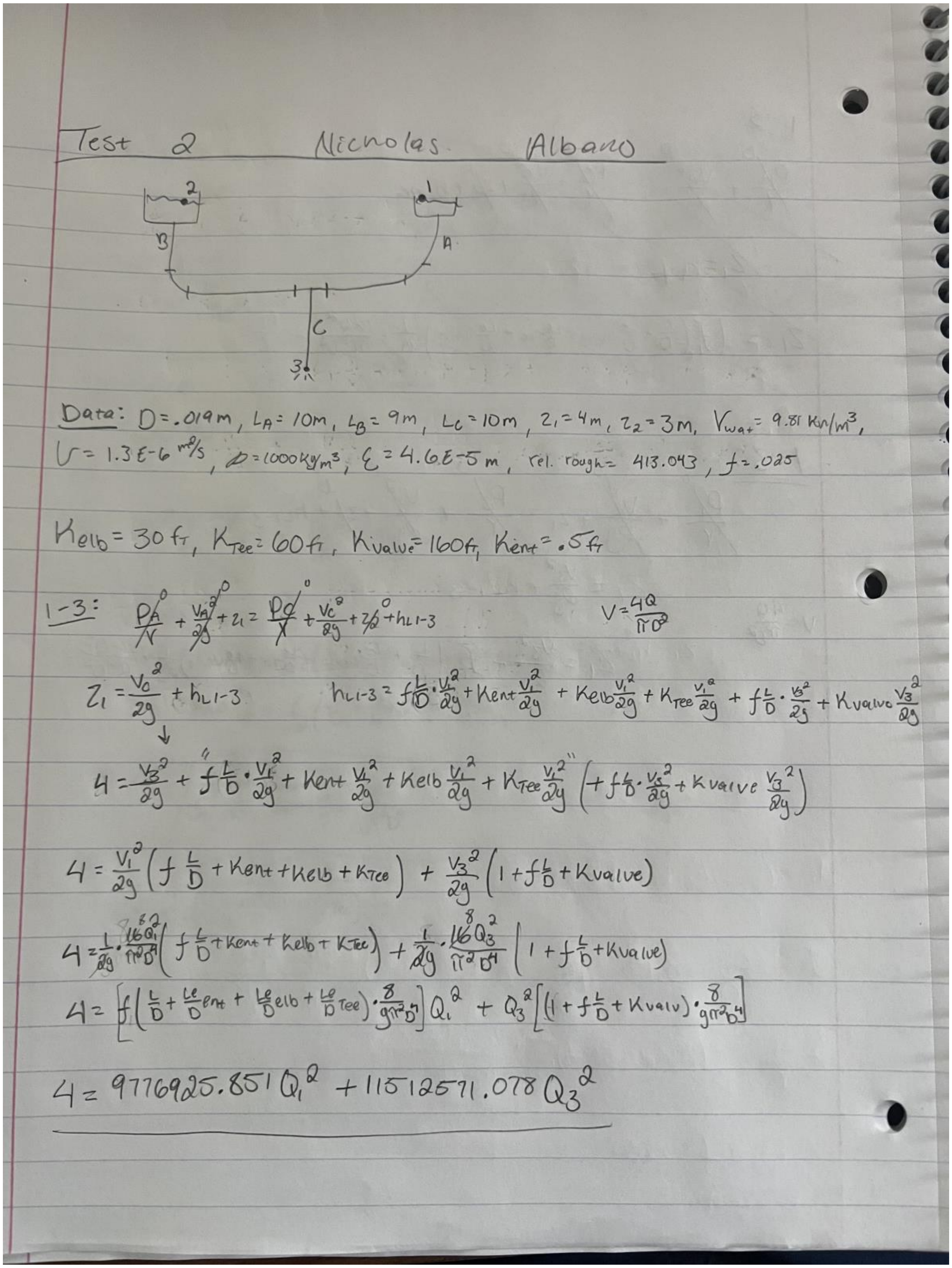
MET330 Test 2 Nicholas Albano



Test 2 Nicholas Albano

Data: $D = .019\,m$, $L_A = 10m$, $L_B = 9m$, $L_C = 10m$, $z_1 = 4m$, $z_2 = 3m$, $\gamma_{wat} = 9.81\,KN/m^3$, $\nu = 1.3E{-6}\,m^2/s$, $\rho = 1000\,kg/m^3$, $\varepsilon = 4.6E{-5}\,m$, rel. rough = 413.043, $f = .025$

