Homework #1.4

Ch 7 General Energy Equation

Ch8 Reynolds Number, Laminar Flow, Turbulent Flow,

and Energy loses due to friction

MET 330 Virginia Beach Distance Learning WC2 and

Campus

Nathanael Yapnayon - Aaron Jackson - Zach Hollifield

Due Date: 09/19/19

Zach Hollifield

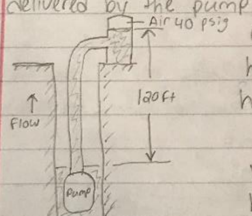
Zach Hollifield

Homework 1.4

1) During lecture and the solved problems we learned the importance of Bernoulli's equation and how we can use it to find the values a problem is asking for. A reference point is needed to determine elevation in the problem. We also learned about Reynolds number, laminar flow, Turbulent flow, and energy losses due to friction. Table 8.2 is used to find the values for pipe roughness. Friction factors are found on the Moody chart.

Chapter 7 11, 16, 22, 30, 35, 42

11) A submersible deep-well pump delivers 745 gal/h of water through a 1-inch schedule 40 pipe when operating the system. An energy loss of 10.5 lb-ft/lb occurs in the piping system. Calculate the power delivered by the pump to the water. If the pump draws 1 hp calulate efficiency.



$Q = 745$ gal/h $\quad z_1 - z_2 = 120$ ft

$h_L = 10.5$ lb-ft/lb $\quad P_1 = 1$ hp $\quad P_2 = 40$ psig

$$h_A + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_R + h_L$$

$$z_1 + h_A - h_2 = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} \rightarrow h_A = \frac{p_2}{\gamma} + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$$

$$V = \frac{Q}{A} = \frac{\frac{745}{499} \cdot \frac{1}{60}}{0.006} = 4.61 \text{ ft/s}$$

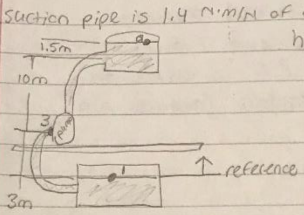
$$h_A = \frac{5760.03}{62.4} + 120 + \frac{4.61^2}{2 \times 32.2} + 10.5 = 223.14$$

$$P_A = 223.13 \times 62.4 \times \frac{745}{499 \times 60} = 385.04 \text{ lb-ft/s} \times \frac{1 \text{ hp}}{550 \text{ lb-ft/s}} = 0.70$$

$$\boxed{P_A = 0.7 \text{ hp}}$$

$$\text{efficiency} = \frac{P_A}{P_1} = \frac{0.7}{1} = 0.70 \times 100 = \boxed{70\% \text{ efficiency}}$$

16) A pump delivering 840 L/min of crude oil ($sg = 0.85$) from an underground storage drum to the first stage of a processing system. If the total energy loss in the system is 4.2 N·m/N of oil flowing calculate the power delivered by the pump. If the energy loss in the suction pipe is 1.4 N·m/N of oil flowing, calculate pressure at pump inlet.



$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L12}$$

$$P = \gamma Q h_A$$

$$h_A = \frac{P_2 - \cancel{P_1}}{\gamma} + \frac{\cancel{V_2^2 - V_1^2}}{2g} + Z_2 - Z_1 + H_{L12}$$

$$h_A = \frac{P_2}{\gamma} + Z_2 + h_{L12}$$

$$h_A = \frac{825\ kPa}{0.85 \times 9810\frac{N}{m^3}} + 14.5m + 4.2m = 117.64m$$

$$P = (0.85 \cdot 9810\ \tfrac{N}{m^3}) \cdot 0.014\tfrac{m^3}{s} \cdot 117.64\ m$$

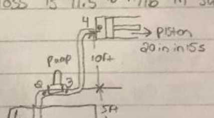
$$\boxed{P = 13.733\ kW}$$

$$\frac{\cancel{P_1}}{\gamma} + \frac{\cancel{V_1^2}}{2g} + \cancel{Z_1} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3 + h_{L13} \rightarrow \frac{P_3}{\gamma} \qquad V_3 = \frac{Q}{A_3}$$

$$V_3 = \frac{0.014\frac{m^3}{s}}{3.09\times10^{-3} m^2} = 4.531\ m/s$$

$$P_3 = (0.85 \cdot 9810\ \tfrac{N}{m^3})\left(-\frac{(4.531\frac{m}{s})^2}{2\times 9.81\frac{m}{s^2}} - 3m - 1.4m\right) \qquad \boxed{P_3 = -45.41\ kPa}$$

22) The pump draws oil with $sg = 0.90$ from reservior and delivers it to the cylinder diameter = 5.0in and in 15s the piston must travel 20 in exerting force 11000 lb. Energy loss is 11.5 lb-ft/lb in suction pipe, 35.0 lb-ft/lb in discharge



$$A_{cylinder} = \frac{\pi d^2}{4} = \frac{\pi (5)^2}{4} = 19.635\ in^2$$

$$Q = \frac{A_{cylinder} L}{t} = \frac{(19.635 in^2)(20 in(\frac{1ft}{12in}))}{15s} \cdot \left(\frac{1 ft^2}{144 in^2}\right) = \boxed{Q = 0.01515\ ft^3/s}$$

$$P_4 = \frac{F}{A_{cylinder}} = \frac{11000\ lb}{19.635\ in^2} \cdot \left(\frac{144 in^2}{1 ft^2}\right) = \boxed{P_{cylinder} = 80672.27\ lb/ft^2}$$

$$V_3 = \frac{Q}{A_3} = \frac{0.01515\ ft^3/s}{0.000976\ ft^2} = \text{Velocity at 3 and 4} = 15.52\ ft/s$$

$$\gamma_{oil} = 0.90(62.4\ lb/ft^3) = 56.16\ lb/ft^3 \quad V_4 = \frac{L}{t} = \frac{20 in}{15s}\left(\frac{1ft}{12in}\right) = 0.1111\ ft/s$$

$$\frac{P_3}{\gamma_{oil}} + \frac{V_3^2}{2g} + Z_3 - h_{LD} = \frac{P_4}{\gamma_{oil}} + \frac{V_4^2}{2g} + Z_4 \rightarrow \frac{P_3}{\gamma_{oil}} = \frac{P_4}{\gamma_{oil}} + \frac{V_2^2}{2g} + Z_4 - \frac{V_C^2}{2g} - Z_3 + h_{LD}$$

$$P_3 = P_4 + \gamma_{oil}\left[\left(\frac{V_4^2 - V_3^2}{2g}\right) + (Z_4 - Z_3) + h_{LD}\right] \rightarrow 80672.27 + 56.16\left[\left(\frac{1.1111^2 - 15.52^2}{2(32.2)}\right) + (10-0) + 35\right]$$

$$\boxed{\text{Pressure at outlet of pump} = 82990.499\ lb/ft^2}$$

$$\frac{P_1}{\gamma_{oil}} + \frac{V_1^2}{2g} + Z_1 + h_{LS} = \frac{P_2}{\gamma_{oil}} + \frac{V_2^2}{2g} + Z_2 \rightarrow P_2 = \gamma_{oil}\left[(Z_1 - Z_2) - \frac{V_2^2}{2g} - h_{LS}\right] = 56.16\left[(-5-0) - \frac{(15.52)^2}{2\cdot 32.2} - 11.5\right]$$

$$\boxed{\text{Pressure at inlet of pump} = -1136.69\ lb/ft^2}$$

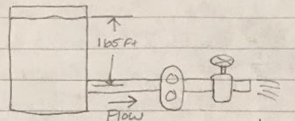
$$\frac{P_1}{\gamma_{oil}} + \frac{V_1^2}{2g} + Z_1 + h_A - h_{LS} - h_{LD} = \frac{P_4}{\gamma_{oil}} + \frac{V_4^2}{2g} + Z_4 \rightarrow h_A = \frac{P_4}{\gamma_{oil}} + \frac{V_4^2}{2g} + (Z_4 - Z_1) + h_{LS} + h_{LD}$$

$$\frac{80672.27}{56.16} + \frac{(0.1111)^2}{2\cdot 32.2} + (10-(-5)) + 11.5 + 35 = 1497.97\ ft$$

$$P = \frac{h_A \gamma_{oil} Q}{550} = \frac{(1497.97ft)(56.16\ lb/ft^3)(0.01515\ ft^3/s)}{550} \qquad \boxed{\text{Power by pump} = 2.32\ hp}$$

Zach Hollifield

30) Water at 60°F flows from a large reservoir through a fluid motor at the rate of 1000 gal/min in the system. If the motor removes 37 hp from the fluid, calculate the energy losses in the system.



