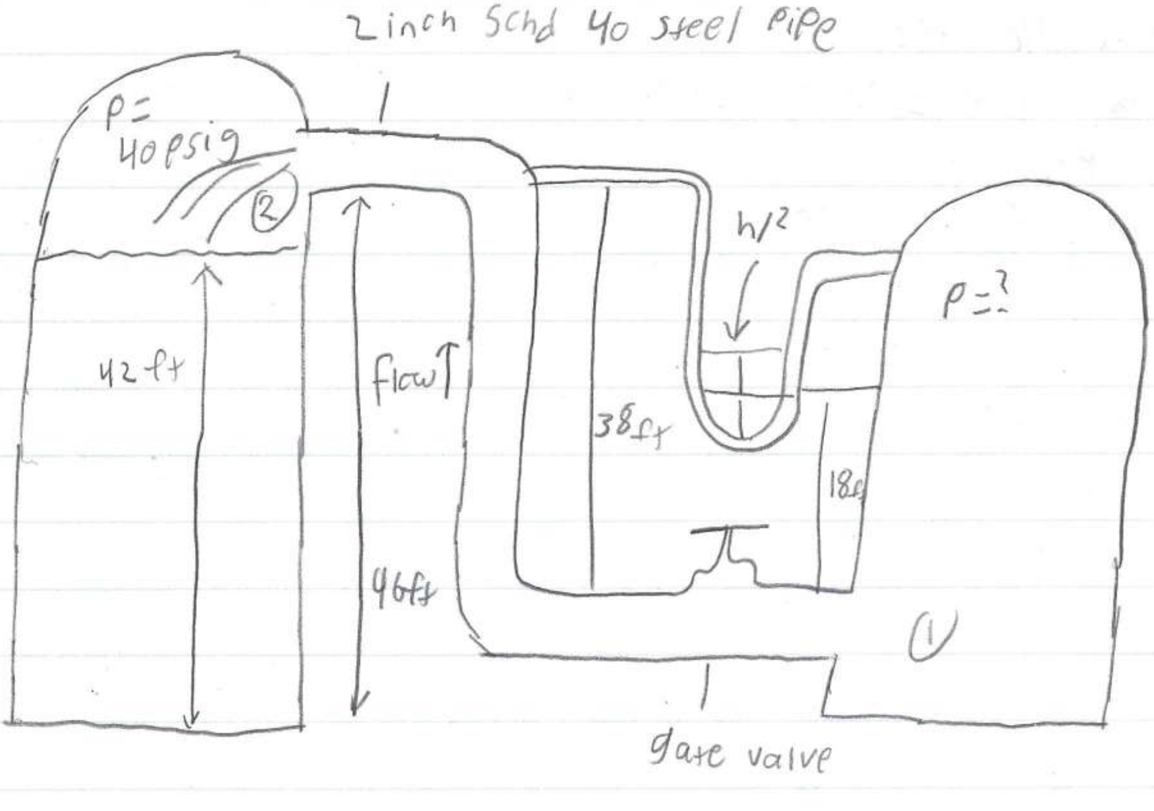
Ben Smithson Fluid mechanics test 2

Part A

Purpose: Determine the force magnitude through the pipe system, then calculate the horizontal and vertical forces for the system to be supported. Also, check the pressure drop out of the nozzle and factor in the effect of a water hammer.

Diagram:



Sources: Applied Fluid Mechanics Eighth edition
Mott, Untener.

Design considerations:

1) incompressible fluids
2) static fluid
3) system is horizontal and vertical
4) minor losses

Data & variables
Schedule 40 pipe
blind flange = 2inch diameter
150 gpm
water temp is 71°F

Materials:
water
ethyl alcohol
steel pipe.

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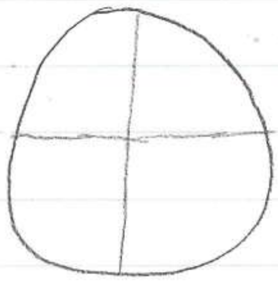
procedure: First, I will draw the diagram. Then, find the points on the diagram in order to see pressure. Next, using static flow of liquids I will find the force magnitude at the blind flange. After that, I will continue to use static flow of liquids to determine the horizontal & vertical forces required to support the system. In the last steps I will use the general energy equation to calculate pressure drop out of the nozzle. Finally, using equation 11-9 I can find the effect of the water hammer on the system to see if there will be damage.

