Name: David Vermaak **UIN:** 01069782

Sources:

Mott, R., and Untener, J. Applied Fluid Mechanics. 7th Ed. 2015

Materials:

* Ethyl Alcohol
* Mercury
* Air

Purpose:

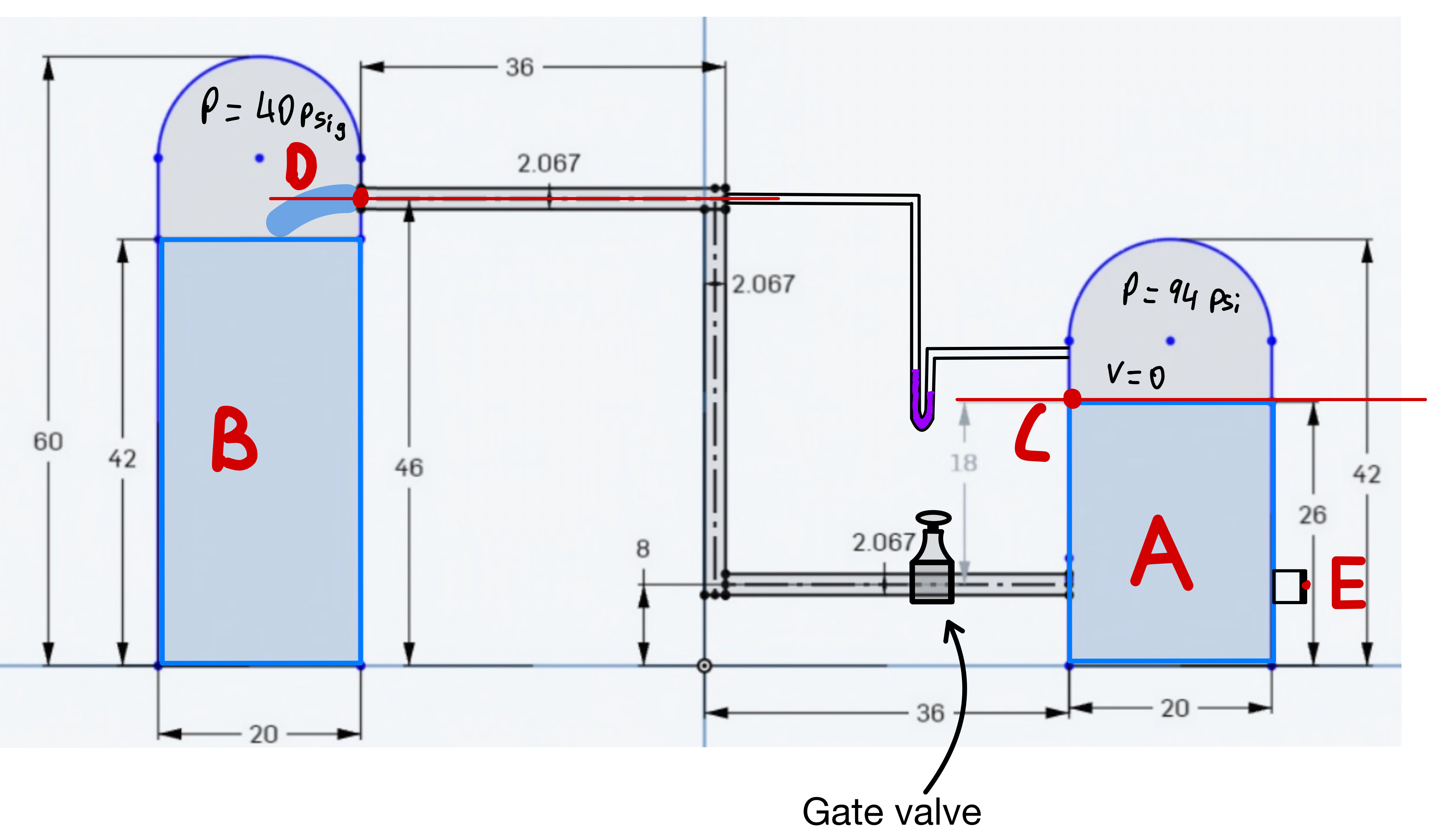
The purpose of this task is to analyze various aspects of a pipeline system carrying ethyl alcohol at a flow rate of 150 gpm. Specifically, it involves determining the force magnitude and location on a blind flange at the pipeline inlet, calculating the total horizontal and vertical forces in the pipe-elbows-valve system for support design, evaluating the pressure drop across a proposed flow nozzle with a diameter ratio of 0.5, and assessing the potential for water hammer and cavitation in the event of sudden valve closure. The analysis requires calculating the pressure at the pipeline inlet and outlet, using appropriate equations to determine forces, pressure drops, and pressure increments, and verifying the design against potential failures due to water hammer or cavitation.