$K_{elb} = 30 f_T$, $K_{Tee} = 60 f_T$, $K_{valve} = 160 f_T$, $K_{ent} = .5 f_T$

1-3: $\cancel{\frac{P_A}{\gamma}}^{0} + \cancel{\frac{V_A^2}{2g}}^{0} + z_1 = \cancel{\frac{P_C}{\gamma}}^{0} + \frac{V_C^2}{2g} + \cancel{z_C}^{0} + h_{L1\text{-}3}$ $\qquad V = \frac{4Q}{\pi D^2}$

$z_1 = \frac{V_C^2}{2g} + h_{L1\text{-}3}$ $\qquad h_{L1\text{-}3} = f\frac{L}{D}\cdot\frac{V_1^2}{2g} + K_{ent}\frac{V_1^2}{2g} + K_{elb}\frac{V_1^2}{2g} + K_{Tee}\frac{V_1^2}{2g} + f\frac{L}{D}\cdot\frac{V_3^2}{2g} + K_{valve}\frac{V_3^2}{2g}$

$\downarrow$

$4 = \frac{V_3^2}{2g} + "f\frac{L}{D}\cdot\frac{V_1^2}{2g} + K_{ent}\frac{V_1^2}{2g} + K_{elb}\frac{V_1^2}{2g} + K_{Tee}\frac{V_1^2}{2g}" \left(+ f\frac{L}{D}\cdot\frac{V_3^2}{2g} + K_{valve}\frac{V_3^2}{2g}\right)$

$4 = \frac{V_1^2}{2g}\left(f\frac{L}{D} + K_{ent} + K_{elb} + K_{Tee}\right) + \frac{V_3^2}{2g}\left(1 + f\frac{L}{D} + K_{valve}\right)$

$4 = \frac{1}{\cancel{2}g}\cdot\frac{\overset{8}{\cancel{16}}Q_1^2}{\pi^2 D^4}\left(f\frac{L}{D} + K_{ent} + K_{elb} + K_{Tee}\right) + \frac{1}{\cancel{2}g}\cdot\frac{\overset{8}{\cancel{16}}Q_3^2}{\pi^2 D^4}\left(1 + f\frac{L}{D} + K_{valve}\right)$

$4 = \left[f\left(\frac{L}{D} + \frac{L_e}{D}ent + \frac{L_e}{D}elb + \frac{L_e}{D}Tee\right)\cdot\frac{8}{g\pi^2 D^4}\right]Q_1^2 + Q_3^2\left[\left(1 + f\frac{L}{D} + K_{valv}\right)\cdot\frac{8}{g\pi^2 D^4}\right]$

$4 = 9776925.851\,Q_1^2 + 11512571.078\,Q_3^2$

$$\underline{2\text{-}3:}\quad \cancel{\frac{P_B}{\gamma}}^{0} + \cancel{\frac{V_B^2}{2g}}^{0} + z_2 = \cancel{\frac{P_C}{\gamma}}^{0} + \frac{V_C^2}{2g} + \cancel{z_3}^{0} + h_{L\,B-C}$$

$$z_2 = \frac{V_C^2}{2g} + h_{L\,B-C} \qquad h_{L2-3} = f\frac{L}{D}\cdot\frac{V_2^2}{2g} + K_{ent}\frac{V_2^2}{2g} + K_{elb}\frac{V_2^2}{2g} + K_{Tee}\frac{V_2^2}{2g} + f\frac{L}{D}\cdot\frac{V_3^2}{2g} + K_{va}\frac{V_3^2}{2g}$$

$$3 = \frac{V_3^2}{2g} + f\frac{L}{D}\cdot\frac{V_2^2}{2g} + K_{ent}\frac{V_2^2}{2g} + K_{elb}\frac{V_2^2}{2g} + K_{Tee}\frac{V_2^2}{2g} + \left(f\frac{L}{D}\cdot\frac{V_3^2}{2g} + K_{valve}\frac{V_3^2}{2g}\right)$$