calculations:

Part A

#1



blind flange   d = 0.166 ft

$$A = \frac{\pi D^2}{4} = \frac{\pi (0.166)^2}{4} = 0.0216\ ft^2$$

$F = A \cdot \rho \cdot P$

F= pressure @ 150 gpm

~~P~~ already carculated

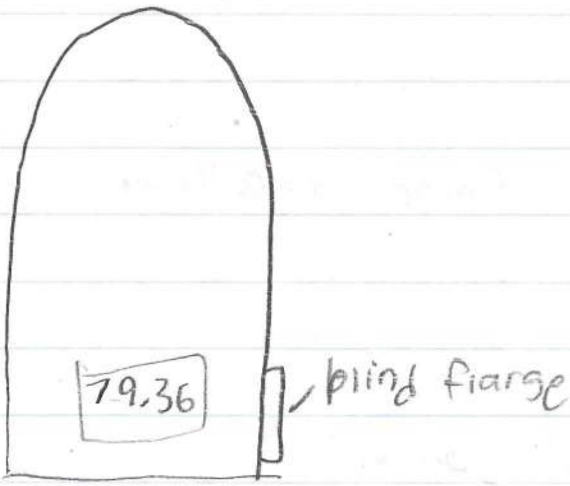
$= 77$ psi

$\Delta P = \gamma \cdot h$

$\Delta P = P_{outlet} + sg_{ethyl} \cdot \gamma_{water}$

$P_e = 40$ psi $+ 0.787 \cdot 9.81 = 47.72$

$F = 77 \cdot 47.72 \cdot 0.0216\ ft^2 = \boxed{79.36}$



Fluids test 2 Ben Smithson

Part A

2. Pressure in Second tank

$$P_1 = P_2 + \gamma\left(z_1 - z_2 + \frac{V_2^2}{2g}\right) + h_L$$

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

$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.172)^2 = 0.0232\ ft^2$

$Q = 150\ gpm = 0.4013\ ft^3/s$

$V = \frac{0.4013}{0.0232} = 17.29\ ft/s$

$Re = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$

$Re = \frac{17.29\ ft/s \cdot 0.172\ ft}{1.37 \cdot 10^{-5}} = 2.1707 \cdot 10^5$

$\frac{D}{e} = \frac{0.172}{1.5 \cdot 10^{-4}} = 1.146e^{-5} = 1146$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{1146} + \left(\frac{5.74}{(2.17 \cdot 10^5)^{0.9}}\right)\right)\right]^2} = 0.0267$$

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

$= 0.0267 \cdot \frac{110}{0.172ft} \cdot \frac{17.29^2}{2 \cdot 32.2} = 79.26$

$h_{elbow} = K \frac{V3}{2g}$ $K = 20\ ft$

$= 20(0.0267) \frac{17.29^2}{2 \cdot 32.2} = 2.47 \cdot 2 = 4.95$

h_L gate v $= K \frac{V2}{2g}$

$= 8(0.0267) \frac{17.29^2}{2 \cdot 32.2} = 0.99\ ft$

h_L total $= 85.21 ft$

$P_1 = P_2 + y(z_1 - z_2 + \frac{V_2^2}{2g}) + h_L$

$P_1 = 5760\ lb/ft^2 + 49.01((38-18) + \frac{(17.29^2)}{2 \cdot 32.2} + 85.21\ ft)$

$P_1 = 11143.84\ lb/ft^2 = 77.38\ psi$

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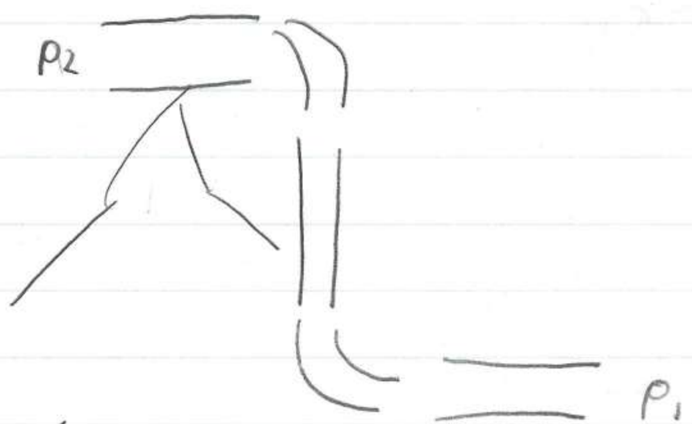
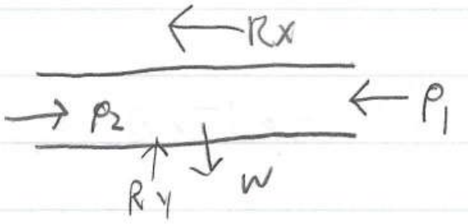
Part A