Design Considerations:

* Incompressible fluid
* Isothermal process
* Newtonian Fluid
* T = 77 °F
* Ethyl alcohol and Mercury do not mix
* Standard elbows

Drawings:

Figure 1:



Procedure:
Given that the pressure of the air in Tank A is 64.25 psi and the height of the water to the center of the blind flange is 18 ft, with a 2 in. diameter, we can use the gamma_h equation to calculate the pressure at the center of the circle. Then the force can be calculated using F = P*A.

Data and Variables:

PB (psi)	40
PB (lb/ft^2)	5760
Q (gal/min)	150
Q (ft^3/s)	0.334
D	0.1723
A	0.0233
h	20
γe	49.01
γm	844.9
ε	0.00015
Re	180083
Rr	1148
VB	14.3230
Velocity head	3.1855
f	0.0208
fT	0.019
hL	48.05
PA (lb/ft^2)	9251
PA (psi)	64.25
ΔP (in Hg)	12.64

Part 1:

$$P_A = \gamma_e \cdot h$$

$$P_A = 49.01\ lb/ft^3 \cdot 18\ ft$$

$$P_A = 882.18\ lb/ft^2$$

$$P_A = 882.18\ lb/ft^2 \cdot \left(\frac{1\ ft}{12\ in}\right)^2$$

$$P_A = 6.126\ psi$$

$$P_E = 64.25\ psi + 6.126\ psi$$

$$P_E = 70.38\ psi$$

$$A_E = \pi r^2$$

$$A_E = \pi \cdot 1^2 = 3.1416\ in^2$$

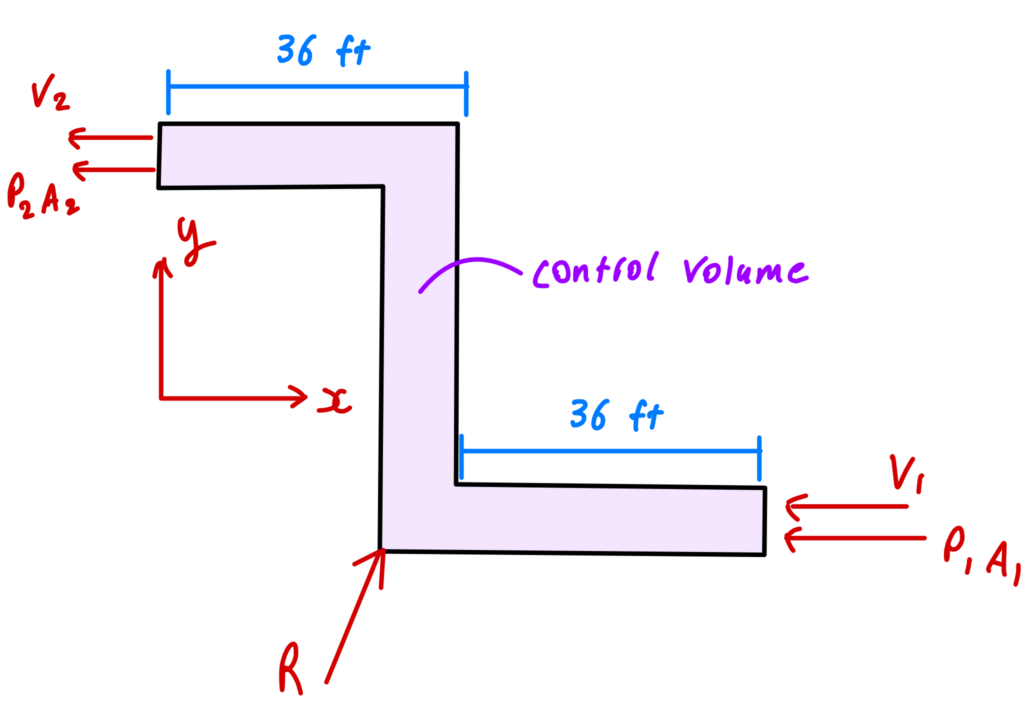
$$F = P_E \cdot A_E$$

$$F = 70.38\ lb/in^2 \cdot 3.1416\ in^2$$

$$\boxed{F = 221\ lbf}$$ in the center of the circle

Part 2:

