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MET 330

Dr. Ayala

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HW #3.2

Devon Moore: From the slides and lectures I learned that you must use a separate Bernoulli's equation for each branch in a parallel system. It is also important to have a good understanding of where the system is experiencing energy losses. The ft can be found using the equation if the pipe diameter and roughness are known, which it normally is. To find f you must use the iteration process. Q is also found using the iteration process in combination with the f that was found. These types of problems must be done in excel and require a lot of patients.

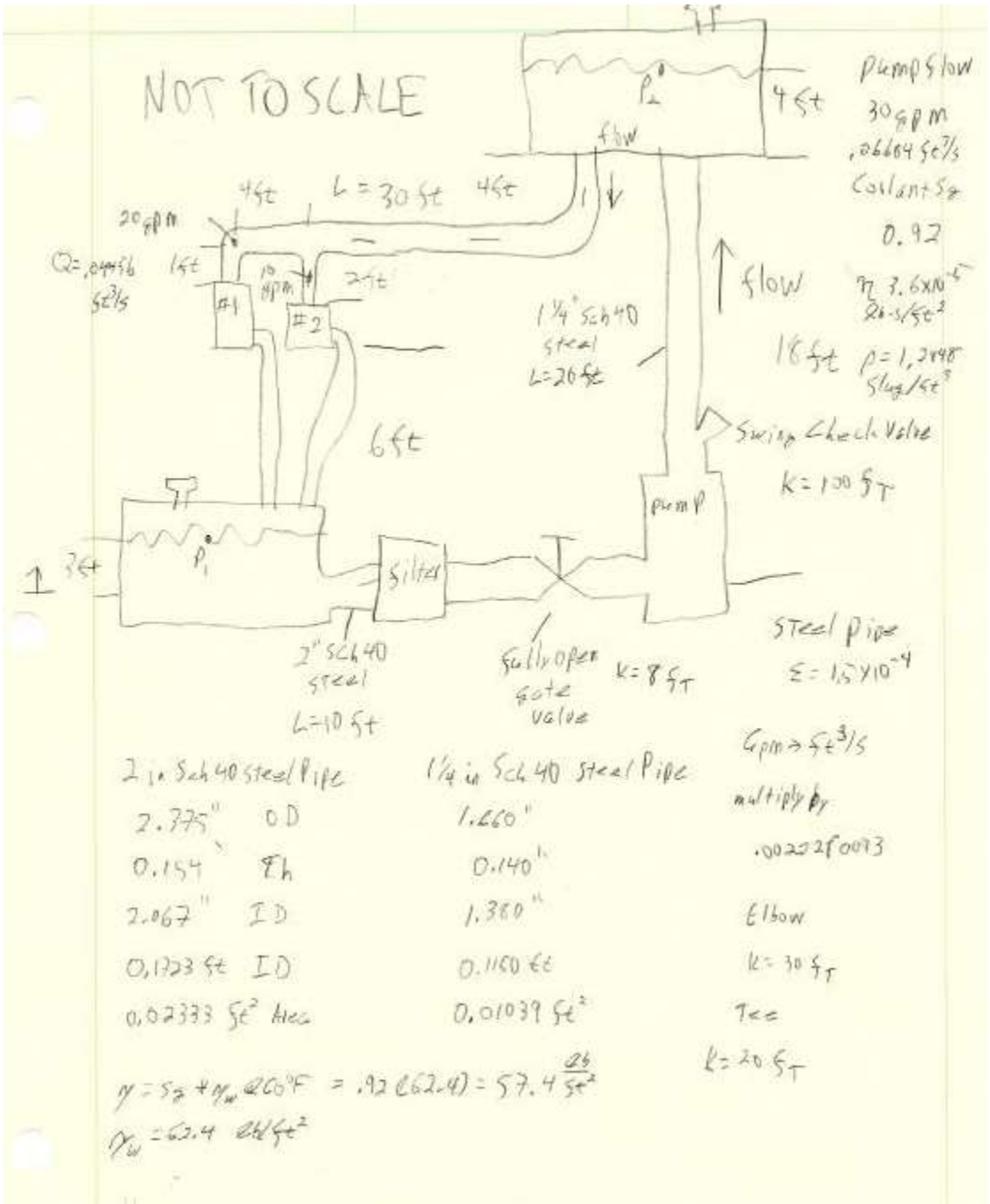
Dave Buonconsiglio: This week I learned a lot about how to let the computer do my work, but that there is still a lot to do to get it all set up. Once I have the aha moment, and can see where the Bernoulli's equation is leading me, I have actually found the process simple to understand, and almost enjoyable. I believe I have finally figured out Bernoulli's and I hope to do well on this weekend's test.