2 cont.





$$Rx = \frac{P_1 - P_2}{A} = \frac{77 - 40}{0.023212} = \boxed{132.9}$$

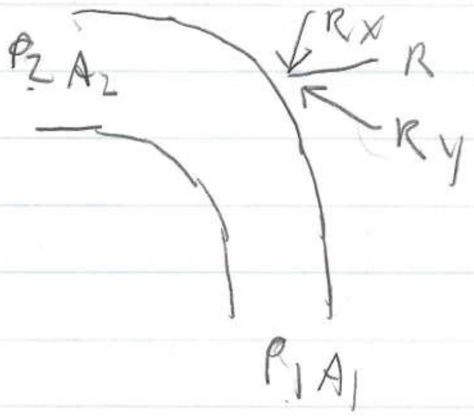
$Ry = W$

specific weight, book (1-6)

$\gamma = w / V$

$w = \gamma \cdot V$

$w = 49.01 \cdot 17.29 = \boxed{847.38} = Ry$



$R_X = P_1 A_1 + \rho Q V_1$

$R_x = 11143.84 \cdot 0.0232 + 1.53 \cdot 0.4013 \cdot 17.29$

$R_X = \boxed{269.15}$

$R_y = \rho Q V_2 + W + P_2 A_2$

$11143.84 \cdot 0.4013 \cdot 17.29 + 5760 \cdot 0.0233 + 847.38$

$R_Y = \boxed{1457.32}$

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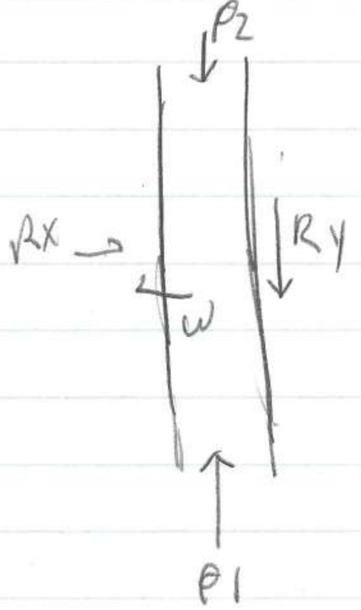
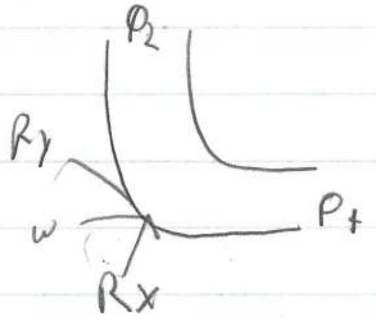
2. cont.



$R_x = W$

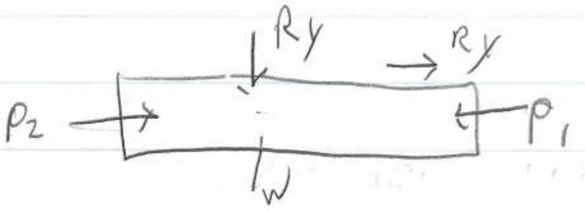
$= \boxed{847.38}$

$R_y = \frac{P_1 - P_2}{A} = \frac{77 - 40}{0.0232 \cdot 12} = \boxed{132.9}$



$R_x = P_1 A_1 + \rho V Q = \boxed{269.15}$

$R_y = \rho Q V_2 + W + P_2 A_2 = \boxed{1457.32}$



$Rx = \frac{P_1 - P_2}{A} = \boxed{132.9}$

$Ry = w = \boxed{847.39}$

$Rx\ total = \boxed{1651.48}$

$Ry\ total = \boxed{4742.3}$

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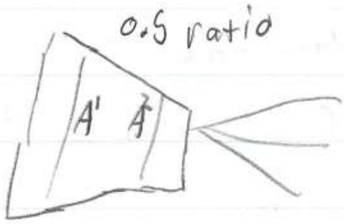
3. given $\beta = 0.5$

flow nozzle from notes

$C = 0.9975 - 6.53 \sqrt{B / N_R}$



$R_e = \frac{\rho V D}{\mu} = \frac{V D}{\nu}$

$V = \frac{Q}{A} = Q = 150 gpm = 0.401 \; ft^3/s$

$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (0.172)^2 = 0.0232 \; ft^2$

