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MET 330

Dr. Ayala

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HW #1.4

Devon Moore: Looking at the exams from previous semesters I learned how the formatting of the questions should look and the level of detail that is expected for the summary and analysis. These exams also involve static analysis aspects from previous courses that were not touched on in this class. Buoyancy force was used in both test and can be solved for by knowing the specific weight of the fluid and the volume displaced by the object. The problems covered in the Minor Losses lecture explain how to find and use Reynold's Number in more detail. The slides also show how to account for the minor losses of multiple bends in the same pipe. The importance of placing your points in the right locations is also emphasized by the slides showing how terms of Bernoulli's Equation can be easily canceled out with the correct points.

David Buonconsiglio: I had heard of Bernoulli's law and how it pertains to fluid flowing through a restricted volume, but I had no idea how important and useful the equation is. The terms and the applications are new to me, in that while I understood the basics of choosing pipes in a residential construction, and replacing equipment in commercial HVAC, I never saw or knew the calculations behind the data. I was just the wrench monkey doing the work, not the engineer designing the systems. As a maintainer, I almost always hated the engineers who designed the systems I was working on, as it was always difficult to work in the confined spaces, or there are other systems that need to be removed to repair the broken system. As I am learning more about fluids, which includes air, I am understanding the reasons for such system designs, and have developed a new respect for the engineers designing these systems.

Bernoulli's equation has been a challenge for me, but the more I use it, the more I understand it and how to set it up. The difficult part really is the set-up. Once the set up is in place, it is just algebraic cancellations and plug and chug to find the answer. I don't feel truly confident in proper set-up yet, but I am improving, and will get there.

Traveon Williams: These exams taught me the basic layouts of the exams. The exams are usually between 2-4 questions. When taking the exam we must follow the rubric to receive all points necessary. The Max points from the test is 80 with 10 coming form technical writing and another 10 coming from the homework. During the test you should include plenty of drawings and should have plenty of words to explain out each step.

Richard Harrell: Bernoulli's equation formula is very important when working with pressure and its energies that associate with in when concerning with pipes or something that restricts the flow of a liquid or gas. The formals base for is easy to flow until you start trying to fill in the variables then it gets confusing. Once you get it set up correctly (hard part) it just a bunch of cancellations and algebra. Before the class I had heard of Bernoulli's equation but never really used it, this has given me a high level of approbation to pipe fitters and engineers how work with piping.

7.11

HW 1.4

$P = E_{pump}\,\gamma Q$

$P_1/\gamma + z + (V_1^2/2g) + E_{pump} - E_L = P_2/\gamma + z_2 + \left(\frac{V_2^2}{2g}\right)$

$E_{pump} = (P_2/\gamma) + z_2 - z_1 + \left(\frac{V_2^2}{2g}\right) + E_L$

$V_2 = Q/A = 745\ \text{gal/h} / 0.06 = 4.61\ \text{ft/s}$

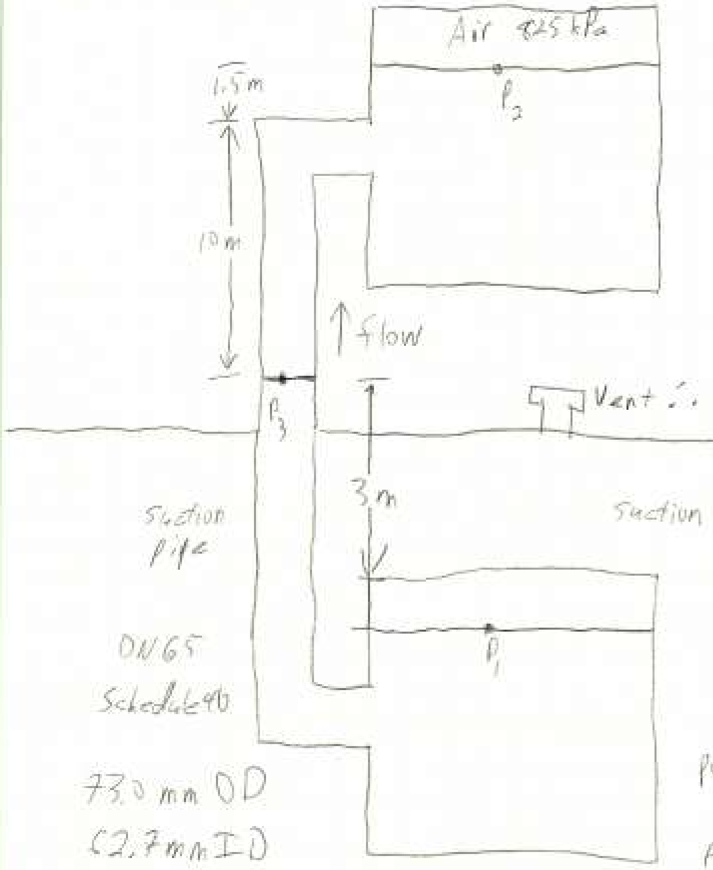
$E_{pump} = \left(\frac{5700.3}{62.4}\right) + 110 + \left(\frac{4.61^2}{2 \times 32.2}\right) + 10.5 = 223\ \text{ft}$

$P_A = 223 \times 62.4 \times \left(\frac{745}{449 \times 60}\right) = 0.7\ \text{hp}$

$\text{eff} = P_A / P_1 = 0.7/1 = .7 = 70\%$

7.16

7-16



$\Delta Z = 14.5\,m$

Suction $h_L = 1.4\,Nm/m$

$h_L = 4.2\,Nm/m$

$\dot{Q} = 840\,L/min$

$sg = 0.85$

$power = \rho g h_a \dot{Q}$

$\rho = \frac{sg_{oil}}{sg_{water}}$

DN65

Schedule 40

73.0 mm OD

62.7 mm ID

3.090×10^{-3} flow Area

$\left(\frac{kg}{m^3}\right)\left(\frac{m}{s^2}\right)\left(\frac{J}{\frac{kg\,m}{s^2}}\right)\left(\frac{L}{min}\right)$

$\frac{825\,kPa}{(.85)(9810\,\frac{N}{m^3})}$

$N = \frac{kg\,m}{s^2}$

$1\,kPa = 1000\,\frac{N}{m^2}$

$\frac{825000\,\frac{N}{m^2}}{(.85)(9810\,\frac{N}{m^3})} = \frac{825000}{(.85)(9810)}\,m$

$J = Nm$

$L = .001\,m^3$

$\left(\frac{kg}{m^3}\right)\left(\frac{m}{s^2}\right)\left(\frac{Js^2}{kg\,m}\right)\left(\frac{.001\,m^3}{min}\right)\ \frac{J}{min}$

