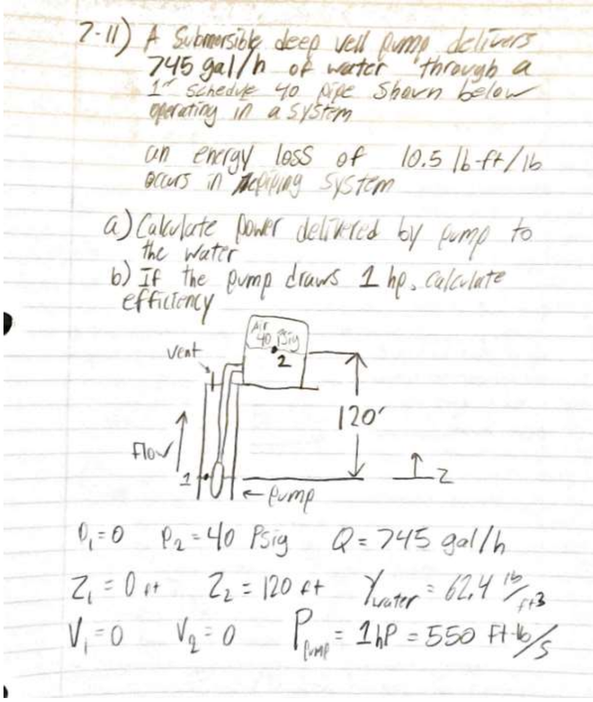
# Homework 1.4

This week we learned about Reynolds number, energy loss, minor loss, and different types of flows. Reynolds number was developed by a guy name Osborne Reynolds, and developed an equation that helps us find energy loss. When we divide fluid inertia forces by viscous forces, we can look at a graph to find out what the energy loss is. If Re < 2100, then the flow is laminar, if Re > 4000 then the flow is turbulent. There was another person who developed a similar way to find energy loss. Darcy developed the equation: $H_L = f * \frac{L}{D} * \frac{v^2}{2g}$, which also uses an overly complicated graph that no one can read for exact values. If the flow is laminar we can use the equation, $f = \frac{64}{n_r}$ and if the flow is turbulent (and god has abandoned you) we use $f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$. It is important to know these values, as it helps design piping diagrams and understand what is going on inside them.

In open channel systems, the Reynolds number changes from Re < 2100 and Re > 4000 to Re < 500 and Re > 2000. The Reynolds equation also changes to $N_R = \frac{vR}{v}$. If friction is less than 1, it is sub critical flow, If it is equal to 1, then it is critical flow, and if it is greater than 1, it is super critical flow.

Homework Problems

7.11



7-11) A Submersible deep well pump delivers 745 gal/h of water through a 1" Schedule 40 pipe shown below operating in a system

an energy loss of 10.5 lb-ft/lb occurs in ~~the~~ piping system

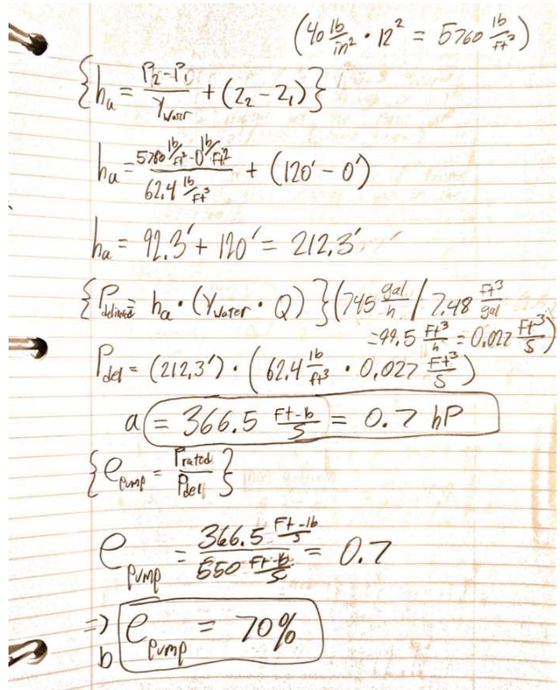
a) Calculate power delivered by pump to the water
b) If the pump draws 1 hp, calculate efficiency



$P_1 = 0 \quad P_2 = 40\ \text{Psig} \quad Q = 745\ \text{gal/h}$

$Z_1 = 0\ \text{ft} \quad Z_2 = 120\ \text{ft} \quad \gamma_{water} = 62.4\ \text{lb/ft}^3$

$V_1 = 0 \quad V_2 = 0 \quad P_{pump} = 1\ \text{hP} = 550\ \text{ft-lb/s}$



$\left(40\ \frac{\text{lb}}{\text{in}^2} \cdot 12^2 = 5760\ \frac{\text{lb}}{\text{ft}^2}\right)$

$\left\{ h_a = \frac{P_2 - P_1}{\gamma_{water}} + (Z_2 - Z_1) \right\}$

$h_a = \frac{5760\ \text{lb/ft}^2 - 0\ \text{lb/ft}^2}{62.4\ \text{lb/ft}^3} + (120' - 0')$

$h_a = 92.3' + 120' = 212.3'$

$\left\{ P_{delivered} = h_a \cdot (\gamma_{water} \cdot Q) \right\} \left(745\ \frac{\text{gal}}{\text{h}} / 7.48\ \frac{\text{ft}^3}{\text{gal}} = 99.5\ \frac{\text{ft}^3}{\text{h}} = 0.027\ \frac{\text{ft}^3}{\text{s}}\right)$