$V = \frac{0.401}{0.0232} = 17.28 \; ft/s$

$Re = \frac{17.28 \cdot 0.172}{1.37 \cdot 10^{-5}} = 216945.98$ - Appendix

$C = 0.9975 - 6.53 \sqrt{0.5 / 216945.98}$

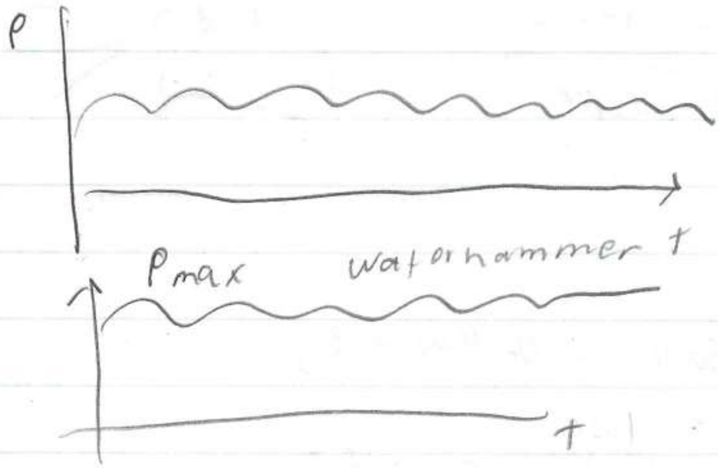
$C = 0.9875$

$V_1 = C \sqrt{\frac{2g(p_1 - p_2)/\gamma}{(A_1/A_2)^2 - 1}}$

$17.28 = 0.9875 \sqrt{\frac{(2 \cdot 32.2)(p_1 - p_2) / 49.01}{(0.172 / (0.172/2))^2 - 1}}$

$p_1 - p_2 = 699.09 \; lb/ft^2 = \boxed{4.85 \; psi}$

4. water hammer



$$C = \frac{\sqrt{E_0/\rho}}{\sqrt{1 + \frac{E_0 D}{E g}}}$$

2 inch Schedule 40 pipe
thickness = 0.154 inch = 0.1283
Appendix F

Pg 11 in book

$$C = \frac{\sqrt{130{,}000\ psi / 1.93\ slug/ft^3}}{\sqrt{1 + \frac{130000 psi \cdot 0.172}{200 gpa \cdot 0.154 in}}}$$ > ethyl alcohol

$$C = \frac{\sqrt{18720000 / 1.53}}{\sqrt{1 + \frac{1872000 \cdot 0.172}{4.177086894.6 \cdot 0.1283}}}$$ = ... lb/ft³

$\Delta p = \rho c v = (1.53)(3397.33)(17.28) = 89\,819.97\ lb/ft^3$

$p_{max} = p_{op} + \Delta p = 77.38\ psi + 89{,}819.97\ lb/ft^3$

$= 11143.84 + 89{,}819.97\ lb/ft^3 = 100{,}963.53\ lb/ft^3 = \boxed{701.1\ psi}$

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4 cont.

Pg 282

basic wall thickness calculation

$$t = \frac{PD}{2(SE + PY)}$$

P design press = 701.1 psi

D pipe outside diameter = 2.375 in (Appendix pg 494)

S allowable stress intension = 1371 psi (engineering toolbox)

E longitudinal joint quality factor = 0.85 (pg 282 welded)