Taking the entire system as a control volume, calculate the resultant forces.



$$\Sigma F_x = \rho Q (V_{x_2} - V_{x_1})$$

$$-P_1 A_1 + R_{1x} + P_2 A_2 = \rho Q (V_{x_2} - V_{x_1})$$

$$R_x = A(P_1 - P_2) + \rho Q \cancel{(V_{x_2} - V_{x_1})}$$ zero

$$R_x = 0.0233\,ft^2\,(9250 - 5760)$$

$$\boxed{R_x = 81.317\ lbf}$$

$$\Sigma F_y = \rho Q (\cancel{V_{y_2}} - \cancel{V_{y_1}})$$ zero

$$R_y - W = 0$$

$$W = m \cdot g = \rho \cdot V \cdot g$$

$$V = \pi r^2 \cdot L$$

$$V = \pi \cdot (0.08615\ ft)^2 \cdot 110\ ft$$

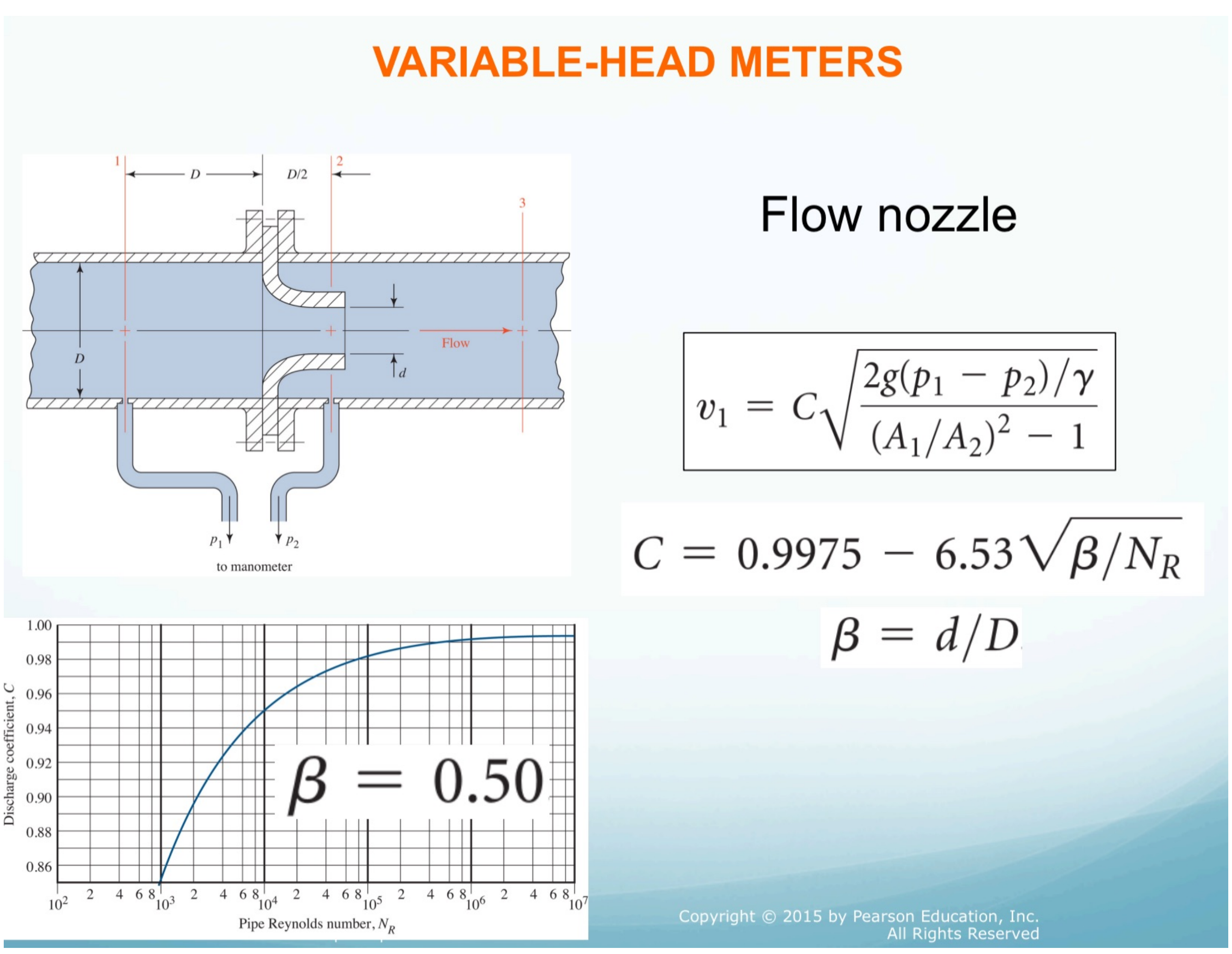
$$V = 2.564\ ft^3$$

$$W = 49.01\ lb/ft^3 \cdot 2.564\ ft^3$$

$$W = 125.7\ lb$$

$$\boxed{R_y = 125.7\ lbf}$$

Part 3:



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

$$V_1^2 = C^2\left(\frac{2g\cdot(\Delta P)/\gamma}{(A_1/A_2)^2 - 1}\right)$$

$$\Delta P = \frac{V^2 \cdot \gamma \cdot \left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}{2g \cdot C^2}$$

$$C = 0.9975 - 6.53 \cdot \sqrt{\beta / Re}$$

$$\beta = d/D = 0.5$$

$$\gamma = 49.01\ lb/ft^3$$

$$d = 0.0861\ ft$$

$$A_1 = 0.0233\ ft^2$$

$$A_2 = 0.00583\ ft^2$$

Q (gal/min)	150
Q (ft^3/s)	0.33420
D (ft)	0.17225
d (ft)	0.08613
A1 (ft^2)	0.02330
A2 (ft^2)	0.00583
h (ft)	20
γe (lb/ft^3)	49.01
ε (ft)	0.00015
Re	1.80E+05
[redacted]	[redacted]
VB (ft/s)	14.3417
C	0.987
ΔP (lb/ft^2)	2412.053
ΔP (psi)	16.7504

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

$$V = Q/A$$

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