Given:	Q	840	L/min	0.84	m^3/min	0.014	m^3/s
	crude oil	0.85	sg	γ	8338.5		
	h_f	4.2	N*m/N		5.6 N*m/N	total	
	$h_{fsuction}$	1.4	N*m/N				
	Δz (z_2-z_1)	14.5	m				
	DN 65 Sch 40		73	OD	62.7	ID	mm
			3.090*10	m flow area			
	p_2	825	kPa	p_1	101.25	kPa	
	z_3	3	m				
Data:	sg_{water}	1000	kg/m^3				
	g	9.81	m/s^2				

Formulae:

$$\rho = \frac{sg_{oil}}{sg_{water}}$$

$$power = \gamma h_A \dot{Q}$$

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

$$v = \frac{\dot{Q}}{A}$$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_3}{\gamma} + z_3 + \frac{v_3^2}{2g} + h_{f-3}$$

$$h_A = \frac{p_2}{\gamma} + z_2 + h_f$$

$$\frac{Nm}{s} = W$$

$$p_3 = -\gamma\left(\frac{v_3^2}{2g} + z_3 + h_{ftotal}\right)$$

Solve:	ρ_{oil}	850	kg/m^3		
	v_3	4.53074	m/s		
	p_2/γ	98.9387			
	h_A	117.639			
	power	13733	≈13.7 kW		
	v_3^2	20.5276	/(9.81*2)	0.0140793	
	p_3	-36806.8	N/m^2	-36.8068	≈-36.8 kPa

7.22

Given:	sg_{oil}	0.9	ρ_{oil}	0.0324	lb/in^3	γ	1.04328
	Cyl ID	5	in	55.9872	lb/ft^3	γ	1802.788
	15	s					
	20	in	travel	1.333333	in/s		
	11000	lbf					
	$h_{Lsuction}$	11.5	lb-ft/in				
	$h_{Ldischarge}$	35	lb-ft/in				
	3/8 Sch 80	1.05	OD	0.742	ID	0.003	flow A
	Δz	15	ft				

Formulae: $Q = Av$

$$h_A = \frac{p_2}{\gamma} + z_2 + h_L$$

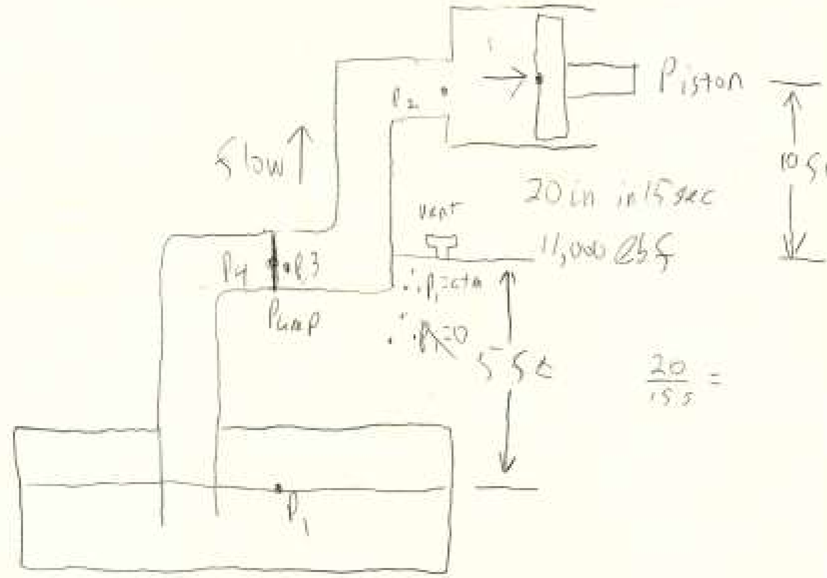
$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$p_2 = \gamma(z_2 + \frac{v_2^2}{2g} + h_L)$$

$$power = h_A * \gamma * Q$$

Solve:	A_{cyl}	19.63495	in^2		
	Q_{cyl}	26.17994	in^3/s		
	$v_2=v_3$	0.07854	in/s		
	Q_{pump}	0.000236	in^3/s		
	$p_2=p_3$	64.16182	psi		
	p_4	17.21422	psi		
	h_A	123.0001			
	power	0.030236	lbf-in/s	0.00252	lb ft/s

7-22



$\frac{20}{15.5} =$

3/8" Sch 80 1.050 OD
0.742 ID

0.00300 ft² flow Area

$P_1 = 0$ $\frac{\overset{0}{P_1}}{\gamma} + \overset{0}{z_1} + \frac{\overset{0}{v_1^2}}{2g} + h_A - h_R - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$

$-h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$

$-\frac{P_2}{\gamma} = z_2 + \frac{v_2^2}{2g} + h_L$

$-P_2 = (z_2 + \frac{v_2^2}{2g} + h_L)\gamma$

$P_2 = \gamma (z_2 + \frac{v_2^2}{2g} + h_L) = P_3$ (pipe flow)

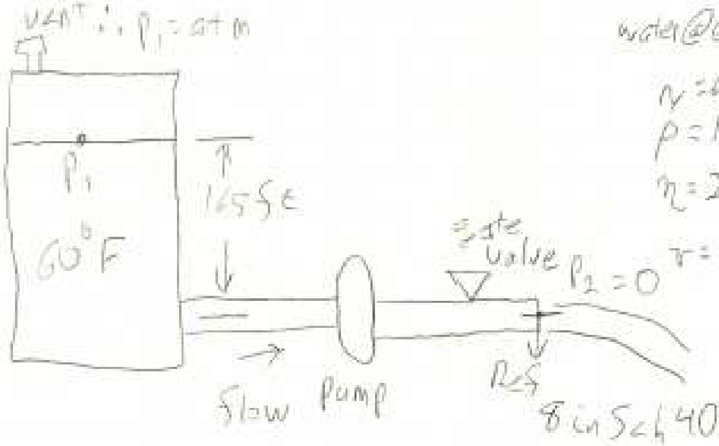
$P_4 = \gamma (z_4 + \frac{v_4^2}{2g} + h_L)$ suction

$P = h_A \gamma Q$ 1 lbf = 32.174 lb in/s²

$h_A = \frac{P_2}{\gamma} + z_2 + h_L$

7.30

7-30



water @ 60°F

$\gamma = 62.4\ lb/ft^3$

$\rho = 1.94\ sl/ft^3$

$\eta = 2.35 \times 10^{-5}\ lb\text{-}s/ft^2$

$\nu = 1.21 \times 10^{-5}\ ft^2/s$

$1\ ft^3/s = 448.3\ gal/min$

$1\ ft^3/m = 7.48\ gal/min$

Q 1,000 gal/min $\Delta z = 165\ ft$

P_R 37 hp

h_L

8.625 OD

7.981 ID

0.3472 ft^2 flow A

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

No energy added

gal/min → ft^3/s → /449

$z_1 + h_R - h_L = z_2 + \frac{v_2^2}{2g} \rightarrow z_2 - z_1 - h_R + \frac{v_2^2}{2g} = -h_L$