I was told in my Circuits class that the series and parallel flow was almost identical, but I had a hard time picturing that until this week and the review of the parallel branches. I can finally understand why you enjoy this subject so much, these calculations, while time-consuming, are quite satisfying to solve, almost, but not quite, fun, dare I say?

Richard Harrell:

Traveon Williams:

11.23

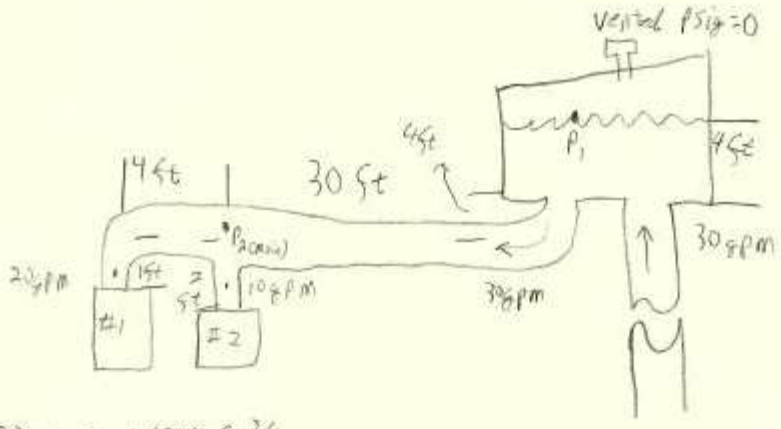

NOT TO SCALE
P_2
4 ft
flow
pump flow
30 GPM
.06684 ft³/s
Coolant Sg
0.92
η 3.6x10⁻⁴
lb-s/ft²
ρ = 1,948
slug/ft³
4ft
L = 30 ft
4ft
20 GPM
Q = .0445 ft³/s
1ft
10 GPM
2ft
#1
#2
1¼" Sch 40 steel
L = 20 ft
flow
16 ft
Swing Check Valve
K = 100 ft_T
6ft
pump
P_1
3ft
1
silter
2" Sch 40 steel
L = 10 ft
fully open gate valve
K = 8 ft_T
steel pipe
ε = 1.5 x 10⁻⁴
2 in Sch 40 steel Pipe
2.375" OD
0.154" th
2.067" ID
0.1723 ft ID
0.02333 ft² Area
1¼ in Sch 40 steel Pipe
1.660" OD
0.140" th
1.380" ID
0.1150 ft ID
0.01039 ft² Area
Gpm → ft³/s
multiply by
.002228 0093
Elbow
K = 30 ft_T
Tee
K = 20 ft_T
γ = Sg + γw @ 60°F = .92 (62.4) = 57.4 lb/ft³
γw = 62.4 lb/ft³

Problem 11.23

Given										
Class 1 system										
Pump	Z (Z2-Z1)	Sp. Gav. Of Fluid	dy. Viscosoty	Gravity	2in Schedule 40 (s)			1.25in Schedule 40 (d)		Steel Roughness (∈)
30 gal/min	18 ft	0.92	0.000036 lb-s/ft^2	9.81 m/s^2	diameter	Aera	Length	diameter	Aera	0.000046
			3.6*10^-5 lb-s/ft^2	32.19 ft/s^2	0.1723 ft	0.02333 ft^2	20 ft	0.115 ft	0.01039 ft^2	4.6*10^-5

