Test 2

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

Take home – Due Wednesday October 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, 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 3 main different parts, each one is worth 80/3 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.

The company that hired you to start the design of the system in the figure is happy with your work (NOTE: THE FIGURE IS NOT TO SCALE). The want to hire you again to continue with the design. Let us remember that the system is to deliver 60 °F water from the lower open channel to the upper open channel at a rate of 3.387 ft³/s. They want you to complete the following tasks:

a. Design the pumped pipeline system, for that:
- First select a pipe diameter from table F1 in the appendix of the book. The pipe diameter is such that the fluid flow velocity in the pipe is close to 3 m/s.
- Determine the required pump power (in HP), assuming a pump efficiency of 60%. The total suction pipe length is 11 ft, while the total discharge pipe length is 2500 ft. Neglect the losses due to all fittings.
- Compute the pressure at the pump inlet and at the pump outlet.
- 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.
- The company also wonders whether the selected pipe was a good choice. To facilitate the answer to this equation, use the spreadsheet to run the calculations for different commercial pipe diameters. Then, make a table with the different commercial pipe internal diameters , and the corresponding pump powers, and inlet and outlet pump pressures. Finally, plot pump power vs. pipe diameter and inlet and outlet pump pressures vs. pipe diameter.
- Review your results and provide comments in the "analysis" section of your solution. Why do the results make sense?

b. Your client also proposes to use a flow nozzle to measure the flow. For a nozzle diameter to pipe diameter ratio of 0.5:
- What is the pressure drop across the nozzle?
- With this addition to the system (which is an additional energy loss), by how much (show it in percentage) would the pump power increase?

  Please note that the equation for pressure drop you derived for the 1st question is the total pressure drop that includes the pressure drop due to the fluid acceleration and the pressure drop due to energy losses. To get the portion of the energy loss you could use this equation:

  $$\Delta p_{loss} = (1 - C^2)\Delta p_{total}$$

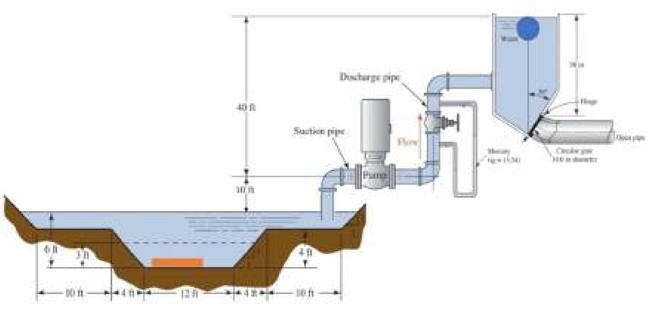
  where Δp_{total} is what you calculated for the 1st question.

  NOTE: If you derive this equation for Δp_{loss}, I will give you 5 extra points.

- 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 nozzle diameter to pipe diameter ratio and make a table with the different nozzle diameter to pipe diameter

ratios and the corresponding pressure drop across the nozzle. Finally, plot pressure drop across the nozzle vs. nozzle diameter to pipe diameter ratio.
- Review your results and provide comments in the "analysis" section of your solution. Why do the results make sense?

c. For a good working system, the amount of pumped water should not be too much to dry the lower open channel. The company wants to know whether the amount of pumped water is negligible compared to the total flow rate running through the lower open channel. Please note that this is a natural channel with light brush and its average slope is 0.00015.
- Compute the flow rate running through the lower open channel.
- Compute the percentage of pumped water flow with respect to the lower open channel 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 total water elevation in the lower open channel (go from 4 ft to 8 ft) and make a table with the different total water elevations and the corresponding percentage of pumped water flow. Finally, plot percentage of pumped water flow vs. water elevation.
- Review your results and provide comments in the "analysis" section of your solution. Why do the results make sense?



