HW 2.2

#11.22 Compute the pressure @ the pump inlet. The filter has a resistance coefficient of 1.85 based on the velocity head in the suction line.

→ This problem ~~is~~ seems pretty complex. Don't panic. Stay calm and work through it slowly.

$\gamma_{coolant} = (s.g._{coolant})(\gamma_{H_2O}) = (0.92)(62.4\ lb/ft^3)$
$= 57.41\ lb/ft^3$

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

$V_1 = Q/A_1$
$V_2 = Q/A_2$

→ $Q = V \cdot A \qquad V_1 \cdot A_1 = V_2 \cdot A_2$

→ Pick two points based on where I need to know something, and/or where I know the most.

→ Pt. 1 is right in front of pump

→ Pt. 2 is at top of open tank

→ h_L = sum of general/minor losses in system from output of pump to pump input (pt. 1)

$= h_{L_{swing\ valve}} + h_{L_{\text{~~sudden expansion~~ exit loss}}} + h_{L_{\text{entrance loss}}} + h_{L_{elbow}} + h_{L_{tee}} + h_{L_{elbow}} + h_{L_{filter}} + h_{L_{gate\ valve}}$

$$h_L = \left(K_{s.v.} \overset{\times V_1^2}{} + 1.0_{e.L.} \overset{\times V_1^2}{} + 0.5_{e.L.} \overset{\times V_2^2}{} + K_{elb} \overset{\times}{} + K_{tee} + K_{elb} + K_{filter} + K_{g.v.} + f\frac{L}{D_1} + f\frac{L}{D_2}\right)$$

$$= 100f_{T_1} + 1.0 + 0.5 + 30f_{T_1} + \underbrace{20f_{T_1} + 60f_{T_1}}_{\text{same tee, different scenarios}} + 30f_{T_1} + 1.85 + 8f_{T_2} + f\left(\frac{61\cancel{ft}}{.1150\cancel{ft}}\right) + f_2\left(\frac{10\cancel{ft}}{.1723\cancel{ft}}\right)$$

→ Compute Reynold's #:

→ $\frac{\rho \cdot V \cdot D}{\mu} \Rightarrow \rho_{coolant} = (S.G.)(\rho_{H_2O}) = (0.92)(1.94\ slugs/ft^3) = \boxed{1.785\ slugs/ft^3 = \rho_{coolant}}$

$V_{avg} = \frac{\boxed{Q/A_1} + \cancel{Q/A_2}}{\cancel{2}} = 30\ gal/min = (0.0668\ ft^3/s) / \left(\frac{\pi(.1150ft)^2}{4}\right)$

$\boxed{V_{avg,1} = } = 6.43 ft/s \quad V_{avg,2} = 2.86 ft/s$

$\boxed{D = (.1150ft)}$

$\boxed{\mu = 3.6 \times 10^{-5}}$

$R_{e,\ Pipe\ 1} = 36,664.4 > 4000 \therefore$ turbulent $\therefore f_{T_1} = 0.021 \qquad f_1 = 0.026$

$R_{e,\ pipe\ 2} = 24,433.58 > 4000 \therefore$ turbulent $\therefore f_{T_2} = 0.019 \qquad f_2 = 0.027$

$h_L = 100(0.021) + 1.0 + 0.5 + 30(0.021) + 20(0.021) + 60(0.021) + 30(0.021) + 1.85 + 8(0.019) + (0.026)(530.4) + (0.027)(58.04)$

$\boxed{h_L = 23.9\ ft}$

$$\rightarrow \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancelto{0}{z_1} = \overset{\text{ref}\ 1}{\cancelto{0}{\frac{P_2}{\gamma}}} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$\rightarrow \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{V_2^2}{2g} + 22\,\text{ft} + 23.9\,\text{ft}$$

$V_1 = 6.43\,\text{ft/s}$

$V_2 = 2.86\,\text{ft/s}$

$$P_1 = \left(\left(\frac{V_2^2 - V_1^2}{2g}\right) + 45.9\,\text{ft}\right)\gamma$$

$$= \left(\frac{(2.86\,\text{ft/s})^2 - (6.43\,\text{ft/s})^2}{2(32.2\,\text{ft/s}^2)} + 45.9\,\text{ft}\right)(57.41\,\text{lb/ft}^3)$$

$$= \cancel{57.41\,\text{lb/ft}^3}$$

$$= 2605.55\,\text{lb/ft}^2$$

$$= \frac{2605.55\,\text{lb}}{\cancel{\text{ft}^2}} \cdot \frac{\cancel{1\,\text{ft}^2}}{144\,\text{in}^2}$$

$$\boxed{P_1 = 18.1\,\text{psi}}$$

11.24 | For the given system, specify the size (diameter) of Schedule 40 steel pipe required to return the fluid to the machines. Machine 1 requires 20gal/min and Machine 2 requires 10 gal/min. The fluid leaves the pipes at the machines at 0psig.

