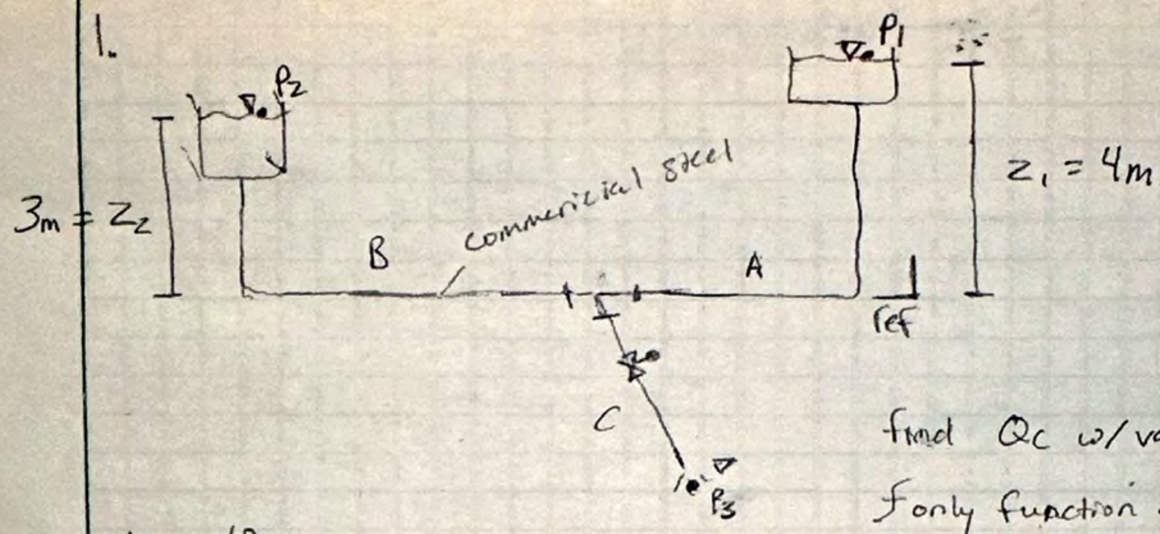
1.



find Q_C w/ valve @ 50% open

f only function of Relative roughness

$V_{max} = 3 m/s$

$L_A = 10m$

$L_B = 9m$

$L_C = 10m$

$D_{inside} = 3/4 \text{ in} \cdot \frac{1m}{39.37 in} = .01905 m$

$\varepsilon = 4.6 \times 10^{-5} m$

$\nu = 1.15 \times 10^{-6} m^2/s$

$\gamma = 9.81 \, kN/m^3$

<u>$P_1 \rightarrow P_3$</u>

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

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

$$z_1 = \frac{V_2^2}{2g} + h_L$$

$$Q_C = Q_A + Q_B$$

$$\cancel{A} V_C = \cancel{A} V_A + \cancel{A} V_B$$

$$V_C = V_A + V_B$$

$$h_L = f \frac{L_A}{D} \cdot \frac{V_A^2}{2g} + f \frac{L_C}{D} \frac{V_C^2}{2g} + K_{elbow} \frac{V_A^2}{2g} + K_{Tee} \frac{V_C^2}{2g} + K_{valve} \frac{V_C^2}{2g} + K_{entry} \frac{V_A^2}{2g}$$

$$h_L = f \frac{L_A}{D} \cdot \frac{16 Q_A^2}{2g \pi^2 D^4} + f \frac{L_C}{D} \frac{16 Q_C^2}{2g \pi^2 D^4} + K_{elbow} \frac{16 Q_A^2}{2g \pi^2 D^4} + K_{Tee} \frac{16 Q_C^2}{2g \pi^2 D^4} + K_{valve} \frac{16 Q_C^2}{2g \pi^2 D^4} + K_{entry} \frac{16 Q_A^2}{2g \pi^2 D^4}$$