Problem solution rubric

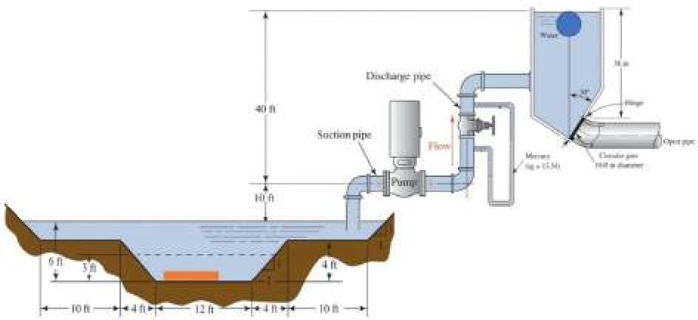
	Exceeds Standard	Meets Standard	Approaches Standard	Needs Attention
	4	3	2	1
	10 points	7 points	4 points	0 points
1. Purpose 5%	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	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 15%	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	The design is discussed and analyzed. Argumentative	The design is discussed and analyzed. Argumentative	The design is discussed and analyzed. No argumentative	The design is not discussed and analyzed.

10%	predictions are made about what might happen in case of change in the operation and how the design could be change.	predictions are made about what might happen in case of change in the operation.	predictions are made about what might happen in case of change in the operation and how the design could be change.	

Part A

Purpose: the purpose of this part is to find the correct diameter of the pipe that allowed the system to have a specific velocity, with that diameter calculate the pump power in the system, calculate the pressure coming in and out of the pump. And make sure all the calculation made are correct when putting in the excel and plotting the information calculated.

Drawing *:*



Source: Robert Mott & Joseph Untener. Applied Fluid Mechanics, 8th edition. Person

Design Considerations:
- Normal atmospheric conditions
- Incompressible fluids
- Isothermal conditions

Materials:
- Water @60F
- Air @ 60F
- Steel pipe

Data and Variables:
- Mass flow = 3.387 ft3/s
- L suction pipe= 11in
- L discharge pipe = 2500 feet
- Velocity of flow = 3 m/s
- Gama Water= 62.4 lb/ft3
- Efficiency of pump = 60%

Procedures:
Calculate the required diameter, based on the flow and velocity provided;
Find the correct diameter of pipe in the F1 table on the back of the book;
Calculate the values of hA and hL, so then we are able to get the pump power;
With the value of the power of the pump calculate the pressure in and out of the pump;

Calculations:

$T = 60°F$

$Q = 3.387\ ft^3/s = 0.096\ m^3/s$

$Q = VA \rightarrow A = Q/V$

$\pi r^2 = \frac{0.096}{3} \rightsquigarrow r = 0.1\ m$

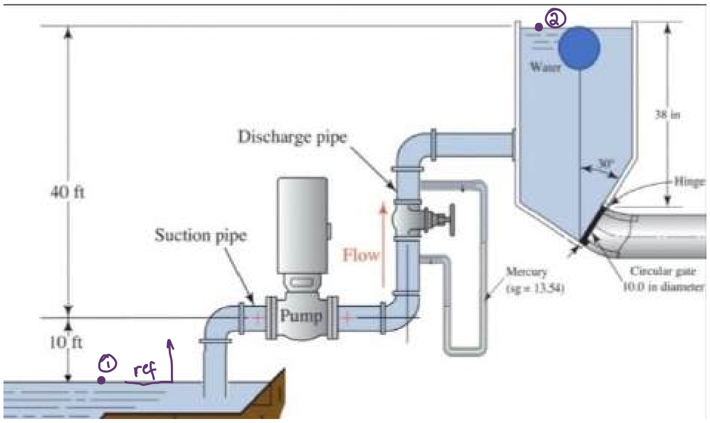
$\therefore d = 0.2m$ or $200mm$

$V = 3\ m/s \rightarrow 9.84\ ft/s$

based in the table F1 the pipe chosen

should be 8 in schedule 40 pipe, which the inside should be the schedule 40 pipe, which the inside

diameter gets the closer to 200 mm, 202.7 mm.



