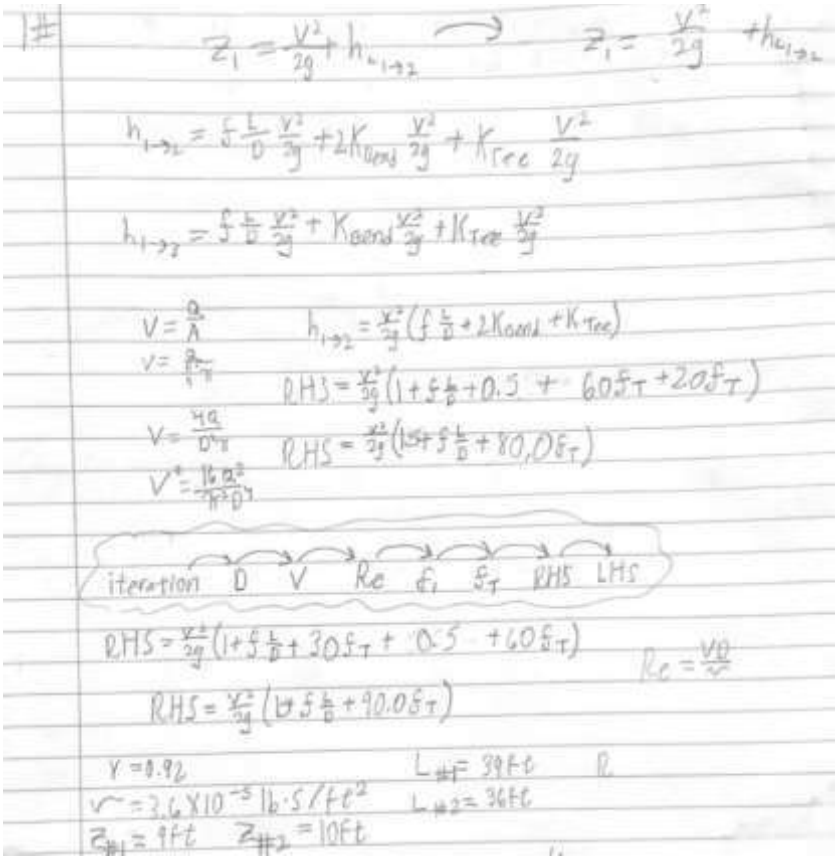
Fluid Mechanics Homework 3.2

11.26

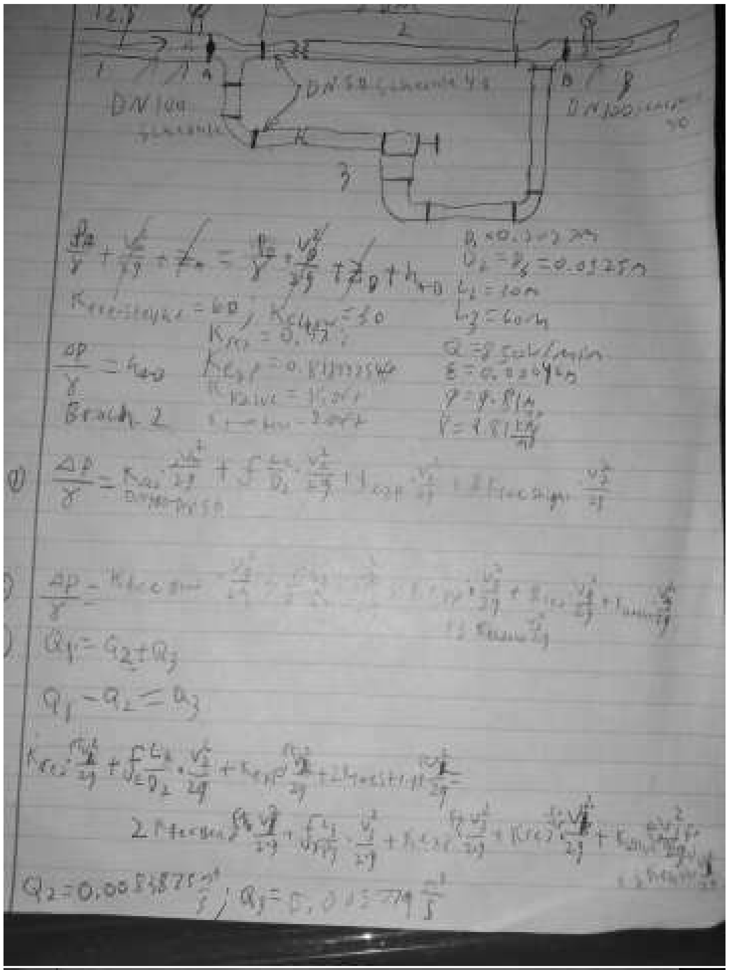


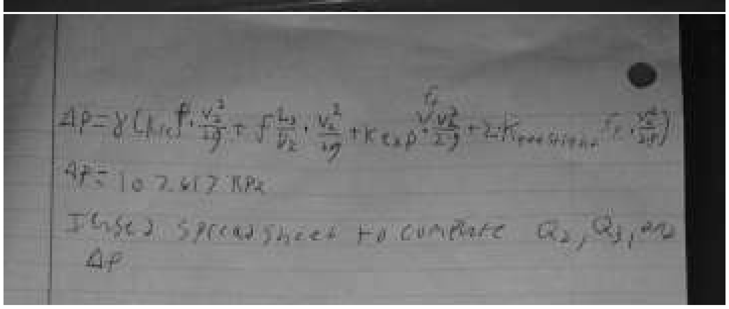
gravity	32.2	ft/s^2
SG	0.92	
dynamic viscosity	0.000036	lb*s/ft^2
Relative roughnes	0.00015	ft
z1	9	ft
z2	10	ft
L1	39	ft
L2	36	ft
LHS1	9	ft
LHS2	10	ft
Q1	20	GPM 0.044543 ft^3/s
Q2	10	GPM 0.022272 ft^3/s

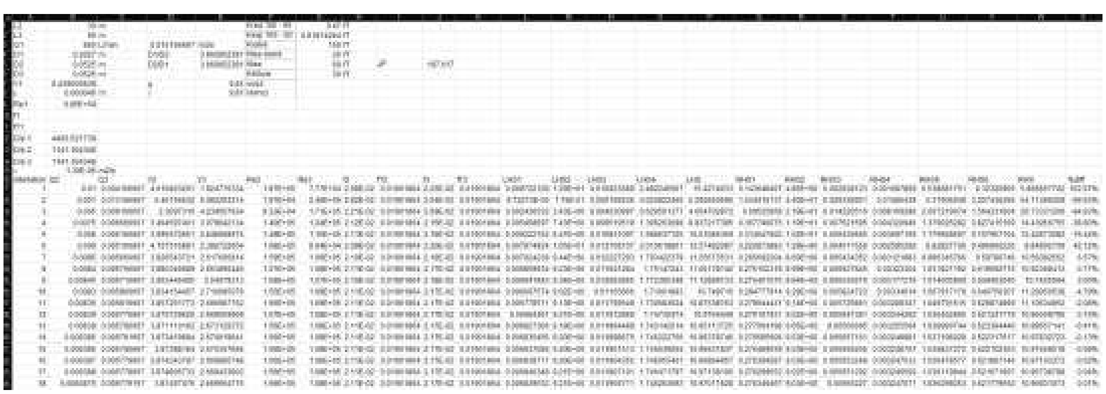
Pipe 1								
Iteration	D	V1	Re1	D/e	f1	fT1	RHS	% Diff
1	1	0.056714	1575.402	6666.667	0.055812	-0.05692	-4.37994E-05	100%
2	10	0.000567	157.5402	66666.67	0.168321	-0.04636	-7.75499E-09	100%
3	10	0.000567	157.5402	66666.67	0.168321	-0.04636	-7.75499E-09	100%
4	20	0.000142	78.77008	133333.3	0.278293	-0.04391	-4.58983E-10	100%
5	50	2.27E-05	31.50803	333333.3	0.718999	-0.04104	-9.77082E-12	100%
6	0.1	5.671446	15754.02	666.6667	0.030448	-0.0737	3.735254997	58%
7	0.15	2.520643	10502.68	1000	0.032289	-0.07006	0.423247738	95%
8	0.09	7.001785	17504.46	600	0.030164	-0.07471	6.542446026	27%
9	0.084	8.037763	18754.78	560	0.030023	-0.07538	9.438858474	-5%
10	0.0848	7.886823	18577.85	565.3333	0.030041	-0.07529	8.975476531	0%