Y correction factor (temp & type) = 0.4 (pg 282)

$$t = \frac{701.1(2.375)}{2((1371 \cdot 0.85) + (701.1 \cdot 0.4))} = \boxed{0.63 \text{ in}}$$

pipe will fail because 0.63 in > 0.154 in (pipe thickness)

cavitation

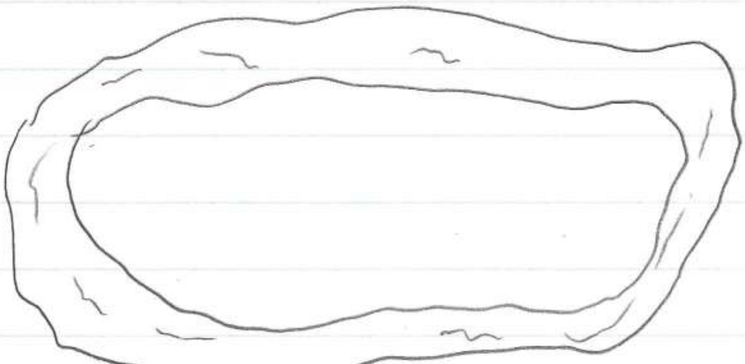
$$\frac{P_S}{\gamma} = \frac{P_0}{\gamma} - \Delta z - \frac{V_S^2}{\gamma} - h_L - S$$

Ben Smithson Fluid mechanics Test 2

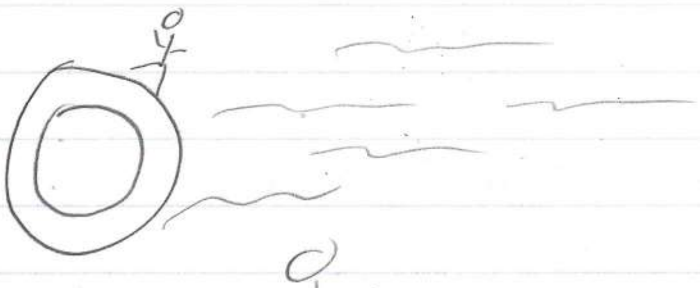
part B:

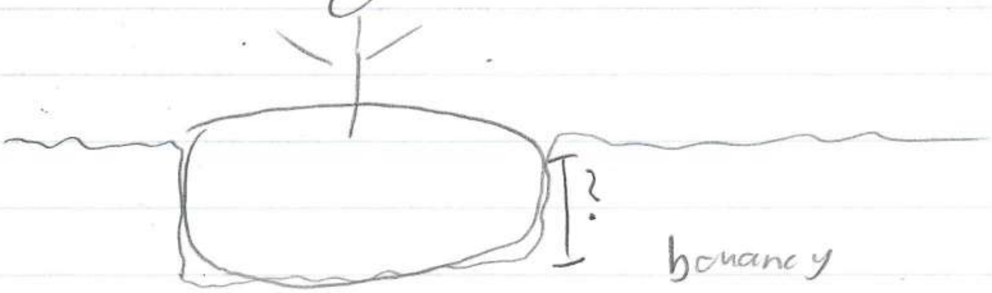
Purpose: The purpose of this question is to design a lazy river that can show the flow rate, be stable, and have a reasonable drag force on individuals riding it.

Diagrams:



drag





bouancy

Source: Mott & Utener. Applied Fluid Mechanics
8th edition

Design considerations:
220 lb. person is floating
4 year old = 0.1% slope
water is flowing

Data & variables
220 lb (bouancy
0.1% slope
flow rate
static forces

Material
- water running out a nozzle to push
individals
- pool float

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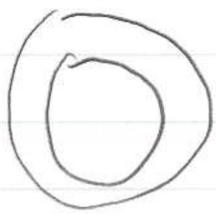
procedure: First, using $Q = VA$ I will find the required flow rate to push a 4 year old. Next, I will use drag force equation to see what drag the kid will feel while going around the lazy river. Finally using bouancy I can see if the river will be stable with a 220 lb person riding.

Calculations:

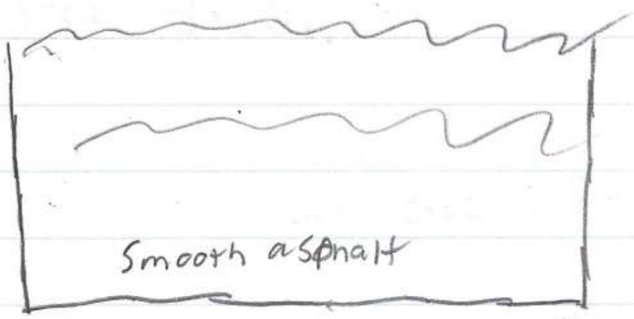
5.