Using the following points, calculate the value of hA and hL:

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

$$h_A = z_2 - z_1 + h_L$$

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$$

$$Re = \frac{\rho V D}{\mu} = \frac{1.94(9.84)(0.6651)}{2.35 \times 10^{-5}} = 540276 > 2100$$

$\therefore$ turbulent flow

$$f = 0.25 \Big/ \left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2$$

$$\frac{D}{\varepsilon} = \frac{0.6651}{1.5 \times 10^{-4}} = 4434$$

$$f = 0.25 \Big/ \left[\log\left(\frac{1}{3.7(4434)} + \frac{5.74}{(540276)^{0.9}}\right)\right]^2$$

$$f = 0.0156$$

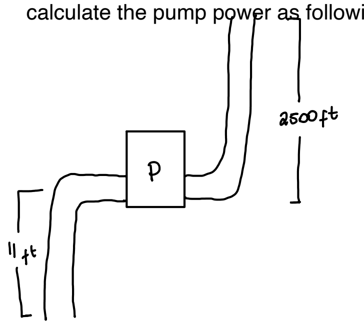
$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g} = 0.0156 \times \frac{50}{0.6651} \times \frac{9.84^2}{2(32.17)}$$

$$h_L = 1.765$$

$$h_A = z_2 - z_1 + h_L = 50 - 0 + 1.765$$

$$h_A = 51.765$$

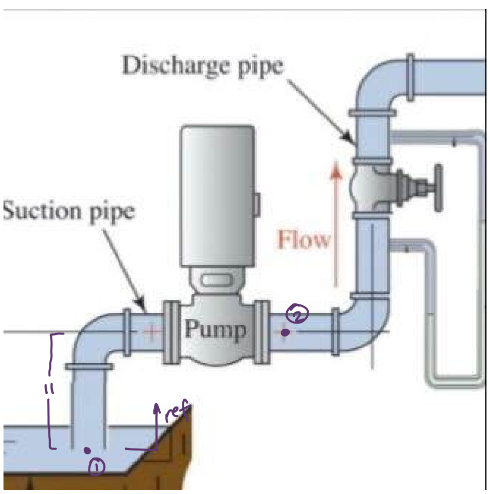
Now with the values of hA and hL, and using the efficiency provided in the problem, 60%. We calculate the pump power as following.



$$\mathbb{P} = \frac{\gamma Q h_A}{\eta}$$

$$\mathbb{P} = \frac{62.4\ (3.387) 51.765}{0.6} = 18234.12\ ft \cdot lb/s \rightarrow 33.15\ HP$$

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



With the points showed in the picture above, and the pump power calculated, we are able to calculate this pressures in and out of the pump in the system

$$\mathbb{P} = \Delta P \times Q$$

$$18234.12 = (P_1 - P_2)\ 3.387$$

$$P_1 = \frac{18234.12}{3.387} + P_2 \rightsquigarrow 5383.5 + P_2$$

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

$$51.765 + \frac{5383.5 + P_2}{62.4} + \frac{9.84^2}{2(32.17} = \frac{P_2}{62.4} + \frac{9.84^2}{2(32.17)} + 11 + 1.765$$