Pipe 2								
Iteration	D	V2	Re2	D/e	f2	fT2	RHS	% Diff
1	1	0.028357	787.7008	6666.667	0.073317	-0.05692	-1.22793E-05	100%
2	10	0.000284	78.77008	66666.67	0.278297	-0.04636	-2.08637E-09	100%
3	20	7.09E-05	39.38504	133333.3	0.54565	-0.04391	-1.14716E-10	100%
4	0.1	2.835723	7877.008	666.6667	0.035359	-0.0737	0.948480077	91%
5	0.5	0.113429	1575.402	3333.333	0.055934	-0.06111	5.48643E-06	100%
6	0.09	3.500892	8752.231	600	0.034735	-0.07471	1.65011337	83%
7	0.05	11.34289	15754.02	333.3333	0.033001	-0.08088	35.92438081	-259%
8	0.08	4.430817	9846.26	533.3333	0.034147	-0.07587	3.060046718	69%
9	0.083	4.116305	9490.371	553.3333	0.034318	-0.0755	2.523166284	75%
10	0.081	4.322089	9724.701	540	0.034203	-0.07574	2.867217023	71%
11	0.08	4.430817	9846.26	533.3333	0.034147	-0.07587	3.060046718	69%
12	0.06	7.877008	13128.35	400	0.03321	-0.07886	13.80511201	-38%
13	0.07	5.787189	11252.87	466.6667	0.033622	-0.07723	6.157812281	38%
14	0.065	6.71177	12118.47	433.3333	0.033397	-0.078	9.077171822	9%
15	0.06	7.877008	13128.35	400	0.03321	-0.07886	13.80511201	-38%
16	0.0638	6.966625	12346.41	425.3333	0.033348	-0.0782	10.00765802	0%

12.3


$Q_1 = Q_2 + Q_3$
$Q_1 - Q_2 = Q_3$


ΔP = 107.617 kPa
I used spreadsheet to compute Q2, Q3, and ΔP



12.4

12.41 HW 3.2 Team 2

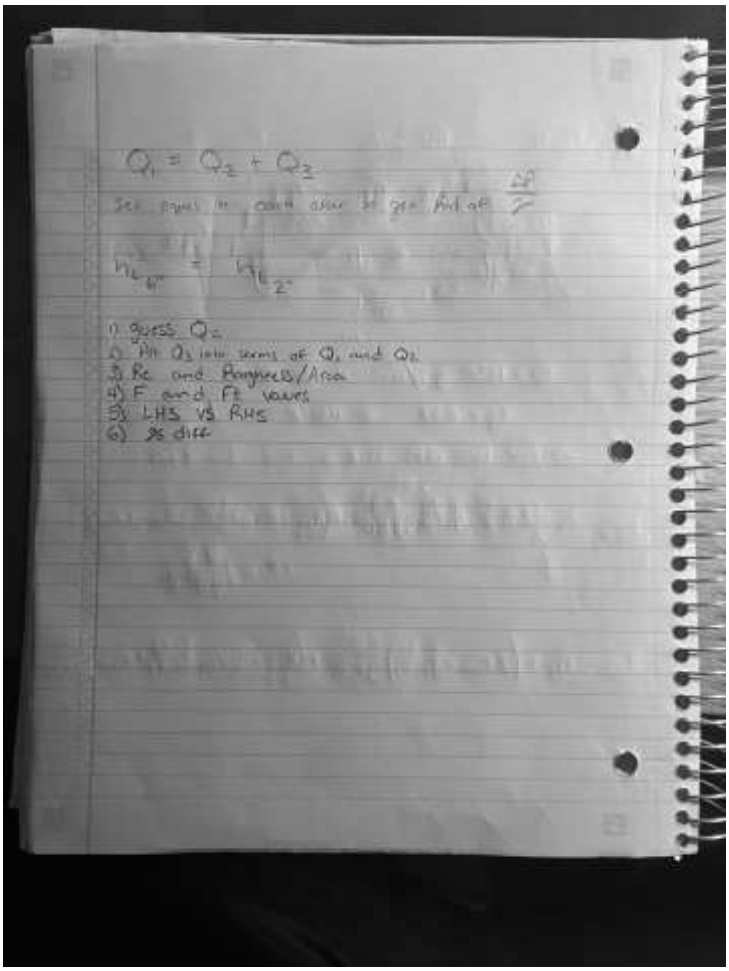
$Q = 1350$ gal/min of benzene

$sg = 0.87$ @ $140°F$ $\Delta P/\gamma = h_L$

→ find flow rate in each branch & ΔP

$$h_L = \left(2K_{bend} + f_1\frac{L_1}{D_1}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} + \left(K_{tee} + 2K_{bend} + f_2\frac{L_2}{D_2} + K_{valve} + K_{valve} + K_{exp}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$

$$h_L = \left(2K_{bend} + f_3\frac{L_3}{D_3}\right)\frac{8Q_3^2}{g\pi^2 D_3^4} + \left(K_{tee} + 2K_{bend} + f_2\frac{L_2}{D_2} + K_{exp}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$