Equaions / Calculations	
Energy Equation	$\frac{p_1}{\gamma}+z_1+\frac{v_1^2}{2g}+h_A-h_L=\frac{p_2}{\gamma}+z_2+\frac{v_2^2}{2g}$
Because	$p_1=p_2=0\ \&\ v_1=v_2=0$
	$h_A=z_2-z_1+h_L$
	$h_L=h_1+h_1+h_3+h_4+h_5+h_6$
	$h_1=k(\frac{v_s^2}{2g})(entrance)$
Conversion	$\frac{30\ gal}{min}\rightarrow\frac{1\ min}{60\ sec}\frac{0.134 ft^3}{1\ gal}=0.0668\frac{ft^3}{sec}$
Velocirt Head Suction	$v_s=\frac{Q}{A_s}=\frac{0.0668}{0.01039}=6.43\frac{ft}{s}$
	$\frac{v_s^2}{2g}=\frac{6.43^2}{2(32.19}=0.64ft$
	k=.5 assuming square-edged inlet
	$h_1=k\left(\frac{v_s^2}{2g}\right)=.5(0.64)=0.32m$
	$h_2=f_s\frac{l}{D}*\frac{v_s^2}{2g}$
	$N_R=\frac{vD\rho}{\eta}=\frac{2.86(0.1723).92}{3.6*10\text{^}-5}=12{,}593>4000=Turbulrnt\ Flow$
	$\frac{D}{\in}=\frac{0.115}{4.6*10\text{^}-5}=2500$
	$f_s=moody=0.03$
	$h_2=f_s\frac{l}{D}*\frac{v_s^2}{2g}=0.03\frac{10}{0.115}0.127=0.034ft$
Velocirt Head Discharge	$h_3=f_{dT}\frac{L_e}{D}*\frac{v_s^2}{2g}$
	$\frac{L_e}{D}=100\ (table\ 10.4\ for\ swingcheck\ valve)$
	$f_{dT}=0.21\ (table\ 10.5\ for\ 1.25in)$
	$v_d=\frac{Q}{A_d}=\frac{0.0668}{0.02333}=2.86\frac{ft}{s}$
	$\frac{v_d^2}{2g}=\frac{2.86^2}{2(32.19}=0.127ft$
	$h_3=f_{dT}\frac{L_e}{D}*\frac{v_s^2}{2g}=0.21(100)0.127=2.667ft$
	$h_4=Elbows\ in\ discharge=0$
	$h_5=f_d\frac{L}{D}\frac{v_s^2}{2g}$
	$f_d=0.019\ (table\ 10.5\ for\ 2in)$
	$h_5=f_d\frac{L}{D}\frac{v_s^2}{2g}=0.019\frac{20}{0.1723}0.127=2.33ft$
	$h_6=1\frac{v_d^2}{2g}=1*0.127=0.127ft$
Solutions	$h_L=h_1+h_1+h_3+h_4+h_5+h_6=0.32+0.034+2.667+0+2.33+0.127=5.478ft$
	$h_A=z_2-z_1+h_L=18+5.478=23.478ft=h_A$
	$Power(P_A)=h_AW=h_AYQ=23.478+\rho g+0.0668=23.54+.92(62.4)=80.89Kw=0.169\ hp=Power(P_A)$

11.24



$30\ gpm = .06684\ ft^3/s$

$gpm \Rightarrow ft^3/s \times by\ .002228\ 0093$

$20\ gpm = .04456\ 0186\ ft^3/s$

$10\ gpm = 0.2228\ 0093\ ft^3/s$

Main pipe

Steel $\varepsilon = 1.5 \times 10^{-4}$

$L = 30\ ft + 4\ ft$

$Q = .06684\ ft^3/s$

Elbow - assume standard 90° $K = 30\ f_T$

$V = \frac{Q}{A} = \frac{Q}{\frac{\pi D^2}{4}} = \left(\frac{4Q}{\pi D^2}\right)^2 = \frac{16Q^2}{\pi^2 D^4}$ $\quad \frac{8Q^2}{g\pi^2 D^4}$

$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} - h_L = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$

$Z_1 = h_L$

$h_1 = k\left(\frac{V^2}{2g}\right)$ Entrance Assume Square, $K = 0.5$ $\quad h_4\ k\left(\frac{V^2}{2g}\right)$ $K = 20\ f_T$ Tee Flow through

$h_2 = f\frac{L}{D}\left(\frac{V^2}{2g}\right)$ pipe

$h_3 = k\left(\frac{V^2}{2g}\right)$ $K = 30 f_T$ elbow

$$4 = 0.5 \frac{8Q^2}{g\pi^2 D^4} + f \frac{L}{D} \frac{8Q^2}{g\pi^2 D^4} + 30 f_T \frac{8Q^2}{g\pi^2 D^4} + 20 f_T \frac{8Q^2}{g\pi^2 D^4}$$

$$f = \frac{0.25}{\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}}\right)^2}$$

$$f_T = \frac{0.25}{\log\left(\frac{1}{3.7(D/\epsilon)}\right)^2}$$

$8Q^2 = 8(.06684^2) = .03574$

$L = 34 ft$

$$4 = 0.5 \frac{.03574}{(32.2)\pi^2 D^4} + \frac{0.25}{\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{.9}}\right)^2} \frac{.03574}{317.8 (.02617) D^4} + 30 \frac{.25}{\log\left(\frac{1}{3.7(D/\epsilon)}\right)^2} \frac{.03574}{317.8 D^4}$$

$$+ 20 \frac{.25}{\log\left(\frac{1}{3.7(D/\epsilon)}\right)^2} \frac{.03574}{317.8 D^4}$$

$$N_R = \frac{VDA}{\eta} = \frac{\frac{4Q}{\pi D^2} D \, 1.748}{3.7 \times 10^{-5}}$$

~~$4Q = 4(.06684) = 0.2673 \cdot 3.7 \times 10^{-5} = 9.62496 \times 10^{-6} D \, 1.748 = 1.68243.06 \times 10^{-5} D$~~