$h_L = (z_1 - z_2) - \frac{v_2^2}{2g} - h_R$

$h_R = \frac{P_R}{\gamma Q}$

Given:	60°F	γ	62.4	lb/ft^3				Solve:	Q	2.227171	ft^3/s
	1000	gal/min	2.227171	ft^3/s							
	P_R	37	hp	20350	lb-ft/s				v	6.414664	ft/s
	Δz	165	ft								
									h_R	146.4287	ft
Data:	8 in Schedule 40 pipe										
									h_L	17.93237	ft
	8.625	OD	7.981	ID	0.3472	flow Area	ft^2				

Formulae:

$$Q = \frac{gal}{449}$$

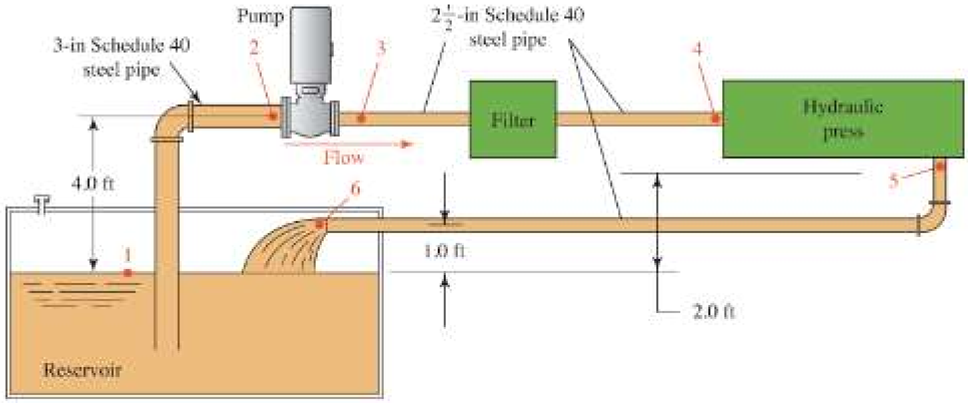
$$v = \frac{Q}{A}$$

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

$$h_R = \frac{P_R * 550}{\gamma Q}$$

$$h_L = (\Delta z) - \frac{v_2^2}{2g} - h_R$$

7.35



sg_{oil}	0.93		γ	58.032			
Q	175	gal/min	0.389755	ft^3/s			
P	28.4	hp	15620	lb-ft/s			
η	80	%	0.8				
$h_{L1\text{-}2}$	2.8	$h_{L3\text{-}4}$	28.5	$h_{L5\text{-}6}$	3.5	lb-ft/lb	
Data:	$A_{1\text{-}2}$	0.05132	ft^2	3.5	OD	3.068	ID
	$A_{3\text{-}4\text{-}5\text{-}6}$	0.03326	ft^2	2.875	OD	2.469	ID
	$v_{1\text{-}2}$	7.594603	ft/s	57.67799	/2g	0.895621	
	v_3	11.71843	ft/s	137.3216			

Formulae:

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

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

$$p_2=\gamma(-z_2-\frac{v_2^2}{2g}-h_L)$$

$$p_3=\gamma(\frac{p_2}{\gamma}+\frac{(v_2^2-v_3^2)}{2g}+h_A)$$

$$p_4=\gamma(\frac{p_3}{\gamma}-h_L)$$

$$p_5=\gamma((z_6-z_5)+h_L)$$

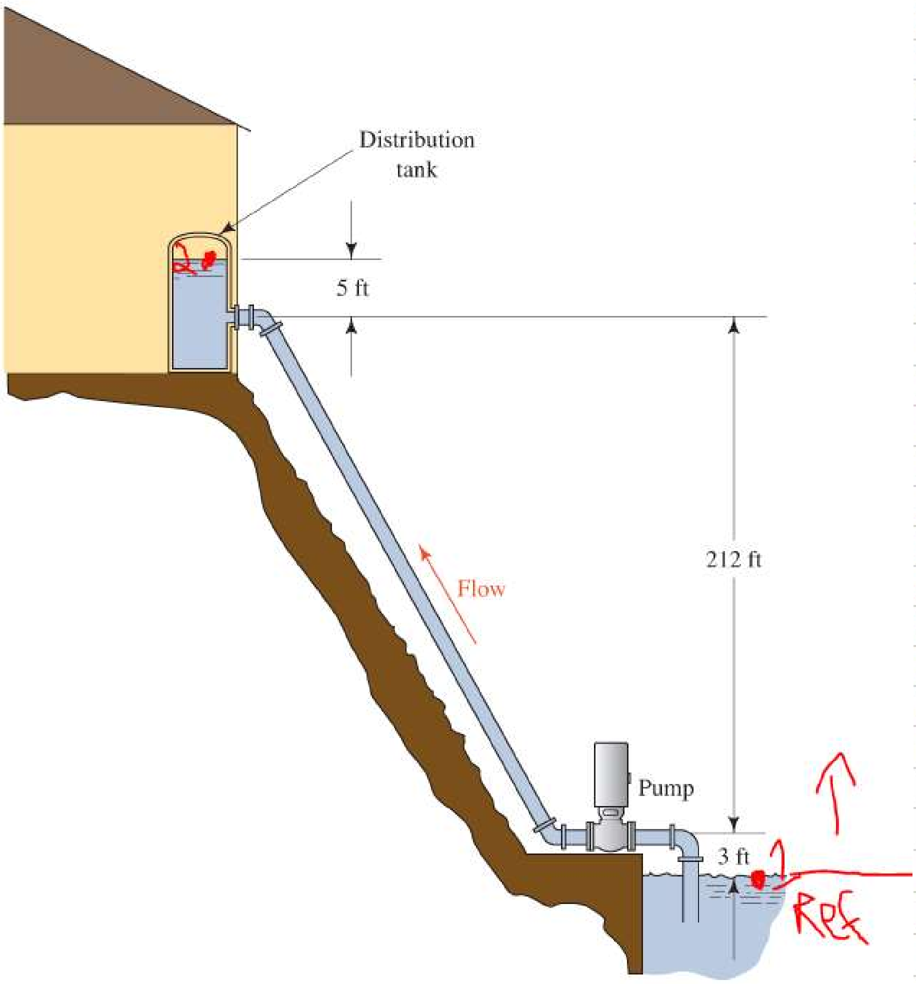
$$h_R=-[\frac{(p_5-p_4)}{\gamma}+(z_5-z_4)$$

$$P_R=h_R\gamma Q$$

$$P_A=\eta*p$$

Solve:	$(-z_2-\frac{v_2^2}{2g}-h_L)$			7.695621	
	p_2	446.5923	3.101137	psi	
	P_A	12496	lb-ft/s		
	h_A	552.4739	lb-ft/lb		
	p_2/γ	7.695621			
	v_2^2-v_3^2	-79.6436	/64.4	-1.2367	ft/s
	p_3	32435.99	225.2499	psi	
	p_4	30782.08	213.7644	psi	
	p_5	145.08	1.0075	psi	
	h_R	525.9328			
	P_R	11895.69	lb-ft/s	21.62852	hp