→ $$\cancelto{0}{\frac{P_1}{\gamma}} + \frac{V_1^2}{2g} + z_1 = \cancelto{0}{\frac{P_2}{\gamma}} + \cancelto{0}{\frac{V_2^2}{2g}} + \cancelto{0}{z_2} + h_L \checkmark$$

→ 2 SCENARIOS

→ 1: go from upper tank to Machine # 1

→ $$h_L = h_{entrance} + (h_{elbow})(2) + h_{tee} + h_{pipe}$$

$$= \underset{0.5''}{K}\left(\frac{V_1^2}{2g}\right) + (30f_T)(2) + 20f_T + f\frac{L}{\boxed{D}} \longleftarrow \text{solve for}$$

Red circles indicate Diameter dependent equations

$$= \left(K\cancel{\left(\frac{\left(\frac{Q_T}{\boxed{A_2}}\right)^2}{2g}\right)} + (30)\underbrace{\left(\frac{0.25}{\left(\log\frac{\left(\frac{1}{3.7}\right)}{\left(\frac{\boxed{D}}{\varepsilon}\right)}\right)^2}\right)}(2) + 20\underbrace{\left(\frac{0.25}{\left(\log\frac{\left(\frac{1}{3.7}\right)}{\left(\frac{\boxed{D}}{\varepsilon}\right)}\right)^2}\right)} + \underbrace{\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{\boxed{D}}{\varepsilon}\right)}\right) + \left(\frac{5.74}{\boxed{N_R}^{0.9}}\right)\right]^2}}\left(\times\frac{L}{\boxed{D}}\right)\right)\left(\frac{V^2}{2g}\right)$$

=

Not going to bother to distribute these to solve for D. I have the equations set up in excel; I will reference those equations in my one long final eqn

[illegible]

$$h_L = \left(K + 30f_T + f\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) + \overbrace{\left(60f_T + f\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)}^{\text{MACHINE \#2} \therefore Q_2} + \overbrace{\left(20f_T + 30f_T + f\frac{L}{D}\right)\frac{V^2}{2g}}^{\text{MACHINE \#1} \therefore Q_1}$$

$$\boxed{h_L = \underbrace{\underbrace{\left(K + 30f_T + f\frac{L}{D}\right)\left(\frac{\frac{16Q_T^2}{\pi^2 D^4}}{2g}\right) + \left(60f_T + f\frac{L}{D}\right)}_{\text{SCENARIO \#2}}\left(\frac{\frac{16Q_2^2}{\pi^2 D^4}}{2g}\right) + \left(20f_T + 30f_T + f\frac{L}{D}\right)}_{\text{SCENARIO \#1}}\left(\frac{\frac{16Q_1^2}{\pi^2 D^4}}{2g}\right)}$$

11.24 cont.

SCENARIO 1:

$Z_2 = 0$ because my ref. is at the top of the tank.

$$\frac{V_1^2}{2g} + z_1 - \overset{0}{\cancel{z_2}} = h_L$$

$$\frac{V_1^2}{2g} + z_1 = \left(\overset{=0.5}{K} + 30f_T + f\frac{L}{D}\right)\left(\frac{\frac{16Q_T^2}{\pi^2 D^4}}{2g}\right) + \left(20f_T + 30f_T + f\frac{L}{D}\right)\left(\frac{\frac{16Q_1^2}{\pi^2 D^4}}{2g}\right)$$

$$\left(\frac{\frac{16Q_{\#1}^2}{\pi^2 D^4}}{2g}\right) + z_1 = \left(0.5 + 30f_T + f\frac{L}{D}\right)\left(''\right) + \left(''\right)\left(''\right)$$

$$Z_1 = \left(''\right)\left(''\right) + \left(''\right)\left(''\right) - \left(\frac{\frac{16Q_{\#1}^2}{\pi^2 D^4}}{2g}\right)$$

