2. (a) liquid B because it is a shorter column than A

(b) pressures - at pt. 1: \( p = 0 \) (atmospheric)

pt. 2: \( p = \rho_{w} g (h_{1} - h_{2}) = \rho_{w} g (h_{1} - h_{2}) \)

pt. 3: \( p = 0 \)

4. Continuity and Bernoulli Eq. application

a) \( V_{1} = 2 \text{ m/s} \) \( D_{1} = 8 \text{ cm} \Rightarrow A_{1} = \pi \left(0.04 \text{ m}\right)^{2} = 0.0016 \pi \text{ m}^{2} \)

\( V_{2} = ? \) \( D_{2} = 3 \text{ cm} \Rightarrow A_{2} = \pi \left(0.015 \text{ m}\right)^{2} = 0.000225 \pi \text{ m}^{2} \)

\( V_{3} = ? \) \( D_{3} = 6 \text{ cm} \Rightarrow A_{3} = 0.0009 \pi \text{ m}^{2} \)

\( Q = V_{1} A_{1} = \left(2 \text{ m/s}\right) \left(0.0016 \pi \text{ m}^{2}\right) = 0.0176 \pi \text{ m}^{3}/\text{s} \)

\( V_{2} = \frac{0.01 \text{ m}^{3}/\text{s}}{0.000225 \pi \text{ m}^{2}} = 14.3 \text{ m/s} \)

\( V_{3} = \frac{0.01 \text{ m}^{3}/\text{s}}{0.0009 \pi \text{ m}^{2}} = 3.57 \text{ m/s} \)

b) Taking \( z = 0 \) at the pipe centerline and noting that 1 psi = 70 cm of H2O

\( H_{1} = \frac{p_{1}}{\gamma} + z_{1} + \frac{V_{1}^{2}}{2g} = 3(70 \text{ cm of H}_2\text{O}) + 0 + \frac{4 \text{ m}^{3}/\text{s}^{2}}{2(9.8)} \)

\( = 2.1 \text{ m} + 0.2 \text{ m} = 2.3 \text{ m} \)

\( H_{2} = H_{1} - H_{L} = 2.3 \text{ m} - 0.5 \text{ m} = 1.8 \text{ m} \)

\( H_{2} = \frac{2g + \frac{V_{2}^{2}}{2g}}{\frac{D_{2}}{2}} \text{ or } \frac{A_{2}}{V} = 1.8 \text{ m} - \frac{(3.57)^{2}}{2(9.8)} = 1.16 \text{ m} \)

\( = 116 \text{ cm of H}_2\text{O} \)

6. The driving force behind the flow is the head loss between the two reservoirs, that is, \( h_{f} = 80 - 65 = 15 \text{ m} \). Assuming turbulent flow

\( h_{f} = f \frac{L}{D} \frac{V^{2}}{2g} = 15 \text{ m} \)

\( V = \sqrt{\frac{1.2 \text{ m} \times 2 \times 7.81 \times 15}{0.025 \text{ m} \times 4.60}} = 1.75 \text{ m/s} \)

\( Q = VA = 1.75 \pi (0.06 \text{ m})^{2} = 0.020 \pi \text{ m}^{3}/\text{s} = 20 \text{ l/sec} \)
8. \( H_1 + H_p = H_2 \); \( Q = 28 \text{l/s} = 0.028 \text{ m}^3/\text{s} \)

\[
\begin{align*}
\text{The manometers indicate a piezometric pressure head because they are referenced to some elevation datum not specified in the problem.}
\end{align*}
\]

\[
\begin{align*}
D_1 = 0.15 \text{ m}, & \quad D_2 = 0.10 \text{ m} \\
V_1 = \frac{0.028 \text{ m}^3/\text{s}}{0.075 \text{ m}^2} = 1.58 \text{ m/s} \\
\frac{V_2}{V_1} = \frac{0.028 \text{ m}^3/\text{s}}{0.05 \text{ m}^2} = 3.565 \text{ m/s} \\
H_p = \left( \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \right) = 30 \text{ m} + \frac{1}{2g}(10.2) = 30.52 \text{ m} \\
P = H_p Q v' = (30.52 \text{ m} \times 0.028 \text{ m}^3/\text{s} \times 9800 \text{ N/m}^2) = 8375 \text{ kW}
\end{align*}
\]

10. Determine the flow rate if \( P = 40 \text{kW} \) rather than 15.55 as above.

\[
\begin{align*}
H_p = H_2 - H_1 = (z_2 - z_1) + \left( \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \right) \quad \text{and} \quad V = \frac{Q}{A} \\
= (21 - 0) + (0 - 6) + \frac{Q^2}{2g} \left( \frac{1}{A_1} - \frac{1}{A_2} \right) = 12 + 2 \times 10^{-3} \text{ m}^3/\text{s} \\
P = 40000 \text{ kW} \left[ 15 + 2450.7 \text{ Q}^2 \right] \text{ Q} = 15 \text{ and } 2450.7 \text{ Q}^2 = 40000 \text{ N/m}^2 \\
2450.7 \text{ Q}^2 + 15 \text{ Q} = 40000 \\
\text{trial & error solution for Q}
\end{align*}
\]

\[
\begin{align*}
Q = 0.102 \text{ m}^3/\text{s} \\
\text{Increasing the pump energy did little for increasing the flow rate!}
\end{align*}
\]

12. Basically, this question is asking for the upstream pressure head.

\[
\begin{align*}
Q = 0.085 \text{ m}^3/\text{s} \\
D_1 = 0.3 \text{ m} \\
D_2 = 0.1 \text{ m} \\
V_1 = 1.2 \text{ m/s} \\
V_2 = 1.82 \text{ m/s} \\
h = 18 \text{ m} + \frac{1}{2g}(V_2^2 - V_1^2) = 18 + \frac{1}{2g}(115.7) = 28.9 \text{ m}
\end{align*}
\]