7.42

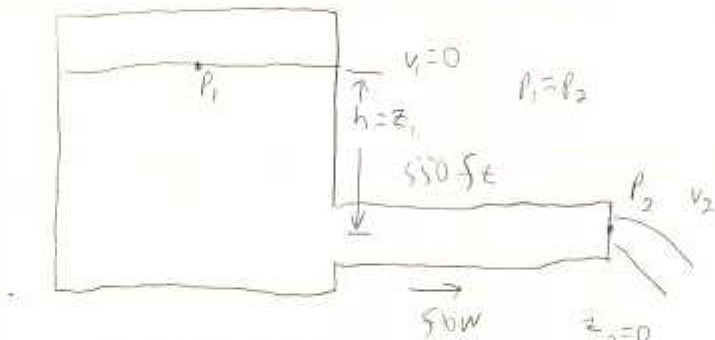


Bernoulli's	
P1	0
yx	62.4
yy	
V1^2	
2g	
Z1	
ha	
P2	4320
V2^2	
Z2	220
hr	
hl	15.5
D1	
D2	
A1	0.0513
A2	0.0333
sgx	
sgy	
Q	0.089
n	1
h	

Pump Power (HP)	
ha	304.7308
P	3.08

8.33

8-33



6 in Sch. 40 pipe

6.625 OD

6.065 ID

.2006 ft² A

$v_2 = \frac{Q}{A} = \frac{2.5}{.2006} =$

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

$$h - h_L = \frac{v_2^2}{2g}$$

$$h = \frac{v_2^2}{2g} + h_L$$

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

$$h = \frac{V_2^2}{2g} + h_L$$

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

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

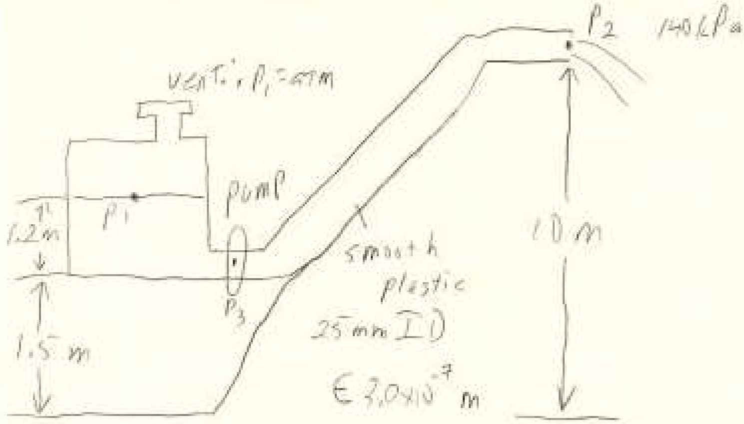
$$N_R = \frac{VD}{\nu}$$

$$R_R = \frac{D}{\epsilon}$$

Data:	V_2	12.46261	ft/s	
	N_R	663011		
	R_R	3369.333		
	f	≈	0.0165	
	$\frac{V_2^2}{2g}$	2.41175		
	h_L	43.30556	ft	
	h	45.71731	ft	

8.38

8-38



Fertilizer solution

sg 1.10

η 2.0×10^{-3} Pa·s dynamic viscosity

$L = 85\ m$

$Q = 95\ L/min \rightarrow \frac{m^3}{10^3 L}\cdot\frac{min}{60 s}$

$\rho = (sg)(\rho_{water})$

$v_1 = v_2 = v = \frac{Q}{A}$

$N_R = \frac{\rho v D}{\eta}$

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

$\frac{p_{atm}}{\gamma} + z_1 + h_A = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$

$h_A = \frac{(p_2 - p_{atm})}{\gamma} + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$

$\left(\frac{p_1}{\gamma} + z_1 + h_A\right) = \frac{p_3}{\gamma} + \left(z_3 + \frac{v_3^2}{2g}\right) \rightarrow \left(\left(\frac{p_1}{\gamma} + z_1 + h_A\right) - \left(z_3 + \frac{v^2}{2g}\right)\right)\gamma = p_3$

Given:	smooth plastic hose			
25	mm	ID		
85	m	length		
95	L/min	Q	0.001583	m^3/s
$2.0*10^{-3}$	Pa*s	η		
sg	1.1			
z_1	2.7	m		
z_2	10	m		
z_3	0	m		

Formulae:

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

$$h_A = \frac{(p_2 - p_{atm})}{\gamma} + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$$

$$p_3 = \left(\left(\frac{p_1}{\gamma} + z_1 + h_A\right) - \left(z_3 + \frac{v^2}{\gamma}\right)\right) * \gamma$$

$$\rho = sg * \rho_{water}$$

$$A = \frac{\pi D^2}{4}$$

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

$$N_R = \frac{\rho v D}{\eta}$$

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

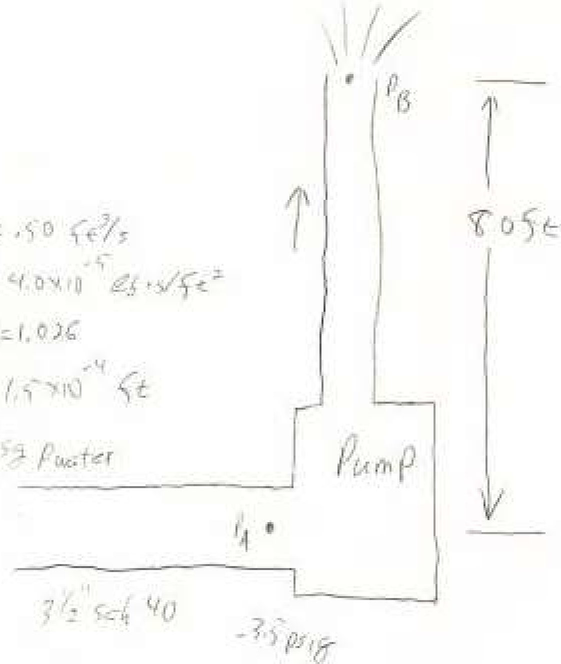
$$P = h_A \gamma Q$$

Data:			
f	0.022	Moody Diagram	
ρ_{water}	1000	kg/m^3	known value
p_{atm}	101	kPa	known value
ϵ	$3.0*10^{-7}$	m	Table 8.2

