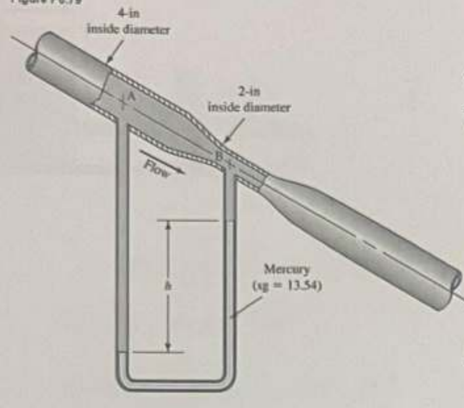
6.79 Oil with a specific gravity of 0.90 is flowing downward through the venturi meter shown in **Fig. P6.79**. If the manometer deflection h is 28 in, calculate the volume flow rate of oil

Figure P6.79



$D_A = 4\text{in} = \frac{4}{12}\text{ft} = .3333\text{ ft}$

$D_B = 2\text{in} = \frac{2}{12}\text{ft} = .167\text{ ft}$

$h = 28\text{in} = \frac{28}{12}\text{ft} = 2.33\text{ ft}$

$sg_m = 13.54$

Flow area @ A

$A_A = \frac{D_A^2 \pi}{4}$

$= \frac{(.3333)^2 \cdot 3.14}{4}$

$A_A = 8.7 \times 10^{-2}\text{ ft}^2$

Flow @ B

$A_B = \frac{D_B^2 \pi}{4}$

$= \frac{(.167)^2 \cdot 3.14}{4}$

$A_B = 2.19 \times 10^{-2}\text{ ft}^2$

$P_A - P_B = \Delta P = (\gamma_m - \gamma_o)h - \gamma_o \cdot x$

γ @ 40°F $= 62.4 \frac{\text{lbf}}{\text{ft}^3}$

$sg_o = \frac{\gamma_o}{\gamma_w} = \gamma_o = sg_o \gamma_w$

$= .9 \cdot 62.4$

$\gamma_o = 56.16 \frac{\text{lbf}}{\text{ft}^3}$

$sg_m = \frac{\gamma_m}{\gamma_w} = \gamma_m = sg_m \cdot \gamma_w$

$= 13.54(62.4)$

$\gamma_m = 844.898 \frac{\text{lbf}}{\text{ft}^3}$

$\frac{P_A}{\gamma_o} + z_A + \frac{v_A^2}{2g} = \frac{P_B}{\gamma_o} + z_B + \frac{v_B^2}{2g}$

$v_B^2 - v_A^2 = 2 \cdot g\left(\frac{\Delta P}{\gamma_o} + x\right)$

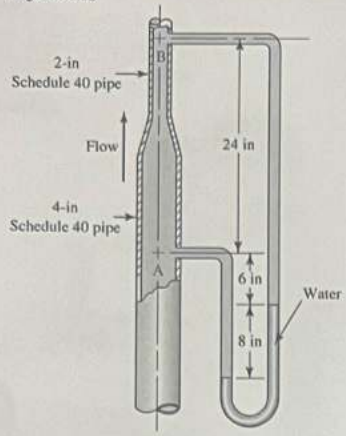
$\left(\frac{Q}{A_B}\right)^2 - \left(\frac{Q}{A_A}\right)^2 = 2g\left(\frac{(\gamma_m - \gamma_o)}{\gamma_o} - \frac{\gamma_o \cdot x}{\gamma_o} + x\right)$

$Q^2 = \sqrt{\frac{A_A^2 - A_B^2}{A_A^2 \cdot A_B^2}} \cdot \sqrt{2gh\frac{\gamma_m - \gamma_o}{\gamma_o}}$

$Q = \sqrt{2 \cdot (32.17)(2.33) \cdot \frac{844.846 - 56.16}{56.16}}$

$\boxed{Q = 1.089 \frac{\text{ft}^3}{s}}$

6.82 Oil with a specific weight of 55.0 $\mathrm{lb/ft^3}$ flows from A to B through the system shown in **Fig. P6.82**. Calculate the volume flow rate of the oil.
Figure P6.82



$\gamma_{oil} = 55.0 \text{ lb/ft}^3$

$\gamma_{water} = 62.4 \text{ lb/ft}^3$

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

$$Q = VA \quad \therefore \quad Q = \sqrt{\frac{2g(P_B - P_A + (z_B - z_A))}{\frac{1}{A_B^2} - \frac{1}{A_A^2}}}$$

$$P_B = P_A + \gamma_{oil}\left(\tfrac{14}{12}\text{ ft}\right) - \gamma_{water}\left(\tfrac{8}{12}\right) - \gamma_{oil}\left(\tfrac{38}{12}\right)$$

$$\Delta P = 55 \tfrac{\text{lb}}{\text{ft}^3}\left(\tfrac{14}{12}\right) - 62.4 \tfrac{\text{lb}}{\text{ft}^3}\left(\tfrac{8}{12}\text{ ft}\right) - 55 \tfrac{\text{lb}}{\text{ft}^3}\left(\tfrac{38}{12}\text{ ft}\right)$$