~~$\frac{5.47}{1.68 \times 10^{-5} D^{.9}}$~~

$\frac{4Q\eta}{\pi D^2} D \; 1.748 \quad \frac{4Q\eta}{\pi D} 1.748$

Pump Flow	30	gpm	0.06684	ft^3/s
Coolant sg	0.92	γ	57.408	lb/ft^3
Dynamic Visc η	3.60E-05	$lb*s/ft^2$		
Coolant ρ	1.7848	$slug/ft^3$	57.4242	lb/ft^3
Steel Pipe ϵ	1.50E-04	ft		
Pipe Length	34	ft		
K Elbow	30	f_T		
K Tee (through)	20	f_T		

Tanks vented, therefore P=0 psig

$$\frac{p_1}{\gamma}+z_1+\frac{v_1^2}{2g}-h_L+h_A=\frac{p_2}{\gamma}+z_2+\frac{v_2^2}{2g}$$

$z_2 = h_L$ | z_2 | 4 | ft

$h_{L\ entrance} = K(\frac{v^2}{2g})$ | assume square, K =0.5

$h_{L\ pipe} = f\frac{L}{D}(\frac{v^2}{2g})$

$h_{L\ elbow} = K(\frac{v^2}{2g})$ | K=30 f_T

$h_{L\ tee} = K(\frac{v^2}{2g})$ | K=20 f_T

$$f=\frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}+\frac{5.74}{Re^{0.9}}\right)\right]^2}$$

$$f_T=\frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right)\right]^2}$$

$$Re=\frac{VD\rho}{\eta}$$

$$V=\frac{Q}{A}$$

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

$$\frac{v^2}{2g}=\frac{\frac{16Q^2}{\pi^2D^4}}{2g}=\frac{8Q^2}{g\pi^2D^4}$$

$$Re=\frac{\frac{4Q}{\pi D^2}D*\rho}{\eta}$$

$$Re=\frac{4Q\eta}{\pi D}1.748$$

4Qη	9.63E-06
4Qη*1.74	1.68E-05

$$Re=\frac{1.68E-5}{\pi D}$$

$LHS = z_2$	4

$$RHS = 0.5\frac{8Q^2}{g\pi^2D^4} + f\frac{L}{D}\frac{8Q^2}{g\pi^2D^4} + 30f_T\frac{8Q^2}{g\pi^2D^4} + 20f_T\frac{8Q^2}{g\pi^2D^4}$$

$8Q^2$	0.03574
$g\pi^2$	317.801
L	34

Iteration	D ft	Re	f	f_T	V	RHS	% Diff
1	0.25	2.1E-05	1.02E-02	3.55E-02	0.02879	0.10557	-97%
2	1	5.4E-06	0.00831	2.36E-02	0.00011	0.00022	-100%
3	5	1.1E-06	0.00669	1.60E-02	1.8E-07	2.4E-07	-100%
4	0.05	0.00011	0.01344	6.54E-02	17.9941	232.308	5708%
5	0.1	5.4E-05	0.0119	4.91E-02	1.12463	7.87418	97%
6	0.15	3.6E-05	0.01111	4.23E-02	0.22215	1.14031	-71%
7	0.11	4.9E-05	0.01171	4.74E-02	0.76814	4.98294	25%
8	0.115	4.7E-05	0.01162	4.66E-02	0.64301	4.02815	1%
9	0.114	4.7E-05	0.01164	4.67E-02	0.66587	4.19992	5%
10	0.116	4.6E-05	0.0116	4.64E-02	0.62112	3.86488	-3%
11	0.1155	4.6E-05	0.01161	4.65E-02	0.63195	3.94549	-1%
12	0.1154	4.6E-05	0.01161	4.65E-02	0.63414	3.96185	-1%
13	0.1153	4.6E-05	0.01161	4.65E-02	0.63635	3.9783	-1%
14	0.1152	4.6E-05	0.01161	4.66E-02	0.63856	3.99484	0%

Main pipe should be 1 1/4 in Schedule 40 Stee

$LHS = z_2$	4

$$RHS = 0.5\frac{8Q^2}{g\pi^2D^4} + f\frac{L}{D}\frac{8Q^2}{g\pi^2D^4} + 30f_T\frac{8Q^2}{g\pi^2D^4} + 20f_T\frac{8Q^2}{g\pi^2D^4}$$