Solve:			
ρ	1100	kg/m^3	
A	0.000491	m^2	
$v_1=v_2=v$	3.22554	m/s	
N_R	44351.18	>2000, turbulent flow	
D/ϵ	83333.33		
f	0.022	smooth plastic given	
h_L	39.665	m	
γ	10.791	kN/m^3	
h_A	51.10941	m	
P	0.873243	kW	≈873 W
p_1/γ	9.359652		
$v^2/2g$	0.530281		
left side	61.66906		
right side	0.530281		
p_3	659.75	kPa	

8.44

8.44



25.0 psig

80 ft

2½" sch 40

2.875" OD

2.469" ID
0.2058'

0.03326 ft² flow Area

$P_A = P_1$

$P_B = P_2$

$Q = .50\ ft^3/s$

$\eta = 4.0 \times 10^{-5}\ lb \cdot s/ft^2$

$sg = 1.026$

$\epsilon\ 1.5 \times 10^{-4}\ ft$

$\rho = sg\ \rho_{water}$

4.00" OD

3.548" ID
0.2957'

0.06868 flow A ft²

ρ_{water} 1.938 slug/ft³

slug = 32.2 ft/s²

$h_L = f \times \frac{L}{D} \times \frac{v_2^2}{2g}$

$$\frac{p_1}{\gamma} + \overset{0}{z_1} + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{p_1}{\gamma} + 0 + \frac{v_1^2}{2g} + h_A = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$$

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

Given:	Q	0.5	ft^3/s	
	η	$4.0*10^{-5}$	$lb*s/ft^2$	
	sg	1.026		
	3 1/2 in Sch 40			
		4	in	OD
		3.548	in	ID
		0.2957	ft	ID
		0.06868	ft^2	A
	2 1/2 in Sch 40			
		2.875	in	OD
		2.469	in	ID
		0.2058	ft	ID
		0.03326	ft^2	A
	$p_A=p_1$	-3.5	psig	
	$p_B=p_2$	25	psig	
	Δz	80	ft	
Data:	f		Calculated	
	ϵ	$1.5*10^{-4}$	ft	Table 8.2
	ρ_{water}	1.938	$slug/ft^3$	known value
	γ_{water}	62.4	lb/ft^3	

Formulae:

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

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

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

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

$$\gamma = sg * \gamma_{water}$$

$$\rho = sq\rho_{water}$$

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

$$N_R = \frac{v_B \rho_B D_B}{\eta}$$

$$roughness = \frac{D}{\epsilon}$$

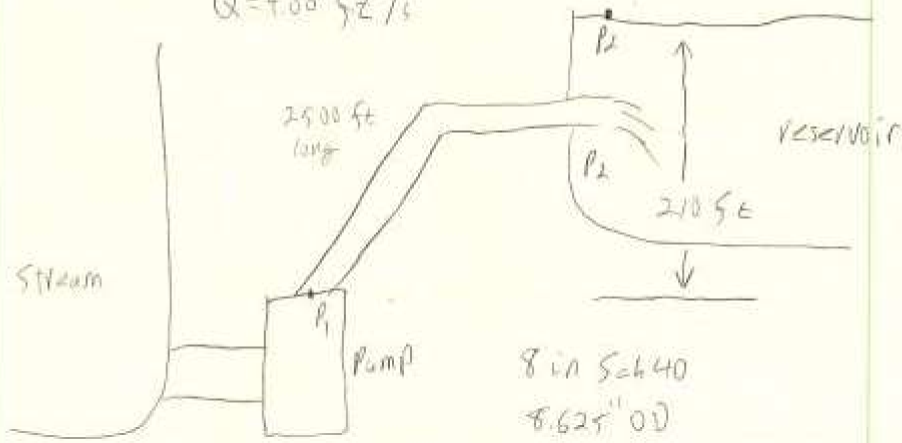
$$P = h_A \gamma Q$$

Solve:	γ	64.0224	lb/ft^3	
	v_1	7.28014	ft/s	
	v_2	15.03307	ft/s	
	ρ	1.988388	$slug/ft^3$	
	N_R	153792.2		
	f	0.016513		
	rough	1372	ft	
	h_L	22.526	ft	
	p_{2-1}/γ	0.445157		
	v_2^2	225.9933		
	v_1^2	53.00044		
	$(v_2^2-v_1^2)$	172.9928	/2g	2.686224
	h_A	105.6574	ft	
	P	3382.22	psi	

8.46

8.46

$Q = 4.00\ ft^3/s$



Water @ 60°F

$\gamma = 62.4\ lb/ft^3$

$\rho = 1.94\ slug/ft^3$

$\eta = 2.35 \times 10^{-5}\ lb \cdot s/ft^2$

$\nu = 1.21 \times 10^{-5}\ ft^2/s$

$v_1 = v_2 = v = \frac{Q}{A}$

8 in Sch 40

8.625" OD

0.322" Thick

7.981" ID

0.6651 ft ID

0.3472 ft² A

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

$$\frac{p_1}{\gamma} + \overset{0}{z_1} + \frac{v_1^2}{2g} + h_A - h_R - h_L = \overset{0}{\frac{p_2}{\gamma}} + z_2 + \frac{v_2^2}{2g}$$

pump pump

$$p_1 = \gamma\left((z_2 - z_1) + h_L\right)$$

Given:	Q	4	ft^3/s				
Data:	Water @60°F				8 in Sch 40 pipe		
	γ	62.4	lb/ft^3		8.625	in	OD
	ρ	1.94	$slug/ft^3$		0.322	in	Thick
	η	$2.35*10^{-5}$	$lb*s/ft^2$		7.981	in	ID
	ν	$1.12*10^{-5}$	ft^2/s		0.6651	ft	ID
					0.3472	ft^2	A
	z_1	0	ft				
	z_2	210	ft				
	2500	ft	L		ϵ	$1.5*10^{-4}$	ft

Formulae:

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

$$p_1 = \gamma((z_2 - z_1) + h_L)$$

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

$$roughness = \frac{D}{\epsilon}$$

$$N_R = \frac{v_B \rho_B D_B}{\eta}$$

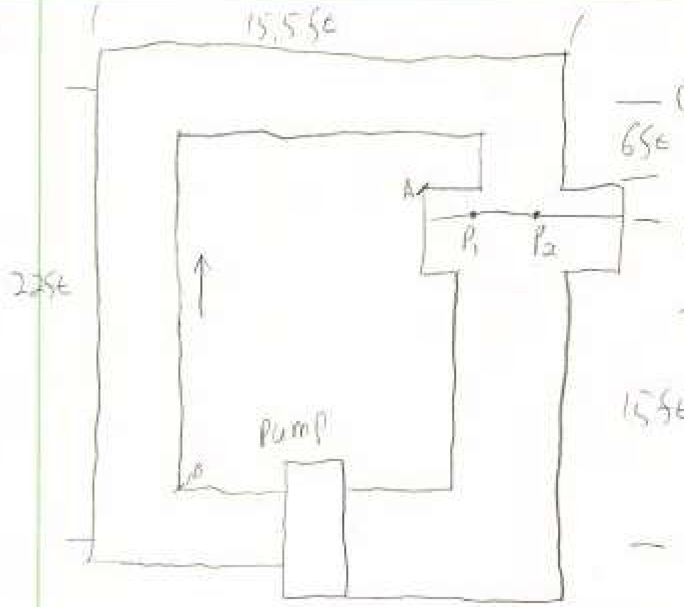
$$f = \frac{0.25}{[\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}}\right)]^2}$$

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

Solve:	v	11.52074	ft/s		
	N_R	632559.1			
	rough	4434			
	f	0.015469			
	h_L	119.8338	ft		
	p_1	20581.63	psf	142.928	psi

8.49

8-47



$Q = 300$ gal/min

gal/min → ft^3/s ÷ 449

$\epsilon = 1.5 \times 10^{-4}$ ft   Table 8.2

$\nu = 2.15 \times 10^{-3}$ ft^3/s App C

$L_3 = 75$ ft $L_4 = 25$ ft

$sg = 0.89$ App C

3 in Sch 40	4 in Sch 40
0.2557 ft ID	0.3355 ft ID
0.05132 ft^2 A	0.08840 ft^2 A

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

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

$$h_A = h_L + z + \frac{v^2}{2g}$$

$$N_R = \frac{vD}{\nu} \quad < 2000 \text{ Laminar flow}$$

$$f = \frac{64}{N_R}$$

$$P = \gamma h_A Q$$

$$\gamma = sg\, \gamma_{water}$$

Given:	Q	300	gal/min	0.668151	ft^3/s
Data:	ϵ	$1.5*10^{-4}$	ft	Table 8.2	
	sg	0.89		App. C	
	v	$2.15*10^{-3}$	ft^3/s	App. C	
		3 in Sch 40			4 in Sch 40
	0.2557	ft	ID	0.3355	ft	ID
	0.05132	ft^2	Area	0.0884	ft^2	Area
	75	ft	Long	25	ft	Long

Formulae:

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

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

$$N_R=\frac{vD}{\nu}$$

$$f=\frac{64}{N_R}$$

$$roughness=\frac{D}{\epsilon}$$

$$\gamma=sg*\gamma_{water}$$

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

$$h_A=h_L+z+\frac{v^2}{2g}$$

$$h_A=h_L$$

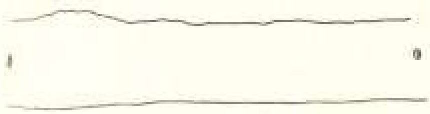
$$P=h_A\gamma Q$$

Solve:	v_1	13.019	ft/s			
	N_{R1}	1548.391				
	v2	7.558	ft/s			
	N_{R2}	1179.442				
	Q	0.668	ft^3/s			
	D/ϵ_1	1704.667				
	D/ϵ_2	2236.667				
		3 in		4 in		
	f	0.041		0.054		
	L/D	293.312		74.516		
	$v^2/2g$	2.632		0.887		
	h_L	31.910		3.587		35.496
	h_A	39.015				
	γ	55.536				
	P	1447.726	W	2.632	hp	

8.62

8-62

12 ft/s



6 in Sch 40

0.5054 ft ID App F

0.2006 ft^2 Area

Heavy Fuel Oil 77°F App C

$sg = 0.906$

$\gamma = 56.53$ lb/ft^3

$\rho = 1.76$ slug/ft^3

$\eta = 2.24 \times 10^{-3}$ lb-s/ft^2

$\nu = 1.27 \times 10^{-3}$ ft^2/s

$$N_R = \frac{v D \rho}{\eta}$$

Steel → $\epsilon = 1.5 \times 10^{-4}$ Table 8.2

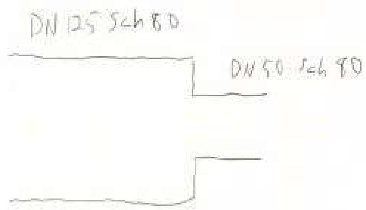
Volumetric Flow	
Q	2.4072
V	12
A	0.2006

Re	
p	1.76
v	12
D	0.5054
n	0.00224
Re	4765.2

fT	D/E	inside LOG
0.038776	3369.333	0.002889778

10.20

10-20



500 L/min

DN 125 Sch 80
0.1223 m ID
1.173×10^{-2} m^2 Area

DN 50 Sch 80
0.049 m ID
1.905×10^{-3} m^2 Area

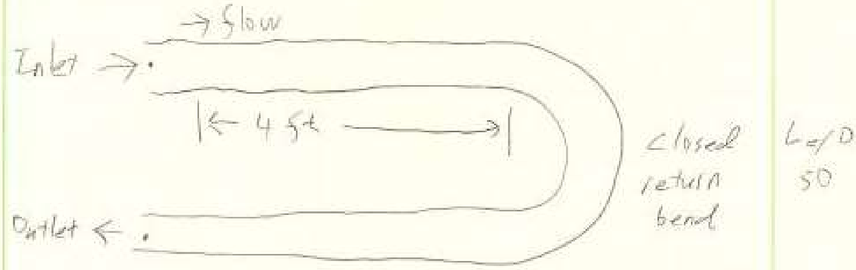
L/min → m^3/s ÷ 60000

K = 0.39 Figure 10.8

Given:	DN 125 Sch 80			DN 50 Sch 80			App F
Data:	0.1223	m	ID	0.049	m	ID	
	$1.173*10^{-2}$	m^2	Area	$1.905*10^{-3}$	m^2	Area	
	500	L/min		K	0.39	Fig 10.8	
Formulae:	$v = \frac{Q}{A}$						
	$diameter\ ratio_{reduction} = \frac{D_1}{D_2}$						
	$h_L = K(\frac{v_2^2}{2g})$						
Solve:	Q	500	L/min	0.008333	m^3/s		
	v_2	4.374453	m/s				
	dr	2.495918					
	$v_2^2/2g$	0.975323					
	h_L	0.380376	m				