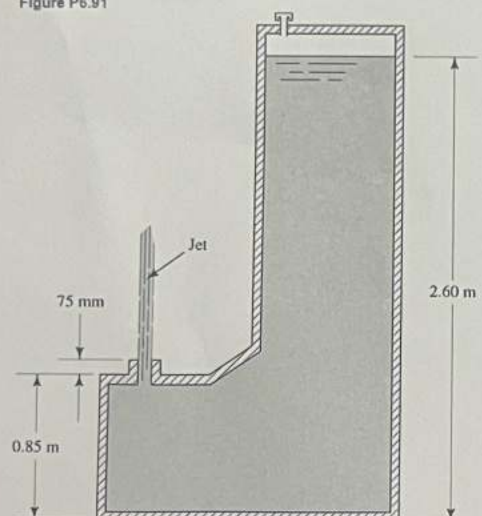
$$\Delta P = 114.93 \text{ lb/ft}^2$$

$$A_A = \tfrac{\pi}{4}(0.333) = .0871 \text{ ft}^2$$

$$A_B = \tfrac{\pi}{4}(.172)^2 = .0232 \text{ ft}^2$$

$$Q = \sqrt{\frac{2(32.3)(114.43/55) + (2)}{\frac{1}{(.0218)^2} - \frac{1}{(.0871)^2}}} = \boxed{0.391 \tfrac{\text{ft}^3}{\text{s}}}$$

6.91 To what height will the jet of fluid rise for the conditions shown in **Fig. P6.91**?
Figure P6.91



$h = 2.60\text{m} \quad h_2 = 75\text{mm} \quad h_3 = .85\text{m}$

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

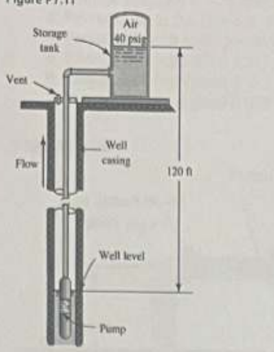
$$z_1 = z_2$$

$$2.6 = 0.85 + .075 + h_1$$

$$\boxed{h = 1.675\text{m}}$$

7.11 A submersible deep-well pump delivers 745 gal/h of water through a 1-in Schedule 40 pipe when operating in the system sketched in Fig. P7.11. An energy loss of 10.5 lb-ft/lb occurs in the piping system. (a) Calculate the power delivered by the pump to the water. (b) If the pump draws 1 hp, calculate its efficiency.

Figure P7.11



$q = 745$ gal/h

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

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

$$h_A = \frac{40\,lb/in^2 \left(\frac{144\,in^2}{ft^2}\right)}{62.4\,lb/ft^3} + (120\,ft) + 10.5\,\frac{lb\,ft}{lb}$$

$h_A = 222.81$ ft

$Q = 745$ gal/h $= .0277$ ft^3/s

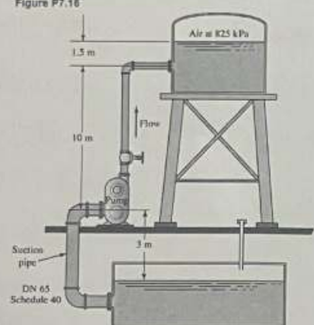
$P_P = h_A \gamma Q = 222.81\,ft(62.4\,lb/ft^3)(0.0277\,ft^3/s)$

$P_P = 385.12\left(\frac{1\,hp}{550\,\frac{lb\,ft}{s}}\right) = .7\,hp$

$$e_P = \frac{P_A}{P_{in}} = \frac{.7}{1} = \boxed{.7 \text{ or } 70\%}$$

7.16 Figure P7.16 shows 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. (b) If the energy loss in the suction pipe is 1.4 N·m/N of oil flowing, calculate the pressure at the pump inlet.

