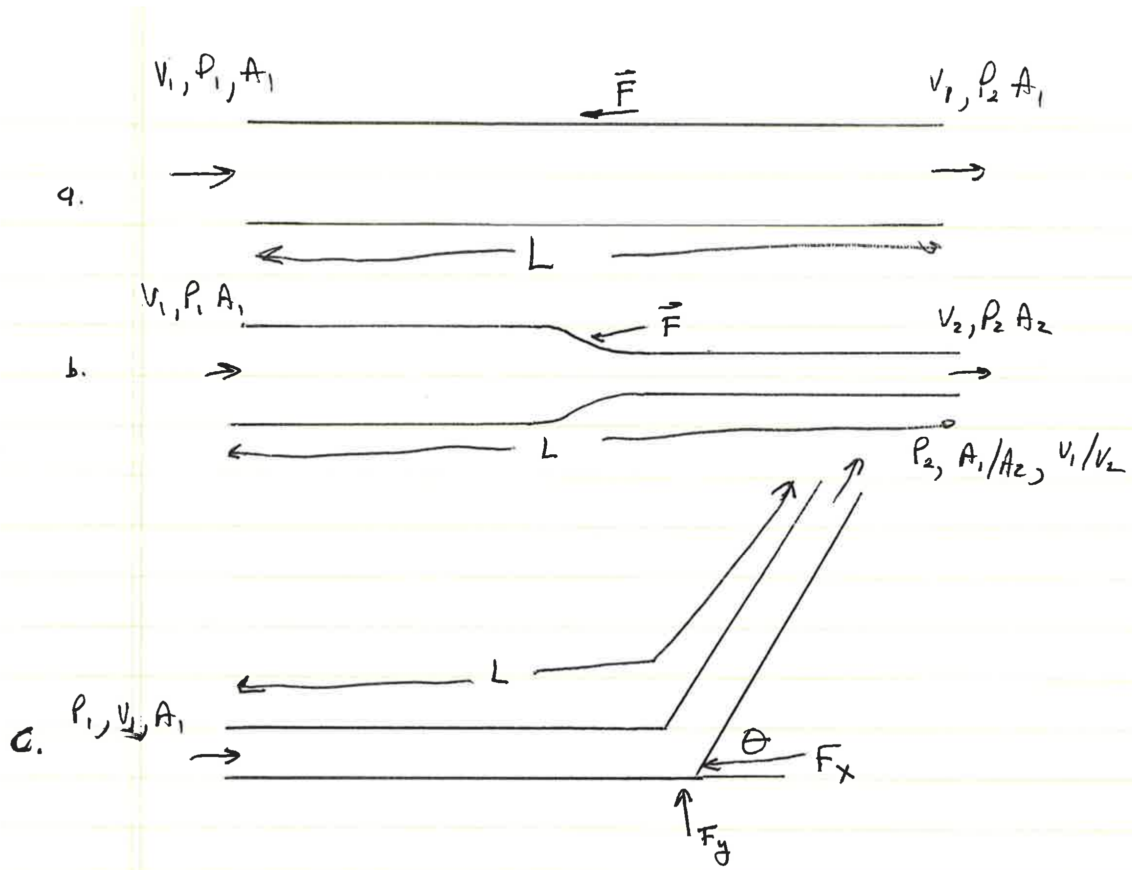
CBE 30357
Fall 2017
Homework #7
Due 11/7/17

1. **Forces on flow geometries**



a. Consider the straight pipe flow shown in a. The pipe has a constant area, A_1 and the total length is L. The flow is fully-developed laminar flow with average velocity, V_1. Find the force necessary to hold the pipe in place.
b. What specific physical process causes the need for an opposing "***F***" that holds the pipe in place.
c. If the Reynolds number were doubled, how much would the force change?
d. Consider the straight pipe flow shown in a. The pipe has a constant area, A_1 and the total length is L. The flow is fully-developed turbulent flow with average velocity, V_1. Find the force necessary to hold the pipe in place.
e. If the Reynolds number were doubled for d, how much would the force change?
f. Now consider the flow created by a "reducing coupling" as shown in figure b. What force is necessary to hold this pipe section in place?
g. How does the force necessary to hold this section in place arise?
h. For a turbulent flow, estimate the ratio of the two contributions to part "g".
i. For flow in a bend (sketch c), find expressions for the force components, F_x and F_y valid for $\theta = 0 - \pi/2$, allowing for the possibility that the area of the pipe is changing as well.