10.37

10-37



1/2 sch 40 App F.1 Steel ϵ 1.5×10^{-4} ft Table 8.2

0.0518 ft ID f_T 0.026

0.00211 ft² Area

Ethylene Glycol @ 77°F App B.2

sg 1.100

γ 68.47 lb/ft³

ρ 2.13 slug/ft³

η 3.38×10^{-4} lb-s/ft²

ν 1.59×10^{-4} ft²/s

12.5 gal/min → ft³/s ÷ 449

$K = f_T (L_e/D)$

$D/\epsilon = \frac{.0518}{1.5\times10^{-4}}$

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

37 Flow rate - 12.5 gal/min $\frac{1}{2}$ in 40 steel pipe

ethylene glycol at 77°F

$z_1 = z_2 \quad v_1 = v_2$

$P_1 - P_2 = \gamma\,(h_L + h_f)$

$\frac{1}{2}$ in 40 steel pipe

$D = .0518\,ft \quad A = .00211\,ft^2 \quad Q = 12.5\,gal/min \quad \frac{12 \times .1337}{60} = .0278\,ft^3/s$

$V = \frac{.0278}{.00211} = 13.175\,ft/s$

$\frac{L_e}{D} = 50 \qquad \epsilon = 1.5 \times 10^{-4}\,ft \qquad D/\epsilon = 345.33$

$K = f(L_e/D) = .028 \times 50 = 1.3$

$h_L = \frac{KV^2}{2g} = 3.5\,ft$

$N_R = \frac{vD}{\nu} = 4292.2$

$h_f = \frac{fLv^2}{2gD} = \frac{.0415 \times 8 \times 13.175^2}{.0518 \times 2 \times 32.2} = 17.275\,ft$

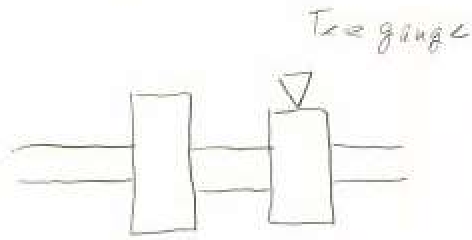
$P_1 - P_2 = \gamma(h_L + h_f)$

$= 68.47(3.5 + 17.25)$

$= 1422.67/144 = 9.87\,psi$

10.39

10-39



3 in Sch 40 $\quad Q = 0.40\ ft^3/s$

0.2557 ft ID

0.05132 ft^2 A

Water @ 50°F

γ 62.4 lb/ft^3

ρ 1.94 $slug/ft^3$

η 2.72×10^{-5} $lb\text{-}s/ft^2$

ν 1.40×10^{-5} ft^2/s

L_e/D 20 $\quad$ Table 10.4

f_T 0.017 $\quad$ Table 10.5

$k = f_T (L_e/D)$

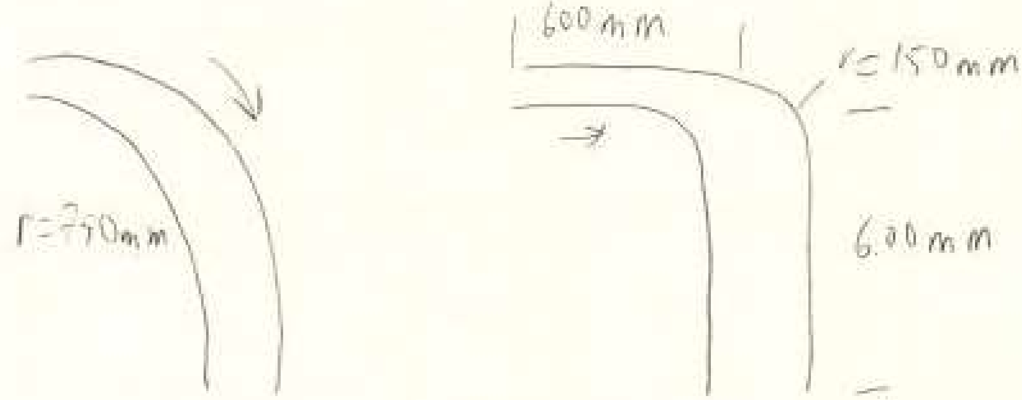
$h_L = k \left(\frac{v^2}{2g}\right)$

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

Given:	3 in Sch 40			App F		Formulae:	$v = \frac{Q}{A}$		
Data:	0.2557	ft	ID						
	0.05132	ft^2	Area						
	Water @ 50°F			App A			$K = f_r(L_e/D)$		
	γ	62.4	lb/ft^3						
	ρ	1.94	$slug/ft^3$						
	η	$2.72*10^{-5}$	$lb\text{-}s/ft^2$				$h_L = K(\frac{v^2}{2g})$		
	ν	$1.40*10^{-5}$	ft^2/s						
	Q	0.4	ft^3/s			Solve:	v	7.794232	ft/s
	L_e/D	20		Table 10.4			$v^2/2g$	0.943324	
	f_r	0.017		Table 10.5			K	0.34	
							h_L	0.32073	ft

10.43

10-43



50mm OD x 2mm wall copper tube ϵ 1.5×10^{-6} m

0.046m ID   Table G2

1.662×10^{-3} m^2 A

750L/min

Propyl Alcohol @ 25°C   App B

sg 0.802

γ 7.87 kN/m^3

ρ 802 kg/m^3

η 1.92×10^{-3} Pa·s

ν 2.39×10^{-6} m^2/s

$r = R_i + D_o/2$

$r = .75 + .025 = 100mm = .1m/.046 = 2.17$

Given:	Q	750	L/min	
Data:	Propyl Alcohol @ 25°C			App B
	sg	0.802		
	γ	7.87	kN/m^3	
	ρ	802	kg/m^3	
	η	$1.92*10^{-3}$	Pa*s	
	v	$2.39*10^{-6}$	m2/s	
	50 mm OD x 2mm Wall Copper			Table G2
	0.046	m	ID	
	$1.662*10^{-}$	m^2	A	
	copper	ϵ	$1.5*10^{-6}$	m