$$\Delta P = \frac{V^2 \cdot \gamma \cdot \left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}{2g \cdot C^2}$$

$$\boxed{\Delta P = 16.75 \text{ psi}}$$

Part 4.

Eo	18720000	lb/ft^2	**Eo**	8.96E+08	N/m^2
p	1.530	slug/ft^3	**p**	788.52959	kg/m^3
D	0.1723	ft	**D**	0.0525018	m
E	4.18E+09	lb/ft^2	**E**	2E+11	N/m^2
t	0.0128	ft	**t**	0.0039116	m
C	3397.22	ft/s	C	1035.47	m/s
			C	3397.38	ft/s

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

$$C = 3397 \text{ ft/s}$$

Basic Wall Thickness Calculation:

$$t = \frac{pD}{2(SE + pY)} \tag{11–9}$$

where

t = Basic wall thickness (in or mm)
p = Design pressure [psig or Pa(gage)]
D = Pipe outside diameter (in or mm)
S = Allowable stress in tension (psi or MPa)
E = Longitudinal joint quality factor
Y = Correction factor based on material type and temperature

Given $P_{op} = 64.25$ psi

$$P_{max} = P_{op} + \Delta P$$

$$\Delta P = \rho \cdot C \cdot V$$

$$\Delta P = 1.52 \cdot 3397 \cdot 14.34 = 514 \text{ psi}$$

$$P_{max} = 64.25 + 514 = 579.25 \text{ psi}$$

Assuming:

$S = 20000$

$Y = 0.40$

$E = 1.00$

ΔP	514.9801133	
Pmax	579.225	psi
t	0.1540	in
D out	2.375	in
S	20000	psi
E	1	
Y	0.4	
tmax	0.0340	in

$t = \frac{P \cdot D}{2(SE + PY)}$

$t_{actual} = 0.154 \text{ in}$

$t_{calc} = 0.034 \text{ in}$

Therefore the pipe would not fail

The vapor pressure of ethyl Alc. is 0.863 psi In the systems current state there is no chance of cavitation happening.

