Florida International University
CWR 3201 Fluid Mechanics, Fall 2019
Mid-term # 2

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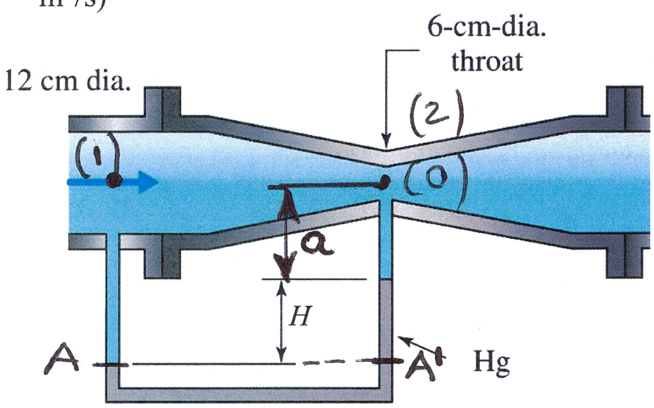
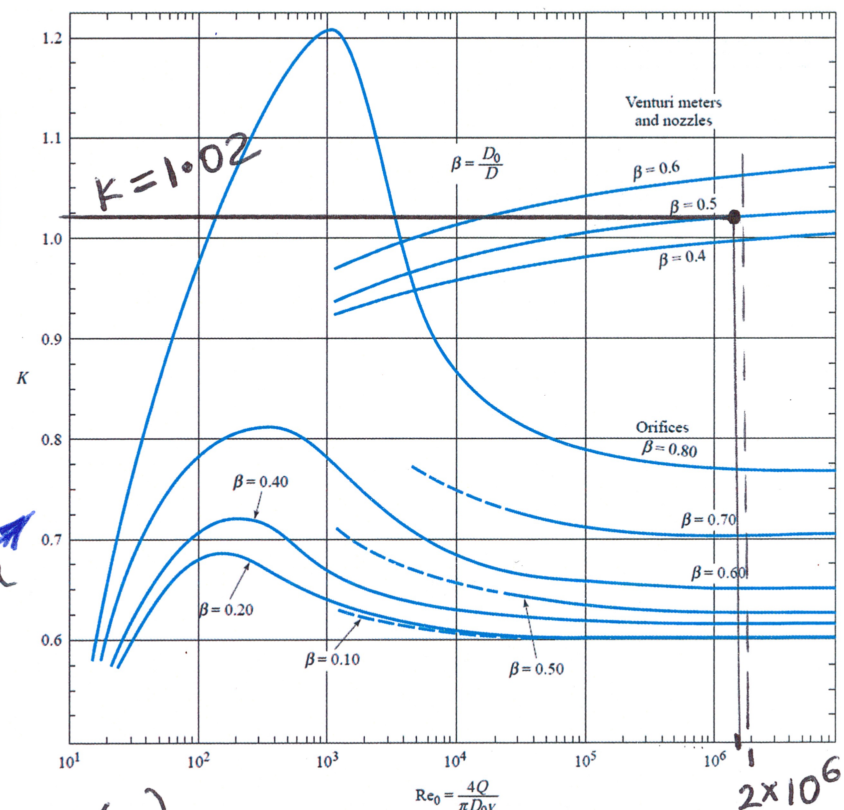
Student Name: Arturo Leon

- ✓ **You will have 1h 15 minutes to complete the exam. The exam is closed book and closed notes**
- ✓ **Only one page (front and back) with handwritten equations are allowed (no photocopies or artificially reduced text will be allowed)**
- ✓ **No cell phones or any type of communication device will be allowed.**

1. **(25 points)** The flow rate of water in a 12-cm-diameter pipe is measured with a 6-cm-diameter venturi meter to be 0.082 m^3/s. Determine H if the water temperature is 20°C (kinematic viscosity at 20°C = 10^{-6} m^2/s)





<u>Manometry</u>

$$P_A = P_{A'}$$

$$P_1 + \gamma_w (H + \cancel{a}) = P_0 + \cancel{\gamma_w a} + 13.6\, \gamma_w H$$

$$P_1 - P_0 = \gamma_w H (13.6 - 1)$$

$$P_1 - P_0 = 12.6\, \gamma_w H \quad \dots (1)$$

<u>Continuity</u>

$$V_1 = \frac{0.082}{\frac{\pi \times 0.12^2}{4}} = 7.25 \text{ m/s}$$

$$V_0 = 29.0 \text{ m/s}$$

$$\beta = \frac{D_0}{D} = \frac{6}{12} = 0.5$$

Flow rate $Q = k A_o \sqrt{2g(h_1-h_2)} = k A_o \sqrt{2g\left(\frac{P_1-P_2}{\gamma_w}\right)}$ from (1)

$$0.082 = k\, \pi * \frac{0.06^2}{4} \sqrt{2g(12.6H)} \quad \therefore (2)$$

To find k, we need Re_o.

