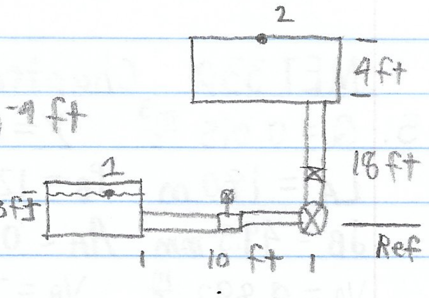
23. $Q = 30 \frac{gal}{min}$ $S.g. = 0.92$ $\eta = 3.6 \cdot 10^{-5} \frac{lb \cdot s}{ft^2}$

Find pump head and pump power. $\varepsilon = 1.5 \cdot 10^{-4}$ ft



$h_a + z_1 = h_L + z_2$ $h_a = h_L + z_2 - z_1$

$z_1 = 3$ ft $z_2 = 22$ ft $Q = 0.067 \frac{ft^3}{s}$

$\rho = 0.92 \cdot 1.94 = 1.78 \frac{slug}{ft^3}$ $V = \frac{4 \cdot Q}{\pi \cdot d^2}$

Suction line: $d = 0.1723$ ft $Re = \frac{4 \cdot Q \cdot \rho}{\eta \cdot \pi \cdot d} = 24980$

$f = 0.25 / \left(\log\left(\frac{1}{3.7 \cdot d/\varepsilon} + \frac{5.74}{Re^{0.9}}\right)\right)^2 = 0.0268$ $h_{LS} = \left(f \cdot \frac{L}{d} + 8 \cdot f_T\right) \frac{8 \cdot Q^2}{\pi^2 \cdot g \cdot d^4}$

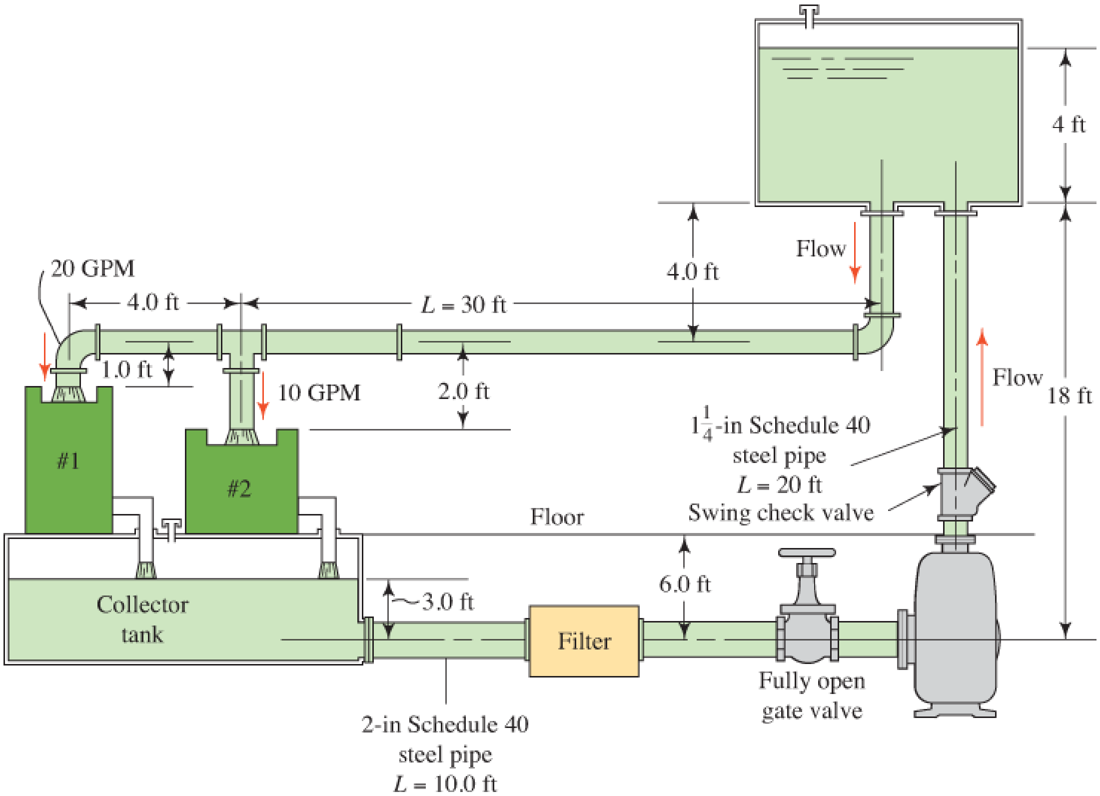
$f_T = 0.019$ from Table 10.5 $h_{LS} = 0.219$ ft

Discharge line: $d = 0.115$ ft $Re = 36678$ $f = 0.026$ $f_T = 0.021$

$h_{Ld} = \left(f \cdot \frac{L}{d} + 100 \cdot f_T\right) \frac{8 \cdot Q^2}{\pi^2 \cdot g \cdot d^4} = 4.28$ ft

$h_a = h_{LS} + h_{Ld} + z_2 - z_1 = 23.5$ ft $P = h_a \cdot \gamma \cdot Q = 90.4 \frac{ft \cdot lb}{s}$