Figure P7.16



$\gamma = sg \cdot \gamma_w$

$= .85 \cdot 9810$

$\gamma = 8338.5\ N/m^3$

$P_P = h_A \cdot \gamma \cdot Q$

$P_P = 4.2 \cdot 8338.5 \cdot (.84)\left(\frac{1}{60}\right)$

$\boxed{P_P = 490.3\,N}$

$P_1 = \gamma\left(z_2 - z_1 + \frac{P_2}{\gamma} + h_L\right)$

$$P_1 = 8338.5\left(14.5 + \frac{825000}{8338.5} + 1.4\right)$$

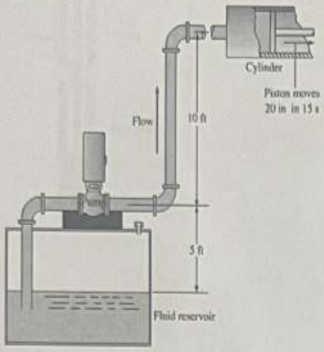
$P_1 = 957582$ Pa

$\boxed{P_1 = 957.582\ kPa}$

7.22 Figure P7.22 shows the arrangement of a circuit for a hydraulic system. The pump draws oil with a specific gravity of 0.90 from a reservoir and delivers it to the hydraulic cylinder. The cylinder has an inside diameter of 5.0 in, and in 15 s the piston must travel 20 in while exerting a force of 11000 lb. It is estimated that there are energy losses of 11.5 lb-ft/lb in the suction pipe and 35.0 lb-ft/lb in the discharge pipe. Both pipes are ¾-in Schedule 80 steel pipes. Calculate:

a. The volume flow rate through the pump.
b. The pressure at the cylinder.
c. The pressure at the outlet of the pump.
d. The pressure at the inlet to the pump.
e. The power delivered to the oil by the pump.

Figure P7.22



$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2}{2g} + z_1 - h_{L1\to 2}$$

$Q = VA$

$A = (\pi \cdot 2.5^2) = 19.63\ in^2$

$V = L/T \qquad Q = \frac{(19.63)}{144}\left(\frac{20}{12}\right)$

$$\boxed{Q = 0.015\ ft^3/s}$$

$P_1 = \frac{F}{A} = \frac{11000}{19.63}$

$P_1 = 560.37\ lb/in^2 \cdot 144 = \boxed{80{,}692.82\ lb/ft^2}$

$V_{out} = \frac{Q}{A_c}\ \frac{.015}{.00098} = 15.31 = ft$

$V_{cyl} = \frac{L}{t} = \frac{20}{15 \cdot 12} = 0.1111\ ft/s$

$\gamma = S_{gOil}(\gamma_{water}) = (.90)(62.4) = 56.16$

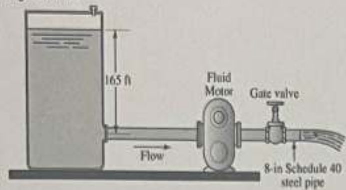
$P_{out} = P_{cyc} + \gamma\left(\frac{V_{cyl}^2 - V_{in}^2}{2g}\right) + z_{cyc} - z_{pump} - h_L$

$P_{out} = 80{,}692.82 + 56.16\left(\frac{.1111^2 - 15.31^2}{2(32.2)}\right) + (15.5) + 35$

$$\boxed{P_{out} = 80{,}533.42\ lb/ft^2}$$

7.30 Water at 60 °F flows from a large reservoir through a fluid motor at the rate of 1000 gal/min in the system shown in Fig. P7.30. If the motor removes 37 hp from the fluid, calculate the energy losses in the system.

Figure P7.30



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

$$h_L = z_1 - h_R - \frac{v_2^2}{2g} = z_1 - h_R - \frac{Q^2}{A^2 2g}$$

$$h_L = 165\ ft - 146.24\ ft - \frac{(2.23\ ft^3/s)^2}{(0.344\ ft)^2 (32.2\ ft/s)}$$

$$h_L = 17.45\ ft$$

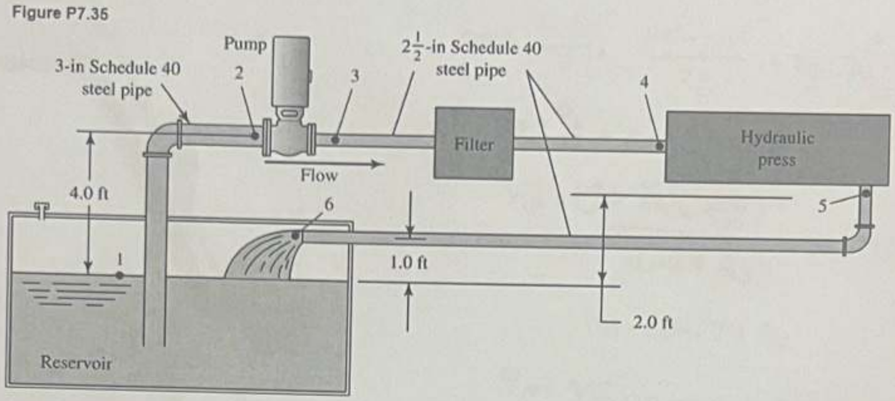
$1000\ gal/min = 2.23\ \frac{ft^3}{s}$

$h_R = \frac{P_R}{\gamma Q} = 146.24\ ft$

$A = \frac{\pi}{4}\left(\frac{.7942}{12}\right)^2 = .344\ ft^2$

1. The fluid is oil ($sg = 0.93$).
2. Volume flow rate is 175 gal/min.
3. Power input to the pump is 28.4 hp.
4. Pump efficiency is 80 percent.
5. Energy loss from point 1 to 2 is 2.80 lb-ft/lb.
6. Energy loss from point 3 to 4 is 28.50 lb-ft/lb.
7. Energy loss from point 5 to 6 is 3.50 lb-ft/lb.