$$\frac{(62.4)\,51.765 - 11 - 1.765 + 53.835}{2} = P_2$$

$P_2 = 169182$

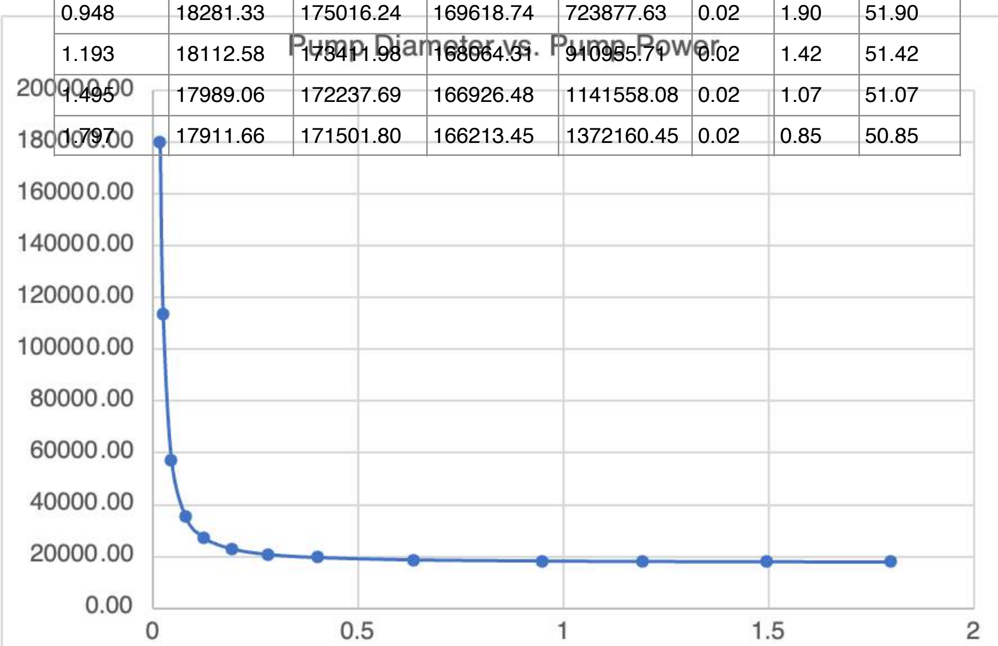
$\therefore$

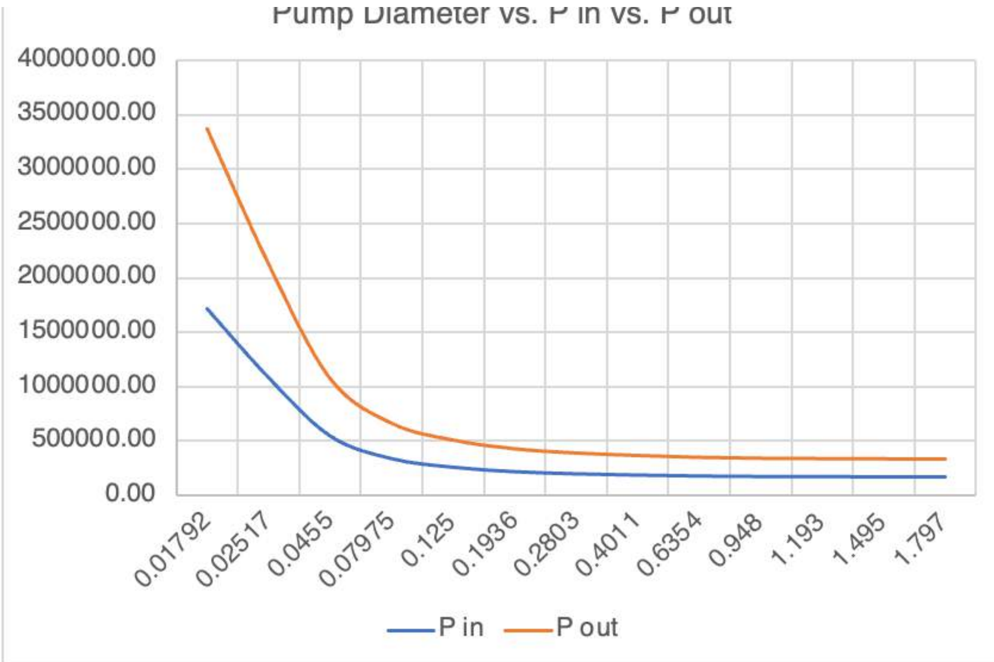
$P_1 = 5383.5 + P_2 \rightarrow 5383.5 + 169182$

$P_1 = 174565.5$

Calculating, tabulating And plotting the results in excel, with different pipes diameter. we have the following table and graph below.