$\frac{4Q}{\pi D^2}$

$$3 = \frac{V_2^2}{2g}\left(f\frac{L}{D} + K_{ent} + K_{elb} + K_{Tee}\right) + \frac{V_3^2}{2g}\left(1 + f\frac{L}{D} + K_{valve}\right)$$

$$3 = \left[f\left(\frac{L}{D} + \frac{L_e}{D}_{ent} + \frac{L_e}{D}_{elb} + \frac{L_e}{D}_{Tee}\right)\cdot\frac{8}{g\pi^2 D^4}\right]Q_2^2 + Q_3^2\left[\left(1 + f\frac{L}{D} + K_{valve}\right)\cdot\frac{8}{g\pi^2 D^4}\right]$$

$$\underline{3 = 8942681.57\,Q_2^2 + 11512571.078\,Q_3^2}$$

$Q_3 = Q_2 + Q_1$

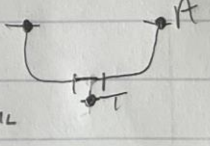
Solving for eQ 1: $\sqrt{\frac{4 - 11512571.078\,Q_3^2}{9776925.851}} = Q_1$

Solve for eQ 2: $\sqrt{\frac{3 - 11512571.078\,Q_3^2}{8942681.57}} = Q_2$

Using excel: $\boxed{Q_3 = .00049413\ m^3/s \rightarrow V = \frac{4Q}{\pi \cdot .019^2} = 1.742\ m/s}$ not violated

$Q_1 = .000349\ m^3/s \rightarrow V = 1.23\ m/s$

$Q_2 = .000145\ m^3/s \rightarrow V = .5114\ m/s$



$\underline{P_T \text{ at Tee Exit:}}$

$$\cancel{\frac{P_A}{\gamma}}^{0} + \cancel{\frac{V_A^2}{2g}}^{0} + z_A = \frac{P_T}{\gamma} + \frac{V_T^2}{2g} + \cancel{z}^{0} + h_L$$

$$z_A = \frac{P_T}{\gamma} + \frac{V_T^2}{2g} + h_L$$

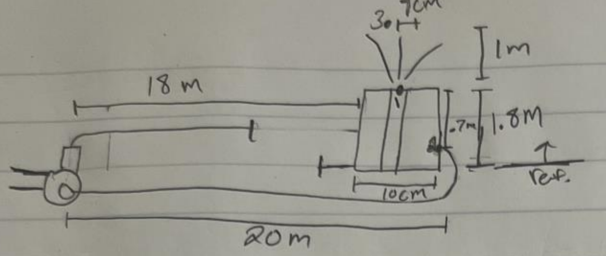
$$P_T = \gamma\left(z_A - \frac{V_T^2}{2g} - h_L\right) \rightarrow 9.81\left(4^m - \frac{1.742^2\,m/s}{2\cdot 9.81\,m^2/s} - 9776925.81\left(.000349^2\,m^3/s\right)\right)$$

$$\boxed{P_{Tee} = 26.04\ PA}$$

-For Problem 1, The purpose was to find the flow out of the system if the gate valve is half open and the pressure at the Tee exit. The drawing of the problem is above, and the sources are Notes/HW and the Fluid mechanics textbook. Design considerations are assumed that it is incompressible fluid, isothermal process, and a steady state. Data, Procedure, and calculations are also above in the images. Summary is that the velocity is 1.742 m/s and the pressure is 26.04 Pa. Materials used in this problem are water and steel pipes.