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

$$z_1 + h_R - h_L = z_2 + \frac{V_2^2}{2g}$$

$$h_L = (z_1 - z_2) - \frac{V_2^2}{2g} - h_R$$

$$P_R = h_R \gamma Q \rightarrow h_R = \frac{P_R}{\gamma Q}$$

$$h_R = \frac{37 \times 550}{62.4 \times 2.227} = 146.43 \text{ ft}$$

$$V_2 = \frac{Q}{A} = \frac{2.227}{0.3472} = 6.41 \text{ ft/s} \qquad h_L = (z_1 - z_2) - \frac{V_2^2}{2g} - h_R$$

$$h_R = 165 - \frac{6.41^2}{2 \times 32.2} - 146.43 = \boxed{\text{Energy loss in the system} = 17.93 \text{ ft}}$$

35) Compute the power removed from the fluid by the press.

$$P_R = h_R \gamma Q$$

$$\frac{P_4}{\gamma} + z_4 + \frac{V_4^2}{2g} - h_R = \frac{P_5}{\gamma} + z_5 + \frac{V_5^2}{2g} \rightarrow \frac{P_4}{\gamma} + z_4 - h_R = \frac{P_5}{\gamma} + z_5$$

$$h_R = -\left[\frac{P_5 - P_4}{\gamma} + (z_5 - z_4)\right]$$

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

$$P_2 = \gamma\left[(z_1 - z_2) - \frac{V_2^2}{2g} - h_L\right] \qquad \gamma = sg \times \gamma_w = 0.93 \times 62.4 = 58.032 \text{ lb/ft}^3$$

$$V_2 = \frac{Q}{A_2} = \frac{0.3899}{0.05132} = 7.57 \text{ ft/s} \qquad P_2 = 58.032\left[-4 - \frac{7.57^2}{2 \times 32.2} - 2.8\right] \cdot \frac{0.006944 \text{ lb/in}^2}{1 \text{ lb/ft}^2}$$

$$P_2 = 3.1 \text{ lb/in}^2$$

$$P_3 = \gamma\left[\frac{P_2}{\gamma} + \frac{(V_2^2 - V_3^2)}{2g} + h_4\right] \qquad P_A = h_A \gamma Q \quad h_A = \frac{P_A}{\gamma Q}$$

$$P_A = (0.8 \times 28.4) \times \left(\frac{550 \text{ lb}\cdot\text{ft/s}}{1 \text{ hp}}\right) = 12496 \text{ lb}\cdot\text{ft/s}$$

$$h_A = \frac{12496}{58.032 \times 0.39} = 552.18 \text{ lb}\cdot\text{ft/lb}$$

2 ½ schedule 40 steel pipe is 0.03326 ft²

$$V_3 = \frac{0.389}{0.03326} = 11.73 \text{ ft/s} \qquad V_2 = \frac{0.389}{0.05132} = 7.6 \text{ ft/s}$$

$$P_3 = 58.032\left[\frac{-446.2}{58.032} + \frac{[7.6^2 - 11.73^2]}{2 \times 32.2} + 552.18\right] = [58.032(-7.69 - 1.24 + 552.18)] \text{ lb/ft}^2$$

$$P_3 = 31525.88 \text{ lb/ft}^2 \times \frac{1}{144} = 219 \text{ psi}$$

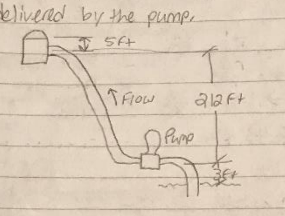
$$P_4 = \gamma\left(\frac{P_3}{\gamma} - h_L\right) = 58.032\left(\frac{31525.88}{58.032} - 28.5\right)\left(\frac{1 \text{ lb/in}^2}{144 \text{ lb/ft}^2}\right) = 1.01 \text{ psi}$$

$$h_R = -\left[\frac{145.08 - 29868.62}{58.032} + (-2)\right] = 514.19 \text{ ft}$$

$$P_R = (514.192 \times 58.032 \times 0.39)\left(\frac{1 \text{ hp}}{550 \text{ lb}\cdot\text{ft/s}}\right)$$

$$\boxed{\text{Power removed by press} = 21.2 \text{ Hp}}$$

42) The distribution tank maintains a pressure of 30.0 psig above the water. There is an energy loss of 15.5 lb-ft/lb in the piping. When the pump is delivering 40 gal/min of water, compute the horsepower delivered by the pump.



$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 + h_A - h_L = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2$$

$$z_1 + h_A - h_L = \frac{p_2}{\gamma} + z_2$$

$$h_A = \frac{p_2}{\gamma} + (z_2 - z_1) + h_L$$

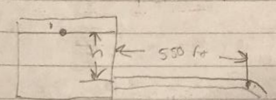
$$h_A = \frac{4320}{62.4} + 220 + 15.5 = 304.73 \text{ ft}$$

$$P_A = h_A \gamma Q = 304.73 \times 62.4 \times 0.089$$

$$P_A = 1692.35 \text{ lb}\cdot\text{ft/s} \times \frac{1 \text{ hp}}{550 \text{ lb}\cdot\text{ft/s}} \quad \boxed{P_A = 3.1 \text{ hp}}$$

Chapter 8 #33, 38, 44, 46, 49, 62

33) Water at 80°F flows from a storage tank through 550 ft of 6 in schedule 40 steel pipe. Calculate required head above pipe inlet to produce a volume flow rate of 2.50 ft³/s.



$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{p_1}{\gamma} + h + 0 - h_L = \frac{p_2}{\gamma} + 0 + \frac{v_2^2}{2g} \qquad p_1 = p_2$$

$$h = h_L + \frac{v_2^2}{2g}$$

$$Q = AV \qquad V = \frac{Q}{A} = \frac{2.5}{0.2006 \text{ ft}^2} = 12.46 \text{ ft/s} \qquad \nu = 9.15 \times 10^{-6} \text{ ft}^2/\text{s}$$

$$N_R = \frac{VD}{\nu} = \frac{12.46 \times 0.5054}{9.15 \times 10^{-6}} = 6.8 \times 10^5$$

$$R_r = \frac{D}{\epsilon} \qquad \epsilon = 1.5 \times 10^{-4} \text{ ft} \qquad R_r = \frac{0.5054}{1.5 \times 10^{-4}} = 3369.3$$

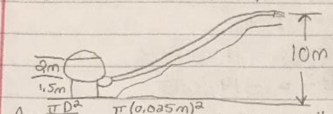
$$f = 0.0165$$

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g} \rightarrow 0.0165 \times \frac{550}{0.5054} \times \frac{(12.46)^2}{2 \times 32.2} = 45.69 \text{ ft}$$

$$\boxed{\text{Required head} = 45.7 \text{ ft}}$$

Zach Hollifield

38) The nozzle on the end of the hose requires 140 kPa of pressure to operate effectively. The hose ID of 25 mm, Fertilizer sg = 1.10 and dynamic viscosity of 2.0×10^{-3} Pa·s, length of hose = 85 m
Flow rate = 95 L/min



$$\frac{P_1}{\gamma}+\frac{v_1^2}{2g}+z_1+h_A=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+h_L$$

$$\frac{P_{atm}}{\gamma}+z_1+0+h_A=\frac{P_2}{\gamma}+z_2+\frac{V^2}{2g}+h_L$$

$$h_A=\left(\frac{P_2}{\gamma}-\frac{P_{atm}}{\gamma}\right)+(z_2-z_1)+\frac{V_2^2}{2g}+h_L$$

$A=\frac{\pi D^2}{4}=\frac{\pi(0.025m)^2}{4}=4.909\times10^{-4}\,m^2$ $\quad Q=95\,L/min\times\frac{1\,m^3}{10^3\,L}\times\frac{1\,min}{60\,s}=1.583\times10^{-3}\,m^3/s$

$V_2=V_3=V=\frac{Q}{A}$ $\quad V=\frac{1.583\times10^{-3}}{4.909\times10^{-4}}=3.22\,m/s$

$Re=\frac{\rho V D}{\eta}$ $\quad \rho=(sg)(\rho_w)=(1.10)(1000\,kg/m^3)=1100\,kg/m^3$

$Re=\frac{1100\times3.22\times0.025}{2\times10^{-3}}=44275$ $\quad f=0.024$ $\quad h_L=f\frac{L}{D}\times\frac{v^2}{2g}$

$h_L=0.024\times\frac{85}{0.025}\times\frac{3.22^2}{2\times9.81}=43.122\,m$ $\quad \gamma=(1.10)(9.81\,kN/m^3)=10.791\,kN/m^3$

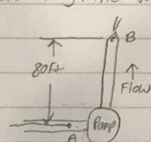
$h_A=\left(\frac{140}{10.791}-\frac{101}{10.791}\right)+(10-(1.5+1.2))+\frac{3.22^2}{2\times32.2}+43.122=54.197\,m$