$P_{del} = (212.3') \cdot \left(62.4\ \frac{\text{lb}}{\text{ft}^3} \cdot 0.027\ \frac{\text{ft}^3}{\text{s}}\right)$

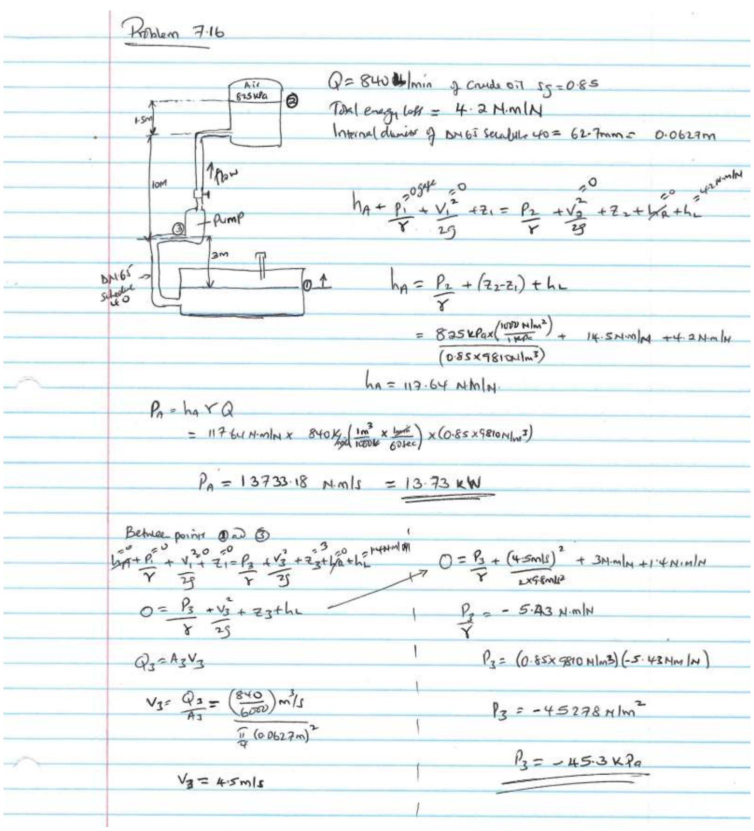
a $\boxed{= 366.5\ \frac{\text{ft-lb}}{\text{s}} = 0.7\ \text{hP}}$

$\left\{ e_{pump} = \frac{P_{rated}}{P_{del}} \right\}$

$e_{pump} = \frac{366.5\ \frac{\text{ft-lb}}{\text{s}}}{550\ \frac{\text{ft-lb}}{\text{s}}} = 0.7$

b $\Rightarrow \boxed{e_{pump} = 70\%}$

7.16



Problem 7.16



$Q = 840\ \text{L/min}$ of crude oil $sg = 0.85$

Total energy loss $= 4.2\ \text{N}\cdot\text{m/N}$

Internal diameter of DN 65 Schedule 40 = 62.7 mm = 0.0627 m

$h_A + \frac{\overset{=0\ \text{gage}}{p_1}}{\gamma} + \frac{\overset{=0}{V_1^2}}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{\overset{=0}{V_2^2}}{2g} + z_2 + \overset{=0}{\cancel{h_R}} + \overset{=4.2\ \text{N}\cdot\text{m/N}}{h_L}$

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

$= \frac{825\ \text{kPa} \times \left(\frac{1000\ \text{N/m}^2}{1\ \text{kPa}}\right)}{(0.85 \times 9810\ \text{N/m}^3)} + 14.5\ \text{N}\cdot\text{m/N} + 4.2\ \text{N}\cdot\text{m/N}$

$h_A = 117.64\ \text{N}\cdot\text{m/N}$

$P_A = h_A \gamma Q$

$= 117.64\ \text{N}\cdot\text{m/N} \times 840\ \text{L/min} \left(\frac{1\ \text{m}^3}{1000\ \text{L}} \times \frac{1\ \text{min}}{60\ \text{sec}}\right) \times (0.85 \times 9810\ \text{N/m}^3)$

$P_A = 13733.18\ \text{N}\cdot\text{m/s} = \underline{\underline{13.73\ \text{kW}}}$

Between points 1 and 3

$\overset{=0}{\cancel{h_A}} + \frac{\overset{=0}{p_1}}{\gamma} + \frac{\overset{=0}{V_1^2}}{2g} + \overset{=0}{z_1} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \overset{=3}{z_3} + \overset{=0}{\cancel{h_R}} + \overset{=1.4\ \text{N}\cdot\text{m/N}}{h_L}$

$0 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_L$

$Q_3 = A_3 V_3$

$V_3 = \frac{Q_3}{A_3} = \frac{\left(\frac{840}{6000}\right)\ \text{m}^3/\text{s}}{\frac{\pi}{4}(0.0627\ \text{m})^2}$

$V_3 = 4.5\ \text{m/s}$

$0 = \frac{P_3}{\gamma} + \frac{(4.5\ \text{m/s})^2}{2 \times 9.8\ \text{m/s}^2} + 3\ \text{N}\cdot\text{m/N} + 1.4\ \text{N}\cdot\text{m/N}$

$\frac{P_3}{\gamma} = -5.43\ \text{N}\cdot\text{m/N}$

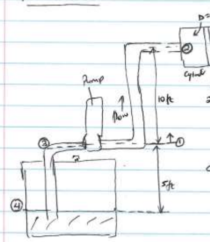
$P_3 = (0.85 \times 9810\ \text{N/m}^3)(-5.43\ \text{N}\cdot\text{m/N})$

$P_3 = -45278\ \text{N/m}^2$

$\underline{\underline{P_3 = -45.3\ \text{kPa}}}$

7.22

Problem 7.22




Oil sg = 0.90

Energy losses

Suction pipe = 11.5 lb·ft/lb

discharge pipe = 35.0 lb·ft/lb

Both pipes are 3/8-in schedule 80 steel pipes

Inside diameter = 0.423 in

a) Volume flow rate.