$Z_1 = 1ft + 4ft + 4ft$ (distance from pt. 2 @ top of tank (+ = downward) ~~outlet of pipe to Machine #1~~ to pt. 1 @ outlet pipe going to Machine #1)

$Z_1 = 9\ ft$

[redacted]

[redacted]

$$Z_1 = \left(0.5 + 30f_T + f\frac{L}{D}\right)\left(\frac{8Q_T^2}{\pi^2 D^4 g}\right) + \left[\left(20f_T + 30f_T + f\frac{L}{D}\right)\left(\frac{8Q_{\#1}^2}{\pi^2 D^4 g}\right) - \left(\frac{8Q_1^2}{\pi^2 D^4 g}\right)\right]$$

$$\boxed{Z_1 = \left(''\right)\left(\frac{8Q_T^2}{\pi^2 g}\right)\left(\frac{1}{D^4}\right) + \left(\left(''\right) - 1\right)\left(\frac{8Q_T^2}{\pi^2 g}\right)\left(\frac{1}{D^4}\right)}$$

→ I'm just gonna solve using Excel from here:

- → what eqns I need to solve
  - → Reynold's #
  - → ~~relative roug.~~ f (laminar)
  - → f (turbulent)
  - → f_T (minor losses)
  - → ~~h_L (Darcy Eqn)~~

11.24 cont.

$$\cancel{\frac{8Q_T^2}{\pi^2 D^4 g}} + z_1 = \left(0.5 + 30f_T + \right.$$ [redacted] $$\left. + 20f_T + 30f_T + f\frac{L}{D}\right)\frac{8Q_T^2}{\pi^2 D^4 g} - \frac{8Q_T^2}{\pi^2 D^4 g}$$

$$z_1 = \left(\left(\quad '' \quad \right) - 1\right)\left(\frac{8Q_T^2}{\pi^2 \cancel{D^4} g}\right)\left(\frac{1}{D^4}\right)$$

$$\frac{\pi^2 g z_1}{8Q_T^2} = \left(\left(0.5 + 80f_T + \left(f\frac{L}{D}\right)\right)\cancel{\frac{1}{D^4}} - 1\right)\left(\frac{1}{D^4}\right)$$

$$\frac{\pi^2 (32.2\,ft/s^2)}{}$$ [redacted] $$\frac{(9ft)}{8(\quad 0.0668\,ft^3/s)^2} = \left(\quad '' \quad \right)$$ [redacted]

L = 39ft

[redacted] $= \left(\quad '' \quad \right)$

→ "Goal seek" in Excel

→ D = [redacted] for SCENARIO 1
0.11 ≅ 0.125 in

SCENARIO 2:

$$\frac{V_1^2}{2g} + z_1 = h_L$$

$$\frac{8Q_T^2}{\pi^2 D^4 g} + z_1 = \left(0.5 + 30f_T + f\frac{L}{D} + 60f_T\right)\frac{8Q_T^2}{\pi^2 D^4 g}$$

$$z_1 = \left(\left(0.5 + 90f_T + f\frac{L}{D}\right) - 1\right)\left(\frac{8Q_T^2}{\pi^2 g}\right)\left(\frac{1}{D^4}\right)$$

L = 36ft

$$\frac{\pi^2 g z_1{=}10}{8\,Q_T^2} = \left(0.5 + 90f_T + f\frac{L^{=}}{D}\right) - 1\Big)\left(\frac{1}{D^4}\right)$$

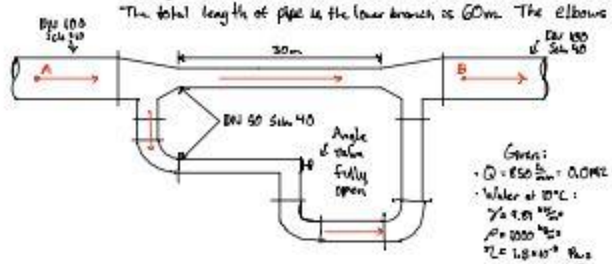
D = 0.104 in ≅ 0.125 in for SCENARIO 2

Problem 12.3) In the branched pipe system shown in Fig 12.8, 850 L/min of water at 10°C is flowing in a DN 100 Schedule 40 pipe at A. The flow splits into DN 50 schedule 40 pipes as shown and then rejoins at B. Calculate:

(a) The flow rate in each of the branches

(b) The pressure difference $P_A - P_B$

- Include the effect of the minor losses in the lower branch of the system. The total length of pipe in the lower branch is 60m. The elbows are standard.