$P=h_A\times\gamma\times Q=54.197\times10.791\times1.58\times10^{-3}=$ $\boxed{\text{Power delivered by pump} = 0.924\text{ kW}}$

$$\frac{P_1}{\gamma}+z_1+\frac{v_1^2}{2g}+h_A=\frac{P_3}{\gamma}+z_3+\frac{V_3^2}{2g}\rightarrow\frac{P_1}{\gamma}+z_1+0+h_A=\frac{P_3}{\gamma}+z_3+\frac{V_3^2}{2g}$$

$\frac{101.0}{10.791}+1.2+54.197=\frac{P_3}{10.791}+\frac{3.22^2}{2\times9.81}=$ $\boxed{\text{Pressure at pump outlet} = 693.084\text{ kPa}}$

44) The pressure at point B must be 25.0 psig. The pressure at point A is -3.50 psig. The volume flow rate is 0.50 ft³/s. DV is 4.0×10^{-5} lb·s/ft², sg = 1.026



$V_A=\frac{Q}{A_A}=\frac{0.50\,ft^3/s}{0.06868\,ft^2}=7.28\,ft/s$

$V_B=\frac{Q}{A_B}=\frac{0.50\,ft^3/s}{0.03326\,ft^2}=15.03\,ft/s$

$\rho_F=sg(\rho_w)=1.026(1.94\,slugs/ft)=1.9904\,slugs/ft$

$N_R=\frac{V_B D_B \rho_F}{\mu}=\frac{(15.03\,ft/s)(0.2058\,ft)(1.9904\,slugs/ft^3)}{4.0\times10^{-5}\,lb\cdot s/ft^2}=1.54\times10^5$

$R_r=\left(\frac{D_B}{\varepsilon}\right)=\frac{0.2058\,ft}{1.5\times10^{-4}\,ft}=1372$

$f=\frac{0.25}{\left[\log\left(\frac{1}{3.7(\frac{D}{\varepsilon})}+\frac{5.74}{N_R^{0.9}}\right)\right]^2}=\frac{0.25}{[\log(3.1427\times10^{-4})]^2}=0.020$

$h_L=\frac{f L V_B^2}{2g D_B}=\frac{(0.020)(80)(15.03)^2}{2(32.2)(0.2058)}=27.27\,ft$ $\quad \gamma_F=1.026(62.4\,lb/ft^3)=64.0224\,lb/ft^3$

$$\frac{P_A}{\gamma_F}+\frac{V_A^2}{2g}+z_A+h_A-h_L=\frac{P_B}{\gamma_F}+\frac{V_B^2}{2g}+z_B\rightarrow\left(\frac{P_B-P_A}{\gamma_F}\right)+(z_B-z_A)+\left(\frac{V_B^2-V_A^2}{2g}\right)+h_L$$

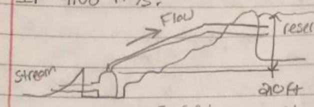
$h_A=\left(\frac{25-(-3.5)}{64.0224}\left(\frac{144\,in^2}{ft^2}\right)\right)+(80-0)+\left(\frac{15.03^2-7.28^2}{2(32.2)}\right)+27.27=174.485\,ft$

$P=\frac{h_A\gamma_F Q}{550}=\frac{(174.485)(64.0224\,lb/ft^3)(0.50\,ft^3/s)}{550}=10.2$

$\boxed{\text{power delivered by pump} = 10.2\text{ hp}}$

Zach Hollifield

46) Water at 60°F is being pumped from a stream to a reservoir 210 ft above the pump. The pipe 8 in schedule 40 steel 2500 ft long IF 4.00 ft^3/s.



$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 + h_A - h_L = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2$$

$$P_1 = \gamma\left[(z_2 - z_1) + h_L\right]$$

$$v = \frac{Q}{A} = \frac{4}{\frac{\pi}{4}\left(\frac{8}{12}\right)^2} = 11.46 \text{ ft/s}$$

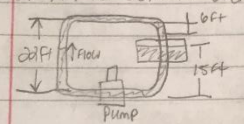
$\nu = 1.21 \times 10^{-5}$ ft^2/s $\quad N_R = \frac{vD}{\nu} = \frac{(11.46)\left(\frac{8}{12}\right)}{1.21 \times 10^{-5}} = 631404.95$

$\varepsilon = 1.5 \times 10^{-4}$ ft $\quad \frac{\varepsilon}{d} = \frac{1.5 \times 10^{-4}}{8/12} = 0.000225$

$$h_L = f \frac{L}{d} \frac{v^2}{2g} = 0.0153 \times \frac{2500}{\left(\frac{8}{12}\right)} \times \frac{(11.46)^2}{2 \times 32.2} = 117 \text{ ft}$$

$P_1 = \gamma\left[(z_2 - z_1) + h_L\right] = 62.4 \times \left[(210 - 0) + 117\right] \times \frac{1}{144} = \boxed{141.7 = \text{pressure at outlet}}$

49) Pump recirculating 300 gal/min of heavy machine lube oil at 104°F, Total length of 4 in is 25.0 ft and the total length of 3 in is 75.0 ft



$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 - h_L + h_A = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$h_A = h_L + (z_2 - z_1) + \frac{v_2^2}{2g}$$

$$V_D = \frac{Q}{A} = \frac{0.668}{0.05132} = 13.024 \text{ ft/s}$$

$$V_S = \frac{0.668}{0.0884} = 7.56 \text{ ft/s}$$

$$N_R = \frac{vD}{\nu} = \frac{13.024 \times 0.2557}{2.15 \times 10^{-3}} = 1548.947$$

$f_D = \frac{64}{N_R} = \frac{64}{1548.947} = 0.04132 \qquad N_{RS} = \frac{7.56 \times 0.3355}{2.15 \times 10^{-3}} = 1179.711$

$$f_S = \frac{64}{1179.711} = 0.054$$

$$h_D = f_D \frac{L_D}{D_D} \times \frac{V_D^2}{2g} = \frac{0.04132 \times 75 \times 13.024^2}{0.2557 \times 2 \times 32.2} = 31.92 \text{ ft}$$

$$h_S = f_S \frac{L_S}{D_S} \times \frac{V_S^2}{2g} = \frac{0.054 \times 25 \times 7.56^2}{0.3355 \times 2 \times 32.2} = 3.57 \text{ ft}$$

$$h_L = h_D + h_S = 31.92 + 3.57 = 35.49 \text{ ft}$$

$$\gamma = sg \times \gamma_w = 0.89 \times 62.4 = 55.536 \text{ lb/ft}^3$$

$$h_A = 35.49 + 1 + \frac{13.024^2}{2 \times 32.2} = 39.1 \text{ ft}$$

$P = 55.536 \times 0.6684 \times 39.1 \times \frac{1}{550} = \boxed{2.64 \text{ hp power delivered by pump}}$

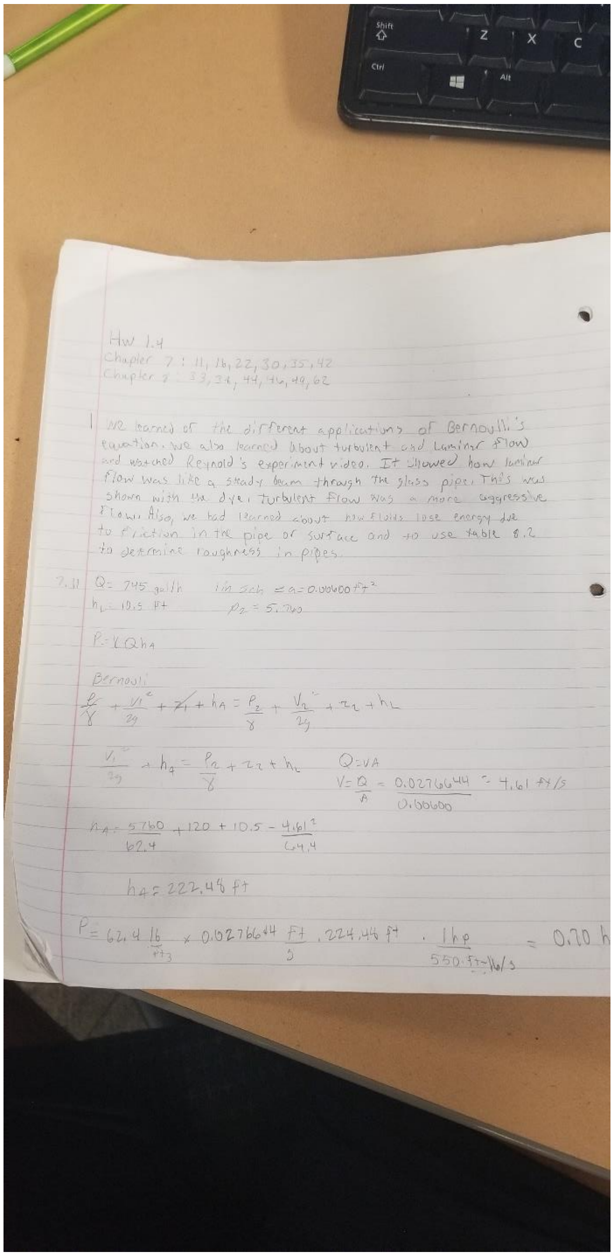
62) Heavy oil at 77°F flows in a 6 in schedule 40 steel pipe at 12 ft/s