⇒ makes the piston to move 20 in in 15 seconds.

$Q = VA$

$= \left(\frac{20}{12} ft\right)\frac{1}{15 sec} \times \frac{\pi}{4}\left(\frac{5}{12} ft\right)^2$

$\underline{Q = 0.0152\ ft^3/s}$

b) Pressure at the cylinder:

$P = F/A = \frac{11000 lb}{\frac{\pi}{4}(5/12)^2 ft^2} = 80672.5\ lb/ft^2$

c) Pressure at the outlet of the pump

$h_A^{=0} + \frac{P_1}{\gamma}^{=?} + \frac{v_1^2}{2g} + z_1^{=0} = \frac{P_2}{\gamma}^{=80672.5 lb/ft^2} + \frac{V_2^2}{2g} + z_2^{=10} + h_R^{0} + h_L^{=35 lb·ft/lb}$

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

$Q = VA$ $\quad V_1 = \frac{Q}{A_1} = \frac{0.0152 ft^3/s}{\frac{\pi}{4}(0.\frac{423}{12} ft)^2} = 15.58\ ft/s$

$V_2 = \frac{Q}{A_2} = \frac{0.0152 ft^3/s}{\frac{\pi}{4}(5/12)^2} = 0.1115\ ft/s$

$\frac{P_1}{\gamma} = \left(\frac{80672.5 lb/ft^2}{0.9 \times 62.4 lb/ft^3}\right) + \frac{(0.1115^2 - 15.58^2) ft^2/s^2}{2 \times 32.2 ft/s^2} + 10 lb·ft/lb + 35 lb·ft/lb$

$\frac{P_1}{\gamma} = 1436.48\ lb·ft/lb + -3.77\ lb·ft/lb + 10\ lb·ft/lb + 35\ lb·ft/lb$

$P_1 = (0.9 \times 62.4 lb/ft^3)(1477.71 lb·ft/lb)$

$\underline{P_1 = 82988.2\ lb/ft^2}$

d) Pressure at the inlet to the pump.

$h_A^{=0} + \frac{P_4}{\gamma}^{=0} + \frac{V_4^2}{2g}^{=0} + z_4^{=0} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3^{=5ft} + h_R^{=0} + h_L^{=11.5 lb·ft/lb}$ $\quad V_3 = V_1 = 15.58\ ft/s$ - same flow rate and equal area

$0 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_L$

$0 = \frac{P_3}{\gamma} + \frac{(15.58 ft/s)^2}{2 \times 32.2 ft/s^2} + 5\ lb·ft/lb + 11.5\ lb·ft/lb$

$\frac{P_3}{\gamma} = -3.77\ lb·ft/lb - 5\ lb·ft/lb - 11.5\ lb·ft/lb$

$= -20.27\ lb·ft/lb$

$P_3 = (0.9 \times 62.4\ lb/ft^3)(-20.27\ lb·ft/lb)$

$\underline{P_3 = -1138.36\ lb/ft^2}$

e) Power delivered by the pump.

$h_A + \frac{P_4}{\gamma}^{=0 gage} + \frac{V_4^2}{2g}^{\approx 0} + z_4^{=0} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_R^{=0} + h_L$

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

$= \left(\frac{80672.5 lb/ft^2}{0.9 \times 62.4 lb/ft^3}\right) + \frac{(0.1115 ft/s)^2}{2 \times 32.2 ft/s^2}^{\approx 0} + 15\ lb·ft/lb + (11.5 + 35)\ lb·ft/lb$

$h_A = 1436.48\ ft + 61.5\ ft = 1497.98\ ft$

$P_A = h_A \gamma Q$

$= 1497.98\ ft \times 0.9 \times 62.4\ lb/ft^3 \times 0.0152\ ft^3/s$

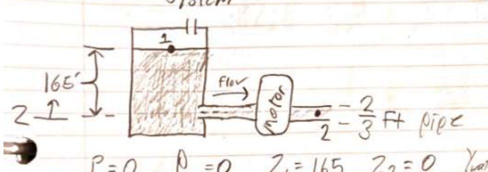
$= 1278.73\ lb·ft/s \times \frac{1 hp}{550\ lb·ft/s}$

~~$P_A = 2.56 hp$~~ $\underline{P_A = 2.32 hp}$

7.30

7-30) Water at 60°F Flows from a large reservior through a fluid motor at the rate of 1000 gal/min (shown below)

If the motor removes 37 hp from the fluid, Find energy losses in the System




$P_1 = 0 \quad P_2 = 0 \quad Z_1 = 165 \quad Z_2 = 0 \quad \gamma_{water} = 62.4 \frac{lb}{ft^3}$

$V_1 = 0 \quad V_2 = \frac{Q}{A} \quad Q = 1000 \frac{gal}{min} \quad P_{gen} = 37 hp$

$\{A = \pi r^2\} \quad A = \pi \cdot \left(\frac{2/3 ft}{2}\right)^2 = 0.34\ ft^2$

$\left\{V_2 = \frac{Q}{A}\right\} \quad V_2 = \frac{1000\ gal/min}{0.34\ ft^2} = 2864.8 \frac{ft}{min}$

