

Week 4 HW

Saturday, June 13, 2026 12:35 AM

Complete at least 2 of the following problems from each of chapter:

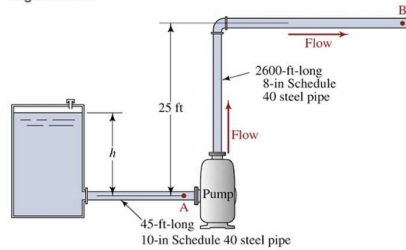
Chapter 8 - 33, 38, 44, 46, 49, 62

8.33 Figure P8.33 shows a portion of a fire protection system in which a pump draws water at 60°F from a reservoir and delivers it to a point B at the flow rate of 1500 gal/min.

a) Calculate the required height h of the water level in the tank in order to maintain 5.0 psig pressure at point A.

b) Assuming that the pressure at point A is 5.0 psig, calculate the power delivered by the pump to the water in order to maintain the pressure at point B at 85 psig. Include energy losses due to friction, but neglect any other energy losses.

Figure P8.33



Fire protection system for [Problem 8.33](#)

Specific weight (γ): 62.4 lb/ft³

Kinematic Viscosity (ν): 1.21×10^{-5} ft²/s

Pipe Roughness (ϵ): 1.5×10^{-4} ft (Commercial steel)

Volumetric flow rate (Q): 1500 gal/min = $\frac{1500}{448.83} = 3.342$ ft³/s

Calculate height h

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} - h_{L2} = \frac{P_A}{\gamma} + z_A + \frac{V_A^2}{2g}$$

$$P_1 = 0 \text{ psig}$$

$$V_1 = 0 \text{ ft/s}$$

$$z_A = 0 \text{ ft}$$

$$z_1 = h$$

$$h = \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + h_{L2}$$

inside diameter (D_i) = 10.02 in = 0.8350 ft

Flow Area $A_i = 0.5479 \text{ ft}^2$

Velocity (V_A)

$$V_A = \frac{Q}{A_i} = \frac{3.3428 \text{ ft}^3/\text{s}}{0.5479 \text{ ft}^2} = 6.10 \text{ ft/s}$$

Velocity head

$$\frac{V_A^2}{2g} = \frac{(6.10)^2}{2 \times 32.2} = 0.578 \text{ ft}$$

Reynolds Number Re_i

$$Re_i = \frac{V_A D_i}{\nu} = \frac{6.10 \times 0.8350}{1.21 \times 10^{-5}} = 4.21 \times 10^5$$

Relative Roughness:

$$\frac{D_i}{\epsilon} = \frac{0.8350}{1.5 \times 10^{-4}} = 5567 \Rightarrow f_i = 0.0156$$

head loss ($h_{L,i}$)

$$h_{L,i} = f_i \left(\frac{L_i}{D_i} \right) \left(\frac{V_A^2}{2g} \right) = 0.0156 \left(\frac{45}{0.8350} \right) (0.578) = 0.482 \text{ ft}$$

height?

$$\frac{P_A}{\gamma} = \frac{5.016/\text{in}^2 \times 144 \text{ in}^2/\text{ft}^2}{62.4 \text{ lb/ft}^3} = 11.54 \text{ ft}$$

$$h = 11.54 \text{ ft} + 0.578 \text{ ft} + 0.482 \text{ ft} = 12.60 \text{ ft}$$

$$b) h_A = \frac{P_B - P_A}{\gamma} + (Z_B - Z_A) + \frac{V_B^2 - V_A^2}{2g} + h_{L2}$$

fin schedule 40 steel pipe

$$D_i = 7.981 \text{ in} = 0.6651 \text{ ft}$$

$$A_i = 0.3472 \text{ ft}^2$$

$$V_B = \frac{Q}{A_i} = \frac{3.342 \text{ ft}^3/\text{s}}{0.3472 \text{ ft}^2} = 9.63 \text{ ft/s}$$

velocity head

$$\frac{V_B^2}{2g} = \frac{9.63^2}{2 \times 32.2} = 1.44 \text{ ft}$$

Reynolds #

$$N_{Re} = \frac{V_B D_i}{\nu} = \frac{9.63 \times 0.6651}{1.21 \times 10^{-5}} = 5.27 \times 10^5$$