$$Re_o = \frac{4Q}{\pi D_o \nu} = \frac{4 \times 0.082}{3.14 \times 0.06 \times 10^{-6}} = 1.74 \times 10^{6}$$

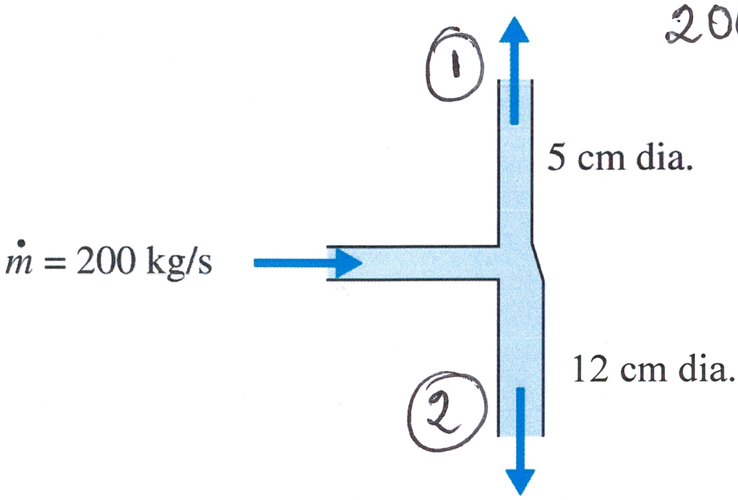
$$\boxed{k = 1.02}$$

In (2)

$$0.082 = 1.02\, \pi \times \frac{0.06^2}{4} \sqrt{2 \times 9.8 \times 12.6\, H}$$

$$\boxed{H = 3.27 \text{ m}}$$

2. **(20 points)** The pipe below transports 200 kg/s of water. The pipe tees into a 5-cm-diameter pipe and a 12-cm-diameter pipe. If the average velocity in the smaller-diameter pipe (5-cm-diameter pipe) is 37 m/s, calculate the flow rate in the larger pipe (12-cm-diameter pipe).



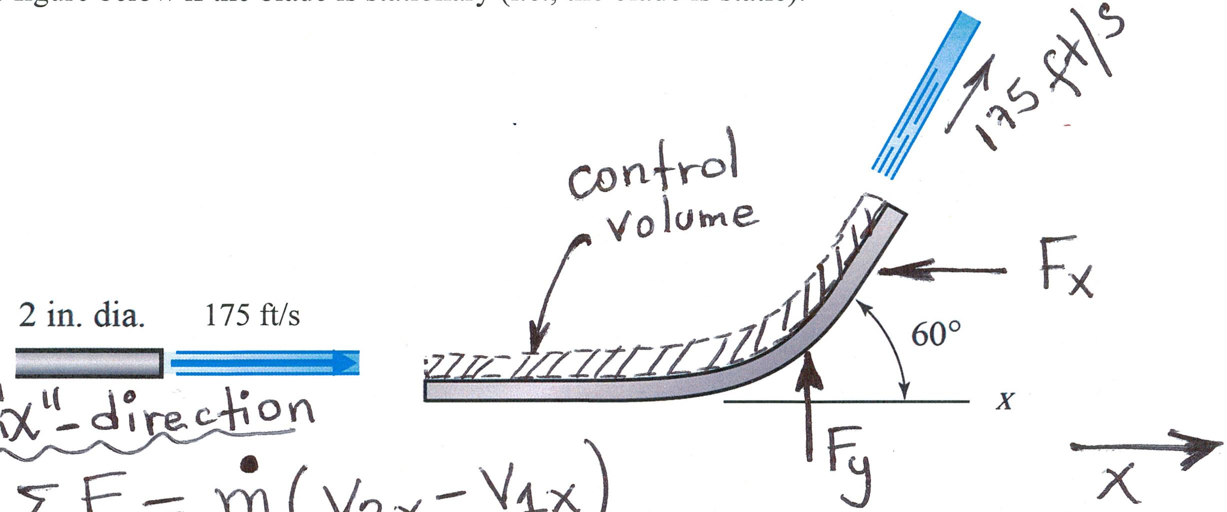
$$200 = \rho A_1 V_1 + \rho A_2 V_2$$

$$200 = 1000 \times \frac{\pi \times 0.05^2}{4}(37) + 1000 \times \underbrace{\frac{\pi \times 0.12^2}{4} V_2}_{Q_2}$$

$$200 = 72.649 + 1000\, Q_2$$

$$\boxed{Q_2 = 0.127\ m^3/s}$$

3. (20 points) Determine the "x" and "y" components of the force of the water acting on the deflecting blade shown in the figure below if the blade is stationary (i.e., the blade is static).