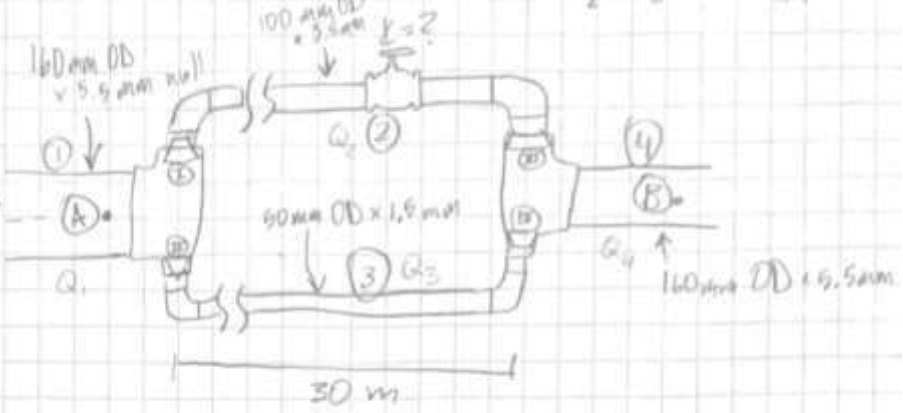
D1_D4	8 in	0.2032 m		Q3												**LHS 1**	**RHS 1**	
D2	6 in	0.1524 m		Top												**LHS 2**	**RHS 2**	
D3	2 in	0.0508 m		Bottom														
								Q3=Q1-q2			Fi are the same							
Sg	0.87							guess Q2			F formula in book							
Q1	1450 gal/min	0.0852 m^3/s						Re 2 and 3										
								F and ft values			LHS Vs RHS							
L1	10 ft							Roughness										
L2	500 ft							Area										
				Iter.	Q2	Q3	Re2	Re3	Ft2	Ft3	LHS	RHS	%diff					
K rad 1-2	0.111																	
K exp 2-4	250			1	0.01													
K tee	200			2														
K elb	150																	
f 1_4																		
f 2																		
f 3																		
grav	32.2 ft/s^2																	
γ	54.55 lb/ft^3																	
ρ	54.64 lb/ft^3																	
ν	1.41E-05 ft^2/s																	
Roughness	175913	1.16E-06																
Area																		

12.5

12.5)

$Q_2 = Q_3 = 500 \frac{L}{min}$

H_2O @ 10°C



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

$Q_1 = Q_4$

$Q_4 = 1000 \frac{L}{min}$

$Q_1 = Q_2 + Q_3$

$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_{L_{A \to B}}$

② $\frac{\Delta P}{\gamma} = h_{L_{A \to B_2}} = h_{L_{red_I}} + 2h_{L_{elb}} + 2h_{L_{tee}} + h_{L_{valve}} + h_{L_{exp_{III}}} + h_{L_2}$

$V^2 = \frac{16Q^2}{\pi^2 D^4}$

$\frac{\Delta P}{\gamma} = \frac{8Q_1^2}{g\pi^2 D_1^4}\left(2K_{tee} + f_4 \frac{L_4}{D_4}\right) + \frac{8Q_2^2}{g\pi^2 D_2^4}\left(2K_{elb} + K_{valve} + f_{L_2} \frac{L_2}{D_2} + K_{red_I} + K_{exp_{III}}\right)$

③ $\frac{\Delta P}{\gamma} = h_{L_{A \to B_3}} = h_{L_{red_{II}}} + h_{L_{exp_{III}}} + 2h_{L_{elb}} + h_{L_3}$

$\frac{\Delta P}{\gamma} = \frac{8Q_1^2}{g\pi^2 D_1^4}\left(2K_{tee} + f_4 \frac{L_4}{D_4}\right) + \frac{8Q_3^2}{g\pi^2 D_3^4}\left(2K_{elb} + K_{red_{II}} + K_{exp_{III}} + f_3 \frac{L_3}{D_3}\right)$