Q	0.04456
$8Q^2$	0.01588
$g\pi^2$	317.801
L	4

Iteration	D ft	Re	f	fT	V	RHS	% Diff
1	0.25	2.1E-05	0.01023	0.0355	0.02879	0.10557	-97%
2	1	5.4E-06	0.00831	0.02359	0.00011	0.00022	-100%
3	5	1.1E-06	0.00669	0.01599	1.8E-07	2.4E-07	-100%
4	0.05	0.00011	0.01344	0.06543	17.9941	232.308	5708%
5	0.1	5.4E-05	0.0119	0.04913	1.12463	7.87418	97%
6	0.15	3.6E-05	0.01111	0.04228	0.22215	1.14031	-71%
7	0.11	4.9E-05	0.01171	0.04738	0.76814	4.98294	25%
8	0.115	4.7E-05	0.01162	0.04659	0.64301	4.02815	1%
9	0.1155	4.6E-05	0.01161	0.04652	0.63195	3.94549	-1%
10	0.1152	4.6E-05	0.01161	0.04656	0.63856	3.99484	0%

Pipe between pumps should be 1 1/4 in Schedule 40 steel pipe

$LHS = z_2$	4

$$RHS = f\frac{L}{D}\frac{8Q^2}{g\pi^2D^4} + 60f_T\frac{8Q^2}{g\pi^2D^4}$$

Q	0.02228
$8Q^2$	0.00397
$g\pi^2$	317.801
L	2

Iteration	D ft	Re	f	fT	V	RHS	% Diff
1	0.11	4.9E-05	0.01171	0.04738	0.76814	4.9628	24%
2	0.12	4.5E-05	0.01154	0.04586	0.54236	3.26484	-18%
3	0.115	4.7E-05	0.01162	0.04659	0.64301	4.00624	0%

Pipe to pump #2 should be 1 1/4 in Schedule 40 steel pipe

$LHS = z_2$	4

$$RHS = f\frac{L}{D}\frac{8Q^2}{g\pi^2D^4} + 30f_T\frac{8Q^2}{g\pi^2D^4}$$

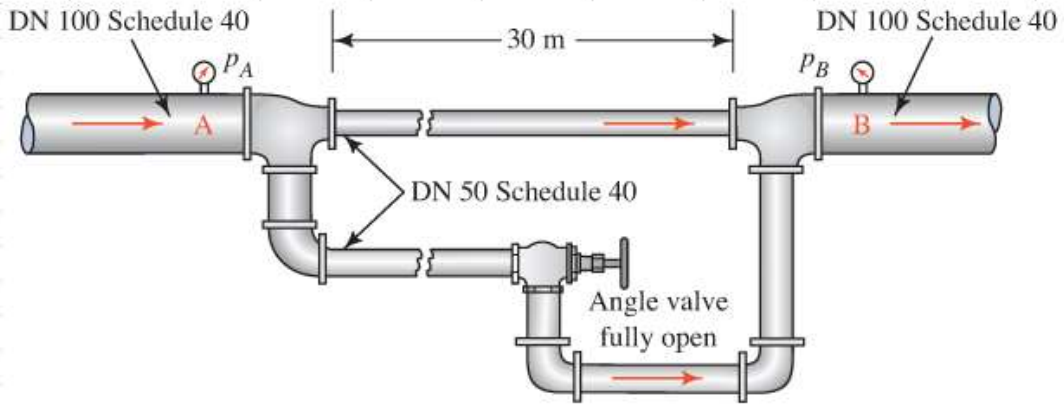
Q	0.04456
$8Q^2$	0.01588
$g\pi^2$	317.801
L	1

Iteration	D ft	Re	f	fT	V	RHS	% Diff
1	0.11	4.9E-05	0.01171	0.04738	0.76814	3.871	-3%
2	0.1	5.4E-05	0.0119	0.04913	1.12463	6.20673	55%
3	0.105	5.1E-05	0.0118	0.04822	0.92524	4.87332	22%
4	0.1075	5E-05	0.01175	0.04779	0.84213	4.33735	8%
5	0.108	5E-05	0.01174	0.04771	0.82664	4.23887	6%
6	0.109	4.9E-05	0.01172	0.04754	0.79672	4.04989	1%
7	0.1095	4.9E-05	0.01171	0.04746	0.78227	3.95923	-1%
8	0.10925	4.9E-05	0.01172	0.0475	0.78945	4.00425	0%