$\left\{h_R = (z_2 - z_1) + \frac{V_2^2 - V_1^2}{2g}\right\}$

$h_R = (0 - 165) + \left(\frac{2864.8^2 \frac{ft^2}{min^2} - 0^2}{2 \cdot 1970 \frac{ft}{min}}\right)$

$h_R = -165 + 2137.3 = 1972.2'$

$1000 \frac{gal}{min} = 16.7 \frac{gal}{s} = 2.2 \frac{ft^3}{s}$

$\{P_{gen} = h_R \cdot (\gamma_{water} \cdot Q)\}$

$P_{gen} = 1972.2' \cdot \left(62.4 \frac{lb}{ft^3} \cdot 2.2 \frac{ft^3}{s}\right)$

$P_{gen\ calc} = 273112.8 \frac{ft \cdot lb}{s}$ = 496.5 hp

$P_{gen\ act} = 37 hp \cdot 550 = 20350 \frac{ft \cdot lb}{s}$

$\Rightarrow \frac{20,350}{273,112.8} \frac{ft \cdot lb}{s} = 0.07 = 7°$ efficiency Motor

$\left\{h_L = (z_1 - z_2) - \frac{V_2^2}{2g} - P_{gen\ act}\right\} \quad \left(2864.8 \frac{ft}{min}/60 = 47.7 \frac{ft}{s}\right)$

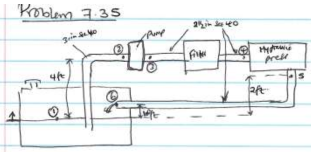
$h_L = (165') - \left(\frac{47.7 \frac{ft}{s}}{2 \cdot 32 \frac{ft}{s}}\right) - 20,350 \frac{ft \cdot lb}{s}$

$h_L = 164.3 - 20,350 \frac{ft \cdot lb}{s}$

$h_L = -20,185 \frac{ft \cdot lb}{s} = -36.7 hp$

7.35

Problem 7.35




Oil sg = 0.9

$Q = 175$ gal/min

$P_I = 28.4$ hp

$e_m = 80\%$

$h_{L_{1-2}} = 2.8$ lb·ft/lb

$h_{L_{3-4}} = 28.5$ lb·ft/lb

$h_{L_{5-6}} = 3.5$ lb·ft/lb

Power removed by the press.

$$h_A + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_6}{\gamma} + \frac{v_6^2}{2g} + z_6 + h_R + h_L$$

$$h_A = \frac{v_6^2}{2g} + z_6 + h_R + h_L$$

$$h_R = h_A - \frac{v_6^2}{2g} - z_6 - h_L$$

$$= 570.53\ \text{lb·ft/lb} - \frac{(11.72\ \text{ft/s})^2}{2 \times 32.2\ \text{ft/s}^2} - 1\ \text{lb·ft/lb} - 34.8\ \text{lb·ft/lb}$$

$h_R = 532.6$ lb·ft/lb

$P_R = h_R \gamma Q$

$= 532.6\ \text{lb·ft/lb} \times 56.16\ \text{lb/ft}^3 \times 0.39\ \text{ft}^3/\text{s}$

$= 11665.21824\ \text{ft·lb/s} \times \frac{1\ \text{hp}}{550\ \text{ft·lb/s}}$

$= 21.21$ hp

$$\boxed{P_R = 21.21\ \text{hp}}$$

$\Rightarrow e_m = \frac{P_A}{P_I}$ $P_A = e_m P_I$

$= 0.8 \times 28.4$ hp

$P_A = 22.72$ hp

$\Rightarrow P_A = h_A \gamma Q$

$\gamma = 0.9 \times 62.4\ \text{lb/ft}^3$

$h_A = \frac{P_A}{\gamma Q}$ $\gamma = 56.16\ \text{lb/ft}^3$

$Q = 175\ \text{gal/min} \times \frac{1\ \text{ft}^3/\text{s}}{449\ \text{gal/min}}$

$Q = 0.39\ \text{ft}^3/\text{s}$

$$h_A = \frac{22.72\ \text{hp} \times \frac{550\ \text{ft·lb/s}}{1\ \text{hp}}}{56.16\ \text{lb/ft}^3 \times 0.39\ \text{ft}^3/\text{s}}$$

$h_A = 570.53$ lb·ft/lb

$\Rightarrow h_L = h_{L_{1-2}} + h_{L_{3-4}} + h_{L_{5-6}}$

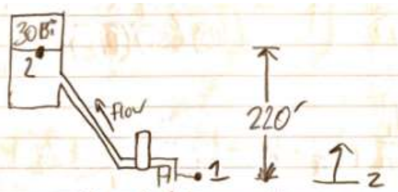
$= (2.8 + 28.5 + 3.5)$ lb·ft/lb

$h_L = 34.8$ lb·ft/lb

$\Rightarrow Q = vA$ $v_6 = \frac{Q}{A} = \frac{0.39\ \text{ft}^3/\text{s}}{\frac{\pi}{4}(0.2058\ \text{ft})^2}$

$v_6 = 11.72$ ft/s

7.42




$P_1 = 0$ $P_2 = 30\ \frac{\text{lb}}{\text{in}^2} = 4320\ \frac{\text{lb}}{\text{ft}^2}$ $V_1 = 0$ $V_2 = 0$

$Z_1 = 0$ $Z_2 = 220'$ $Q = 40\ \frac{\text{gal}}{\text{min}} = \frac{2}{3}\ \frac{\text{gal}}{\text{s}} = 0.089\ \frac{\text{ft}^3}{\text{s}}$