14. The slope of the pipe is the same as the head loss per meter, or \( h_f/L \).

Assuming turbulent flow again.

\[
\frac{h_f}{L} = \frac{f}{D} \frac{V^2}{2g} \quad \text{and} \quad V = \frac{Q}{A} = \frac{200 \text{ l/s}}{10 \text{ m}^2} \times \frac{\text{m}^3}{1000 \text{ l}} = 0.025 \text{ m/s}
\]

\[
\begin{align*}
\frac{f}{D} = \frac{0.36 \text{ mm}}{1000 \text{ mm}} = 0.00036 \\
S = 0.018 \\
(Moody \, \text{Diagram}) \\
R = \frac{V D}{v} = \frac{(0.255 \times 2 \times 1 \text{ m})}{1.31 \times 10^{-6} \text{ m}^2/\text{s}} = 194388 \\
\frac{h_f}{L} = \text{slope} = \frac{0.018 \times (0.255)^2}{2(0.8)} = 0.00006 \text{ or } 0.006 \%
\end{align*}
\]

\[
\begin{align*}
\frac{S}{0.00006} \\
100000 \\
\text{100000}
\end{align*}
\]
Q = ACTRS. \[ C = \frac{R V_0}{h} \]

1. Area:
   \[ 1m^2 + \frac{1}{2} (1m) (1m) \times 2 = 2m^2 \]

2. \[ W_p = 1m + 2 (1.4m) = 3.8m \]

3. \[ R \text{ (hydraulic radius)} = \frac{2m^2}{3.8m} = 0.526 \]

4. \[ C = \frac{2.0}{0.526} = 3.74 \]

5. \[ Q = \frac{(2m^2) \times (3.74) \times 0.024 \times (0.526)}{0.024} = 1.72 \text{ m}^3/\text{s} \]

Note: units don't work out.

**Q = 1.79 \text{ m}^3/\text{s}**

**20. Open-Channel Problem**

\[ Q = ACTRS_0 \text{ and } C = \frac{R^{0.6}}{n} \]

\[ Q = 200 \text{l/sec} = 0.2 \text{ m}^3/\text{sec} \]

\[ S = 0.001 \]

\[ n = 0.04 \]

\[ A = \frac{1}{2} [1.5m + (1.5 + 2(1.5y))] \]

\[ W_p = 1.5 + 2(1.5y) (y^2)^{1/2} = 1.5 + 1.5ny \]

\[ R = \frac{A}{W_p} = \frac{1.5(y^2 + 1.5y^2)}{1.5 + 1.5ny} = \frac{y^2}{1 + 0.8y} \]

\[ AR^{3/2} = Q \eta \sqrt{S_o} = 0.2 \times (0.04)(0.001)^{1/2} = 0.253 \]

\[ f(y) = 0.5 (y-y_0) \left[ \frac{y+y_0}{1+0.8y} \right]^{3/2} = 0.258 \]

Requires a trial & error solution.

\[ y = 0.29 \text{ m} \]

(a) Water depth = \( y = 29 \text{ cm} \)

(b) Top width = \( 1.5 + 3(0.9) = 4.17 \text{ m} \)

(c) Water surface width = 2.37 m
Force balance problem similar to class notes - convert to SI units for ease

\[ F + (P_1A_1 - P_2A_2) = \rho \bar{Q} (v_2 - v_1) \]

where \( D_1 = 1 \text{ in} = 0.0254 \text{ m} \)
\( D_2 = \frac{1}{4} \text{ in} = 0.0063 \text{ m} \)

\( \bar{Q} = 20 \text{ gal/min} \cdot \frac{m^3}{264.2 \text{ gal}} = 0.073 \text{ m}^3/\text{min} \)

Absolute pressures are necessary (1 atm = 14.7 psi = 10130 cm of Hg)

\( P_1 = 45 + 14.7 \text{ psi} = 59.7 \text{ psi} \cdot \frac{0.704 \text{ m}}{\text{psi}} \cdot \frac{9800 \text{ N}}{\text{m}^2} = 411.9 \text{ kPa} \)

\( P_2 = 14.7 \text{ psi} = 14.7 (0.704 \times 9800) = 101.4 \text{ kPa} \)

\( (P_1A_1 - P_2A_2) = (411.9 \text{ kPa} \times 0.0254 \text{ m})^2 \cdot \frac{\pi}{4} - (101.4)(0.0063)^2 \cdot \frac{\pi}{4} \)

\[ = 208.7 \text{ N} - 3.16 \text{ N} \]
\[ = 205.5 \text{ N} \]

\( \rho \bar{Q} (v_2 - v_1) = (1000 \frac{\text{kg}}{\text{m}^3})(0.073 \frac{\text{m}^3}{\text{min}})(\frac{\text{min}}{60 \text{ sec}})(v_2 - v_1) = 44.5 \text{ N} \)

\( v_1 = \frac{Q}{A_1} = \frac{0.073 \frac{\text{m}^3}{\text{min}}}{\frac{\pi}{4} (0.0254 \text{ m})^2} \cdot \frac{\text{min}}{60 \text{ sec}} = 2.4 \text{ m/s} \)

\[ (v_2 - v_1) = 36.16 \frac{\text{m}}{\text{s}} \]

\( v_2 = \frac{0.073}{\frac{\pi}{4} (0.0063)^2} \cdot \frac{1}{60} = 39.0 \text{ m/s} \)

\[ F = 44.5 \text{ N} - 205.5 \text{ N} = -161 \text{ N} \] (the minus sign indicates \( F \))