Pump Diameter (ft)	Pump Power	P in	P out	Re	f	Hl	Ha
0.01792	179986.54	1712337.76	1659197.36	13683.43	0.11	460.97	510.97
0.02517	113541.48	1080648.60	1047125.88	19219.41	0.09	272.33	322.33
0.0455	57377.23	546698.55	529758.12	34743.07	0.07	112.89	162.89
0.07975	35463.30	338364.21	327893.79	60895.82	0.05	50.68	100.68
0.125	27189.96	259710.11	251682.37	95448.00	0.05	27.19	77.19
0.1936	22906.62	218988.62	212225.52	147829.86	0.04	15.03	65.03
0.2803	20847.19	199409.77	193254.71	214032.60	0.03	9.18	59.18
0.4011	19633.55	187871.77	182075.03	306273.54	0.03	5.74	55.74
0.6354	18727.03	179253.53	173724.44	485181.27	0.03	3.16	53.16
0.948	18281.33	175016.24	169618.74	723877.63	0.02	1.90	51.90
1.193	18112.58	173411.98	168064.31	910955.71	0.02	1.42	51.42
1.495	17989.06	172237.69	166926.48	1141558.08	0.02	1.07	51.07
1.797	17911.66	171501.80	166213.45	1372160.45	0.02	0.85	50.85





Analysis:
After tabulating and running the calculations through excel, the results make sense. The difference of pressure in the system is all cases have been higher in the pump then when exiting the pump, that is due to the energy losses. And the power in the pump increased due to smaller diameter of pipes, that happen since we need to keep the flow even with the smaller diameter, the velocity that the water is moving needs to be higher.

Part B

Purpose: the purpose of this part is to calculate the pressure drop in a possible nozzle inserted in the system, with the nozzle, calculate the pressure difference in the system and what this pressure difference does to the pump power, calculating the percentage the power increases. Afterwards, plug all the calculations in excel to confurme them, again tabulating and ploting the results with different diameters of pipes and nozzles

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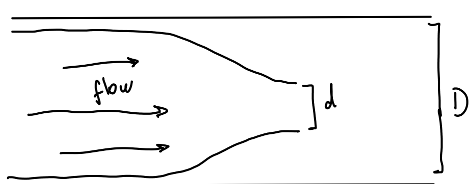


Source: Robert Mott & Joseph Untener. Applied Fluid Mechanics, 8th edition. Person

Design Considerations:
- Normal atmospheric conditions
- Incompressible fluids
- Isothermal conditions

Materials:
- Water @60F
- Air @ 60F
- Steel pipe

Data and Variables:
- Mass flow = 3.387 ft3/s
- Diameter pipe = 0.6651 ft
- Velocity of flow = 3 m/s

- Gama Water= 62.4 lb/ft3
- Diameter ratio = 0.5

Procedure:
Calculate the value of teh discharge coefficient;
Calculate the area of both pipe and nozzle;
Calculate the pressure difference on the nozzle;
Calculate the pressure difference losse;
With the pressure difference, calcualte the hL, reynolds number, flow and hA of the system;
Calculate the power after the addition of the nozzle, and the % difference in the system

Calculations:

For this case, we are using the values provided at part a of the exam. So the diameter of the pipe being used is 0.6651 feet.

The problem stated that the ratio for the nozzle and its diameter is 0.5.

So in this case, D2 is 0.33255

The equation for flowmeter of the nozzle is given by:

$$Q = CA_1 \sqrt{\frac{2g\frac{\Delta P}{\gamma}}{(A_1/A_2)^2 - 1}}$$

where:

$$\Delta P = \frac{\gamma}{2g} \frac{Q^2}{C^2 A_1^2}\left[\left(A_1/A_2\right)^2 - 1\right]$$

to find C:

$$C = 0.9975 - 6.53\sqrt{\frac{d/D}{Re}}$$

The ratio is stated and the problem: 0.5 and the value of Reynolds number was calculated on part one. We just have two put those values into the equation to find the discharge coefficient

$$Re = 540276$$

$$\text{so} \quad C = 0.9975 - 6.53\sqrt{\frac{0.5}{540276}}$$

$$C = 0.9912$$

With the value of the discharge coefficient calculated, now we calculate the area of both pipe and nozzle, so we are able to solve the equation.