Relative Roughness

$$\frac{k_s}{\epsilon} = \frac{0.6651}{1.5 \times 10^{-4}} = 4434 \Rightarrow f_L = 0.0157$$

$$h_{L2} = f_L \left(\frac{L}{D_i} \right) \left(\frac{V_B^2}{2g} \right) = 0.0157 \left(\frac{2600}{0.6651} \right) (1.44) = 89.9 \text{ ft}$$

total pump head

$$\frac{P_B - P_A}{\gamma} = \frac{(95.9 - 50) \times 144}{62.4} = 104.62 \text{ ft}$$

$$Z_B - Z_A = 25 \text{ ft}$$

Velocity head difference: $1.44 \text{ ft} - 0.55 \text{ ft} = 0.89 \text{ ft}$

$$h_A = 104.62 \text{ ft} + 25 \text{ ft} + 0.89 \text{ ft} = 130.51 \text{ ft}$$

$$P_w = \frac{h_A \cdot \gamma \cdot Q}{550} = \frac{130.51 \text{ ft} \times 62.4 \text{ lb/ft}^3 \times 3.342 \text{ ft}^3/\text{s}}{550 \text{ ft} \cdot \text{lb/lb} \cdot \text{min} \cdot \text{hp}} = 113.8 \text{ hp}$$

8.38 For the pipeline described in Problem 8.37, consider that the oil is to be heated to 100°C to decrease its viscosity.

a) How does this affect the pump power requirement?

b) At what distance apart could the pumps be placed with the same pressure drop as that from Problem 8.37?

Fluid: Crude oil ($\rho_o = 0.93$, $\mu = 730 \text{ kg/m}^3$)

$$Q: 1200 \text{ L/min} = 0.020 \text{ m}^3/\text{s}$$

Pipe: 60 150 Schedule 80 Steel Pipe

$$D = 146.4 \text{ mm} = 0.1464 \text{ m}$$

$$A = 0.01683 \text{ m}^2$$

$$E = 4.6 \times 10^{-4} \text{ m}$$

$$L = 3.2 \text{ km} = 3200 \text{ m}$$

Baseline at 60°C: $h_L = 93.53 \text{ m}$

Power required = 17.1 kW

$$V = \frac{Q}{A} = \frac{0.020 \text{ m}^3/\text{s}}{0.01683 \text{ m}^2} = 1.188 \text{ m/s}$$

$$\frac{V^4}{2g} = \frac{(1.188)^2}{2 \times 9.81} = 0.0719 \text{ m}$$

$$2. \quad N_R = \frac{\rho V D}{\mu} = \frac{930 \times 1.188 \times 0.1464}{0.0077} = 20,419$$

$$3. \quad h_L = f \left(\frac{L}{D} \right) \left(\frac{V^4}{2g} \right) = 0.0262 \left(\frac{3200}{0.1464} \right) (0.0719) = 41.1 \text{ m}$$

$$4. \quad P = \rho g h_L Q = 930 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 41.1 \text{ m} \times 0.020 \text{ m}^3/\text{s} = 7.5 \text{ kW}$$

$$\begin{aligned} \text{B)} \quad h_{\text{new}} &= L \left(\frac{h_{L, \text{target}}}{h_{L, \text{at } 100^\circ\text{C}}} \right) \\ &= 3200 \text{ m} \left(\frac{93.53 \text{ m}}{41.1 \text{ m}} \right) = 7282 \text{ m} \\ &\approx 7.3 \text{ km} \end{aligned}$$

10.20 Determine the energy loss for a 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.

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

$$\text{DN 125 } D_1 = 122.3 \text{ mm} = 0.1223 \text{ m}$$

$$\text{DN 50 } D_2 = 49.3 \text{ mm} = 0.0493 \text{ m}$$

$$A_2 = \frac{\pi D_2^2}{4} = \frac{\pi (0.0493 \text{ m})^2}{4} = 1.909 \times 10^{-3} \text{ m}^2$$

$$2) \quad Q = 500 \frac{\text{L}}{\text{min}} \times \frac{1 \text{ m}^3/\text{s}}{60000 \frac{\text{L}}{\text{min}}} = 0.008333 \text{ m}^3/\text{s}$$

$$v_2 = \frac{Q}{A_2} = \frac{0.008333 \text{ m}^3/\text{s}}{1.909 \times 10^{-3} \text{ m}^2} = 4.366 \text{ m/s}$$