Given:

- $Q = 850\,\frac{L}{min} = 0.0142\,\frac{m^3}{s}$
- Water at 10°C:
  - $\gamma = 9.81\,\frac{kN}{m^3}$
  - $\rho = 1000\,\frac{kg}{m^3}$
  - $\eta = 1.3\times10^{-3}\,Pa{\cdot}s$
  - $\nu = 1.3\times10^{-6}\,\frac{m^2}{s}$
- DN 50:
  - $d = 52.5\,mm,\ A_{1}= 2.168\times10^{-3}\,m^2$
- DN 100:
  - $d = 102.3\,mm,\ A_{2} = 8.213\times10^{-3}\,m^2$
- Angle valve fully open: $\frac{L_e}{D} = 150$
- 90° standard elbow: $\frac{L_e}{D} = 30,\ K = 30f_T$
- f_T of DN 50 steel pipe: $f_T = 0.019$ (complete turbulence)

a) $Q_1 = A_1V_1 + A_2V_2$

$850\,\frac{L}{min} = 0.0142\,\frac{m^3}{s}$

- $h_1 = f_1\left(\frac{L}{D}\right)\left(\frac{V_1^2}{2g}\right)$

  $= 0.016\left(\frac{30m}{52.5\times10^{-3}m}\right)\left(\frac{V_1^2}{2g}\right)$

  $= 58.9\left(\frac{V_1^2}{2g}\right)$

- $h_2 = 3K_3\left(\frac{V_2^2}{2g}\right) + K_4\left(\frac{V_2^2}{2g}\right) + K_5\left(\frac{V_2^2}{2g}\right)$

  $= \left[3(0.57) + 2.85 + 27675.27(0.018)\right]\left(\frac{V_2^2}{2g}\right)$

  $h_2 = 502.71\left(\frac{V_2^2}{2g}\right)$

$K_3 = (30)(0.019) = 0.57$

$K_4 = (150)(0.019) = 2.85$

$K_5 = f_b\left(\frac{60m}{2.168\times10^{-3}m^2}\right) = 27675.27f_b$

with $\frac{D}{\epsilon} = \frac{[illegible]}{[illegible]} = 1445.3$

$\hookrightarrow f_b = 0.018$

- $h_1 = h_2$

  $58.4\left(\frac{V_1^2}{2g}\right) = 502.71\left(\frac{V_2^2}{2g}\right)$

  $\hookrightarrow V_1 = 2.93V_2$

- $Q = A_1(2.93V_2) + A_2V_2$

  $Q = V_2(2.93A_1 + A_2)$

  $V_2 = \frac{Q}{2.93A_1 + A_2} = \frac{0.0142\,\frac{m^3}{s}}{2.93(8.213\times10^{-3} + 2.168\times10^{-3}\,m^2)}$

  $\hookrightarrow V_2 = 0.46\,\frac{m}{s}$

- $\overset{V_2}{V_1 = 2.93(0.46)}$

  $V_1 = 1.36\,\frac{m}{s}$

- $Q_1 = A_1V_1$

  $= (8.213\times10^{-3})(1.36)\,m^2\cdot\frac{m}{s}$

  $= 0.0117\,\frac{m^3}{s}$

  $= 0.0117\,\frac{m^3}{s}\cdot\frac{60s}{1min}\cdot\frac{1\,gal}{0.003785\,m^3}$

  $\underline{Q_1 = 172.3\,\frac{gal}{min}}$

- $Q_2 = A_2V_2$

  $= (2.168\times10^{-3})(0.46)\,m^2\cdot\frac{m}{s}$

  $= 9.97\times10^{-4}\,\frac{m^3}{s}$

  $= 9.97\times10^{-4}\,\frac{m^3}{s}\cdot\frac{60s}{1min}\cdot\frac{1\,gal}{0.003785\,m^3}$

  $\underline{Q_2 = 15.82\,\frac{gal}{min}}$

b) • Continuity Equation : $Q = VA$

- $V_1 = \frac{Q}{A_{flow}} = \frac{0.0142\ \frac{m^3}{s}}{8.213\times10^{-3}\ m^2} \longrightarrow V_1 = 1.73\ \frac{m}{s}$