$$h_L = \frac{8 Q_A^2}{g \pi^2 D^4} \left(f \frac{L_A}{D} + K_{elbow} + K_{entry} \right) + \frac{8 Q_C^2}{2 \pi^2 D^4} \left(f \frac{L_C}{D} + K_{Tee} + K_{valve} \right)$$

$$z_1 = \frac{16 Q_C^2}{2g \pi^2 D^4} + h_L = \frac{8 Q_C^2}{g \pi^2 D^4} + h_L$$

$$z_1 = \frac{8Q_A^2}{g\pi^2 D^4}\left(F\frac{L_A}{D} + K_{elbow} + K_{entry}\right) + \frac{8Q_c^2}{g\pi^2 D^4}\left(f\frac{L_c}{D} + 1 + K_{Tee} + K_{valve}\right)$$

$$f = \frac{.25}{\left(\log\left(\frac{1}{3.7 \cdot \frac{.01905m}{4.5\times10^{-5}m}}\right)\right)^2} = .02449$$

$K_{elbow} = f_T \cdot 30 = .024 \cdot 30 = .72$

$f_T = .024$

$K_{entry} = .5$

$K_{Tee} = 60 f_T = 60 \cdot .024 = 1.44$

$K_{valve} = 160 f_T = 160 \cdot .024 = 3.84$

$$4m = \frac{8Q_A^2}{9.81m/s^2 \, \pi^2 (.01905m)^4}\left(\left(.02449 \frac{10m}{.01905m}\right) + .72 + .5\right) + \frac{8Q_c^2}{9.81m/s^2 \cdot \pi^2 \cdot .01905m^4}\left(.02449 \frac{10m}{.01905m} + 1.44 + 1 + 3.84\right)$$

$4m = 8330793.373\, Q_A^2 + 12005613.98\, Q_c^2$

$$Q_c = \sqrt{\frac{4 - 8330793.373\, Q_A^2}{12005613.98}}$$

$\underline{P_2 \to P_3}$ Calculations the same except for L_B + z_2

$$3m = \frac{8Q_B^2}{9.81 \cdot \pi^2 \cdot .01905^4}\left(.02449 \frac{9m}{.01905m} + .72 + .5\right) + 12005613.98\, Q_c^2$$

$3m = 8024436.272\, Q_B^2 + 12005613.98\, Q_c^2$

$$Q_B = \sqrt{\frac{3 - 12005613.98\, Q_c^2}{8024436.272}}$$

$Q_C = Q_A + Q_B$

$Q_A = Q_C - Q_B$

Iterative process

① guess Q_A

② solve for Q_C

③ use Q_C to solve for Q_B

④ Calculate new Q_A w/ $Q_A = Q_C - Q_B$

⑤ compare new Q_A to Q_A; if greater than 1% diff, use new Q_A for next Q_A guess + go again

$Q_A = .0003669382 \ m^3/s$

$Q_B = .0001227654 \ m^3/s$

$\boxed{Q_C = .0004897035 \ m^3/s}$

$Q_C = V_C A_C$

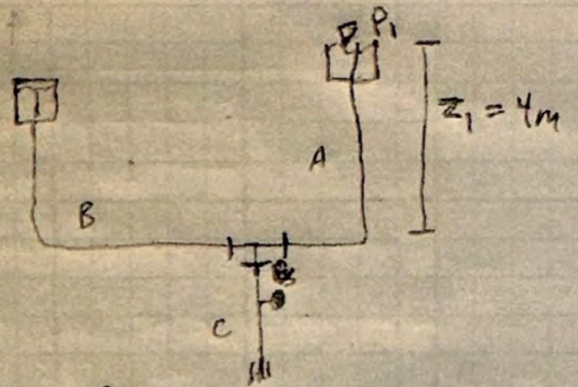
$$V_C = \frac{Q_C}{A_C} = \frac{4 Q_C}{\pi D^2} = \frac{4 \cdot .0004897035}{\pi \cdot .01905^2} = 1.718 \ m/s$$