$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2} \qquad N_R = \frac{vD}{\nu} \qquad \nu = 1.27 \times 10^{-3}$ ft^2/s $\quad D = 0.5054$ ft

$$N_R = \frac{(12)(0.5054)}{1.27 \times 10^{-3}} = 4775.43$$

$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.5054}{1.5 \times 10^{-4}}\right)} + \frac{5.74}{(4775)^{0.9}}\right)\right]^2} = \boxed{\text{Friction factor} = 0.0388}$

Aaron Jackson



Hw 1.4
Chapter 7 : 11, 16, 22, 30, 35, 42
Chapter 8 : 33, 36, 44, 46, 49, 62

1 We learned of the different applications of Bernoulli's equation. We also learned about turbulent and laminar flow and watched Reynold's experiment video. It showed how laminar flow was like a steady beam through the glass pipe. This was shown with the dye. Turbulent flow was a more aggressive flow. Also, we had learned about how fluids lose energy due to friction in the pipe or surface and to use table 8.2 to determine roughness in pipes.

7.11 $Q = 745$ gal/h 1 in sch $= a = 0.00600\ ft^2$
$h_L = 10.5$ ft $p_2 = 5.760$

$P = \gamma Q h_A$

Bernoulli

$$\cancel{\frac{p_1}{\gamma}} + \frac{v_1^2}{2g} + \cancel{z_1} + h_A = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L$$

$$\frac{v_1^2}{2g} + h_A = \frac{p_2}{\gamma} + z_2 + h_L$$

$Q = vA$

$V = \frac{Q}{A} = \frac{0.0276644}{0.00600} = 4.61\ ft/s$

$$h_A = \frac{5760}{62.4} + 120 + 10.5 - \frac{4.61^2}{64.4}$$

$h_A = 222.48$ ft

$$P = 62.4\ \frac{lb}{ft^3} \times 0.0276644\ \frac{ft}{s} \cdot 224.46\ ft \cdot \frac{1\ hp}{550\ ft\text{-}lb/s} = 0.70\ h$$

$E = \frac{0.70}{1} = 70\%$

7.16 $Q = 840\ L/min$ $\quad P_2 = 825\ kPa$

$sg = 0.85$ $\quad A = 3.090 \times 10^{-3}\ m^2$

$h_L = 4.2$

$Q = VA \quad V = \frac{Q}{A}$

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

$$h_A = \frac{825}{8.3385} + \frac{\left(\frac{0.014}{3.0903}\right)^2}{19.62} + 14.5 + 4.2$$

$h_A = 118.69$

$9.81\ \frac{kN}{m^3} \cdot 0.014 \cdot 118.69\ m = 16.30\ \frac{kN \cdot m}{s}$

b) $\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1}{2g}} + \cancel{z_1} = \frac{P_2}{\gamma} + 1.05 + 3m + 1.4$

0

$\frac{P_2}{\gamma} = -5.45m$

$P_2 = -5.45m \cdot 9.81\ \frac{kN}{m^3}$

$P = -53.47\ kPA$

7.22 $Sg = 0.90$ $h_L = 35$

$ID = 5.0\,in$

$h_L = 11.5\,ft$

$\gamma_o = 56.16\ \frac{lb}{ft^3}$

a) $Q = \frac{A_L}{t}$

$Q = \frac{\frac{5}{4} \cdot 20}{15} = 26.19 = 0.015$

b) $P = \frac{F}{A}$

$\frac{11000}{19.63} = 560.23 = 90.673\ \frac{lb}{ft}$

c) $\frac{P_1}{\gamma_o} + \frac{V_1^2}{2g} + \cancel{z_1}^{0} = \frac{P_2}{\gamma_o} + \frac{V_2^2}{2g} + z + h_L$

$\frac{P'}{56.16} + \frac{\frac{0.015}{.000970}}{64.4} = \frac{80.673}{56.16} + 20 + 10 + 35$

$P_1 = 1477.82 \cdot 56.16 = 62{,}994$

D $P_2 + \frac{V_2^2}{2g} + z + hL$

$\frac{P_2}{56.16} + \frac{15.37^2}{64.4} + 5 + 11.5$

$P_2 = -20.17 \cdot 56.16 = -1132.65 \frac{lb}{ft^2}$

F $P = \gamma Q h_A$

$h_A = \frac{80.673}{56.16} + \frac{0.111^2}{64.4} + 15 + 46.5 = 1497.69 \cdot 0.015 \cdot 56.16 = 1261.91$

$\frac{1261.91}{550} = 2.29\ hp$

7.30 $Q = 1000\ gal/min = 2.23\ ft^3/s$

Sch 40 $= 0.3472\ ft^2$

$\gamma = 62.4$

$P = \gamma Q h_a$

$139.152 hR = 20350$

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z + h_a + hL$

$V = \frac{Q}{A} = \frac{2.23}{0.34722} = 6.42 \frac{ft}{s}$

$$\frac{6.4.2}{64.4} + 146.24 h_L = 165$$

$h_L = 16.12$ ft

7.35 55 = 0.95

$Q = 175$ gal

$P_{in} = 28.4$

$$\frac{P_1}{\gamma} + \frac{V^2}{2g} + z + h_A = \frac{P_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_R + h_L$$

$P = \gamma Q h_A$

$P = (26.4)(0.4)(550) = 12496$

$21.90 h_A = 12496$

$h_A = 570.53$ ft

$$V = \frac{Q}{A} = \frac{0.34}{0.03326}$$

$= 11.73$

$h_L = 2.8 + 28.50 + 3.5$

$h_L = 34.6$

$$\frac{11.73^2}{64.4} + 1 + h_R + 34.8 \qquad h_R = 532.54$$

$$P = \frac{532.54 \cdot 0.34 \cdot 56.16}{550} = 21.2$$

$$\frac{6.4.2}{64.4} + 146.24h_L = 165$$

$h_L = 16.12$ ft

7.35 55 = 0.95

$Q = 175$ gal

$P_{in} = 28.4$

$$\frac{P_1}{\gamma} + \frac{V^2}{2g} + z + h_A = \frac{P_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_R + h_L$$

$P = \gamma Q h_A$

$P = (26.4)(0.4)(550) = 12496$

$21.90 h_A = 12496$

$h_A = 570.53$ ft

$$V = \frac{Q}{A} = \frac{0.34}{0.03326}$$

$= 11.73$

$h_L = 2.6 + 28.50 + 3.5$

$h_L = 34.6$

$$\frac{11.73^2}{64.4} + 1 + h_R + 34.6 \qquad h_R = 532.54$$

$$P = \frac{532.54 \cdot 0.34 \cdot 56.16}{550} = 21.2$$

7.42 $\frac{P_1}{\gamma} + \frac{V_2}{2g} + z_1 + h_A = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$

$h_A \frac{4320}{62.4} + 37.5$

$h_A = 304.73$

$P = \gamma Q h_A$
$= (62.4)(0.089)(304.73)$

$1692.35 \frac{lb}{s} ft \rightarrow \frac{1692.35}{550} = 3.08 hp$

8.33 $R_e = \frac{\rho v D}{\eta}$

$v = \frac{Q}{A} = \frac{2.50}{0.2006} = 12.46 ft/s$

$Re = \frac{1.93 \cdot 12.46 \cdot 0.5045}{1.77 \times 10^{5}}$

0.0160

$= 6.87 \times 10^5$

$h_L = (0.0160)\left(\frac{550}{0.5054}\right)\left(\frac{12.46}{64.4}\right)^2 = 4.96$

$\frac{P_1}{\gamma} + \frac{V^2}{2g} + z_1 = \frac{P^2}{\gamma} + \frac{V^2}{2g} + z_2 + h_L$

$z_1 = \frac{12.46^2}{64.4} + 41.96$ $z_1 = 44.37 ft$

8.38 $v_2 = 3.22$ m/s

$Re = 44275$

$f = 0.0214$ — Excel

$h_L = 38.43m$

a) $\frac{P_1}{\gamma} + \frac{v^2}{2g} + z_1 + h_A = \frac{P_2}{\gamma} + \frac{v^2}{2g} + z_2 + h_L$