$h_L = 15.5\ \frac{\text{lb-ft}}{\text{lb}}$ $\gamma_{water} = 62.4\ \frac{\text{lb}}{\text{ft}^3}$ $h_R = 0$

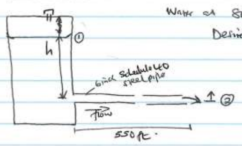
$$\left\{ h_A - h_L = \frac{P_2}{\gamma_{water}} + Z_2 \right\}$$

$$\Rightarrow h_A = \frac{4320\ \frac{\text{lb}}{\text{ft}^2}}{62.4\ \frac{\text{lb}}{\text{ft}^3}} + 220' + 15.5\ \frac{\text{lb-ft}}{\text{lb}} = 304.7\ \frac{\text{lb-ft}}{\text{lb}}$$

$$\frac{304.7}{550} = \boxed{0.554\ \text{HP}}$$

8.33

Problem 8.33




Water at 80°F $\gamma = 62.2\ lb/ft^3$

Desired $Q = 2.50\ ft^3/s$

$h = ?$

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

$v = \frac{Q}{A} = \frac{2.5\ ft^3/s}{\pi/4 (0.5054 ft)^2}$

$v = 12.46\ ft/s$

$\varepsilon = 1.5 \times 10^{-4}$

$D = 0.5054\ ft$

$\nu = 9.5 \times 10^{-6}\ ft^2/s$

$N_R = \frac{vD}{\nu} = \frac{12.46 ft/s \times 0.5054 ft}{9.5 \times 10^{-6}\ ft^2/s} = 6.6 \times 10^5$

Relative Roughness $= \frac{D}{\varepsilon} = \frac{0.5054 ft}{1.5 \times 10^{-4} ft} = 3369.$

Using Moody's diagram

$f = 0.0165$

$h_L = 0.0165 \times \frac{550 ft}{0.5054 ft} \times \frac{(12.46 ft/s)^2}{2 \times 32.2 ft/s^2}$

$h_L = 43.29\ ft.$

$\cancel{h_A}^{0} + \frac{\cancel{p_1}^{0}}{\gamma} + \frac{\cancel{v_1^2}^{0}}{2g} + z_1 = \frac{\cancel{p_2}^{0}}{\gamma} + \frac{v_2^2}{2g} + \cancel{z_2}^{0} + \cancel{h_R}^{0} + h_L$

$z_1 = \frac{v^2}{2g} + \cancel{h_R} + h_L$

$z_1 = \frac{(12.46 ft/s)^2}{2 \times 32.2 ft/s^2} + 43.29\ ft.$

$z_1 = 45.7\ ft$

$\boxed{h = z_1 = 45.7 ft}$

8.38

8-38) The figure below Shows a System for delivering liquid lawn fertilizer. The nozzle on the end of the hose requires 140 kPa of pressure. Internal diameter of the hose is 25 mm, The fertilizer has a Specific gravity of 1.1 and a dynamic viscosity of $2.0 \cdot 10^{-3}$ Pa·S.

If the length of the hose is 85m Find

a) Power delivered by pump to the solution

b) Pressure at the outlet of the pump


Nozzle

$P = 140\ kPa$

Hose

$d_i = 25\ mm = 0.025\ m$

$L = 85\ m$ $A = 4.9e{-4}\ m^2$

Fertilizer

$\eta = 2 \cdot 10^{-3}\ Pa \cdot S$

$SG = 1.1$ $\rho = 1100\ \frac{kg}{m^3}$

$\gamma = 10780\ \frac{kg}{m^3}$

Info

$P_1 = 0$ $P_2 = 140\ kPa$

$V_1 = 0$ $V_2 = \frac{Q}{A} = 193532.4\ \frac{m}{min}$

$Z_1 = 1.5m$ $Z_2 = 10m$

$Q = 95\ L/min$

$P_3 =$ $Z_3 = 1.5m$

$193532.4/_{60} = 3225.5\ \frac{m}{s}$

140 ·

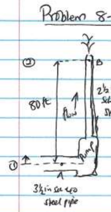
a) $h_a = \frac{140 kPa}{10780 \frac{kg}{m^3}} + (10_m - 1.5_m) + \frac{3225.5 \frac{m}{s}^2}{2 \cdot 9.8 \frac{m}{s}}$

$\boxed{ha = 173\ \frac{kg\text{-}m}{s}}$

$\boxed{b)\ P_3 = 140\ kPa = P_2}$

8.44

Problem 8-44




Pressure at B = 25.0 psig

Pressure at A = −3.50 psig

$Q = 0.5\ ft^3/s$

Dynamic viscosity $\mu = 4.0\times10^{-5}\ lb\cdot s/ft^2$

$Sg = 1.026$ $\quad \gamma = 1.026 \times 62.4\ lb/ft^3 = 64.02\ lb/ft^3$

Compute $h_A$, considering $h_L$ in the discharge line

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g} \qquad v = \frac{Q}{A} = \frac{0.5\ ft^3/s}{\frac{\pi}{4}(0.2058\ ft)^2}$$

$\varepsilon = 1.5\times10^{-4}\ ft$

$D = 0.2058\ ft$ $\qquad v = 15.03\ ft/s$

$\nu = \mu/\rho = \mu/(Sg \times \rho_{water})$ $\quad \mu = 4.0\times10^{-5}\ lb\cdot s/ft^2$

$$\nu = \frac{4.0\times10^{-5}\ lb\cdot s/ft^2}{1.026\times 62.4\ lb/ft^3} = 6.25\times10^{-7}\ ft^2/s$$

$$N_R = \frac{vD}{\nu} = \frac{15.03\ ft/s \times 0.2058\ ft}{6.25\times10^{-7}}$$