$\frac{D_4}{D_2} = \frac{149\,mm}{93\,mm} \Rightarrow K_{exp_{III}} = 0.41$

$\frac{D_4}{D_3} = \frac{149\,mm}{47\,mm} \Rightarrow K_{exp_{IV}} = 0.48$

$\varepsilon = 1.5 \times 10^{-6}\ m$

$K_{red_I} \Rightarrow \frac{D_1}{D_2} = \frac{149\,mm}{93\,mm} \Rightarrow K_{red_I} = 0.044$

$K_{red_{II}} \Rightarrow \frac{D_3}{D_4} = \frac{149\,mm}{47\,mm} \Rightarrow K_{red_{II}} = 0.045$

$K_{elb} = 30 f_T$

$K_{tee} = 60 f_T$

$K_{valve} = ? f_T$

$\nu_{H_2O@10°C} = 1.3 \times 10^{-6}$

Set equal

$$\frac{8Q_1^2}{g\pi^2 D_1^4}\left(2K_{tee}+f_4\frac{L_4}{D_4}\right)+\frac{8Q_2^2}{g\pi^2 D_2^4}\left(2K_{elb}+K_{valve}+f_2\frac{L_2}{D_2}+K_{red\,I}+K_{exp\,III}\right)=$$

$$\frac{8Q_1^2}{g\pi^2 D_1^4}\left(2K_{tee}+f_4\frac{L_4}{D_4}\right)+\frac{8Q_2^2}{g\pi^2 D_2^4}\left(2K_{elb}+K_{red\,II}+K_{exp\,IV}+f_3\frac{L_3}{D_3}\right)$$

$$\frac{8Q_2^2}{g\pi^2 D_2^4}\left(2K_{elb}+K_{valve}+f_2\frac{L_2}{D_2}+K_{red\,I}+K_{exp\,III}\right)=\frac{8Q_3^2}{g\pi^2 D_3^4}\left(2K_{elb}+K_{red\,II}+K_{exp\,IV}+f_3\frac{L_3}{D_3}\right)$$

$$\frac{Q_2^2}{D_2^4}\left(2K_{elb}+K_{valve}+f_2\frac{L_2}{D_2}+K_{red\,I}+K_{exp\,III}\right)=\frac{Q_3^2}{D_3^4}\left(2K_{elb}+K_{red\,II}+K_{exp\,IV}+f_3\frac{L_3}{D_3}\right)$$

$$2K_{elb}+K_{valve}+f_2\frac{L_2}{D_2}+K_{red\,I}+K_{exp\,III}=\frac{D_2^2Q_3^2}{D_3^2Q_2^2}\left(2K_{elb}+K_{red\,II}+K_{exp\,IV}+f_3\frac{L_3}{D_3}\right)$$

$$K_{valve}=\frac{D_2^2Q_3^2}{D_3^2Q_2^2}\left(2K_{elb}+K_{red\,II}+K_{exp\,IV}+f_3\frac{L_3}{D_3}\right)-2K_{elb}-K_{red\,I}-K_{exp\,III}-f_2\frac{L_2}{D_2}$$

RHS 1 RHS 2 RHS 3

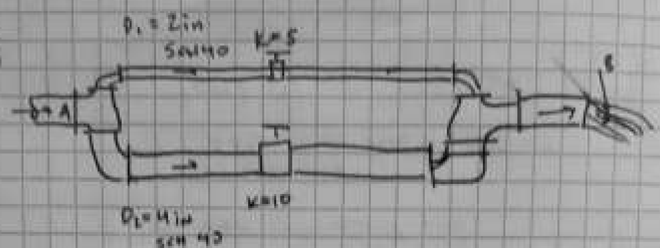
As per Excel: $\boxed{K_{valve}=160.043\,f_T}$

	A	B	C	D	E
1	D_1 =	149	mm	1.49	m
2	D_2 =	93	mm	0.93	m
3	D_3 =	47	mm	0.47	m
4	D_4 =	149	mm	1.49	m
5					
6	Q_1 =	1000	L/min	0.01667	m^3/s
7	Q_2 =	500	L/min	0.008335	m^3/s
8	Q_3 =	500	L/min	0.008335	m^3/s
9					
10	L_2 =	30	m		
11	L_3 =	30	m		
12	L_4 =	10	m		
13	g =	9.81	m/s^2		
14	v =	1.30E-06	m^2/s		
15	e =	1.50E-06	m		
16					
17					
18	K_elb =	30	f_T		
19	K_tee =	60	f_T		
20	K_red(I) =	0.044			
21	K_red(II) =	0.045			
22	K_exp(III) =	0.41			
23	K_exp(IV) =	0.48			
24					
25	D/e_1 =	9.93E+05	f_T1=	5.80E-03	
26	D/e_2 =	6.20E+05	f_T2=	6.18E-03	
27	D/e_3 =	3.13E+05	f_T3=	6.80E-03	