$2.7 + h_A = \frac{140}{10.791} + \frac{3.22^2}{19.62} + 10 + 38.43$

$h_A = 59.23m$

$P = \gamma Q h_A$

$= 10.791 \cdot 0.00156 \cdot 59.23$

$= 1.01$ kW

b) $\frac{P_1}{\gamma} + \frac{v^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v^2}{2g} + z_2$

$2.7 + 59.23 = \frac{P_2}{10.791} + \frac{3.22^2}{19.62} + 1.5$

$\frac{-P_2}{10.791} = 0.53 + 1.5 - 2.7 - 59.23$

$P_2 = 646.4$ kPa

8.44 $V_1 = \frac{Q}{A}$

$\frac{0.5}{0.06886} = 7.28 \text{ ft/s}$

$R_e = \frac{\rho v D}{\eta} =$

$\frac{1.94 \cdot 15.03 \cdot 0.2050}{4 \times 10^{-3}}$

$= 153.085$

$f = 0.0204$

$h_L = (f)\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$

$= (0.204)\left(\frac{80}{0.2058}\right)\left(\frac{15.03^2}{2(32.2)}\right)$

$= 27.91 \text{ ft}$

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

$\frac{-504}{64.02} + \frac{7.28^2}{64.4} + h_A = \frac{3600}{64.02} + 15.03^2 + 80 + 27.9$

$h_A = 174.7$

$P = \gamma Q h_A = \frac{64.02 \cdot 0.5 \cdot 174.7}{550} = 10.17 \text{ hp}$

8.46 $v_1 = \frac{Q}{A}$

$$\frac{4}{0.347} = 11.52 \text{ ft/s}$$

$$Re = \frac{\rho v D}{\eta}$$

$$= \frac{1.94 \cdot 11.52 \cdot 0.6651}{2.35 \times 10^{-5}}$$

$$= 632.51$$

$$f = 0.0155$$

$$h_L = (f)\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$$

$$= 0.0155 \cdot \frac{2500}{0.6651} + \frac{(11.52)^2}{64.4} = 120$$

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

$$\frac{P}{62.4} \quad \frac{11.52^2}{64.4} = 210 + 120$$

$$P_1 = 20.463 \frac{lb}{ft^2}$$

8.49 $Q = 300\ gal/min$

$= 0.6684\ \frac{ft^3}{s}$

$104°F$ oil $= sg = 0.89$

$\gamma = 55.54 \quad \rho = 1.73$

$D = 0.3355$ – 4in sch 40 $\quad A = 0.08840$

$D = 0.2557 \quad A = 0.05132$

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

$= \frac{0.6684}{0.08840} = 7.56\ ft/s$

$\frac{0.6684}{0.05132} = 13.02\ ft/s$

$R_e = \frac{\rho V D}{n} = \frac{1.73 \cdot 7.56 \cdot 0.3355}{3.72 \cdot 10^{-3}}$

$= 1180$

$\frac{\rho V D}{n} = \frac{1.73 \cdot 13.02 \cdot 0.2557}{3.72 \times 10^{3}} =$

$= 1346$

$f = \frac{64}{1140} = 0.0542$

$f = \frac{64}{1366} = 0.0468$

$h_L = (f)\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right) = 0.0542 \cdot \frac{75}{0.3355} \cdot \frac{7.56^2}{64.4}$

$= 3.54 \text{ ft}$

$0.0468 \cdot \frac{75}{0.2557} \cdot \frac{13.02^2}{64.4} = 34.13 \text{ ft}$

$h_L \text{ total} = 39.71 \text{ ft}$

$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{v_1^2}{2g}} + \cancel{z_1} + h_A = \cancel{\frac{P_2}{\gamma}} + \frac{v_2^2}{2g} + z_2 + h_L$

$h_A = \frac{v^2}{2g} + z_2 + h_L$

$= \frac{13.02^2}{2(32.2)} + 1 + 39.71$

43.34 ft

$P = \frac{43.34 \cdot 0.6684 \cdot 55.54}{550}$

2.49 hp

8.62 $R_e = \frac{\rho v D}{\eta}$

6 in sch 40 = $D = 0.5054$

$\rho = 1.76$

$\eta = 2.24 \times 10^{-3}$

$$\frac{1.726 \cdot 12 \cdot 0.5054}{2.24 \times 10^{-3}}$$

$= 4765.2$

Excel

$\downarrow$

$f = 0.038800$

Nathanael Yapnayon

Nathanael Yapnayon

8/30/19

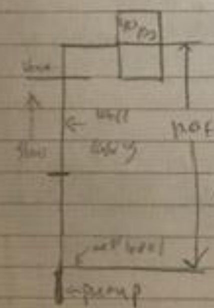
HW 1-4

1 When dealing with open channel flow, use the equation $\left(V = \frac{1.0}{n} S^{1/2} R^{2/3}\right)$. If I want to design a channel flow, I need a geometry, material, and typical slope to handle the quantity $Q = \frac{1.0}{n} A S^{1/2} R^{2/3}$. Examples are rectangle, triangles, trapezoid, or circle for open channel sections. For the same amount of energy in an open channel, the system is stable. If velocity too high or too low, it changes the system's energy. Designing a slower channel can help hold in a lot of the water.

CH7. 11, 16, 22, 30, 35, 42

Problem 11

A submersible deep well pump delivers 745 gal/h of water through a 1 in Schedule 40 pipe when operating in the system 120 ft sketched in fig 7.18. An energy loss of 10.5 lb·ft/lb occurs in the piping system



Given

$Q = 745 \text{ gal/h}$

$Z_1 - Z_2 = 120 \text{ ft}$ $\quad h_L = 10.5 \text{ lb}\cdot\text{ft/lb}$

$P_1 = 1 h_p$ $\quad P_2 = 40 \text{ psi}$

Power pump equations $P_A = h_A \gamma Q$

Bernoulli's equation

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A + h_R - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$h_R = 0$

P_1 is $= 0$ $\quad v_1 = 0$

$$z_1 + h_A - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

Solve for h_A $\qquad$ 1 in / 40 steel pipe = 0.006 in²

$$h_A = \frac{P_2}{\gamma} + (z_2 - z_1) + \frac{V_2^2}{2g} + h_L$$

1 in² = 0.00694

a) the velocity of flow $\quad Q = VA \quad$ find V

$$V = \frac{Q}{A} = \frac{\frac{745 \text{ gal/h}}{(449 \cdot 60)}}{0.006} = 4.61 \text{ ft/s}$$

$$h_A = \frac{5760.36}{62.4} + 120 + \frac{4.61^2}{2(32.18)} + 10.5$$

$$h_A = 223.13\,ft$$

$$P_A = h_A \gamma Q$$

$$P_A = (223.13)(62.4)\left(\frac{745}{449 \times 60}\right)\left(\frac{1\,hp}{550\,lb \cdot ft/s}\right)$$

$$P_A = 0.70\,hp$$

b) Efficiency of the pump

$$e_M = \frac{P_A}{P_I} = \frac{0.70}{1} = 0.70$$

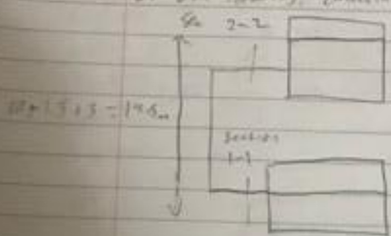
$$\boxed{e_M = 70\%}$$

Nathaniel [illegible]

7.16

A pump delivering 840 L/min of crude oil (sg = 0.85) from an underground storage drum to the first stage of a processing system

(a) If the total energy loss in the system is 4.2 N·m/N of oil flowing, calculate the power delivered by the pump



Based on the figure 7.21

Power pump

$P = \dot{m} W_p$

Density of crude oil

$sg = \frac{\rho_{oil}}{\rho_{water}}$ $\rho_{water} = 1000\ kg/m^3$

$0.85 = \frac{\rho_{oil}}{1000}$ $\rho_{oil} = 850\ kg/m^3$

Find mass flow rate

$\dot{m} = \rho_{oil} Q$

convert to kg/sec

$\dot{m} = (850\ kg/m^3)(840\ \frac{L}{min})(\frac{1 m^3}{1000 L})(\frac{1 min}{60 sec})$

$\dot{m} = 11.9\ kg/sec$

Find Wp

use Bernoulli's equation

$\frac{P_1}{\rho_{oil}} + \frac{v_1}{2} + z_1 g = \frac{P_2}{\rho_{oil}} + \frac{v_2}{2} + z_2 g + W_p + L_f$