Pipe to pump #1 should be 1 1/4 in Schedule 40 steel pipe

12.3

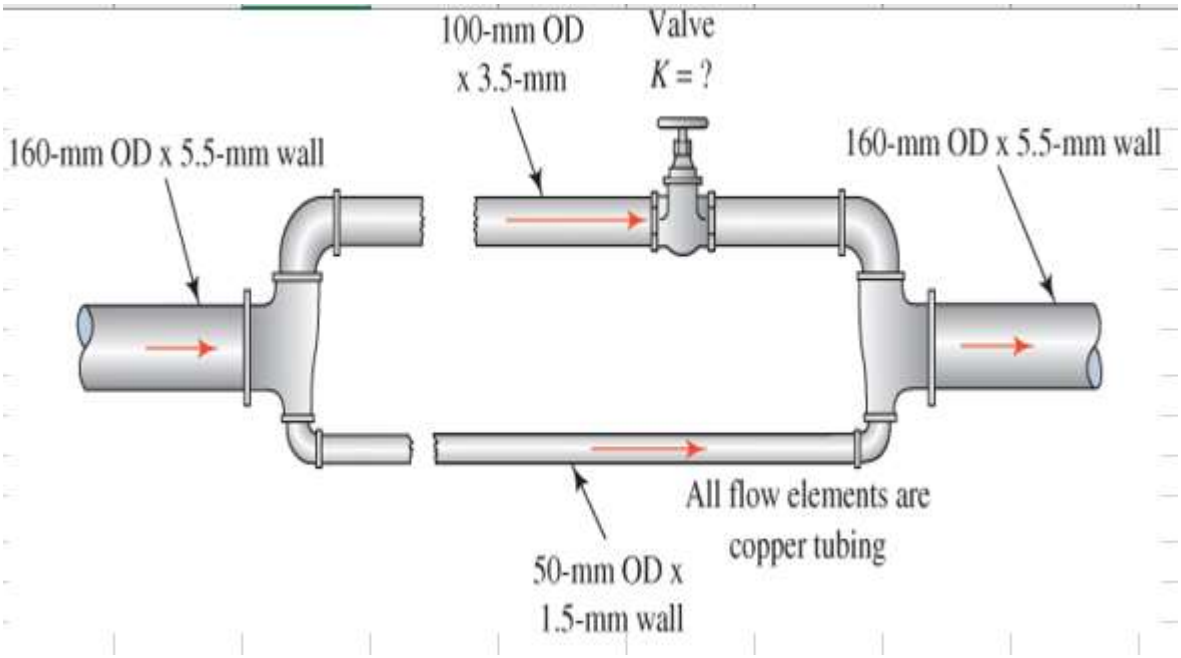
						hL_lower	
					hL_50	0	Xf_Qb^2
Q	800	L/min	Viscosity	1.30E-06	hL_teebr	652582.3	Xft_Qb^2
	0.013333	M^3/s			hL_elb	978873.4	Xft_Qb^2
					hL_red	652.5823	Xft_Qb^2
A_100	8.21E-03	m^2			hL_exp	7287.169	Xft_Qb^2
A_50	2.17E-03	m^2			hL_valve	1631456	Xft_Qb^2
						3270851	Xft_Qb^2
						hL_upper	
D_100	0.1023	m			hL_50	0	Xf_Qa^2
D_50	0.0525	m			hL_teerun	217527.4	Xft_Qa^2
					hL_red	652.5823	Xft_Qa^2
V_a^2-V_b^2/2g	0				hL_exp	7287.169	Xft_Qa^2
						225467.2	
					ft	0.021601	



Iteration	1						
	Guess Q2 (m3/s)	V2 (m/s)	Re2	f2	deltaP /gamma (m)		
	0.007	0.85164	6.70E+04	0.0779	0.24		
		f3	Q3 (m3/s	V3 (m/s)	Re3	f3	%diff
		0.01	0.007	0.85164	6.70E+04	0.0779	-679.044
		0.0779	0.007	0.85164	6.70E+04	0.0779	0
	Guess Q2	%diff					
	0.00633	9.52381					
Iteration	2						
	Guess Q2 (m3/s)	V2 (m/s)	Re2	f2	deltaP /gamma (m)		
	0.00633	0.77053	6.06E+04	0.0779	0.20		
		f3	Q3 (m3/s	V3 (m/s)	Re3	f3	%diff
		0.01	0.00633	0.77053	6.06E+04	0.0779	-67905%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
	Guess Q2	%diff					
	0.007	-10.5263					
Iteration	3						
	Guess Q2 (m3/s)	V2 (m/s)	Re2	f2	deltaP /gamma (m)		
	0.007	0.85164	6.70E+04	0.0779	0.24		
		f3	Q3 (m3/s	V3 (m/s)	Re3	f3	%diff
		0.01	0.007	0.85164	6.70E+04	0.0779	-67904%
		0.0779	0.007	0.85164	6.70E+04	0.0779	0%
		0.0779	0.007	0.85164	6.70E+04	0.0779	0%
	Guess Q2	%diff					
	0.00633	9.52381					