$P = 0.16$ hp



Flow Rate		
Q	30	gal/min
	0.0668	ft^3/s

P1	0	psig
P2	0	psig
Z1	9	ft
Z2	0	ft

Head Loss		
HL	9	ft

Diameter		
D	0.10591	ft

Length Pipe		
L	39	ft

Density		
d	57.43284	lb/ft^3

Dynamic Visocsity		
Dv	0.0011592	lbs/ft^2

Pipe thickness		
E	0.00015	ft

Kenematic Viscosity		
v	2.01836E-05	ft^2/s

Specifit gravity	0.92
Water density	62.427

Equation 11-8				
E^1.25	(LQ^2/HLg)^4.75	v	Q^9.4	(L/HLg)^5.2
1.66002E-05	4.98845E-16	2.01836E-05	8.9722E-12	2.95546E-05

24 Head loss

$HL = Z_1 - Z_2$

$HL = 9ft$

Density = $Sg \cdot \rho_{water}$

Density ρ = $57.43\ lb/ft^3$

Kinimatic viscosity

$$V = \frac{\text{Dynamic viscosity}}{\rho}$$

Kinimatic viscosity $V = 2.018 \cdot 10^{-5}\ ft^2/s$

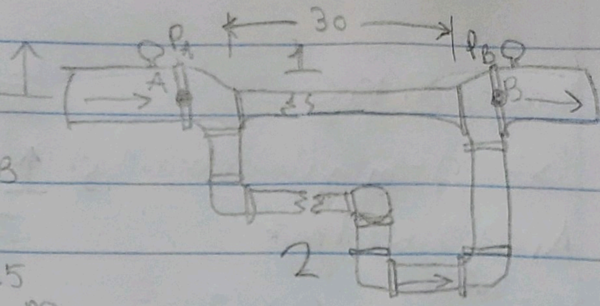
Diameter =

$$D = 0.66\left(\varepsilon^{1.25}\left(\frac{LQ^2}{gHL}\right)^{4.75} + VQ^{9.4}\left(\frac{L}{gHL}\right)^{5.2}\right)^{0.04}$$

$$\underline{D = 0.106 ft}$$

12.3 $h_L = f\frac{L}{D}\frac{V^2}{2g}$

$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_{LAB}$



$\frac{P_A - P_B}{\gamma} = h_{LAB}$

a) $R_r = D/\varepsilon = 0.0525\,m / 4.6\times10^{-5}\,m$

$R_r = 1141.3$, $(Le/D)_{elbow} = 30$, $(Le/D)_{valve} = 150$

$h_{LAB_1} = f_1\left(\frac{30m}{0.0525m}\right)\frac{V_a^2}{2g}$

$h_{LAB_2} = hf + hv + 3he$

$= f_2\left(\frac{L}{D}\right)\frac{V_2^2}{2g} + f_{2T}\left(\frac{Le}{D}\right)_v\frac{V_2^2}{2g} + 3f_{2T}\left(\frac{Le}{D}\right)_e\frac{V_2^2}{2g}$

$= (1142f_2 + 4.56)\frac{V_2^2}{2g}$

$h_{LAB_1} = h_{LAB_2}$

$V_1 = 1.55v_2 \rightarrow V_1 = 3.97\,m/s$

$N_R = \frac{V_2 D_2}{\nu} = 1.3\times10^5$

$N_R = \frac{V_1 D_1}{\nu} = 1.6\times10^5$

From moody diagram $\rightarrow f_1 = f_2 = 0.0215$

$V_2 = 2.55\,m/s$, $V_1 = 3.98\,m/s$

$f_1 = f_2 = 0.0215$

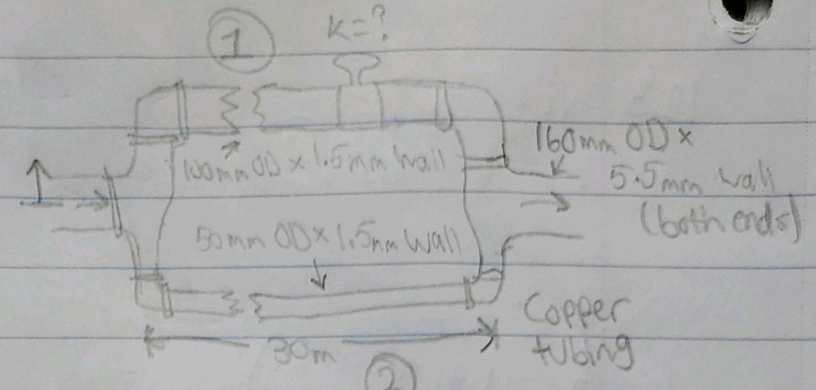
$Q_1 = AV = 518\,L/min$

$Q_2 = 332\,L/min$

b) $\frac{\Delta P}{\gamma} = h_{LAB} \rightarrow \Delta P = \gamma h_{LAB}$

$\Delta = 95.06\,kPa$

12.5 Water @ 10°C



$Q = 500\ L/min$ (both branches)