$V_C \leq 3 \ m/s$

Max velocity is not violated

Iteration	1				
	Guess QA (m3/s)	QC	QB	NEW QA	%diff
	0.0004000000	0.0004713274	0.0002036986	0.0002676288	33.09%
	0.0003900000	0.0004771074	0.0001824591	0.0002946483	24.45%
	0.0003800000	0.0004826745	0.0001590508	0.0003236237	14.84%
	0.0003700000	0.0004880360	0.0001323278	0.0003557083	3.86%
	0.0003657083	0.0004902756	0.0001193004	0.0003709753	1.44%
	0.0003660000	0.0004901245	0.0001202255	0.0003698991	1.07%
	0.0003670000	0.0004896054	0.0001233498	0.0003662556	0.20%
	0.0003669000	0.0004896574	0.0001230405	0.0003666168	0.08%
	0.0003668112	0.0004897035	0.0001227654	0.0003669382	0.03%
		Vc (m/s)		Va (m/s)	
		1.718119659		1.287398697	

Tee exit pressure



$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + z_1 = \frac{P_3}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}^{0} + h_L$$

$$P_3 = \gamma\left(z_A - \frac{V_A^2}{2g} - h_{LA}\right)$$

$h_{LA} = 8330993.373\, Q_A^2 \rightarrow$ from previous h_L

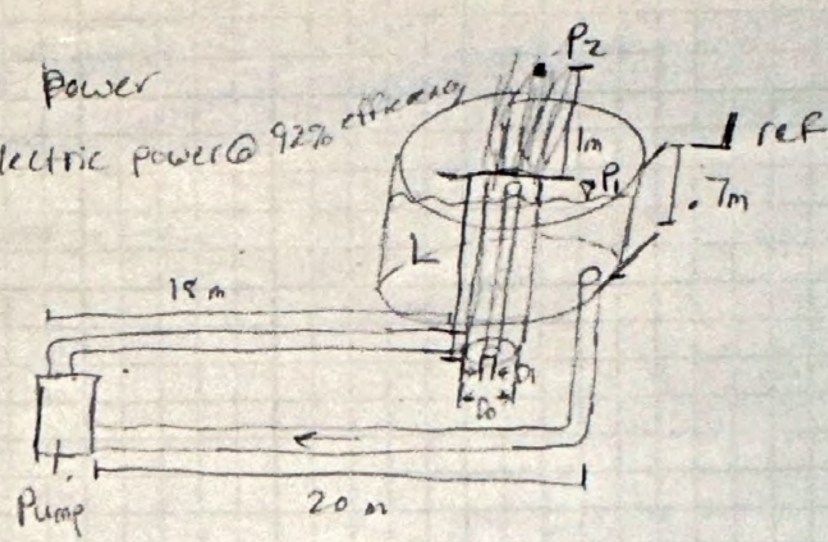
$$P_3 = 9.81\,\frac{kN}{m^3}\left(4m - \frac{(1.287\,m/s^2)^2}{2\cdot 9\,m/s^2} - 8330993.373\cdot(.0003669382\,m^3/s)^2\right)$$

$$\boxed{P_3 = 26.7\ kPa}$$

Problem 2

Find Pump Power

determine electric power @ 92% efficiency



$L_{AP} = 1.8m$

$L_{OUT} = 18m$

$L_{in} = 20m$

$K_{exp} = 2$

$D_o = 10cm \to .10m$

$D_i = 7cm \to .07m$

$\gamma = 9.81\ KN/m^3$

$\nu = 1.3\times10^{-6}\ m^2/s$

$\varepsilon = 3\times10^{-7}\ m$

$A_A = \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(.1m^2 - .07m^2) = .004005\ m^2$