Iteration	4						
	Guess Q2 (m3/s)	V2 (m/s)	Re2	f2	deltaP /gamma (m)		
	0.00633	0.77053	6.06E+04	0.0779	0.20		
		f3	Q3 (m3/s	V3 (m/s)	Re3	f3	%diff
		0.01	0.00633	0.77053	6.06E+04	0.0779	-67905%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
	Guess Q2	%diff					
	0.007	-10.5263					
Iteration	5						
	Guess Q2 (m3/s)	V2 (m/s)	Re2	f2	deltaP /gamma (m)		
	0.007	0.85164	6.70E+04	0.0779	0.24		
		f3	Q3 (m3/s	V3 (m/s)	Re3	f3	%diff
		0.01	0.00633	0.77053	6.06E+04	0.0779	-67905%
		0.0779	0.00633	0.77053	6.06E+04	0.0779	0%
	Guess Q_A (m3/s)	%diff					
	0.007	0					
Q_T=Q_A+Q_B	0.00633						
delta_P	2.34112	kPa					

12.5


100-mm OD
x 3.5-mm
Valve
K = ?
160-mm OD x 5.5-mm wall
160-mm OD x 5.5-mm wall
All flow elements are
copper tubing
50-mm OD x
1.5-mm wall

Assuming standard elbows

Q	500	L/m	0.008333	m^3/s

100 mm OD Pipe			50 mm OD Pipe		
0.093	m	ID	0.047	m	ID
6.79E-03	m^2	Area	1.74E-03	m^2	Area
1.40E-07		D/ϵ	3.13E+04		D/ϵ

