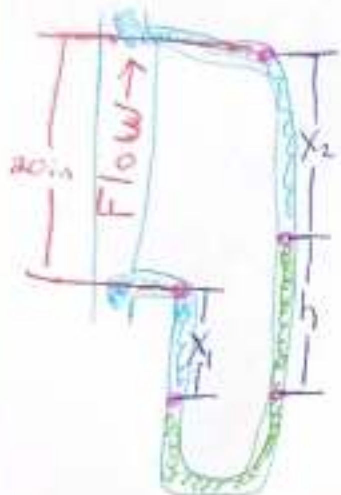
The buoy is stable while pulling the gate. This is because the buoy is completely submerged and solid making it naturally stable. When calculating the different angles of the gate there is some correlation to the size of the buoy. However, it does not change much. To use a smaller buoy the angle of the gate must be larger. This is demonstrated in the graph. As the angle of the gate increases then the volume of the buoy decreases. After 170 degrees the volume of the buoy does not change. The gate would also be vertical. Since the buoy pulls vertically it would not open. The force on the gate decreases as the angle gets smaller due to less force being put on the gate.

Spencer Reed
MET 330
Test 1

Part B:

Purpose:

Find the displacement (h) of mercury



Sources:

Applied Fluid Mechanics 8th edition; Mott and Utner. Pearson Online

Given Data:

$\Delta p = 3.393$ psi

$sg_m = 13.54$
$\gamma_m = 844.9\ lb/ft^3$
Table B-2

$sg_w = 1$
$\gamma_w = 62.4\ lb/ft^3$
Table A-2

Design Considerations:

Mercury + H_2O Do Not Mix
$T_w = 60°F$
P_A is higher than P_B due to valve

Materials:

H_2O + Mercury

Procedure + Calcs:

First I need to setup the problem adding or subtracting each point times the label at that point.

$$P_A + \gamma w(x_1) - \gamma m(h) - \gamma w(x_2) = P_B$$

P_2 P_4 P_5

$P_1 = P_A$ — $P_2 = P_3$ — $P_5 = P_B$ all because they're on the same horizontal

Looking at the points in comparison to the x_1, x_2 and h values I can determine

$$x_2 + h = x_1 + 20$$

$$x_1 - x_2 = 20 - h$$

We need to solve for h in the following eq.

$$P_A + \gamma w x_1 - \gamma m h - \gamma w x_2 = P_B$$

$$P_B - P_A = \gamma w x_1 - \gamma m h - \gamma w x_2$$

$$\Delta P = \gamma w (x_1 - x_2) - \gamma m h$$

$$\Delta P = \gamma w (20 - h) - \gamma m h$$

$$\Delta P = \gamma w 20 - \gamma w h - \gamma m h$$

$$\Delta P = \gamma w 20 - h(\gamma w - \gamma m)$$

solve for

$$\frac{\Delta P - \gamma w 20}{\gamma w - \gamma m} = \frac{-h(\gamma w - \gamma M)}{\gamma w - \gamma m}$$

$$\frac{\Delta P - \gamma w 20}{\gamma w - \gamma m}$$ ← insert values

Convert to lb/ft^2

$$\frac{3.393\,psi - 62.4\,lb/ft^3(20\,in)}{62.4\,lb/ft^3 - 844.9\,lb/ft^3}$$

$$3.393\,psi \times \frac{144\,lb/ft^2}{1\,psi} = 488.59\,lb/ft^2$$

$$20\,in \times \frac{1\,ft}{12\,in} = 1.667\,ft$$

Substitute in

$$-h = \frac{488.59\,lb/ft^2 - 62.4\,lb/ft^3(1.667\,ft)}{62.4\,lb/ft^3 - 844.9\,lb/ft^3}$$