Momentum "x"-direction

$$\Sigma F = \dot{m}(V_{2x} - V_{1x})$$

$$-F_x = \rho A V (175 \cos 60° - 175)$$

$$-F_x = 1.94 \frac{\pi}{4}\left(\frac{2}{12}\right)^2 \times 175 (175 \cos 60° - 175)$$

$$\boxed{F_x = 648.1 \text{ lb}}$$

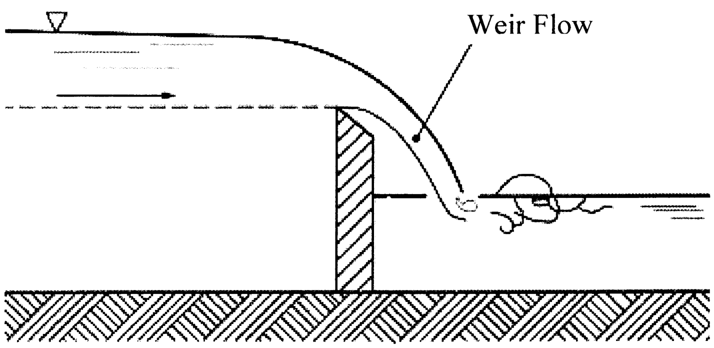
Momentum "y"-direction

$$F_y = \dot{m}(V_{2y} - V_{1y})$$

$$F_y = 1.94 \frac{\pi}{4}\left(\frac{2}{12}\right)^2 \times 175 (175 \sin 60° - 0)$$

$$\boxed{F_y = 1122.5 \text{ lb}}$$

4. **(15 points)** The flow rate of water over a weir is 2 m^3/s. A 1:17 scale model of the weir is tested in a water channel. If a force of 27 N is measured on the model, what force would be expected on the prototype?



Typical side view of a weir

Gravity flow:

$$Fr_m = Fr_p$$

$$\frac{V_m}{\sqrt{g_m l_m}} = \frac{V_p}{\sqrt{g_p l_p}}$$

$$g_m = g_p$$

$$\therefore \frac{V_m}{V_p} = \left(\frac{l_m}{l_p}\right)^{1/2}$$

$$\frac{F_m}{F_p} = \frac{\rho_m V_m^2 l_m^2}{\rho_p V_p^2 l_p^2} \qquad \rho_m = \rho_p$$

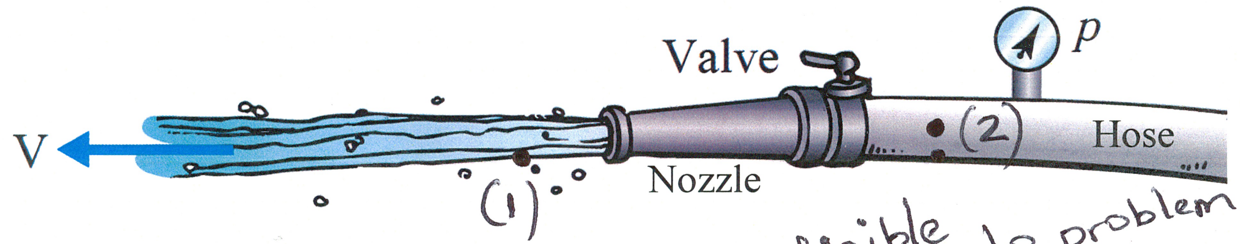
$$\frac{F_m}{F_p} = \left(\frac{V_m}{V_p}\right)^2 \left(\frac{l_m}{l_p}\right)^2 = \left(\frac{l_m}{l_p}\right)^3$$

$$\frac{27}{F_p} = \left(\frac{1}{17}\right)^3$$

$$F_p = 132{,}651 \text{ N}$$

$$\boxed{F_p = 132.6 \text{ KN}}$$

5. **(20 points)** A water hose is pressurized to 562 kPa with a nozzle in the OFF position. If the nozzle is opened a small amount, as shown in the figure below, determine the exiting velocity of the water. Assume the velocity inside the hose to be negligible.



Bernoulli

0 (atmospheric)

negligible according to problem

$z_1 = z_2$

$$\frac{\cancel{P_1}}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2}$$

$$\frac{V_1^2}{2\times \cancel{9.8}} = \frac{562\cancel{000}}{\cancel{9.8}\times \cancel{1000}}$$

$$V_1^2 = 1124 \rightarrow \boxed{V_1 = 33.5\ m/s}$$