Summary:

The analysis determined the force on the blind flange (221 lbf), resultant horizontal and vertical forces for support design (81.317 lbf, 125.7 lbf), pressure drop across a proposed flow nozzle (16.75 psi), and the required pipe wall thickness to withstand water hammer (0.034 inches) which is less than the actual thickness (0.154 inches). Cavitation is unlikely as the system's lowest pressure exceeds the vapor pressure of ethyl alcohol.

Analysis:

The force calculations are crucial for proper installation and support. The pressure drop across the nozzle is essential for accurate flow measurement. Evaluating water hammer and cavitation ensures safe operation and prevents failures. Comparing the required and actual pipe thicknesses assesses the system's ability to withstand transient events. Checking against vapor pressure ensures avoiding cavitation-related damage. The analysis covers design, operation, and safety aspects, providing insights for optimization and risk mitigation.

Problem B

Purpose:

The purpose of this task is to design a lazy river attraction in a water park that can accommodate at least two lazy river tubes side-by-side. The design must consider the appropriate water depth for a 4-year-old child to stand safely, a slope of 0.1%, and any necessary assumptions for dimensions not provided. Additionally, the task requires calculating the water flow rate required for the lazy river, determining the drag force experienced by a 4-year-old child modeled as a cylinder, and evaluating the stability of a lazy river tube carrying a person weighing 220 lbs. This involves analyzing the depth to which the tube would submerge and verifying its stability based on the provided dimensions and assumptions about the tube's shape and properties.

Design Considerations:

* Incompressible fluid
* Isothermal process
* Newtonian Fluid

- T = 70 °F
- Open channel flow

Sources:

Mott, R., and Untener, J. Applied Fluid Mechanics. 7th Ed. 2015

Materials:

- Water
- Plastic tubes
- Concrete

Part 5:

Process:

Data and Variables:

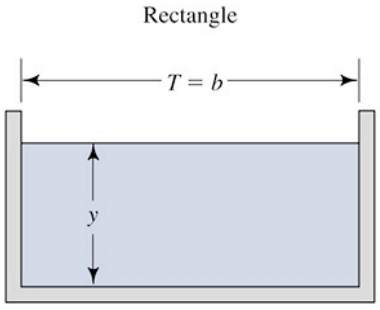
find the average height of a 4-year old (37 in.) $\cdot$ 0.8 = (29.6 in)

water height = 0.75 m.

Tube diameter = 96 cm

channel width = (96 cm x 2) + 8 cm = 200 cm = 2 m.

Table 14.2 Geometry of open-channel sections

Section	Area A	Wetted Perimeter WP	Hydraulic Radius R
Rectangle 	by	$b + 2y$	$\frac{by}{b+2y}$
Triangle			

Calculate the flow rate

Y	0.75	m
B	2	m
A	1.5	m^2
R	0.42857143	m
n	0.013	
S	0.001	
Q	2.07410171	m^3/s
V	1.38273447	m/s

$Q = V \cdot A$

for design:

$$A \cdot R^{2/3} = \frac{n\,Q}{S^{1/2}}$$

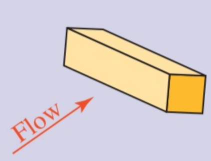
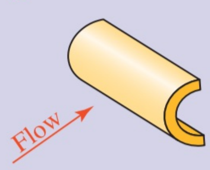
$$Q = \frac{A R^{2/3} \cdot S^{1/2}}{n}$$

$$\boxed{Q = 2.074 \; m^3/s}$$

Part 6:

Use a drag profile of a cylinder.

TABLE 17.1 Typical drag coefficients (*continued*)

Shape of body	Orientation	C_D
Square cylinder Flow is perpendicular to the flat front face.		1.60
Semitubular cylinders		1.12

$$C_D = \frac{F_D / A}{\frac{1}{2} \rho V^2}$$

$$F_D = C_D \left(\frac{\rho V^2}{2}\right) A$$

C_D = drag coefficient

F_D = drag force

A = Area

ρ = density

V = velocity

Using a square cylinder to approximate a 4 year old child.

$$F_D = 1.6 \cdot \frac{1}{2}\left(1000\,kg/m^3 \cdot (1.38\,m/s)^2\right) \cdot 1.5\,m^2$$