$N_R = 4.95\times10^6$

Relative roughness $= \frac{D}{\varepsilon} = \frac{0.2058\ ft}{1.5\times10^{-4}\ ft}$

$\frac{D}{\varepsilon} = 1372$

Moody's diagram $f = 0.017$

$$h_L = 0.017 \times \frac{80\ ft}{0.2058\ ft} \times \frac{(15.03\ ft/s)^2}{2\times 32.2\ ft/s^2}$$

$h_L = 23.18\ ft$

$$\overset{?}{h_A} + \frac{\overset{=-3.5\,psig}{p_1}}{\gamma} + \frac{v_1^2}{2g} + \overset{=0}{z_1} = \frac{\overset{=25\,psig}{p_2}}{\gamma} + \frac{\overset{=15.03}{v_2^2}}{2g} + \overset{=80}{z_2} + \overset{=0}{h_R} + \overset{=23.18\,ft}{h_L}$$

$Q = vA \qquad v_A = \frac{Q}{A} = \frac{0.5\ ft^3/s}{\pi/4\,(0.2557\ ft)^2}$

$v_A = 9.737\ ft/s$

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

$$= \left[\frac{(25+3.5)\ lb/in^2 \times 144\ in^2/ft^2}{64.02\ lb/ft^3}\right] + (80\ ft - 0\ ft) + \frac{(15.03^2 - 9.737^2)}{2\times 32.2\ ft/s^2} + 23.18\ ft$$

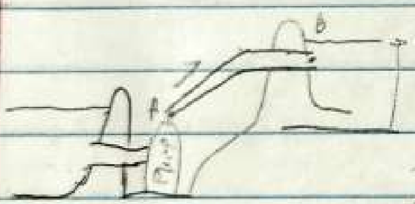
$h_A = 64.10\ ft + 80\ ft + 2.04\ ft + 23.18\ ft = 169.32\ ft$

$P_A = h_A \gamma Q = 169.32\ ft \times 64.02\ lb/ft^3 \times 0.5\ ft^3/s = 5419.73\ lb\cdot ft/s \times \frac{1\ hp}{550\ lb\cdot ft/s}$

$\boxed{P = 9.85\ hP}$

8.46

8.46




water @ 60 F $\quad D_A = 8$ in $\quad L = 2500$ fT

219 fT $\quad Q = 4.00\ ft^3/s$

$$\frac{p_A}{\gamma} + z_A + \cancel{\frac{v_A^2}{2g}} + \cancel{h_A} - h_L = \cancel{\frac{p_B}{\gamma}} + z_B + \cancel{\frac{v_B^2}{2g}}$$

$$p_A = \gamma(z_B - z_A + h_L)$$

$A = \frac{\pi}{4}\left(\frac{8}{12}\right)^2 = 0.35 \quad v = \frac{4}{0.35} = 11.43\ ft/s$

water @ 60 $\quad \nu = 1.21\cdot10^{-5}\ ft^2/s \qquad R_E = \frac{(11.43)(0.66)}{1.21\cdot10^{-5}} = 629752.066$

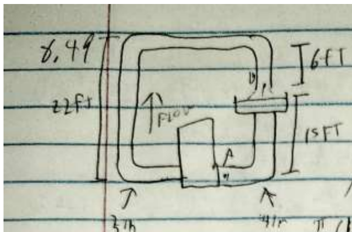
$\frac{\varepsilon}{d} = \frac{1.5\cdot10^{-4}}{8/12} = 0.000255 \qquad f = 0.0155$

$$h_L = 0.0155\cdot\frac{2500}{(0.66)}\cdot\left(\frac{11.43^2}{2(32.2)}\right) = 119.11\ ft$$

$P_A = 62.4\,(210 + 119.11)\cdot\frac{1}{144} = 142.61$ PSIa

8.49

8.49




$Q = 300 \text{ gal/min} = 0.67 \text{ ft}^3/\text{s}$

oil @ $104°F = 2.15 \cdot 10^{-3}$ $\quad L_{4in} = 25 \text{ FT}$

$\gamma = 0.85 \cdot 62.4 = 55.536$ $\quad L_{3in} = 75 \text{ FT}$

$\cancel{\frac{P_A}{\gamma}} + z_A + \cancel{\frac{V_A^2}{2g}} - h_L + h_A = \cancel{\frac{P_B}{\gamma}} + z_B + \frac{V_B^2}{2g}$

$h_A = (z_B - z_A) + \frac{V_B^2}{2g} + h_L$

$\frac{\pi}{4}\left(\frac{1}{4}\right)^2 = 0.049 \text{ ft}^2$ $\quad V_{3in} = \frac{0.67}{0.049} = 13.67 \text{ ft/s}$

$\frac{\pi}{4}\left(\frac{1}{3}\right)^2 = 0.087$ $\quad V_{4in} = \frac{0.67}{0.087} = 7.70 \text{ ft/s}$

$N_{R_{3in}} = \frac{(13.67)(0.85)}{2.15 \cdot 10^{-3}} = 1589.53$ $\quad \frac{64}{1589.53} = 0.0403$

$N_{R_{4in}} = \frac{(7.70)(0.35)}{2.15 \cdot 10^{-3}} = 1181.86$ $\quad \frac{64}{1181.86} = 0.0542$

$h_{3in} = \frac{(0.0403)(75)(13.67)^2}{(0.25)(2 \cdot 32.2)} = 35.08 \text{ ft}$

$h_{4in} = \frac{(0.0542)(25)(7.70)^2}{(0.33)(2 \cdot 32.2)} = 3.12 \text{ ft}$

$h_L = 35.08 + 3.12 = 38.20 \text{ ft}$

$h_A = 38.20 + \frac{13.67^2}{2(32.2)} = 41.1 \text{ ft}$

$P = 55.536 \cdot 0.67 \cdot 41.1 \cdot \frac{1}{550} = 2.78 \text{ hp}$

8.62

Problem 8.62

Compute the friction factor for:

Heavy fuel oil at 77°F flows in a 6-in schedule 40 steel pipe at 12 ft/s.