$P_1, v_1, z_1, v_2 = 0$

$W_p = -\frac{823 \times 10^3}{850} - (14.5(9.81)) - (4.2 \times 9.81)$

$W_p = -1154.035\ m/kg$

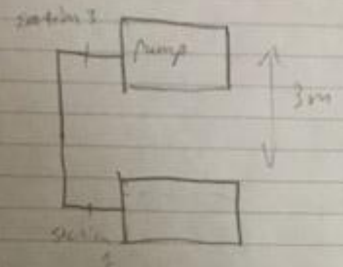
$P = \dot{m} W_p$

$P = 11.9(-1154.035)$

$P = 13732.0165\ N \cdot m/sec$

$\boxed{P = 13733\ W}$

(b) If energy loss in the suction pipe is 1.4 N.m/N of oil flowing, calculate the pressure at the pump inlet



flow rate $Q = A_3 V_3$ section 3

$Q = \left(\frac{\pi}{4} d^2\right) V_3$ Find Velocity in Section 3

$V_3 = \frac{Q}{\left(\frac{\pi}{4} d^2\right)} =$ $Q = 840 L/min \left(\frac{1 m^3}{1000 L}\right)\left(\frac{1 min}{60 sec}\right)$

$Q = 4.534$

$d = 0.0427$

$= \frac{4.534 m}{\frac{\pi}{4}(0.0427^2)}$

Bernoulli's equation

$P_1, V_1, z_1 = 0$

$\cancel{\frac{P_1}{\rho_{oil}}} + \cancel{\frac{V_1}{2}} + \cancel{z_1 g} = \frac{P_3}{\rho_{oil}} + \frac{V_3}{2} + z_3 g + h_L g$

All 3 $\quad 0 = \frac{P_3}{850} + \frac{4.534^2}{2} + (3 \times 9.81) + (1.4 \times 9.81)$

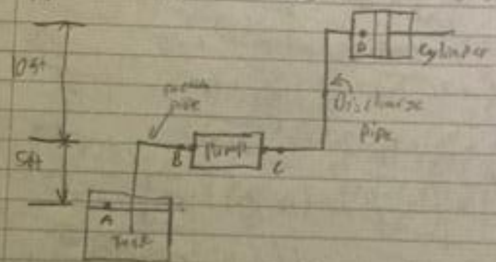
$P_3 = 850\left(-\left(\frac{4.534^2}{2}\right) - (3 \times 9.81) - (1.4 \times 9.81)\right)$

$\boxed{P_3 = -45.42 kPa}$

Nathaniel Yeganegan

Problem 22

The pump draws oil with sg = 0.90 from a reservoir and delivers it to the hydraulic cylinder. Cylinder has $d = 5.0$ in, $t = 15$ s in the piston must travel 30 in while exerting a force of 11000 lb. Energy losses 11.5 lb-ft/lb / 35.0 lb-ft/lb discharge pipe. Both pipes are 3/8 in Schedule 80 steel pipes



Area of cylinder $A_{cyl} = \frac{\pi d^2}{4} = \frac{\pi (5)^2}{4} = 19.635 \text{ in}^2$

(a) Vol flow rate through pump

$Q = \frac{A_{cyl}\, L}{t} = \frac{(19.635 \text{ in}^2)(30 \text{ in})}{15 \text{ s}} \left(\frac{1 \text{ ft}}{12 \text{ in}}\right)^3$

$\boxed{Q = 0.01515 \text{ ft}^3/\text{s}}$

(b) Pressure at the cylinder

$P_D = \frac{F}{A_{cyl}} = \frac{11000 \text{ lb}}{19.635 \text{ in}^2} \left(\frac{144 \text{ in}^2}{1 \text{ ft}^2}\right) =$

$\boxed{P_D = 80672.269 \text{ lb/ft}^2}$

From Table F.2 schedule 80 steel pipe (3/8 in)

e) Velocity of the water at the outlet of the pump

$$V_C = \frac{Q}{A_C} = \frac{0.01515 \ ft^3/s}{0.000976 \ ft^2} = 15.52 \ ft/s$$ at point B

Velocity at point D $V_D = \frac{L}{t}$

$$V_D = \frac{20 \ in}{15 \ s}\left(\frac{1 \ ft}{12 \ in}\right) = 0.1111 \ ft/s$$

Bernoulli's equations at points C/D

$$\frac{P_C}{\gamma_0} + \frac{V_C^2}{2g} + z_C - h_{CD} = \frac{P_D}{\gamma_0} + \frac{V_D^2}{2g} + z_D$$

$$\frac{P_C}{\gamma_0} = \frac{P_D}{\gamma_0} + \frac{V_D^2}{2g} + z_D - \frac{V_C^2}{2g} - z_C + h_{CD}$$

$$P_C = P_D + \gamma_0\left[\left(\frac{V_D^2 - V_C^2}{2g}\right) + (z_D - \cancel{z_C}) + h_{CD}\right]$$

$$P_C = 80672.27 + 56.16\left[\left(\frac{1.1111^2 - 15.53^2}{2(32.2)}\right) + (10) + 35\right]$$

$$\boxed{P_C = 82780.499 \ lb/ft^2}$$

f) Use the Ber equation at points A/B

$$\frac{P_A}{\gamma_0} + \frac{V_A^2}{2g} + z_A - h_{LS} = \frac{P_B}{\gamma_0} + \frac{V_B^2}{2g} + \cancel{z_B}$$

Find P_B

$$P_B = \gamma_0\left[(z_A - 0) - \frac{V_B^2}{2g} - h_{LS}\right]$$

$$P_B = 56.16\left[-5 - \frac{(15.52)^2}{2(32.2)} - 11.5\right]$$

$$\boxed{P_B = -1136.69 \ lb/ft^2}$$

Problem 22

c) The power delivered Bernoulli's equation points A/D

$$\frac{p_A}{\gamma_o}+\frac{v_A^2}{2g}+z_A+h_A-h_{LP}=\frac{p_D}{\gamma_o}+\frac{v_D^2}{2g}+z_D$$

Find h_A

$$z_A+h_A-h_{LS}-h_{LD}=\frac{p_D}{\gamma_o}+\frac{v_D^2}{2g}+z_D$$

$$h_A=\frac{p_D}{\gamma_o}+\frac{v_D^2}{2g}+(z_D-z_A)+h_{LS}+h_{LD}$$

$$h_A=\frac{80672.27}{56.16}+\frac{(0.1111)^2}{2(32.2)}+(10-(-5))+11.5+35$$

$= 1436.47 + (1.91\times10^{-4}) + 15 + 46.5$

$= 1497.99 \text{ ft}$

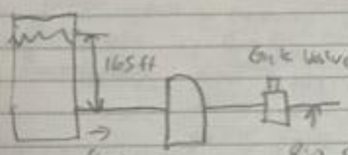
Calculate the power

$$P=\frac{h_A\gamma Q}{550}=\frac{(1497.99\text{ ft})(56.16\text{ lb/ft}^3)(0.01515\text{ ft}^3/\text{s})}{550}$$

$$\boxed{P=2.32\text{ hp}}$$

Problem 30

Water at 60°F flows at the rate of 1000 gal/min system shown in the figure.
If the motor removes 37 hp from the fluid, calculate losses in the system



8 in Schedule 40 steel Pipe $= 0.3472 ft^2$

Ber. equation

$$\cancel{\frac{P_1}{\gamma}} + z_1 + \cancel{\frac{v_1^2}{2g}} + \cancel{h_A} + h_g - h_L = \cancel{\frac{P_2}{\gamma}} + z_2 + \frac{v_2^2}{2g}$$

No energy added to the system

$$z_1 + h_g - h_L = z_2 + \frac{v_2^2}{2g}$$

Find h_L

$$h_L = (z_1 - z_2) - \frac{v_2^2}{2g} - h_R$$

Power delivered to fluid

$P_R = h_R \gamma Q$ Find $h_R = \frac{P_R}{\gamma Q} = \frac{37(550)}{62.4(2.227)} = 146.43 ft$

Velocity of flow

$$V = \frac{Q}{A} = \frac{2.227}{0.3472} = 6.41 ft/s$$

$$h_L = (z_1 - z_2) - \frac{v_2^2}{2g} - h_g$$

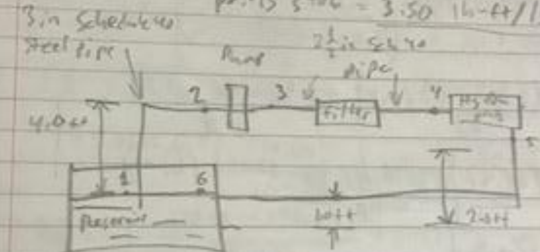
$$= 165 - \frac{6.41^2}{2(32.2)} - 146.43 = 17.932 ft$$

$$= \boxed{18 ft}$$

Problem 35

Figure 7.36 shows a diagram of a fluid power system for a hydraulic press used to extrude rubber parts