← waterpark tube width = 42 inches

$2 \cdot 42 = 84$ inches → 96 inches to be safe or 8 ft wide

depth about 3.5 ft deep



3.5 ft = y

8 ft = b

$A = by = 8 \cdot 3.5 = \underline{28\ ft^2}$

$R = \frac{by}{b+2y} = 1.866\ ft$

$WP = b + 2y = \underline{15\ ft}$

5. cont.

Slope = 0.1%

Smooth asphalt $n = 0.013$ Table 14.1

$$Q = \left(\frac{1.00}{n}\right) A R^{2/3} S^{1/2}$$

$$Q = \left(\frac{1.00}{0.013}\right)(28)(1.86)^{2/3}\ 0.001^{1/2}$$

$$\boxed{Q = 103.012\ ft^3/s}$$

6.

$$A = \frac{\pi D^2}{4} = \frac{\pi \cdot 1^2}{4} = 0.785$$

Water @ 70° F

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

$\nu = 1.05 \cdot 10^{-5}\ ft^2/s$ (A.2)

$$V = \frac{Q}{A} = \frac{103.12}{28} = 3.679\ ft/s$$

$$N_R = \frac{3.679 \cdot 1}{1.05 \cdot 10^{-5}} = 350382.69 = 3.50 \cdot 10^5$$

CD = 0.8 based off graph (page 433)

$$F_D = C_D\left(\frac{\rho V^2}{2}\right) A = 0.8\left(\frac{1.94 \cdot 3.679^2}{2}\right) 0.785$$

$$\boxed{F_D = 8.24}$$

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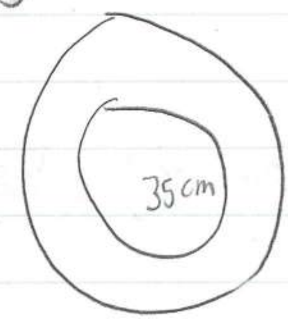
Part B

7.



W = 224.09 lbs with guy and tube

2 kg weight = 4.409 lbs

3.14 ft
1.14 ft } diameters

Volume hollow cylinder

$V = \pi (R^2 - r^2) h$

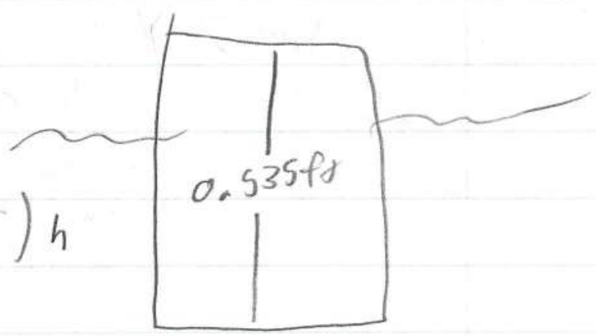
$W = \gamma_B V$

$224.09 = 62.3 (V)$

$V = 3.596$

$3.596 = \pi (1.57^2 - 0.57^2) h$

$h = 0.635$ ft



Stability

$MB = I / V_d$

$I = \frac{\pi (D^4)}{64} \rightarrow$ hollow $\frac{\pi (D^4 - D^4)}{64} = \frac{\pi (3.14^4 - 1.14^4)}{64}$

$I = 4.688$

$MB = \frac{4.688}{3.596} = 1.303$ ft

#7 cont.

$$y_{mc} = y_{cb} + MB$$

y_{cb} = half of draft (fig 5.13 pg 105) = 1/2 (0.535)

$$y_{cb} = 0.2675$$

$$y_{mc} = 0.2675 + 1.303 \text{ ft} = \boxed{1.57 \text{ ft}}$$

$$y_{cg} = 1/2(0.535) = 0.2675$$

$$y_{mc} > y_{cg}$$

∴ The tube & person are stable because the metacenter is above the center of gravity.

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Summary

Part A

The pipe system with the blind flange can occur with the location on the end. with the system for the civil engineers, they will have to hold up a decent amount of weight. Also, the pressure drop in the nozzle is significant & the water hammer could damage the system.

Part B.

The tube for the water park should be able to handle two rafts at a small flow rate with the drag force not being too significant. Also, the 220 lb man would have a stable raft in the lazy river.

Analysis:

Part A. overall the system would most likely fail under a water hammer & with the weight of the system it may be unfeasable to spend money on.

Part B.

the lazy river is able to have a flow of just over 100 ft/s [illegible]. the drag force on a leg is 8.24 the 220 lb man is stable as well so overall the system is a sucess.