$D = 0.5054 \text{ ft}$

$V = 12 \text{ ft/s}$

$\varepsilon = 1.5 \times 10^{-4} \text{ ft}$

$\nu = 1.27 \times 10^{-3} \text{ ft}^2/\text{s}$

$N_R = \frac{VD}{\nu} = \frac{12 \text{ ft/s} \times 0.5054 \text{ ft}}{1.27 \times 10^{-3} \text{ ft}^2/\text{s}}$

$= \underline{4.8 \times 10^3}$

Relative roughness $\frac{D}{\varepsilon} = \frac{0.5054 \text{ ft}}{1.5 \times 10^{-4} \text{ ft}}$

$= \underline{3369}$

Using Moody's diagram,

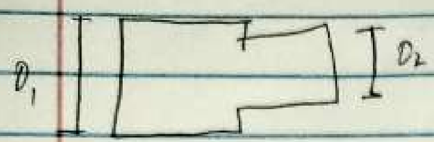
$\boxed{f = 0.04}$

10.20

10.20 sudden contraction from a DN 125 schedule 80 steel pipe

To a DN 50 schedule 80 pipe for a flow rate of 500 L/min

$$h_L = K\left(\frac{v_2^2}{2g}\right)$$




DN 125 S.80  OD = 141.3 mm  ID = 122.3

wall = 9.53 mm  $F_A = 1.173 \cdot 10^{-2}\ m^2$

DN 50 S.80  OD = 60.3 mm  ID = 49.3 mm

wall = 5.54 mm  $F_A = 1.905 \cdot 10^{-3}\ m^2$

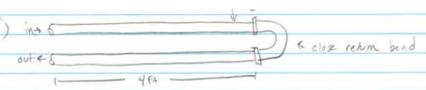
$D_1 = 122.3$ mm  $D_2 = 49.3$ mm  $A_2 = 1.905 \cdot 10^{-3}$  $Q = 500$ L/min

$122.3 / 49.3 = 2.48$  $\frac{500}{1.905 \cdot 10^{-3}} \cdot \frac{1}{60000} = 4.37$ m/s

$\frac{(4.37)^2}{2(9.81)} = 0.973$ m  $K = 0.39$  $h_L = (0.39)(0.973) \sim 0.379$ m

10.37

10.37)




$\Delta p$ if $Q = 12.5$ gal/min of ethylene glycol @ 77°F

$\gamma = 68.47\ lb/ft^3$

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

$$\frac{p_1}{\gamma} - \frac{p_2}{\gamma} = h_f + h_L \rightarrow p_1 - p_2 = \gamma(h_f + h_L)$$

$h_L = K(v^2/2g)$  $D = 0.0518$ ft

$A = 0.00211\ ft^2$

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

$Q = 12.5 \frac{gal}{min}\left(\frac{0.1337\ ft^3}{1\ gal}\right)\left(\frac{1\ min}{60\ sec}\right) = 0.0279\ ft^3/s = Q$

$Q = Av \rightarrow v = \frac{Q}{A} \rightarrow v = \frac{0.0279\ ft^3/s}{0.00211\ ft^2} = 13.22\ ft/s = V$

$K = 50 f_T \rightarrow 50 = \frac{L_e}{D}$

$K = f_T\left(\frac{L_e}{D}\right)$  $\epsilon = 1.5 \times 10^{-4}$ ft  $\frac{D}{\epsilon} = \frac{0.0518}{0.00015} = 345.33$

Moody Diagram: $0.026 = f_T$

$K = f_T\left(\frac{L_e}{D}\right) = 0.026 \times 50 = 1.3 = K$

$h_L = K\left(\frac{v^2}{2g}\right) = 1.3\left(\frac{(13.22)^2}{2(32.2)}\right) = 3.53$ ft

Reynolds Number: $N_R = \frac{vD}{\nu}$  $\nu = 0.000159\ ft^2/s$  $N_R = \frac{(13.22)(0.0518)}{0.000159}$

$N_R = 4306.9$

10.37) cont...

Moody's Diagram: $f = 0.04$

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

$h_f = 0.04 \times \frac{8\ ft}{0.0518} \times \frac{(13.22\ ft/s)^2}{2 \times 32.2} = 16.76$ ft

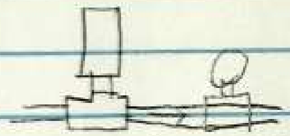
$p_1 - p_2 = \gamma(h_L + h_f)$

$= 68.47(3.53 + 16.76\ ft) = \frac{1389.26\ lb/ft^2}{144}$

$= \boxed{9.65\ psi}$

10.39

10.39




$Q = 0.40\ ft^3/s$ water @ 50°F

3 in S40 OD = 3.5 in ID = 3.068 in

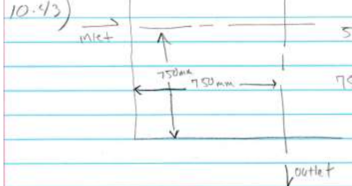
wall = 0.216 in $f_A = 0.05132\ ft^2$

$V = \frac{0.40}{0.05132} = 7.79\ ft/s$ $f = 0.017$ $L_e/D = 20$

$h_L = (0.017)(20)\left(\frac{7.79^2}{2(32.2)}\right) = 0.32\ ft$

10.43

10.43)