$A_1 = 0.00679\ m^2$

$V_1 = 0.00833\ m^3/s / 0.00679\ m^2$

$V_1 = 1.22\ m/s$

$N_R = \frac{V_1 D_1}{\nu} = 87{,}276.9$

$R_r = D/\varepsilon = 1.61 \times 10^{-5}$

from moody diagram: $f_1 = 0.018$

$A_2 = 0.00173\ m^2$

$V_2 = Q/A_2 = 4.02\ m/s$

$N_R = \frac{V_2 D_2}{\nu} = 174{,}080$

$R_r = D/\varepsilon = 3.19 \times 10^{-5}$

from moody diagram: $f_2 = 0.016$

$h_{L1} = h_f + h_v + 2h_e$

$\hookrightarrow = f_1\left(\frac{L}{D}\right)\frac{V_1^2}{2g} + k\frac{V_1^2}{2g} + 2f_{1T}\left(\frac{L_e}{D}\right)_e\frac{V_1^2}{2g}$

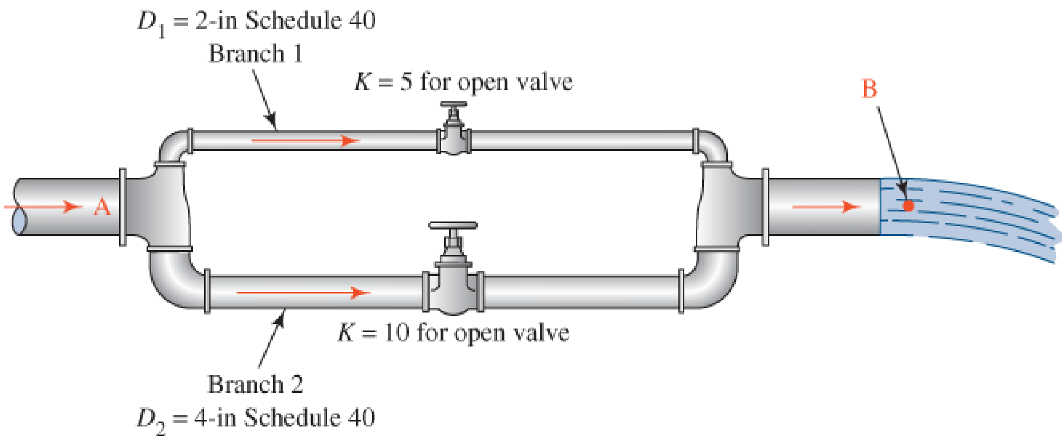
$\hookrightarrow = (6.56 + k)\frac{V_1^2}{2g}$

$h_{L2} = h_f + 2h_e \rightarrow f_2\left(\frac{L}{D}\right)\frac{V_2^2}{2g} + 2f_{2T}\left(\frac{L_e}{D}\right)_e\frac{V_2^2}{2g}$

$\hookrightarrow = 10.81\frac{V_2^2}{2g}$

$(6.56 + k)\left(\frac{(1.22\ m/s)^2}{2(9.81\ m/s^2)}\right) = 10.81\left(\frac{(4.02\ m/s)^2}{2(9.81\ m/s^2)}\right)$

$k = 161.85$



K elbow	0.9
Kvalve up	5
Kvalve low	10

Gravity	
32.2	ft/s^2

Diameters		
branch 1	2	in
branch 1	0.166667	ft
branch 2	4	in
branch 2	0.333333	ft

Head loss		
HL upper	46.15	ft
HL lower	46.15	ft

Pipe Area		
Branch 1	0.021806	ft^2
Branch 2	0.087222	ft^2

Velocity		
Vupper	20.90616	ft/s
Vlower	15.8704	ft/s

Flow Rate		
Both open	1.840122	ft^3/s
Branch 1	0.45587	ft^3/s
Branch 2	1.384251	ft^3/s

b $A_{upper} = \frac{\pi \cdot 0.166^2}{4}$

$A_{upper} = 0.0218 \; ft^2$

$A_{lower} = \frac{\pi \cdot 0.333^2}{4}$

$A_{lower} = 0.0872 \; ft^2$

$hl_{upper} = 2 \cdot K_e \frac{V_U^2}{2g} + K_V \frac{V_U^2}{2g}$

$hl_{upper} = 6.8 \frac{V_U^2}{2g}$

$hl_{lower} = 2 \cdot K_e \frac{V_L^2}{2g} + K_V \frac{V_L^2}{2g}$

$hl_{lower} = 11.8 \frac{V_L^2}{2g}$

$hl_{upper} = hl_{lower} = 46.15 \; ft$

$V_U^2 = \frac{46.15 \cdot 32.2 \cdot 2}{6.8}$

$V_U = 20.906 \; ft/s$

$V_L^2 = \frac{46.15 \cdot 32.2 \cdot 2}{11.8}$

$V_L = 15.87 \; ft/s$

A. $\underline{Q_U + Q_L = 1.84 \; ft^3/s}$

$Q_U = A_U \cdot V_U$

C $\underline{Q_U = 0.455 \; ft^3/s}$

$Q_L = A_L \cdot V_L$

B $\underline{Q_L = 1.384 \; ft^3/s}$