$WP = \pi(d_o + d) = \pi(.1m + .07m) = .53m$

$R = \frac{A_A}{W_P} = \frac{.004005\ m^2}{.53m} = .007499\ m$

$N_R = \frac{v(4R)}{\nu}$

flow rate of Annular Assume $v = 3m/s$

$Q_A = v \cdot A_A = 3m/s \cdot .004005\ m^2 = .012015\ m^3/s$

$P_1 \to P_2$

$$\cancel{\frac{P_1}{\gamma}}^0 + \cancel{\frac{V_1^2}{2g}}^0 + \cancel{Z_1}^0 + h_a = \cancel{\frac{P_2}{\gamma}}^0 + \cancel{\frac{V_2^2}{2g}}^0 + Z_1 + h_L$$

$$h_a = Z_1 + h_L$$

$$h_L = h_{entry} + 2h_{elbow} + h_{inlet} + h_{out} + h_{expand} + h_{Annular}$$

$$h_{entry} = .5\frac{V_2^2}{2g}$$

$K = .5$

$$h_{elbow} = K \frac{V^2}{2g} = .24 \frac{V^2}{2g}$$

$$K = f_T \frac{L_e}{D} = .24 \qquad \frac{L_e}{d}_{elbow} = 30$$

$$f_T \rightarrow \frac{D}{\varepsilon} + \text{Moody's Chart} \qquad \frac{.071409\,m}{3\times10^{-7}\,m} = 238030$$

$$f_T = .008$$

$$K = f_T \cdot 30$$

$$h_{inlet} = f \frac{L}{D} \cdot \frac{V_1^2}{2g}$$

$$h_{outlet} = f \frac{L}{D} \cdot \frac{V^2}{2g}$$

$$f = \frac{.25}{\left(\text{Log}\left(\frac{1}{3.7\cdot\frac{D}{\varepsilon}} + \frac{5.74}{Re^{.9}}\right)\right)^2} = \frac{.25}{\left(\text{Log}\left(\frac{1}{3.7\cdot\frac{.071409m}{3\cdot10^{-7}m}} + \frac{5.74}{164791^{.9}}\right)\right)^2} =$$

$$.007074$$

$$Re = \frac{V\cdot D}{\nu} = \frac{3m/s \cdot .071409m}{1.3\times10^{-6}\,m^2/s} = 164,791.278$$

$$h_{expand} = K \cdot \frac{V^2}{2g} = 2 \cdot \frac{V^2}{2g}$$

$$K = 2$$

$$h_{annular} = f \frac{L}{4R} \cdot \frac{V^2}{2g}$$

$$f \rightarrow \frac{4R}{\varepsilon} = \frac{4 \cdot .007499m}{3\cdot10^{-7}\,m} = 100000$$

$$f \text{ from moody's} = .008$$

$$Q = AV = \frac{\pi}{4} D^2 \cdot V \qquad D = \sqrt{\frac{Q\cdot4}{\pi V}} = \sqrt{\frac{.012015\,m^3/s \cdot 4}{\pi \cdot 3m/s}}$$

$$Q = .012015\,m^3/s \qquad D = .071409\,m$$

Assume $V = 3m/s$

$$h_L = \frac{(3\,m/s)^2}{2g}\left(.5 + (2 \cdot .24) + \left(.07074 \frac{20\,m}{.07409\,m}\right) + \left(.07074 \frac{18\,m}{.07409\,m}\right) + 2 + \left(.008 \cdot \frac{1.8\,m}{4 \cdot .07499\,m}\right)\right)$$

$h_L = 18.656\,m$

$h_a = z_1 + h_L = 1\,m + 18.656\,m = 19.656$

$z_1 = 1\,m$

$$P = \gamma \cdot Q \cdot h_a = 9.81\,\frac{kN}{m^3} \cdot .012015\,m^3/s \cdot 19.656\,m$$

$$= 2.316\,\frac{kN \cdot m}{s} = 2.316\,kW$$

Pump Power required is $\boxed{2.316\,kW}$

Electrical power $\eta = .92$

$$\eta = \frac{P_{out}}{P_{in}} \qquad P_{in} = \frac{P_{out}}{\eta} = \frac{2.316\,kW}{.92} = \boxed{2.5\,kW}$$