50mm OD × 2mm wall

copper

750 L/min propyl alcohol @ 25°C

$Q = 750\ L/min = \frac{1\ m^3/s}{60\,000} \times 750 = 0.0125\ m^3/s$

$d = D - 2t \rightarrow d = 50 - 2(2) = 46\ mm = 0.046\ m$

$A = \frac{\pi d^2}{4} = \frac{\pi (0.046)^2}{4} = 0.00166\ m^2$

$V = \frac{Q}{A} = \frac{0.0125\ m^3/s}{0.00166} = 7.53\ m/s$

$\frac{r}{D} = \frac{750}{46} = 16.3$ $Re = \frac{VD}{\nu} = \frac{7.53(46)}{2.39 \times 10^{-6}}$

$\frac{L_e}{D} = 42$ $\epsilon = 1.5 \times 10^{-6}\ m$ $= 144928.9$

$\frac{D}{\epsilon} = \frac{0.046}{1.5 \times 10^{-6}} = 30666.7$

$f_T = 0.09$

$f = 0.016$

$K = f_T\left(\frac{L_e}{D}\right) = 0.09(42) = 0.378$

$h_L = K\frac{V^2}{2g} = 0.378\left(\frac{(7.53\ m/s)^2}{2(9.81)}\right) = \boxed{1.092\ m} = h_L$

10.43) cont...

$\frac{r}{D} = \frac{150}{46} = 3.26$

$\frac{L_e}{D} = 13$

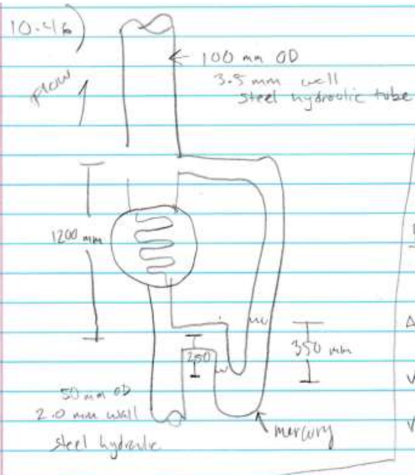
$h_{L_{bend}} = f_T \frac{L_e}{D} \frac{V^2}{2g} = 0.09(13)\left(\frac{7.53^2}{2(9.81)}\right) = 0.45\ m$

$h_{L_{tube}} = 0.016\left(\frac{1.2\ m}{0.046}\right)\left(\frac{7.53^2}{2(9.81)}\right) = 1.2\ m$

$1.2 + 0.45 = \boxed{1.65\ m}$

10.46

10.46)




Water @ 50°C

$6.0 \times 10^{-3}\ m^3/s$

Pipe 1

$d_1 = D_1 - 2t_1$

$= 50 - 2(2) = 46 = 0.046\ m$

$A_1 = \frac{\pi}{4} d_1^2 = 0.00166\ m^2$

Pipe 2

$d_2 = D_2 - 2t_2$

$= 100 - 2(3.5) = 93 = 0.093\ m$

$A_2 = \frac{\pi}{4} d_2^2 = 0.00679\ m^2$

$V_1 = \frac{Q}{A_1} = \frac{0.006}{0.00166} = 3.61\ m/s$

$V_2 = \frac{Q}{A_2} = \frac{0.006}{0.00679} = 0.88\ m/s$

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

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

$\gamma = 9.69\ kN/m^3$

$z_1 - z_2 = -1.2\ m$

manometer: $P_1 + \gamma_w(0.25) + \gamma_m(0.35) - \gamma_w(1.10) = P_2$

$P_1 - P_2 = \gamma_m(0.35) + \gamma_w(1.10 - 0.25)$

$\frac{P_1 - P_2}{\gamma_w} = \frac{\gamma_m(0.35)}{\gamma_w} + \frac{\gamma_w(0.85)}{\gamma_w}$

$\frac{P_1 - P_2}{\gamma_w} = \frac{132.8(0.35)}{9.69} + \frac{9.69(0.85)}{9.69}$

$4.8 + 0.85 = 5.65\ m$

$h_L = 5.65 - 1.2 + \left(\frac{3.61^2 - 0.88^2}{2(9.81)}\right) = \boxed{5.15\ m}$

$h_L = K\left(\frac{V^2}{2g}\right)$

$5.15 = K\left(\frac{3.61^2}{9.81(2)}\right)$

$5.15 = 0.664\ K$

$K = \frac{5.15}{0.664} = \boxed{7.76}$

10.48

10.48 energy loss in 90° bend in steel tube $1\frac{1}{4}$ OD, wall = 0.083 in

mean bend radius = 3.25 in  $Q = 27.5$ gal/min  hydraulic oil

$r = 3.25 + (1.25)/2 = 3.875$ in  $3.875 / (1.120) = 3.46$

$V = \left(27.5 \cdot \frac{0.1337}{60}\right) / 6.842 \cdot 10^{-3} = 8.96$ ft/s  $\varepsilon$ $1.5 \cdot 10^{-4}$ ft

$\left(\frac{1.120}{12}\right) / (1.5 \cdot 10^{-4}) = 622.22$  $k = (0.022)(13) = 0.286$

$0.286 \left(\frac{8.96}{(2)(32.2)}\right) = 0.357$ ft