$A = \frac{Q}{V} \rightarrow Q = V \cdot A$

7cm = .07 m
10cm = .1 m



- expansion loss $K = 2$
- $U_{max} = 3$ m/s
- $\gamma = 9.81$ m/s
- $\varepsilon = 3E-7$ m
- $\nu = 1.3E-6$ m²/s

Question: pump power required for flow? If pump-motor has 92% efficiency determine electrical power components.

$$\cancelto{0}{\frac{P_1}{\gamma}} + \frac{V^2}{2g} + z_1 = \cancelto{0}{\frac{P_3}{\gamma}} + \cancelto{0}{\frac{V_3^2}{2g}} + z_3 + \cancelto{0}{h_{L1-3}}$$

open

negligible @ Annulus

$$\frac{V_1^2}{2g} + z_1 = z_3 \rightarrow \frac{V_1^2}{2g} = z_3 - z_1 \rightarrow \sqrt{V_1^2 = (\cancel{2.8}\,1.8)2g}$$

$V_1 = 4.429$ m/s

$Q = V \cdot A \rightarrow 4.429(.1^2 - .07^2) \cdot \frac{\pi}{4}$

$Q = .0177$ m/s

- Velocity criteria: $A = \frac{Q}{V} \rightarrow \frac{\pi}{4}D^2 = \frac{.0177}{3_{max}}$

$$D = \sqrt{\frac{4(.0177)}{3(\pi)}} = .0866\text{ m} = 86.6\text{mm} \rightarrow D_0 = 125\text{mm}$$

$V = \frac{Q}{A} \rightarrow \frac{.0117}{\frac{\pi}{4} \cdot .125^2} = 1.44$ m/s

$Re = \frac{VD}{\nu} = \frac{1.44(.125)}{1.3E-6} = 138461.538$ $\varepsilon = 3E-7$

$f = .01672$, $f_T = .006528$

$h_1 = K_{exp} + K_{ent} + f\frac{L}{D}\cdot\frac{V^2}{2g}_{inlet} + f\frac{L}{D}\cdot\frac{V^2}{2g}_{outlet} + K_{elb}(2)$

$$\cancel{\frac{P_1}{\gamma}}^{0} + \frac{V_1^2}{2g} + z_1 + h_1 = \cancel{\frac{P_2}{\gamma}}^{0} + \cancel{\frac{V_2^2}{2g}}^{0} + z_2 + h_{L1}$$

$$\frac{V_1^2}{2g} + z_1 = z_2 + h_L + -z \rightarrow \frac{V_1^2}{2g} + z_1 - z_2 + h_1 = h_L$$

small enough to neglect "1.1"

$$h_L = \cancel{\frac{V_1^2}{2g} + z_1 - z_2} + h_1$$

$$h_L = \frac{V_1^2}{2g} + K_{exp}\frac{V_1^2}{2g} + K_{ent}\frac{V_1^2}{2g} + f\frac{L}{D}\cdot\frac{V^2}{2g}_{inlet} + f\frac{L}{D}\cdot\frac{V^2}{2g}_{out} + 2\cdot K_{elb}$$