$$-h = \frac{384.6}{-782.5}$$ $$-h = -0.49\,ft$$

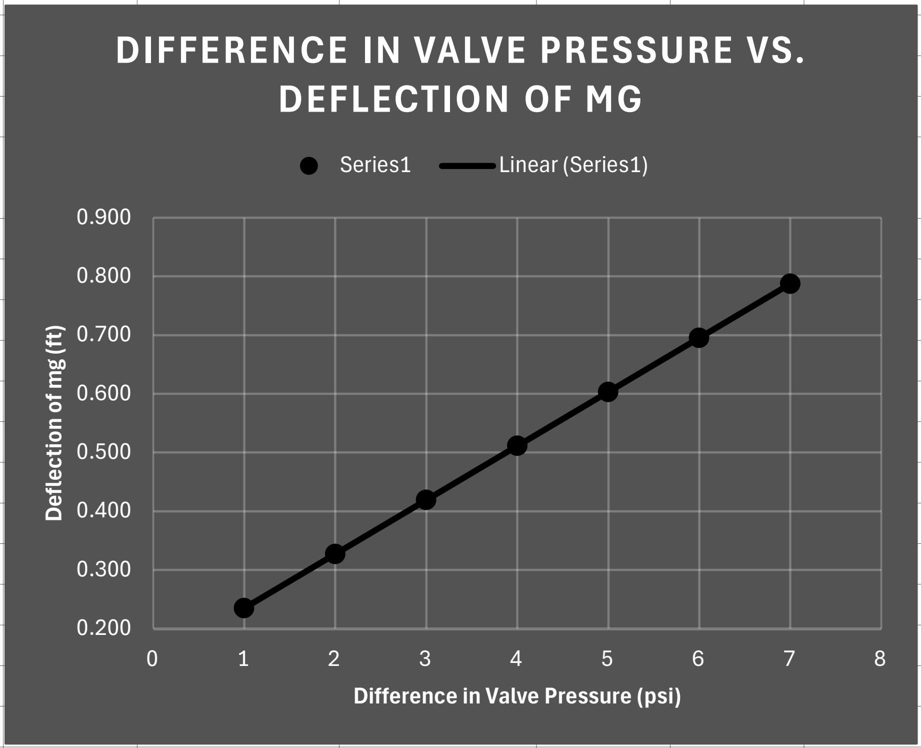
$\times -1$ $\times -1$

$h = 0.49\,ft$ of deflection

Increment of Pressure Equation =	Pa+yw(x1)-ym(h)-yw(x2)=Pb	
Convert 20in to ft	1.667	ft
3.393psi to lb/ft^2	488.592	lb/ft^2
Final Equation	h =((Pb-Pa)-yw(20))/(yw-ym)	ft
h=	0.491491374	ft
Given Data:		
Pb-Pa =	3.393	psi
sgm =	13.54	
sgw =	1	
ym =	844.9	lb/ft^3
yw =	62.4	lb/ft^3
Tap distance	20	in

Given Data:		
Pb-Pa =	3.393	psi
sgm =	13.54	
sgw =	1	
ym =	844.9	lb/ft^3
yw =	62.4	lb/ft^3
Tap distance	20	in
Convert 20in to ft	1.667	ft
3.393psi to lb/ft^2	488.592	lb/ft^2
Final Equation	h =((Pb-Pa)-yw(20))/(yw-ym)	ft
h=	0.491491374	ft
in to ft conv. Factor	0.08	
psi to lb/ft^2 conv. Factor	144	
2 psi	288	lb/ft^2
2.5psi	360	lb/ft^2
3psi	432	lb/ft^2
3.5psi	504	lb/ft^2
4psi	576	lb/ft^2
4.5psi	648	lb/ft^2
5psi	720	lb/ft^2

Deflection of mg in ft		
2 psi	0.235	ft
2.5 psi	0.327	ft
3 psi	0.419	ft
3.5 psi	0.511	ft
4 psi	0.603	ft
4.5 psi	0.695	ft
5 psi	0.787	ft



Analysis Part B

When solving this U-Manometer problem there is a direct correlation between the distance between taps and distances between the points. We see this as add or subtract the points along the manometer to create an equation. With some manipulation you can eliminate a lot of the like terms. The deflection on this problem is small. By increasing or decreasing the pressure the deflection will change based on a higher or lower number than our problem started with. The smaller the difference of pressure across the taps the smaller the deflection and vice versa.