$$\frac{v_2^2}{2g} = \frac{(4.366 \text{ m/s})^2}{2 \times 9.81 \text{ m/s}^2} = 0.971 \text{ m}$$

$$3) \quad \frac{D_1}{D_2} = \frac{122.3 \text{ mm}}{49.3 \text{ mm}} = 2.48$$

$$K_c = 0.42 \left[1 - \frac{D_2}{D_1} \right]^2$$

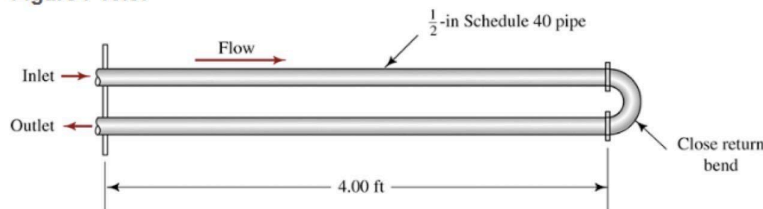
$$= 0.42 \left[1 - (0.403) \right]^2 = 0.352$$

$$4) \quad h_L = 0.352 \times 0.971 \text{ m} = 0.341 \text{ m}$$

10.37 A simple heat exchanger is made by installing a close return bend on two 1/2-in Schedule 40 steel pipes as shown in Fig. P10.37. Compute the pressure difference between the inlet and the outlet for a flow rate of 12.5 gal/min of ethylene glycol at 77°F. The details of the piping are as follows:

The inlet pipe is half-inch schedule 40 pipe laid horizontally. This pipe goes into a close return bend, a U-shaped bend. The pipe coming out from the close return bend is parallel to the inlet pipe below it and is labeled as outlet. The pipe is 4 feet long excluding the close return bend.

Figure P10.37



$$\gamma: 68.616/\text{ft}^3$$

$$\rho: 2.13 \text{ slug/ft}^3$$

$$\mu: 3.38 \times 10^{-3} \text{ lb/ft}^2$$

$$\frac{1}{2} \text{ in Schedule 40 steel pipe}$$

$$D = 0.622 \text{ in} = 0.0518 \text{ ft}$$

$$A: 0.00211 \text{ ft}^2$$

$$\epsilon: 1.5 \times 10^{-4} \text{ ft}$$

$$L: 2 \times 4.00 \text{ ft} = 8.00 \text{ ft}$$

Step 2

$$Q = \frac{12.5 \text{ gal/min}}{4.49 \text{ gal/min per ft}^3/\text{s}} = 0.02784 \text{ ft}^3/\text{s}$$

$$V = \frac{Q}{A} = \frac{0.02784 \text{ ft}^3/\text{s}}{0.00211 \text{ ft}^2} = 13.19 \text{ ft/s}$$

$$\frac{V^2}{2g} = \frac{(13.19)^2}{2 \times 32.2} = 2.70 \text{ ft}$$

Step 3

$$N_R = \frac{DV\rho}{\mu} = \frac{0.0518 \times 13.19 \times 2.13}{3.38 \times 10^{-3}} = 4.31 \times 10^3$$

$$\frac{D}{\epsilon} = \frac{0.0518}{1.5 \times 10^{-4}} = 345 \rightarrow f \approx 0.041$$

$$h_{L, \text{pipe}} = f \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right) = 0.041 \left(\frac{8.00}{0.0518} \right) (2.70 \text{ ft}) = 17.11 \text{ ft}$$

Step 4

$$h_{L, \text{bend}} = f \left(\frac{L_c}{D} \right) \left(\frac{V^2}{2g} \right) = 0.027 \times 50 \times 2.70 \text{ ft} = 3.65 \text{ ft}$$

Step 5

$$h_{L, \text{total}} = h_{L, \text{pipe}} + h_{L, \text{bend}} = 17.11 \text{ ft} + 3.65 \text{ ft} = 20.76 \text{ ft}$$

$$\Delta P = \gamma \cdot h_{L, \text{total}} = 68.616/\text{ft}^3 \times 20.76 \text{ ft} = 1424.116/\text{ft}^2$$

$$= \frac{1424.116/\text{ft}^2}{(4.49 \text{ in}^2/\text{ft}^2)} = 9.87 \text{ psi}$$

Chapter 11 - 5, 13, 20, 22, 23, 24

11.5 Oil is flowing at the rate of $0.015 \text{ m}^3/\text{s}$

in the system shown in Fig. P11.5. Data for the system are as follows:

Oil specific weight $= 8.80 \text{ kN/m}^3$

Oil kinematic viscosity $= 2.12 \times 10^{-5} \text{ m}^2/\text{s}$

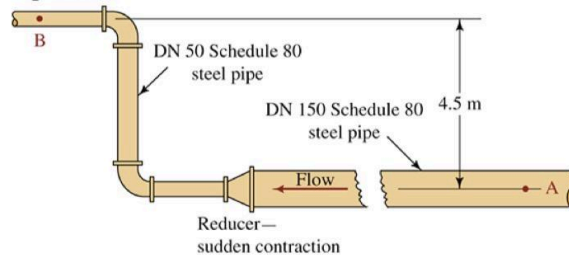
Length of DN 150 pipe $= 180 \text{ m}$

Length of DN 50 pipe $= 80 \text{ m}$

Elbows are long-radius type

Pressure at B $= 12.5 \text{ MPa}$

Figure P11.5



A horizontal pipe DN 150 Schedule 80 steel pipe with a point A labeled at the center of the pipe close to the right end converges suddenly to a pipe of DN 50 Schedule 80 steel pipe through a reducer with sudden contraction. An arrow to the left represents flow of oil through the horizontal pipe. The left end of the contracted horizontal pipe connects upward to a vertical pipe of the same converged size through an elbow on the left side. The top end of the vertical pipe connects leftward to a horizontal pipe through another elbow. A point B is marked in the middle of the horizontal pipe close to the left end. The vertical height between points A and B is labeled 4.5 meters.

Consider all pipe friction and minor losses, calculate the pressure at a

DN 150 Pipe (Section A)

$$D_1 = 146.3 \text{ mm} = 0.1463 \text{ m}$$

$$A_1 = 0.01682 \text{ m}^2$$

DN 50

$$D_2 = 49.3 \text{ mm} = 0.0493 \text{ m}$$

$$A_2 = 0.001908 \text{ m}^2$$

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

Step 2

$$V_A = \frac{Q}{A_1} = \frac{0.015}{0.01682} = 0.892 \text{ m/s}$$

$$\frac{V_A^2}{2g} = \frac{(0.892)^2}{2 \times 9.81} = 0.041 \text{ m}$$

$$V_B = \frac{Q}{A_2} = \frac{0.015}{0.001908} = 7.862 \text{ m/s}$$

$$\frac{V_B^2}{2g} = \frac{(7.862)^2}{2 \times 9.81} = 3.150 \text{ m}$$

Step 3

DN ISO Pipe

$$N_{k1} = \frac{V_{k1} D_1}{V} = \frac{0.492 \times 0.463}{2.12 \times 10^{-5}} \approx 10.56$$

$$\frac{D_1}{L} = \frac{0.463}{4.6 \times 10^{-5}} = 3150 \rightarrow f_1 = 0.0358$$

DN 50 Pipe

$$N_{k2} = \frac{V_{k2} D_2}{V} = \frac{7.862 \times 0.0193}{2.12 \times 10^{-5}} \approx 18283$$

$$\frac{D_2}{L} = \frac{0.0193}{4.6 \times 10^{-5}} = 1072 \rightarrow f_2 = 0.0284$$

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Step 4

$$h_{f1} = f_1 \left(\frac{L_1}{D_1} \right) \frac{V_{k1}^5}{2g} = 0.0358 \left(\frac{15}{0.463} \right) (0.041m) = 1.78m$$

$$h_c = K_c \left(\frac{V_{k1}^5}{2g} \right) = 0.5 \times 2.150m = 1.07m$$

$$h_{f2} = f_2 \left(\frac{L_2}{D_2} \right) \frac{V_{k2}^5}{2g} = 0.0284 \left(\frac{10}{0.0193} \right) 3.150m = 145.16m$$

$$h_c = 2 \times f_2 \left(\frac{L_2}{D_2} \right) \frac{V_{k2}^5}{2g} =$$

$$= 2 \times 0.019 \times 20 \times 3.150m$$

$$= 2.39m$$

$$h_L h_{HL} = 1.78 + 1.07 + 145.16 + 2.39$$

$$= 150.50m$$

Step 5

$$P_D = 12500 \text{ FPa} + 8.8 \text{ kN/m}^3 [4.5m + (3.150m - 0.041m) + 150.50m]$$