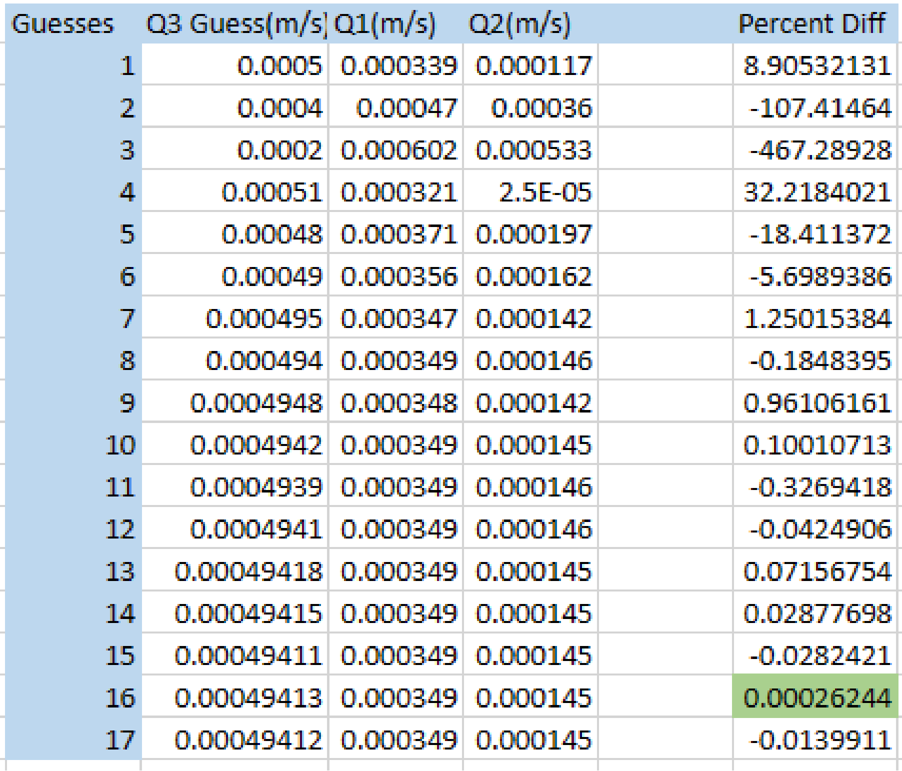
$$h_L = \frac{4.429^2}{2\cdot 9.81} + 2\cdot\overset{ft}{\frac{4.44^2}{2\cdot 9.81}} + .5\overset{ft}{\frac{1.44^2}{2\cdot 9.81}} + .01672\frac{20}{.125}\cdot\frac{1.44^2}{2\cdot 9.81} + .01672\frac{18}{.125} + \frac{1.44^2}{2\cdot 9.81} + 2\cdot .30\overset{ft}{\frac{1.44^2}{2\cdot 9}}$$

$h_L = 1.58$

$$P_m = \frac{P_A}{n_A} = \frac{\gamma Q h_A}{n_A} \rightarrow P_A = \gamma Q h_A = 9.81\overset{m/s}{\cdot}.0177\overset{m/s}{\cdot}1.58$$

$$\boxed{P_A = .2743 \text{ Kw?}}$$

$$n_A = P_m = \frac{P_A}{n_A} = \frac{.2743}{.92} = \boxed{.29815 \text{ Kw?}}$$



Guesses	Q3 Guess(m/s	Q1(m/s)	Q2(m/s)		Percent Diff
1	0.0005	0.000339	0.000117		8.90532131
2	0.0004	0.00047	0.00036		-107.41464
3	0.0002	0.000602	0.000533		-467.28928
4	0.00051	0.000321	2.5E-05		32.2184021
5	0.00048	0.000371	0.000197		-18.411372
6	0.00049	0.000356	0.000162		-5.6989386
7	0.000495	0.000347	0.000142		1.25015384
8	0.000494	0.000349	0.000146		-0.1848395
9	0.0004948	0.000348	0.000142		0.96106161
10	0.0004942	0.000349	0.000145		0.10010713
11	0.0004939	0.000349	0.000146		-0.3269418
12	0.0004941	0.000349	0.000146		-0.0424906
13	0.00049418	0.000349	0.000145		0.07156754
14	0.00049415	0.000349	0.000145		0.02877698
15	0.00049411	0.000349	0.000145		-0.0282421
16	0.00049413	0.000349	0.000145		0.00026244
17	0.00049412	0.000349	0.000145		-0.0139911

-For problem 2, the purpose is to find the pump power for the flow and the electrical power requirements. Drawing is above and the source is notes/HW and the fluid mechanics textbook. The design considerations include incompressible fluid, isothermal process, and a steady state. Data, Procedure, and calculations are all above in the pictures. Summary is the pump power requirement needs .2743 kW and electrical requirement is .29815 kW. Materials used are water and PVC pipes.