Momentum equations for single flow inlet in + x direction.

$$-\rho\langle V_x V_x\rangle A_1 + \rho\langle V_2 V_2\rangle A_2\cos(\theta) = P_1 A_1 - P_2 A_2\cos(\theta) + F_x$$

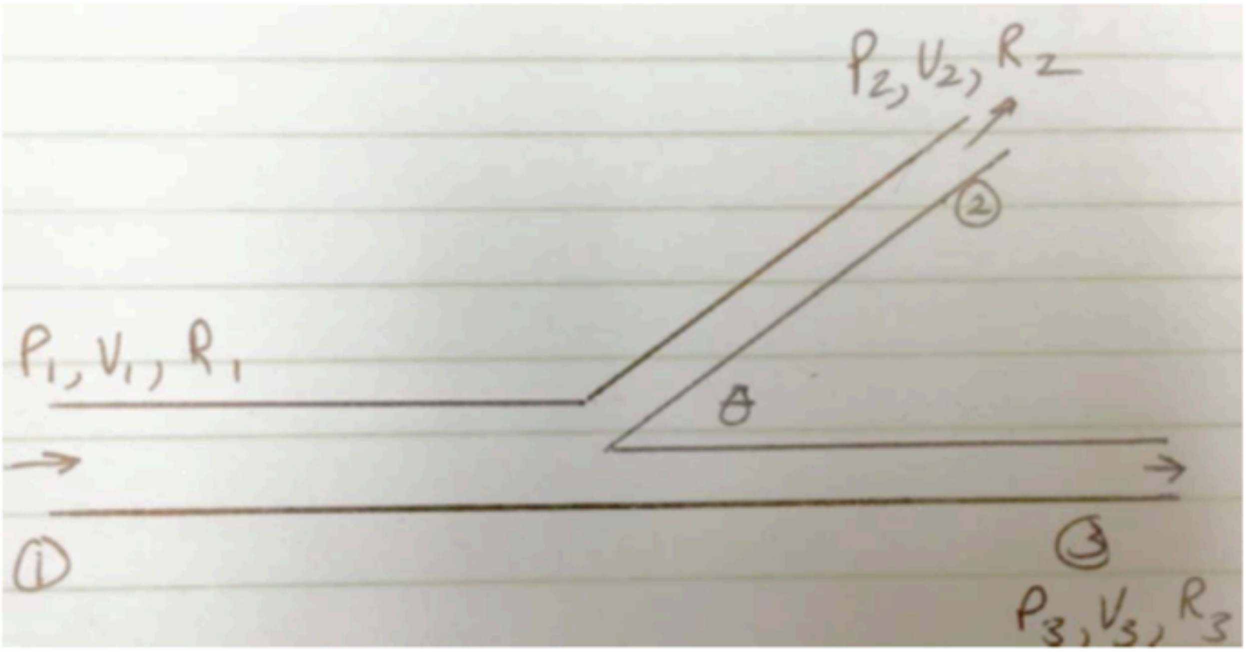
$$+\rho\langle V_2 V_2\rangle A_2\sin(\theta) = -P_2 A_2\sin(\theta) + F_y$$

2. Forces on a pipe with real flows and numbers

i. Consider water flowing in a 1 cm diameter pipe, that is 1 meter long at a Reynolds number of 500. Use equation 4.3.8 to find the force necessary to hold the pipe in place.
ii. Explain how your answer is consistent with using τ_{rz} and the equations in section 2.7.3 in the text.
iii. Consider a 3 cm diameter pipe 10 meters long that contains food-grade glycerine at 25C, flowing at an average velocity of 1.5 m/s. What is the Reynolds number?
iv. What force will be necessary to hold this pipe in place?
v. Consider a 3 cm diameter pipe 10 meters long that contains soybean oil at 90C, flowing at an average velocity of 1.5 m/s. What is the Reynolds number?
vi. What force will be necessary to hold this pipe in place?

3. Artery branching

While many blood vessels have roughly equal splits another common situation is shown here where a smaller vessel splits at some angle from a larger vessel



In general R_2 and R_3 are not equal. However, for this case, (Sochi 2013) notes that θ is generally smaller if the size of the "2" branch is larger.

a. Suppose that all velocities, pressures and radii (e.g., R_1) are known. Find the forces on the branch (and hence the force on the fluid inside the branch) in the x and y directions. (The inlet flow is aligned with the x direction.)
b. If we can write that $R_2 = \beta^{1/2} R_3$, find the velocity in branch 2 in terms of R_1, R_3, V_1, V_3 and β.
c. Suppose that you want the wall shear stress to be the same in all branches what relations have to be true for the pressure drops in the branches?