Given
fluid is oil ($s_g = 0.93$)
Volume flow rate is 175 gal/min
Power input to the pump is 28.4 hp
Pump eff is 80%
Energy loss point 1 to 2 = 2.80 lb-ft/lb
point 3 to 4 = 28.50 lb-ft/lb
points 5 to 6 = 3.50 lb-ft/lb



Point 4 / point 5

$$\frac{P_4}{\gamma} + z_4 + \cancel{\frac{v_4^2}{2g}} - h_R = \frac{P_5}{\gamma} + z_5 + \cancel{\frac{v_5^2}{2g}}$$ Velocities = 0

$$\frac{P_4}{\gamma} + z_4 - h_R = \frac{P_5}{\gamma} + z_5$$

Solving for $h_R = -\left(\frac{P_5 - P_4}{\gamma} + (z_5 - z_4)\right)$

Pressure Point 2 / Point 1

$$\cancel{\frac{P_1}{\gamma}} + z_1 + \cancel{\frac{v_1^2}{2g}} + \cancel{h_A} - \cancel{h_R} - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$z_1 - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$P_2 = \gamma\left((z_1 - z_2) - \frac{v_2^2}{2g} - h_L\right)$$

Find specific weight of oil

$y = sg \times y_w \quad y = (0.93)(62.4) = 58.032 \text{ lb/ft}^3$

Velocity flow at point 2

$$V_2 = \frac{Q}{A_2} = \frac{0.399}{0.05132} = 7.57 \text{ ft/s}$$

using P_2 calculate pressure

$$P_2 = 58.032\left(-4 - \frac{7.57^2}{2(32.2)} - 2.8\right)$$

$$= (496.31 \text{ lb/ft}^2)\left(\frac{0.006944 \text{ lb/in}^2}{1 \text{ lb/ft}^2}\right) = \boxed{3.1 \text{ psi}}$$

$$* \; P_3 = y\left(\frac{P_2}{y} + \frac{(V_2^2 - V_3^2)}{2g} + h_A\right) \qquad h_A = \frac{P_A}{yQ}$$

$$P_A = (0.5)(28.4)\left(\frac{550 \text{ lb·ft/s}}{1 \text{ hp}}\right) = 12496 \text{ lb·ft/s}$$

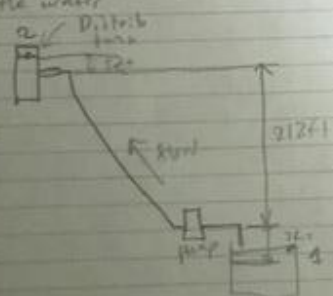
$$h_A = \frac{12496}{(58.032)(0.399)} = 552.18 \text{ lb·ft/s}$$

$A = 2\frac{1}{2}$ in / sched $= 0.03326 \text{ ft}^2 \qquad V_3 = \frac{Q}{A} = \frac{0.399}{0.03326} = 11.73 \text{ ft/s}$

$A = 3$ in / sched $= 0.05132 \qquad V_2 = \frac{0.399}{0.05132} = 7.6 \text{ ft/s}$

Problem 42

The distribution tank in the cabin maintains a pressure of 30.0 psig above water.
There is an energy loss of 15.5 lb-ft/lb in the piping
Pump delivering 40 gal/min of water.
Compute the hp delivered by the pump to the water



Given $p_2 = 30\ \text{psig} \Rightarrow 4320\ \text{lb/ft}^2$

$h_L = 15.5\ \text{lb-ft/lb}$

$z_2 - z_1 = 215 - (-5) = 220\ \text{ft}$

B. equation $\cancel{\frac{p_1}{\gamma}} + z_1 + \cancel{\frac{v_1^2}{2g}} + h_A + \cancel{h_R} - h_L = \frac{p_2}{\gamma} + z_2 + \cancel{\frac{v_2^2}{2g}}$

$z_1 + h_A - h_L = \frac{p_2}{\gamma} + z_2$

Find $h_A = \frac{p_2}{\gamma} + (z_2 - z_1) + h_L = \frac{4320}{62.4} + 220 + 15.5$

$h_A = 304.73\ \text{ft}$

$P_A = (304.73)(62.4)(0.089) = 1692.351\ \text{ft-lb/s} \left(\frac{1\ \text{hp}}{550\ \text{ft-lb/s}}\right)$

$P_A = 3.07699 = \boxed{3.08\ \text{hp}}$

Problem 75

Pressure 3 use P_3 equation

$$P_3 = 58.032\left(\frac{-496.2}{58.032} + \frac{7.6^2 - 11.73^2}{2(32.2)} + 552.18\right)$$

convert

$$= 31525.89\ lb/ft^2\left(\frac{1\ ft^2}{144\ in^2}\right) = 219\ psi$$

Pressure 4

$$P_4 = \gamma\left(\frac{P_3}{\gamma} - h_L\right)\left(\frac{1\ ft^2}{144\ in^2}\right)$$

$$= 58.032\left(\frac{31525.89}{58.032} - 28.5\right) = 207.44\ psi$$

Pressure 5

$$P_5 = \gamma\left[(z_6 - z_5) + h_L\right] = 58.032(-1 + 2.5) = 145.08$$

$$145.08\ lb/ft^2\left(\frac{1\ lb/in^2}{144\ lb/ft^2}\right) = 1.0075\ psi = 1.01\ psi$$

Use h_R

$$h_R = -\left(\frac{145.08 - 29873.67}{58.032} + (-2)\right) = -514.19\ ft$$

Calculate P_R

$$P_R = (514.192)(58.032)(0.39)$$

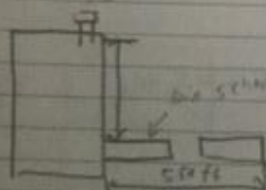
$$= (11638.45\ lb \cdot ft/s)\left(\frac{1\ hp}{550\ lb \cdot ft/s}\right) = 21.15858$$

$$\boxed{P_R = 21.16\ hp}$$

Nathaneal Yaforyan

CH 8: 33, 39, 47, 46, 49, 62

Problem 32 Water at 80°F flows from a storage tank through 550 ft of 6 in Schedule 40 steel pipe. Taking the energy loss due to friction into account.
Calculate the required head h above the pipe inlet to produce a volume flow rate of 2.50 ft^3/s



$P_1 = P_2$

Bernoulli's equation

$$\frac{\cancel{P_1}}{\cancel{\gamma}} + \cancel{z_1} + \cancel{\frac{v_1^2}{2g}} - h_L = \frac{\cancel{P_2}}{\cancel{\gamma}} + \cancel{z_2} + \frac{v_2^2}{2g}$$

$$h = h_L + \frac{v_2^2}{2g}$$

flow rate $Q = AV$ Find V   6 in/40 steel = 0.5054 ft

$$V = \frac{Q}{A} = \frac{2.50\ ft^3/s}{0.2006} = 12.46\ ft/s$$

From 80°F (Table A.1) = 9.15×10^{-6}

Calculate Reynold's # $N_R = \frac{VD}{\nu} = \frac{(12.46)(0.504)}{9.15 \cdot 10^{-6}} = 688277.7576$

$= 6.8 \times 10^5$

Stell rough = 1.5×10^{-4} ft

Calculate relative roughness

$$R_r = \frac{D}{\epsilon} = \frac{\text{diameter}}{\text{roughness}} = \frac{0.5054}{1.5 \times 10^{-4}} = 3369.3$$

moody's diagram (fig 8.6

friction $(f) = 0.0165$

head loss

$$h_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = 0.0165\left(\frac{550}{0.5054}\right)\left(\frac{(12.46)^2}{2(32.2)}\right)$$

$$= 43.29 \text{ ft}$$

$$h = \frac{12.46^2}{2(32.2)} + 43.29^2 = \boxed{45.70 \text{ ft}}$$

Problem 38

The nozzle on the end of the hose requires 140 kPa of pressure to operate effectively. The hose is smooth plastic with an ID of 25 mm. The fertilizer solution has a sg of 1.10 and a dynamic viscosity of 2.0×10^{-3} Pa·s. If the length of the hose is 85 m. The flow rate = 95 L/min

Bernoulli $v_1 = 0$

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$$

$P_1 - P_{atm}$

$$\frac{P_{atm}}{\gamma} + z_1 + h_A = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$$

Find pump $h_A = \left(\frac{P_2}{\gamma} - \frac{P_{atm}}{\gamma}\right) + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$

Find Area of pipe $A = \frac{\pi D^2}{4} = \frac{\pi (0.025m)^2}{4} = 4.909 \times 10^{-4} m^2$