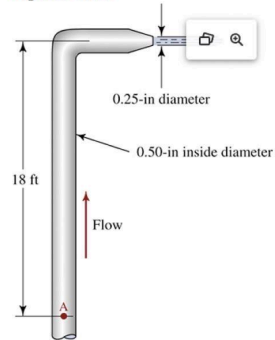
$$P_A = 12500 + 8.8 \times [4.5 + 3.109 + 150.50]$$

$$= 13891.36 \text{ kPa}$$

$$= 13.89 \text{ MPa}$$

11.13 A device designed to allow cleaning of walls and windows on the second floor of homes is similar to the system shown in Fig. P11.13. Determine the velocity of flow from the nozzle if the pressure at the bottom is (a) 20 psig and (b) 80 psig. The nozzle has a loss coefficient K of 0.15 based on the outlet velocity head. The tube is smooth drawn aluminum and has an ID of 0.50 in. The 90-degree bend has a radius of 6.0 in. The total length of straight tube is 20.0 ft. The fluid is water at 100°F. A vertical pipe of length 18 feet with 0.50 inches inside diameter is bent horizontally at the top to the right side from where a stream of water of diameter 0.25 inches flows out from a nozzle of reduced diameter. An upward arrow along the vertical pipe represents the direction of flow of water. The vertical distance from the center of the nozzle till a point A that lies close to the bottom end of the vertical pipe is labeled 18 feet.

Figure P11.13



$$V: 62.0 \text{ ft/s}$$

$$V: 7.37 \times 10^{-6} \text{ ft}^2/\text{s}$$

$$D_t: 0.50 \text{ in} = 0.04167 \text{ ft}$$

$$D_n: 0.25 \text{ in} = 0.02083 \text{ ft}$$

$$L: 20 \text{ ft}$$

$$Z_n - Z_A = 18 \text{ ft}$$

Step 1

$$A_t V_t = A_n V_n \Rightarrow V_t = V_n \left(\frac{D_n}{D_t} \right)^2 = V_n \left(\frac{0.25}{0.50} \right)^2 = 0.25 V_n$$

$$\frac{V_t^2}{2g} = 0.0625 \left(\frac{V_n^2}{2g} \right)$$

Step 2

$$h_f = f \left(\frac{L}{D_t} \right) \frac{V_t^2}{2g} = f \left(\frac{20.0}{0.04167} \right) \left(0.0625 \frac{V_n^2}{2g} \right) = 30.8 \left(\frac{V_n^2}{2g} \right)$$

$$h_m = f \left(\frac{L}{D} \right) \frac{V_n^2}{2g} = 32.2 \left(0.0625 \frac{V_n^2}{2g} \right) = 2.8 \left(\frac{V_n^2}{2g} \right)$$

$$h_n = K \left(\frac{V_n^2}{2g} \right) = 0.15 \left(\frac{V_n^2}{2g} \right)$$

$$\frac{P_A}{\gamma} - 18 = \frac{V_N^2}{2g} - 0.0625 \frac{V_N^2}{2g} + (30f + 2f + 0.18) \frac{V_N^2}{2g}$$

$$\frac{P_A}{\gamma} - 18 = \frac{V_N^2}{2g} [1.0875 + 32f]$$

$$a) \frac{P_A}{\gamma} = \frac{2016 \text{ in}^2 \times 144 \text{ in}^2/\text{ft}^2}{62.016 \text{ ft}^3} = 46.45 \text{ ft}$$

$$46.45 \text{ ft} - 18 \text{ ft} = 28.45 \text{ ft}$$

$$28.45 = \frac{V_N^2}{2g} [1.0875 + 32(0.02)]$$

$$= 1.7275 \frac{V_N^2}{2g} \rightarrow V_N \approx 32.6 \text{ ft/s}$$

$$V_b = 0.15 \times 32.6 = 4.89 \text{ ft/s} \rightarrow N_R = \frac{V_b D_b}{\nu} = \frac{4.89 \times 0.04167}{7.37 \times 10^{-6}} = 46080$$

$$28.45 = \frac{V_N^2}{2g} [1.0875 + 32(0.0212)] = 1.766 \frac{V_N^2}{2g}$$

$$\frac{V_N^2}{2g} = 16.11 \text{ ft} \rightarrow V_N = \sqrt{16.11 \times 2 \times 32.2} = 32.2 \text{ ft/s}$$