	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
19		old	old	old						new							
20	Iteration	f2	f3	K_valve	Re_4 (Re_1)	f1 or f4	RHS_1	RHS_2	RHS_3	K_valve	Re_2	Re_3	f2	f3	%diff_K_valve	%diff_f2	%diff_f3
21	1	0.01	0.01	0.01	1.10E+04	3.02E-02	3.91535	61.1633	-60.457	179.018	8.78E+03	1.74E+02	3.21E-02	1.58E-01	17900.82669	2.21E+00	1.48E+01
22	2	1.74E+02	1.58E-01	179.018	5.48E+03	3.68E-02	3.91535	70.6263	-116.48	160.043	8.78E+03	1.74E+02	3.21E-02	1.58E-01	-0.105994058	########	0.00E+00
23	3	1.74E+02	1.58E-01	160.043	5.48E+03	3.68E-02	3.91535	70.6263	-116.48	160.043	8.78E+03	1.74E+02	3.21E-02	1.58E-01	0	########	0.00E+00
24	4	1.74E+02	1.58E-01	160.043	0.00E+00	#DIV/0!	3.91535	70.6263	-116.48	160.043	8.78E+03	1.74E+02	3.21E-02	1.58E-01	0	########	0.00E+00

12.6

12.6)



$P_A = 20$ psig

$K = 0.9$ @ elbows

neglect loss @ tees + pipe

a) $Q_1 = Q_2 + Q_3$

b) $Q_1 = Q_3$

c) $Q_1 = Q_2$

upper: $h_{upper} = 2K_{elbow}\frac{V_u^2}{2g} + K_{valve}\frac{V_u^2}{2g}$

$= 2(0.9)\frac{V_u^2}{2g} + 5\frac{V_u^2}{2g} = 6.8\frac{V_u^2}{2g}$

lower: $2K_{elbow}\frac{V_l^2}{2g} + K_{valve}\frac{V_l^2}{2g}$

$2(0.9)\frac{V_l^2}{2g} + (10)\frac{V_l^2}{2g} = 11.8\frac{V_l^2}{2g}$

if $h_{upper} = 46.15$ ft, $h_{lower} = 46.15$ ft $\rightarrow$ $h_u = 6.8\frac{V_u^2}{2g}$, $V_u = 20.9$ ft/s; $h_l = 11.8\frac{V_l^2}{2g}$, $V_l = 15.87$ ft/s

$A_u = \frac{\pi d^2}{4} = 0.0218\ ft^2$ $A_l = 0.0872\ ft^2$

a) $Q_1 = Q_2 + Q_3$

$= A_u V_u + A_l V_l = 1.839\ ft^3/s$

b) $Q_1 = Q_3 = A_l V_l = 1.384\ ft^3/s$

c) $Q_1 = Q_2 = A_u V_u = 0.456\ ft^3/s$

Paragraph

Unlike series pipelines where Q is equal throughout the pipe, Q is equal to the sum of all the Q's in a parallel system. Additionally, total head loss is equal throughout the system. These two laws make up the Hardy Cross method. In a typical problem, it's best to set your reference points at the entrance and exit of the pipe where the flow rates are equal. It is important to break up large equations in excel. Doing this makes them significantly simpler to complete and type in. It also makes it easier to find mistakes in the equation that may have been caused by typos. When a massive equation is put into excel, it can be very tricky to copy it over perfectly so, while breaking up the problem into multiple terms in different cells may feel needlessly time consuming, it is the safest way to do it if you are inexperienced in excel. This includes taking every value you know and plugging it in so that you can simplify it to a greater degree, and then using excel to take care of the rest of the problem.
A few other useful excel tricks and tidbits that were learned this week were using f4 to ock a particular cell into an equation and using the symbol font to quickly put in Greek letters. In the past I have looked up the Greek letters on Google and then copy-pasted them into my reports and documents, but this trick made it much faster. Using f4 to lock cells into equations was useful as well because it meant that I could just drag the equations down without having to use a constant. It was much d just drag the equations down without having to use a constant. It was much easier to just reference the cell and put f4 on it rather than typing in its value into the equation.