- $V_2 = \frac{Q}{A_{flow}} = \frac{0.0142\ \frac{m^3}{s}}{2.168\times10^{-3}\ m^2} \longrightarrow V_2 = 6.55\ \frac{m}{s}$

• Reynolds Number:

- $Re_1 = \frac{\rho D V}{\eta} = \frac{(1000\ \frac{kg}{m^3})(0.1023\ m)(1.73\ \frac{m}{s})}{(1.3\times10^{-3})\ Pa\cdot s} = 136137.7 \approx 1.36\times10^5$

- $Re_2 = \frac{\rho D V}{\eta} = \frac{(1000\ \frac{kg}{m^3})(0.0525\ m)(6.55\ \frac{m}{s})}{(1.3\times10^{-3})\ Pa\cdot s} = 264519.2 \approx 2.64\times10^5$

• Relative Roughness factor: D/ε [note: $\varepsilon = 1.5\times10^{-6}$ for drawn steel tubing]

- $D/\varepsilon_1 = \frac{0.1023\ m}{1.5\times10^{-6}\ m} = 68000$
- $D/\varepsilon_2 = \frac{0.0525\ m}{1.5\times10^{-6}\ m} = 0.00258$

• Friction Factor: f_T

- With D/ε_1 and Re_1, $\overset{DN100}{\downarrow}$ $f_{T_1} = 0.016$

- For $\underset{Sch\ 40}{DN50}$, $f_T = 0.019 \leftarrow$ Table 10.5

• Energy Losses, h_L:

$h_{L_1} = n_E \cdot K \left(\frac{L_e}{D}\right)\left(\frac{v^2}{2g}\right)$
↓ $= 3 \cdot 30 f_T (30) \left(\frac{(6.55\ \frac{m}{s})^2}{2(9.81\ \frac{m}{s^2})}\right)$ (elbows)
$= 3 \cdot 30 (0.019)(30)(2.18\ m)$
$h_{L_1} = 111.8\ m$

h_{L_2}: $K = \left(\frac{L_e}{D}\right) f_T = (150)(\overset{\text{Table 10.5}}{0.019}) = 2.85$ (Angle Valve)
$h_{L_2} = K\left(\frac{v^2}{2g}\right) = 2.85 \times 2.18\ m \leftarrow$ previous calculation
$h_{L_2} = 6.213\ m$

$h_L = \Sigma h_L = h_{L_1} + h_{L_2}$
↓ $= 111.8\ m + 5.27\ m$
$h_L = 117\ m$

- Bernoulli's equation

$$\frac{P_A}{\gamma} + \overset{0}{\cancel{z_A}} + \frac{V_A^2}{2g} - h_L = \frac{P_B}{\gamma} + \overset{0}{\cancel{z_B}} + \frac{V_B^2}{2g}$$

$$\frac{P_A - P_B}{\gamma} = \frac{\cancel{V_B^2 - V_A^2}}{2g} + h_L \quad 0 \text{ (same) velocity}$$

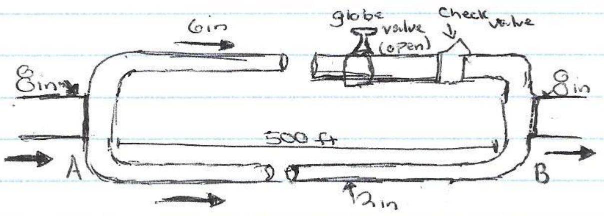
$$P_A - P_B = \gamma \cdot h_L$$

$$\downarrow \quad = 9.81 \frac{kN}{m^3} \cdot 117\,m$$

$$\underline{P_A - P_B = 1147 \text{ kPa}}$$

$$\boxed{\therefore P_A - P_B = 1147 \text{ kPa}}$$

12.4)



$Q_1 = Q_{2 \cdots} = Q_n = Q_{total}$

or $Q_A + Q_B = Q$

energy loss at point

$h_{AB} = h_{L\,pipe} + h_{L\,valve}$

head due to friction

$= f \frac{L}{D} \frac{V}{2g} + K \frac{V^2}{2g}$

pipe

elbow

f= friction factor
L= Length of pipe
D= Diameter of pipe
g= acceleration due to gravity
v= velocity of flow

friction factor need relative roughness

40 steel a 6in Dia $D = .1616$ ft

(roughness table)