Formulae:

$$r = R_i + (\frac{D_o}{2})$$

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

$$K = f_T({}^{L_e}/_{D})$$

$$h_L = K(\frac{v^2}{2g})$$

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

$$N_R = \frac{vD}{v}$$

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

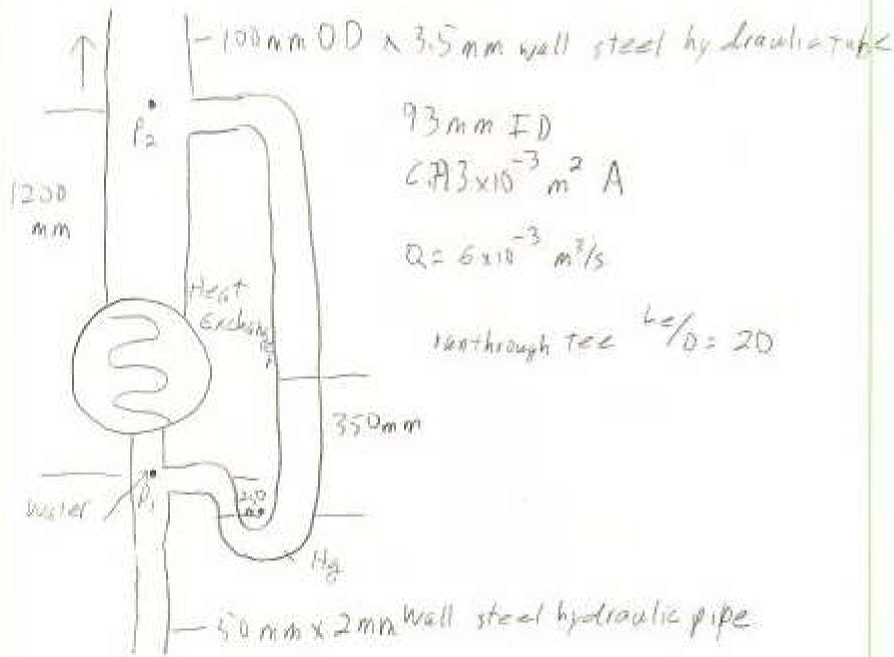
Solve:

Curve b				
r	0.775			
r/D	16.8478			
L_e/D	42	Fig 10.28		
Q	750	L/min	0.0125	m^3/s
v	7.52106	m/s		
$v^2/2g$	2.8831			
D/ϵ	30666.7			
f_T	0.0095	Moody Diagram		
K	0.399			
h_L	1.15035	m		

Curve c					
r	0.175				
r/D	3.80435				
L_e/D	14	Fig 10.28			
Q	750	L/min	0.0125	m^3/s	
v	7.52106	m/s			
$v^2/2g$	2.8831				
D/ϵ	30666.7				
f_T	0.0095	Moody Diagram			
K	0.133				
h_L	0.38345	m	curve		
L/D	13.0435				
N_R	144757	>4000	turbulent		
part 1	8.8E-06				
part 2	0.00013				
total	0.00014				
f	0.0168				
h_L	0.6319	m	*2	1.2638	straight x2
h_{Ltotal}	1.64725	m			

10.46

10.46



93 mm ID

$6.793 \times 10^{-3}\ m^2$ A

$Q = 6 \times 10^{-3}\ m^3/s$

Runthrough tee $L_e/D = 20$

46.0 mm ID   Table G2

$1.662 \times 10^{-3}\ m^2$ A

Water @ 50°C

$\gamma = 9.69\ kN/m^3$

$\rho = 988\ kg/m^3$

$\eta = 5.41 \times 10^{-4}\ Pa \cdot s$

$\nu = 5.48 \times 10^{-7}\ m^2/s$

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

$$p_1 + \gamma_w(0.25) + \gamma_{Hg}(0.35) - \gamma_w(1.10) = p_2 \rightarrow \frac{p_1 - p_2}{\gamma_w} = \frac{\gamma_{Hg}(0.35)}{\gamma_w} + \frac{\gamma_w(0.85)}{\gamma_w}$$

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

Given:	Q	$6*10^{-3}$	m^3/s				
Data:							
	100 mm OD x 3.5 mm Steel			50 mm OD x 2mm Steel			App G
	0.093	m	ID	0.046	m	ID	
	$6.793*10^{-3}$	m^2	A	$1.662*10^{-3}$	m^2	A	
	water @ 50°C			App A			
	γ	9.69	kN/m^3				
	ρ	988	kg/m^3				
	η	$5.41*10^{-4}$	Pa*s				
	ν	$5.48*10^{-7}$	m2/s				
	γ_{Hg}	132.8	kN/m^3				

Formulae:

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

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

$$\frac{p_1-p_2}{\gamma}=\frac{\gamma_{Hg}(0.35)}{\gamma_w}+\frac{\gamma_w(0.85)}{\gamma_w}$$

$$h_L=K(\frac{v^2}{2g})$$

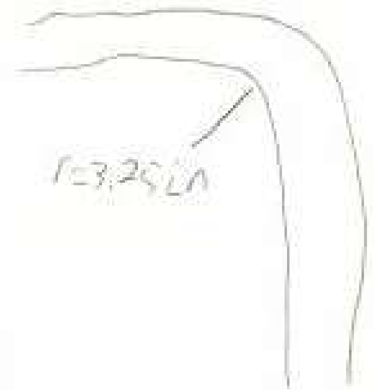
$$K=\frac{h_L}{(\frac{v^2}{2g})}$$

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

Solve:	v_1	3.610108	m/s	
	v_2	0.883262	m/s	
	v_1^2-v_2^2	12.25273	/2g	0.624502
	Δz	-1.2	m	
	pressure difference parts			
	part 1	4.796698		
	part 2	0.85		
	$(p_1$-$p_2)/\gamma$	5.646698		
	h_L	5.0712	ft	
	K	7.634301		

10.48.

10-48



steel fluid power

$1\frac{1}{2}$ in OD × 0.083 in wall

1.334 in ID

0.112 ft ID

9.706×10^{-3} ft^2 A

L_e/D 30

$Q = 27.5$ gal/min

÷ 449

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

$r = R_i + D_o/2$

r/D

figure 10.28

k

Moody Diagram

f_T

$h_L = k\frac{v^2}{2g}$

Volumetric Flow	
Q	0.061247216
V	9.556438764
A	0.0064

Re	
p	1.76
v	9.556438764
D	0.09033
n	0.00224
Re	678.2545892

V^2	2g	fL	fT	D/E	inside LOG
91.32552	64.4		0.079126	602.2	0.016691512

90 Pipe Bends	
r	0.270833
Ri	
D0/2	
Di	0.09033
r/D	2.998266
A	0.006409
Le/D	12.5
k	0.989074
hL	1.402604

Flow Rate Converter	
Gal/M	27.5
Ft^3/s	0.061247