160 mm OD Pipe		
0.149	m	ID
1.74E-02	m^2	Area
9.93E+04		D/ϵ

Water @ 10°C		
γ	9.81	kN/m^3
ρ	1000	kg/m^3
η	1.30E-03	Pa*s
ν	1.30E-06	m^2/s

ϵ	1.50E-06	m

$$Q_b = A_b v_b$$

$v_b = \frac{Q_b}{A_b}$	4.803074	m/s

$$h_{L\,1-2} = h_a = h_b$$

$h_b = f\frac{L}{D}$	10.08624	m

$$Re = \frac{VD}{\nu}$$

Re	1.74E+05

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

fb	0.015802

$$h_a = f\frac{L}{D} + K_{valve}$$

$$Q_a = A_a v_a$$

$v_a = \frac{Q_a}{A_a}$	1.226753	m/s

$$h_a = f\frac{L}{D}$$

$$Re = \frac{VD}{v}$$

Re	8.78E+04

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

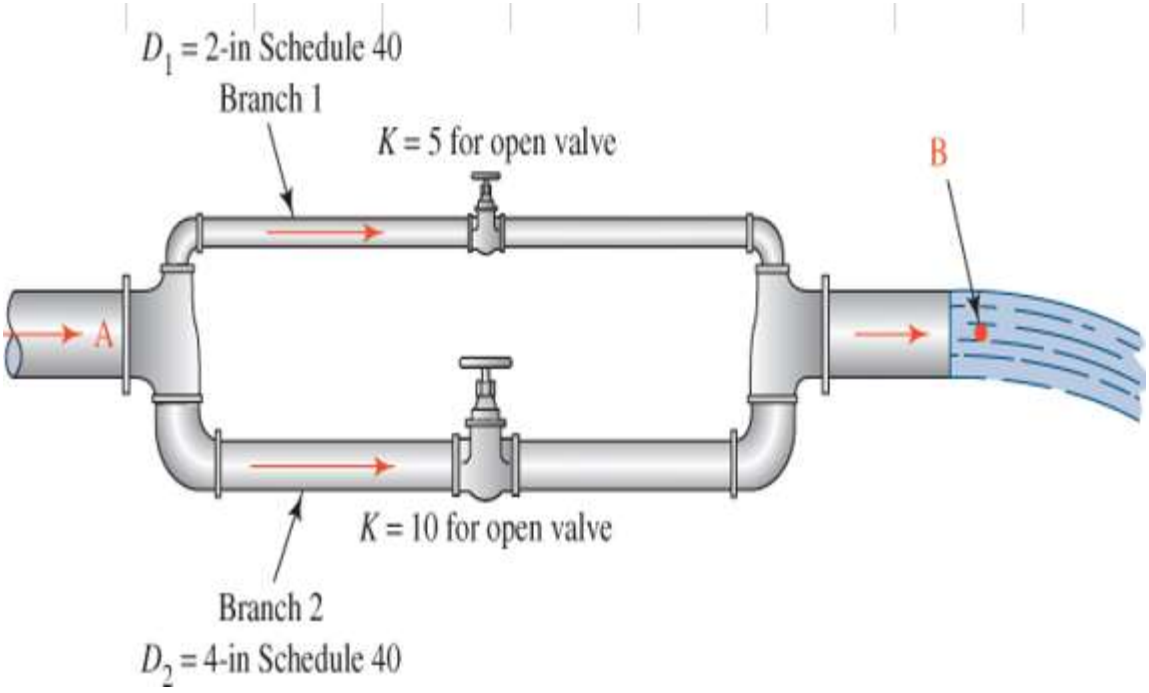
fa	0.018154

LHS	10.08624

Iteration	K	RHS	%Diff
1	30	35.85627	255%
2	20	25.85627	156%
3	10	15.85627	57%
4	5	10.85627	8%
5	2.5	8.356267	-17%
6	3	8.856267	-12%
7	4	9.856267	-2%
8	4.5	10.35627	3%
9	4.25	10.10627	0%

K valve	4.25

12.6


D_1 = 2-in Schedule 40
Branch 1
K = 5 for open valve
B
A
K = 10 for open valve
Branch 2
D_2 = 4-in Schedule 40

a	Both valves open		Q	0.8575	ft^3/s
b	Valve in branch 2 only open		Q	0.37	ft^3/s
c	Valve in branch 1 only open		Q	0.4875	ft^3/s

Water @ 60°F		
γ	62.4	lb/ft^3

Steel Pipe	ϵ	1.50E-04	ft
Elbow K	0.9		

D1 2 in Schedule 40 Pipe			D1 4 in Schedule 40 Pipe		
0.1723	ft	ID	0.3355	ft	ID
0.02333	ft^2	Area	0.0884	ft^2	Area
5		K valve	10		K valve

Pa	20	psig	2880	lb/ft^2

Pb	0	psig	0	lb/ft^2

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{P_a}{\gamma} = h_L$$

D1

$$h_L = 2\left(K\left(\frac{v_1^2}{2g}\right)\right) + K\frac{v_1^2}{2g}$$

$$V = \frac{Q}{A}$$

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

$$\frac{v^2}{2g} = \frac{\frac{16Q^2}{\pi^2 D^4}}{2g} = \frac{8Q^2}{g\pi^2 D^4}$$

$$h_L = 2\left(0.9\frac{8Q^2}{g\pi^2 D^2}\right) + 5\frac{8Q^2}{g\pi^2 D^2}$$

$$h_L = \frac{14.4Q^2}{g\pi^2 D^4} + \frac{40Q^2}{g\pi^2 D^4}$$

$g\pi^2D^4$	0.280089

14.4+40	54.4

$$h_L = \frac{54.4Q^2}{0.280089}$$

$$\frac{P_a}{\gamma} = \frac{\frac{lb}{ft^2}}{\frac{lb}{ft^3}} = \frac{lb}{ft^2}\frac{ft^3}{lb} = ft$$

46.15385	ft

D2

$$h_L = 2\left(K\left(\frac{v_1^2}{2g}\right)\right) + K\frac{v_1^2}{2g}$$

$$V = \frac{Q}{A}$$

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

$$\frac{v^2}{2g} = \frac{\frac{16Q^2}{\pi^2 D^4}}{2g} = \frac{8Q^2}{g\pi^2 D^4}$$

$$h_L = 2\left(0.9\frac{8Q^2}{g\pi^2D^2}\right) + 10\frac{8Q^2}{g\pi^2D^2}$$

$$h_L = \frac{14.4Q^2}{g\pi^2D^4} + \frac{80Q^2}{g\pi^2D^4}$$

$g\pi^2D^4$	4.026482
14.4+80	94.4

$$h_L = \frac{94.4Q^2}{4.026482}$$

$$\frac{P_a}{\gamma} = \frac{\frac{lb}{ft^2}}{\frac{lb}{ft^3}} = \frac{lb}{ft^2}\frac{ft^3}{lb} = ft$$

46.15385	ft

D1

LHS	46.15385

Iteration	Q ft^3/s	RHS	% Diff
1	5	4855.592	10420%
2	1	194.2237	321%
3	0.5	48.55592	5%
4	0.25	12.13898	-74%
5	0.4	31.07579	-33%
6	0.45	39.33029	-15%
7	0.425	35.08165	-24%
8	0.475	43.82172	-5%
9	0.48	44.74914	-3%
10	0.49	46.6331	1%
11	0.485	45.68626	-1%
12	0.4875	46.15847	0%

D2

LHS	46.15385

Iteration	Q ft^3/s	RHS	% Diff
1	5	8425.88	18156%
2	1	337.0352	630%
3	0.5	84.2588	83%
4	0.25	21.0647	-54%
5	0.3	30.33317	-34%
6	0.4	53.92563	17%
7	0.35	41.28681	-11%
8	0.375	47.39558	3%
9	0.37	46.14012	0%