$$A_1 = \frac{1}{4}\pi d_1^2 = \frac{1}{4}\pi (0.6651)^2$$

$$A_1 = 0.35$$

$$A_2 = \frac{1}{4}\pi d_2^2 = \frac{1}{4}\pi (0.33255)^2$$

$$A_2 = 0.087$$

Plugging those values in the formula above:

$$\Delta P = \frac{\gamma}{2g} \frac{Q^2}{C^2 A_1^2}\left[\left(A_1/A_2\right)^2 - 1\right]$$

$$\Delta p = \frac{62.4}{2(32.17)} \frac{3.387^2}{(0.9912)^2 (0.35)^2}\left[\left(\frac{0.35}{0.087}\right)^2 - 1\right]$$

$$\Delta p = 1403.69 \ lb/ft^2$$

Now calculating the change of the pump power in the system with the addition of this nozzle first we calculate the delta p loss for the system

$$\Delta P_{loss} = (1 - C^2)\,\Delta_{P_{total}}$$

where $\Delta_{P_{total}}$ was calculated on part A

so:

$$\Delta_{P_{total}} = 174565.5 - 169182 = 5383.5 \ lb/ft^2$$

$$\Delta_{P_{loss}} = (1 - 0.9912^2)\,5383.5$$

$$\Delta_{P_{loss}} = 94.3327$$

Finding now the hL for the losses due to the new nozzle, that's are due to a half of diameter nozzle in the system

$$h_{L_{Nozzle}} = f \times \frac{L}{D} \times \frac{v^2}{2g}$$

$$Re_{Nozzle} = \frac{\rho V D}{\mu} = \frac{1.94(9.84)(0.33255)}{2.35 \times 10^{-5}} = 270138.14$$

→ > 2100, so it's a turbulent flow

$$f = 0.25 \Big/ \left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2$$

$$\frac{D}{\varepsilon} = \frac{0.33255}{1.5 \times 10^{-4}} = 2217$$

$$f = 0.25 \Big/ \left[\log\left(1/3.7(2217) + 5.74/(270138.14)^{0.9}\right)\right]^2$$

$$f = 0.0182$$

$$V_N = Q/A = 3.387/0.087 = 38.93\ ft/s$$

$$h_{L_{Nozzle}} = f \times \frac{L}{D} \times \frac{v^2}{2g} = 0.0182 \times \frac{50}{0.33255} \times \frac{38.93}{2(32.17}$$

$$h_{L_{Nozzle}} = 1.61745$$

$$h_A = z_2 - z_1 + h_L + h_{L_{Nozzle}}$$

$$h_A = 50 + 51.765 + 1.61745 = 103.38$$

$$P = \frac{\gamma Q h_A}{\eta} = \frac{62.4\ (3.387)(103.38)}{0.6}$$

$$P_2 = 36415.40$$

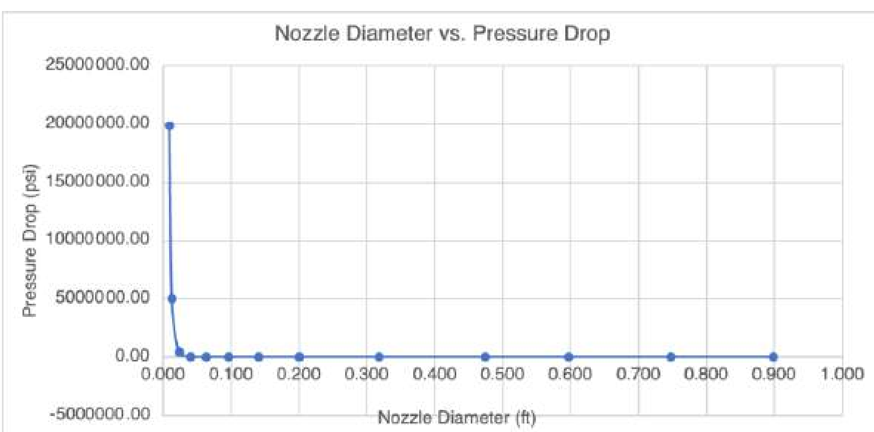
Now with the power of the system after putting the nozzle, we can calculate the difference in the power that is applied by the pump

$$\% \text{ difference} = \frac{P_2 - P_1}{P_1} \times 100$$

$$= \frac{36415.40 - 18234.12}{18234.12} \times 100 = 99.71\%$$

After calculating those by hand, we input the same calculations in excel to make sure they are correct. Then tableling different pipe diameters and nozzles, and how each on of them affects the power of the system and their respective % difference compared ot the system without the nozzle. The table and graphs are shown below:

Diameter	Nozzle diameter (ft)	Pressure Drop (psi)	Re	C	A1	A2
0.01792	0.009	19850683.45	13683.43	0.9580	0.000	0.000
0.02517	0.013	5035256.66	19219.41	0.9642	0.000	0.000
0.0455	0.023	463291.85	34743.07	0.9727	0.002	0.000
0.07975	0.040	48482.20	60895.82	0.9788	0.005	0.001
0.125	0.063	7971.31	95448.00	0.9826	0.012	0.003
0.1936	0.097	1377.07	147829.86	0.9855	0.029	0.007
0.2803	0.140	312.10	214032.60	0.9875	0.062	0.015
0.4011	0.201	74.19	306273.54	0.9892	0.126	0.032
0.6355	0.318	11.73	485257.63	0.9909	0.317	0.079
0.948	0.474	2.36	723877.63	0.9921	0.706	0.176
1.193	0.597	0.94	910955.71	0.9927	1.118	0.279
1.495	0.748	0.38	1141558.08	0.9932	1.755	0.439
1.797	0.899	0.18	1372160.45	0.9936	2.536	0.634

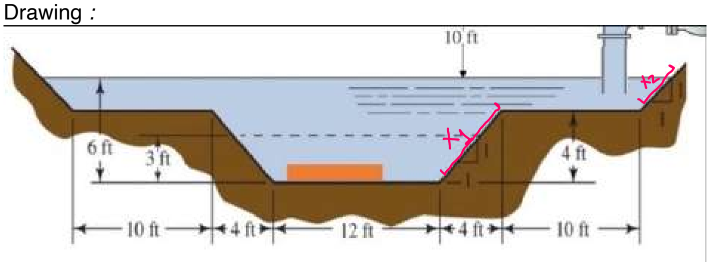


Analysis: The results make sense, as explained in the analysis part of part A, the additong of a nozzle makes the area of flow smaller, making then the power of the pump higher than the system without the nozzle. And the biggle the diameter the nozzle the smaller the pressure drop through that nozzle is

Part C

Purpose: the purpose of this part is to compute the flow in a open channel, and calculate what is the percentage of this flow that is pumped in the system. After calculatin those, tableling, and ploting the same calculations in excel.

Drawing :



Source: Robert Mott & Joseph Untener. Applied Fluid Mechanics, 8th edition. Person

Design Considerations:

- Normal atmospheric conditions
- Incompressible fluids
- Isothermal conditions
- Open channel with light brush

Materials:

- Water @60F
- Air @ 60F
- Light brush open channel

Data and Variables:

- Mass flow of upper system = 3.387 ft3/s
- Gama Water= 62.4 lb/ft3
- Slope = 0.00015
- n = 0.050

Procedure:

Basend on the picture porvided and it's dimensions, calculate the Area of the open channel, and it's wetter perimeter;
Calculate the hydrolical radius of the channel;
Calculate the water flow of the open channel;
Calcualte the percentage differenc of the open channel flow to the flow pumped in the system;

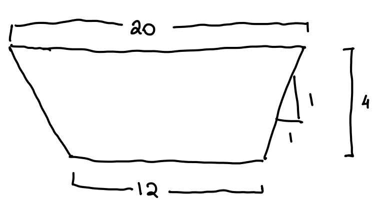
flow rate :

Calculations:

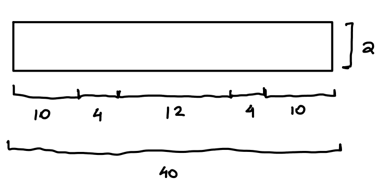
$$Q = \frac{1.49}{n} A S^{1/2} R^{2/3}$$

$$R = A / WP$$

Area

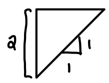


$$A_1 = \frac{b+B}{2} h = \frac{12+20}{2} (4) = 64 \, ft^2$$



$$A_2 = 40 \times 2 = 80 \, ft^2$$

2x :



$$A_3 \text{ and } A_4 = \frac{2 \times 2}{2} = 2 \text{ ft}^2$$

$$A_{total} = 2(2) + 80 + 64 = 148 \text{ ft}^2$$

now calculating the Weter perimeter

$$X_1^2 = 4^2 + 4^2$$

$$X_1 \approx 5.66$$

$$X_2^2 = 2^2 + 2^2$$

$$X_2 \approx 2.83$$

$$WP = 2(2.83) + 2(10) + 2(5.66) + 12$$

$$WP = 48.98$$

$$R = A / WP = 148 / 48.98$$

$$R = 3.02$$

After calculating the Hydraulic radius of the open channel, we can calculate the flow event with the values already provided and calculated.

$n = 0.050$ → provided on table 14.1 of the book

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

$$Q = \frac{1.49}{0.050} (148)(0.00015)^{1/2} (3.02)^{2/3}$$

$$Q = 112.85 \text{ ft}^3/s$$

Now to compute the % of pumped water with respect to the lower open channel flow we use the value of Q provided in part A of the exam.

$$\% \text{ difference} = \frac{Q_{open\ channel} - Q_{pump}}{Q_{pump}} \cdot 100$$

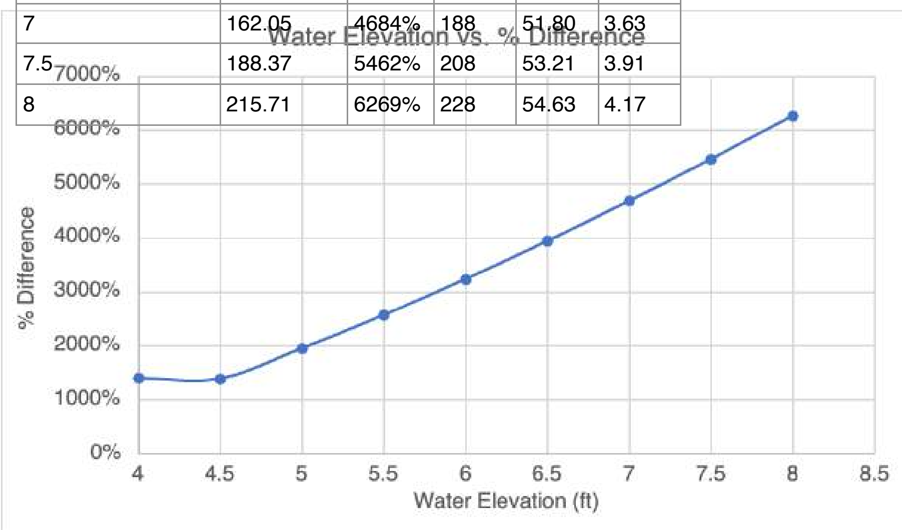
$$= \frac{112.85 - 3.387}{} \cdot 100$$

3.387

% difference = 3231.85 %

Now plotting the calculations and putting different water elevations, and how those would affect the flow and the percentage difference of system flow and the open channel flow:

Water Elevation (ft)	Water Flow	% diff	Area	WP	R
4	50.66	1396%	68	23.31	2.92
4.5	50.43	1389%	88	44.73	1.97
5	69.49	1952%	108	46.14	2.34
5.5	90.39	2569%	128	47.56	2.69
6	112.91	3234%	148	48.97	3.02
6.5	136.85	3940%	168	50.38	3.33
7	162.05	4684%	188	51.80	3.63
7.5	188.37	5462%	208	53.21	3.91
8	215.71	6269%	228	54.63	4.17



Analysis:
So we can see that the flow rate running through the open channel is way higher than the pump flow rate, which means that the pump flow rate is negligible compared to the total flow rate running through the lower open channel. It's also clear that the higher the water elevation the higher the water flow was, which also makes sense since that is more water going through the natural channel.