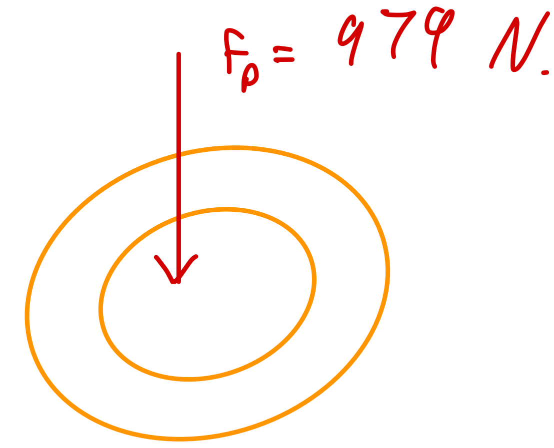
$$\boxed{F_D = 2285 \; kg\,m/s^2 \quad (N)}$$

Using a semitubular cylinder to approximate a 4 year old child.

$$F_D = 1.12 \cdot \frac{1}{2}\left(1000\,kg/m^3 \cdot (1.38\,m/s)^2\right) \cdot 1.5\,m^2$$

$$\boxed{F_D = 1599.7 \; kg\,m/s^2 \quad (N)}$$

Part 7:

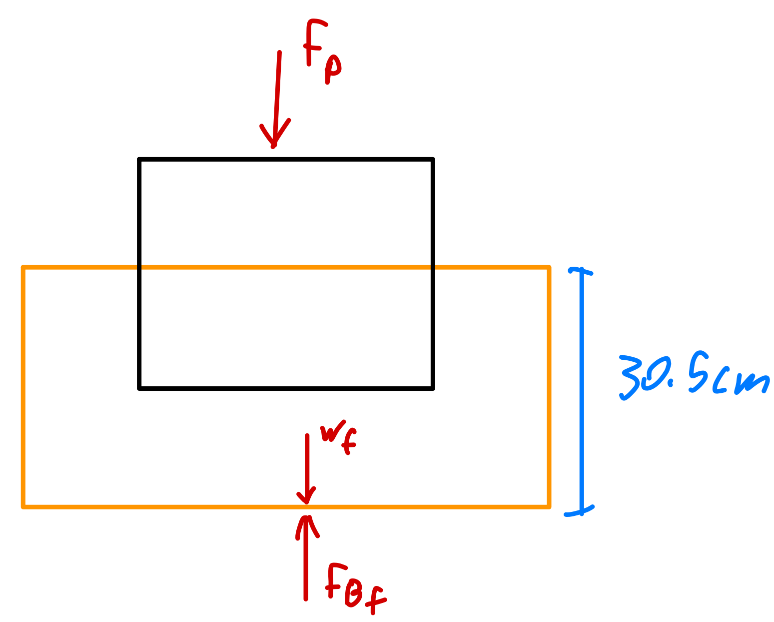


$\gamma_w = 9810 \ N/m^3 \qquad W_f = 2 \ kg$

$$V = \pi \left(\frac{D_o^2 - D_i^2}{4} \right) h$$

$$V = \pi \left(\frac{96^2 - 35^2}{4} \right) \cdot 30.5$$

$$V = 191421 \ cm^3 = 0.1914 \ m^3$$



$\Sigma F_y = 0 \qquad F_{B_f} = \gamma_w \cdot V$

$$0 = F_p + W_f - F_{Bf}$$

$$F_{Bf} = 979 \ N + 19.62 \ N$$

$$F_{Bf} = 998.62 \ N$$

$$998.62 \ N = 9810 \ N/m^3 \cdot V$$

$$V = 0.1018 \ m^3 = 101796 \ cm^3$$

$$V = \pi \left(\frac{D_o^2 - D_i^2}{4} \right) h$$

$$h = \pi \left(\frac{96^2 - 35^2}{4} \right) / 101796$$

$$\boxed{h = 16.22 \ cm}$$

as $h_2 > \frac{h_1}{2}$ unstable!!

Summary:

The task involved designing a lazy river attraction accommodating two tubes side-by-side, ensuring safe water depth for a 4-year-old, maintaining 0.1% slope, and calculating water flow rate. The drag force on a 4-year-old modeled as a cylinder was determined, and the stability of a tube carrying a 220 lb person was evaluated by analyzing submergence depth.

Analysis:

The design considered water depth based on child's height, channel width for two tubes, and calculated water flow rate. The drag force on a cylindrical child model ensured safety. Stability analysis revealed the tube would be unstable when carrying a 220 lb person due to excessive submergence depth, indicating potential safety concerns. Various factors like safety, dimensions, water flow, and stability were considered for a functional lazy river.