$\epsilon = 5.0 \times 10^{-6}$ ft

$\frac{D}{\epsilon} = \frac{.1616}{.000005} =$ [illegible]

$= 32320$

moodys Diagram

$f_T = .0095$

$A = \frac{\pi D^2}{4} = \frac{\pi (Re)^2}{4} = .5236 \text{ ft}^2$

$Q_1 = V_1 A_1$

$Q_2 = V_2 A_2$ $\Big\rangle$ $Q_{12} = V_1 A_1 + V_2 A_2 \ldots$

$$\frac{P_1}{\cancel{\gamma}} + \frac{v_1^2}{2g} + \cancel{Z_1} = \frac{P_2}{\cancel{\gamma}} + \frac{v_2^2}{2g} + \cancel{Z_2} + h_L$$

$$\frac{v_1^2 - v_2^2}{2g} = h_L = h_{L2} = \frac{v_2^2}{2g}\left(f \frac{L}{D} + 2K\right)$$

$$= \frac{v_2^2}{2g}\left(f_2 \frac{500 \text{ ft}}{.1616} + 2 \times (30) \times (.000095)\right)$$

$$= \frac{v_2^2}{2g}\left(f_2 (3094.1) + (.0057)\right)$$

top pipe

$$h_L = 2h_L + (3h_L) \quad (h_L \text{ pipes and 2 valves})$$

$$h_L = 2K\frac{v_1^2}{2g} + K\frac{v_1^2}{2g} + K\frac{v_1^2}{2g} + f\frac{L}{D}\frac{v_2^2}{2g})$$

$$\varepsilon = 1.5 \times 10^{-4} ft \qquad f_T = .0082$$

$$D = \frac{.1723}{.00015} = 1149$$

$$h_L = \frac{v_1^2}{2g}(2(30)(.0082) + (340)(.0082) + 100(.0082) + f_1(1149)$$

$$= \frac{v_1^2}{2g}(.492 + 2.788 + .82 + f_1 1149$$

$$= \frac{v_1^2}{2g}(4.1 + 1149 f_1$$

$$h_{L_{AB}} = h_{L_A} = h_{L_B}$$

$$\frac{v_1^2}{\cancel{3g}}(4.1 + 1149_{f1}) = \frac{v_2^2}{\cancel{2g}}(.0057 + 3094_{f_2})$$

$$v_1^2(4.1 + 1149_{f_1}) = v_2^2(.0057 + 3094_{f_2})$$

makes equation equal

$$f_1 = .008$$

$$f_2 = .006$$

$$v_1^2\ 13.292 = v_2^2\ 18.569$$

$$v_1 = \sqrt{\frac{18.569}{13.292}}$$

$$= 1.18 v_2$$ plus in to Q_{12} formula

$$3 = (1.18_{v_2})(.1810 ft^2) + (.02051 ft^2)v_2$$

$$3 = .2136 v_2 + .02051_{ft} v^2$$

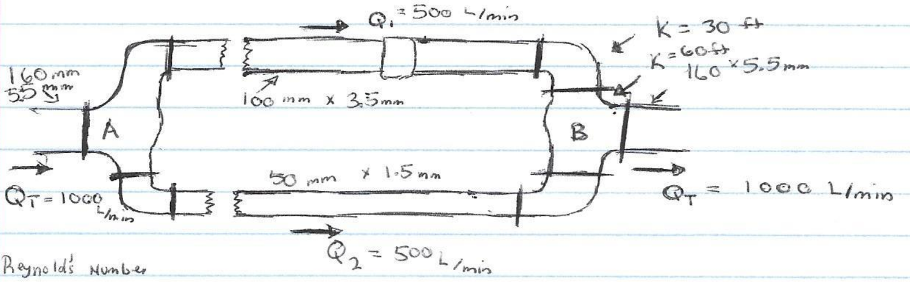
$$3 = .23409 ft^2 v_2 \qquad v_1 = 1.18(12.816)$$

$$v_2 = 12.816 ft/s \qquad = 15.122 ft/s$$

$$Q_1 = 15.122(.1810) = \boxed{2.737 ft^3/s}$$

$$Q_2 = 12.816(.02051) = \boxed{.263 ft^3/s}$$

12.5)



Reynold's Number

$R_e = \frac{P \cdot v \cdot D}{\mu}$ resistance coefficent = (K) = ?