Find Q to m^3/s $Q = 95 \frac{L}{min}\left(\frac{m^3}{10^3 L}\right)\left(\frac{1 min}{60 s}\right) = 1.583 \times 10^{-3} m^3/s$

$V = \frac{Q}{A} = \frac{1.583 \times 10^{-3}}{4.909 \times 10^{-4}} = 3.22 m/s$

Find Reynold number of flow

$Re = \frac{\rho V D}{\eta}$

density

$\rho = (sg)(\rho_w)$

$= (1.10)(1000\ kg/m^3) = 1100\ kg/m^3$

$Re = \frac{\rho V D}{\eta} = \frac{1100(3.22)(0.025)}{2\times10^{-3}} = 44275$

Based on Re, friction factor from Moody's diagram is $f = 0.024$

head loss

$h_L = f\frac{L}{D}\left(\frac{v^2}{2g}\right) = 0.024\left(\frac{85}{0.025}\right)\left(\frac{3.22^2}{2\times9.81}\right)$

$= 43.172\ m$

Specific weight of fertilizer

$\gamma = (1.10)(9.81\ kN/m^3) = 10.791\ kN/m^3$

Input all the values in h_A

$h_A = \left(\frac{146}{10.791} - \frac{101}{10.791}\right) + \left(10 - (2.7)\right) + \frac{3.22^2}{2(9.81)} + 43.172$

$= 54.177\ m$

Power $P = h_A \gamma Q = (54.197)(10.791)(1.58\cdot10^{-3}) = \boxed{0.924\ kW}$

(b) The pressure at the outlet

Bern. equation for point 1 & 3 $\quad v_1 = 0$

$\frac{P_1}{\gamma} + z_1 + \cancel{\frac{v_1^2}{2g}} + h_A = \frac{P_3}{\gamma} + z_3 + \frac{v_3^2}{2g} = \frac{P_1}{\gamma} + z_1 + h_A = \frac{P_3}{\gamma} + \cancel{z_3} + \frac{v^2}{2g}$

$z_3 = 0$

Plug values $\frac{101}{10.791} + 1.2 + 54.177 = \frac{P_3}{10.791} + \frac{3.22^2}{2(9.81)}$

Solve for P_3

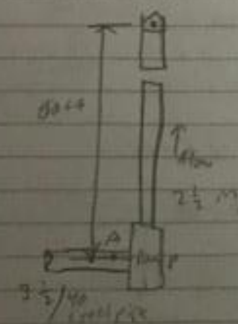
$64.756 = \frac{P_3}{10.791} + 0.528 \quad \boxed{P_3 = 693.08\ kPa}$

$P_3 = (64.756 - 0.528)(10.791)$

Problem 44

Figure 8.18 shows a system used to spray polluted water into the air to increase the water's oxygen content and to cause volatile solvents in the water vaporize. The pressure at point A (pump inlet) is -3.5 psig. Volume flow rate is 0.50 ft³/s. The dynamic viscosity of the fluid is 4.0×10^{-5} lb·s/ft². Sg of the fluid is 1.026

Compute the power delivered by the pump to the fluid, considering friction loss in discharge $P = h_A \gamma_F Q$



$Q = VA$

$V_B = \frac{Q}{A_A}$

Find V_A (Point A

$$V_A = \frac{0.50\ ft^3/s}{0.06868\ ft^2} = 7.28\ ft/s$$

Find V_B

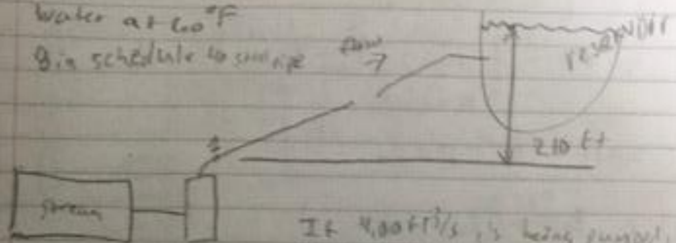
$$V_B = \frac{0.50\ ft^3/s}{0.03326\ ft^2} = 15.03\ ft/s$$

$\rho_F = sg(\rho_w) = 1.026(1.94\ slugs/ft^3) = \underline{1.9904\ slugs/ft^3}$

Problem 46

Water at 60°F

8 in schedule 40 steel pipe



If 4.00 ft³/s is being pumped, compute the pressure at the outlet of the pump.

Bernoulli's equation

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

Find P_1

$$\frac{P_1}{\gamma} = (z_2 - z_1) + h_L \quad = \quad P_1 = \gamma(z_2 - z_1) + h_L$$

velocity $Q = VA$ $\quad V_a = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}d^2} = \frac{4\ ft^3/s}{\frac{\pi}{4}\left(\frac{8}{12}\,ft\right)^2}$

$\underline{V_1 = 11.46}$

60°F Table A-2 $\nu = 1.21 \times 10^{-5}\ ft^2/s$

$$N_R = \frac{V_1 D}{\nu} = \frac{11.46\left(\frac{8}{12}\,ft\right)}{1.21 \times 10^{-5}\ ft^2/s} = 631404.95$$

Relative roughness $\qquad \epsilon = 1.5 \times 10^{-4}$ from table 8.2 pipe

$$= \frac{\epsilon}{d} = \frac{1.5 \times 10^{-4}\ ft}{\frac{8}{12}\ ft} = 0.000225$$

[illegible]

friction factor = 0.0153

Find h_L

$$h_L = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right) =$$

$$= 0.0153\left(\frac{2500}{\left(\frac{8}{12}\right)}\right)\left(\frac{(11.46)^2}{2(32.2)}\right)$$

$$= 117\ ft$$

Use $P_1 = \gamma[(z_2 - z_1) + h_L]$

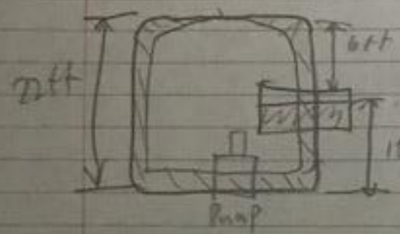
$$= 62.4(210 - 0 + 117)\left(\frac{1\ ft}{12\ in}\right)^2$$

$$= \boxed{141.7\ psi}$$

Nattanon Yupangon

Problem 49

Compute the power delivered by the pump to the oil



Bernoulli's equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 - h_L + h_A = \frac{P_2}{\gamma} + Z_2$$

Find h_A

$$h_A = h_L + (z_2 - z_1) + \frac{V_2^2}{2g}$$

$$V_D = \frac{Q}{A} = \frac{0.668}{0.05132} = 13.024\ ft/s$$

$$V_S = \frac{0.668}{0.0884} = 7.56\ ft/s$$

$$N_R = \frac{V D}{\nu} = \frac{(13.024)(0.2557)}{2.15 \times 10^{-3}} = 1548.947$$

$$F_D = \frac{64}{N_R} = \frac{64}{1548.947} = 0.04132 \quad N_{RS} = \frac{7.56(0.3355)}{2.15 \times 10^{-3}} = 1179.711$$

$$F_S = \frac{64}{1179.74} = 0.054$$

$$h_D = F_D \left(\frac{L_D}{D_D}\right)\left(\frac{V_D^2}{2g}\right) = \frac{(0.04132)(75)(13.024^2)}{(0.2557)(2)(32.2)} = 31.52\ ft$$

$$h_S = F_S \frac{L_S}{D_S}\left(\frac{V_S^2}{2g}\right) = (0.054)\left(\frac{25}{0.3355}\right)\left(\frac{7.56^2}{2 \times 32.2}\right) = 3.57\ ft$$

$$h_L = h_D + h_S = 35.49\ ft$$

$$\gamma = sg \times \gamma_w = (0.86)(62.4) = 53.536\ lb/ft^3$$

$$h_A = 35.49 + 1 + \frac{13.024^2}{2(32.2)} = 39.1\ ft$$

Power delivered $P = (53.536)(0.668)(39.1)\left(\frac{1}{550}\right) = 2.64\ hp$

Problem 62

Heavy oil at 77°F flow in 6 in / 40 steel pipe at 12 ft/s Calculate friction factor

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right)^2}$$

Reynolds # $N_R = \frac{vD}{\nu}$ $\nu = 1.27 \times 10^{-3}\ ft^2/s$ (kinematic viscosity 77°F)

Based table F.1 6 in / schedule 40

$D = 0.5054$ ft

$$N_R = \frac{vD}{\nu} = \frac{12(0.5054)}{1.27 \times 10^{-3}} = 4775.47 > 4000$$

flow turbulent

$$= \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.5054}{1.5 \times 10^{-4}}\right)} + \frac{5.74}{(4775)^{0.9}}\right)\right]^2}$$

$$\boxed{f = 0.0388}$$

friction factor