Figure P7.35



Hydraulic oil circuit for **Problems 7.35–7.40**

7.35 Compute the power removed from the fluid by the press.

Given

$sg = 0.93$

$Q = 175 \frac{gal}{min}$

$P_i = 28.4\ hp$

$e_P = 0.8$

$h_{1-2} = 2.8\ ft$

$h_{L3-4} = 28.5\ ft$

$H_{L5\to 6} = 3.5\ ft$

$d_B = 0.2058\ ft$

$e_P = \frac{P_A}{P_i}$

$P_A = P_i \cdot e_P$

$= 28.4 \cdot 0.8$

$= 22.72\ hp$

$V_6 = \frac{Q}{A_6} = \frac{0.39}{0.03326}$

$V_6 = 11.72\ \frac{ft}{s}$

$P_A = h_A \gamma Q$

$h_A = \frac{P_A}{\gamma Q} = \frac{22.72 \cdot 550}{58.032 \cdot 0.39}$

$= 552.13\ ft$

$Q = \frac{175}{449}$

$= .39\ \frac{ft^3}{s}$

$\gamma = sg \cdot \gamma_w$

$= .93 \cdot 62.4$

$= 58.032\ lb/ft^3$

$h_L = H_{L1\to 2} + H_{L3\to 4} + H_{L5\to 6}$

$h_L = 2.8 + 28.5 + 3.5$

$h_L = 34.8\ ft$

$A_6 = \frac{d_6^2 \pi}{4}$

$A_6 = \frac{(.2058)^2 \cdot 3.14}{4}$

$A_6 = .03326\ ft^2$

$h_R = -34.8 - (-1) + 552.13 - \frac{11.72^2}{2 \cdot 32.2}$

$h_R = 514.2\ ft$

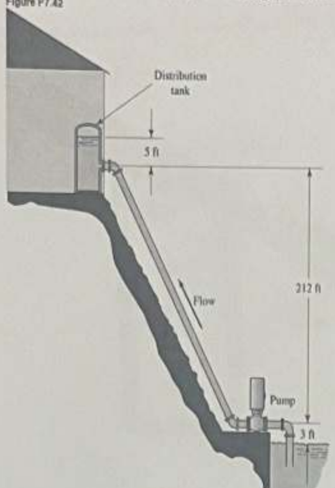
$P_R = h_R \cdot \gamma \cdot Q$

$P_R = 514.2 \cdot 58.032 \cdot .39 \cdot \frac{1}{550}$

$\boxed{P_R = 21.16\ hp}$

7.42 Professor Crocker is building a cabin on a hillside and has proposed the water system shown in Fig. P7.42. The distribution tank in the cabin 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 to the water.

Figure P7.42



$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L,1\to 2}$$

$$h_A = \frac{P_2 - \cancel{P_1}^{\,0}}{\gamma} + \frac{\cancel{V_2^2}^{\,0} - \cancel{V_1^2}^{\,0}}{2g} + z_2 - \cancel{z_1}^{\,0} + h_{L,1\to 2}$$

$$h_A = \frac{P_2}{\gamma} + z_2 + h_{L\,1\to 2}$$

$$h_A = \frac{\left(30\,\frac{lb}{in^2}\right)\left(\frac{12\,in}{1\,ft}\right)^2}{\left(62.4\,\frac{lb}{ft^3}\right)} + (3+212+5) + 15$$

$$h_A = 304.74\ ft$$

$$P_A = \gamma Q h_A = \left(62.4\,\frac{lb}{ft^3}\right)\left(0.089\,\frac{ft^3}{s}\right)(304.74\,ft)$$

$$P_A = 1692.404\ \frac{lb\cdot ft}{s}$$

$$\frac{40\ gal}{1\ min} \cdot \frac{1\ min}{60\ s} \cdot \frac{35.315\ ft^3}{264.17\ gal} = 0.089\ \frac{ft^3}{s}$$

$$P_A = 1692.404 \cdot \frac{1\ hp}{550\ \frac{lb\cdot ft}{s}}$$

$$\boxed{P_A = 3.077\ hp}$$