$= \frac{(1000\ kg/m^3)(1.06)(.018)}{1.30 \times 10^{-3}}$ Inner Dia (D) = .1 mm

Length = 30 m

$R_e = 7{,}276.92$

turbulent ∴ $f = f_T$

$h_{L_1} = h_{L_2}$

$\frac{D}{\varepsilon} = 62000$

head loss due to friction

$f = \cancel{f_T} = .0\cancel{08}9$

$= f \frac{L}{D} \frac{v}{2g} + K \frac{v^2}{2g}$

f = friction factor
L = Length of pipe
D = Diameter of pipe
g = acceleration due to gravity
v = velocity of flow

$f = .019$

$f_T = .0087$

Volume flow rate = v = 500 L/min

$= \frac{500 \times 10^{-3}}{60}$

$Q = vA$

$v_1 = Q/A$

$=$

$v_1 = \frac{4Q}{\pi D^2} = \frac{\pi}{4}(D)^2$

$v_1 = \frac{\frac{500 \times 10^{-3}}{60}}{\frac{\pi}{4}(.1)^2} = 1.06\ m/s$

$v_2 = \frac{v}{\pi/4 (D_2)^2} = \frac{500 \times 10^{-3}}{\pi/4 (.05)^2 \times 60}$

$= 4.25\ m/s$

From point A

$$\frac{(.019)(30)(1.06)^2}{2(9.81)(.1)} + K \frac{(1.06)^2}{2(9.81)} = \frac{(.019)(30)(4.25)^2}{2(9.81)(.05)}$$

$$.33 + K(.06) = 10.29$$

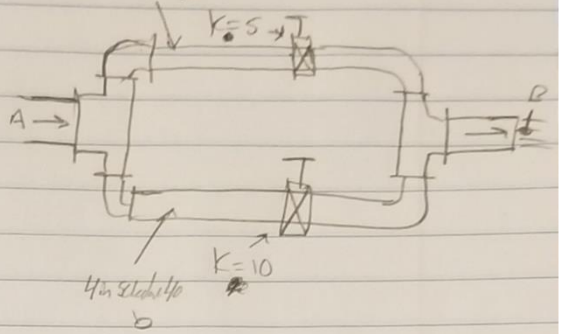
$$-.33 \qquad -.33$$

$$K(.06) = 10.29 - .33$$

$$\frac{K(.06)}{.06} = \frac{9.96}{.06}$$

resistance coefficient = $\boxed{K = 166}$

12.6 $h_L = 2k_1 \frac{V_a^2}{2g} + k_2 \frac{V_a^2}{2g}$



k_1 = elbow

k_2 = upper valve

k_1 = .9 in elbow

$$h_L = 2 \times (.9) \frac{V_a}{2g} + (5) \frac{V_a^2}{2g}$$

$$h_{L_a} = 6.8 \frac{V_a}{2g}$$ upper pipe

$$h_L = 2k_1 \frac{V_b^2}{2g} + k_3 \frac{V_B}{2g} \Rightarrow 2 \times .9 \frac{V_b^2}{2g} + 10\left(\frac{V_b^2}{2g}\right)$$

$$h_{L_b} = 11.8 \frac{V_b^2}{2g} =$$

$\Rightarrow$ Iterated in excel to $(h_L)a = 46.15$ ft

$$46.15 = 6.8 \times \frac{V_a^2}{2 \cdot 32.2} = V_a = 20.9 \text{ ft/sec}$$

$$A = \frac{\pi D}{4} = \frac{\pi \cdot (2/12)^2}{4} = .0218 \text{ ft}^2$$

$Q_a = A_a V_a$

$$.0218 \cdot 20.9 = \boxed{Q_a = .456 \text{ ft}^3/\text{sec}} \leftarrow C$$

$$h_L(b) = 11.8 \cdot \frac{V_b^2}{2 \times 32.2} = V_b = 15.877 \text{ ft/sec}$$

$$A = \frac{\pi D^2}{4} = \frac{\pi \times (4/12)^2}{4} = .0873 \text{ ft}^2$$

$Q_b = .0873 \times 15.877$

$$= \boxed{Q_b = 1.385 \text{ ft}^3/\text{sec}} \leftarrow B$$

$$Q_{total} = Q_a + Q_b = .456 + 1.385 = \boxed{1.841 \text{ ft}^3/\text{sec} = Q_{total}} \leftarrow A$$