CBE 30355 TRANSPORT PHENOMENA I

Mid-Term Exam
10/1/20

This test is closed books and closed notes

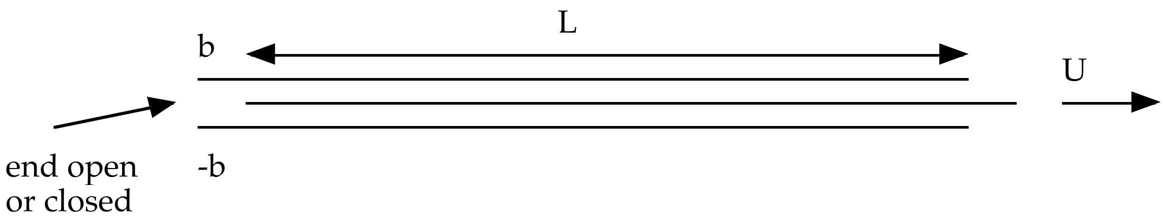
Problem 1. (15 pts) Conservation of Momentum: In a fun WSJ article on water toys for the super-rich, I came across the Jetlev Flyer. It consists of a small boat/pumping unit, a 10m long 10cm ID feed tube, and a jet backpack which redirects the water downwards through two 4 cm ID nozzles. According to their advertisements, you can fly for hours (before the modified jetski boat pump runs out of gas), and travel up to 25mph towing the pump boat behind you. Although more than a bit pricey (it costs a bit more than a new car!) you can actually get a 30 minute ride on one for $200 at a few beaches in Florida. We will study this in more detail later this semester, but here we are just going to look at the flow rate requirements of the pump – the easiest part.

Flyer weight: 100 kg
Jetpack weight: 15 kg
Feed pipe weight: 0.5 kg/m

Using this information, and neglecting all frictional losses (e.g., assume that Bernoulli's equation applies – not a bad approximation for determining the flow rate), determine the required flow rate to support our flyer at the maximum altitude of 10m. Don't forget the weight of the water in the feed pipe! Draw your control volume carefully and this problem is *much* easier!

Problem 2). (10 pts) Hydrostatics/Archimedes Law: You are given the task of determining the gold content of a "red gold" chain (actually a gold/copper alloy), and thus how much it should be insured for. Using a scale, you tare out a beaker of water (e.g., get it so that it reads zero). You dangle the chain via a fine thread in the water so that it is completely immersed (but suspended above the bottom), and find that the scale reads 10g. You then let it settle to the bottom and find that the scale reads 160g. The density of gold is 19.3 g/cm^3 and costs \$60.51/gram and the density of copper is 8.6 g/cm^3 and costs \$0.74/gram. Given this, how much is the metal in the chain worth?

Problem 3). (15 points) Unidirectional Flows: A plate occupies the center of a slot of width 2b and length L (and extension into the paper W) as depicted below. Each side is independent, so you can calculate things just looking one side of the plate. The plate is pulled out with velocity U. The ratio $b/L \ll 1$ so you can assume unidirectional flow.



a. Write down the differential equation governing this problem (assuming unidirectional steady-state flow!) and render the equation dimensionless. Determine the appropriate scale for any pressure gradient produced by the flow.

b. If the slot is open on both ends, no pressure gradient can be produced. For this case, calculate the velocity profile in the slot and tangential force on the plate.

c. If the slot is closed at one end the net flow goes to zero and a pressure gradient is produced, significantly increasing the force on the plate (a much more efficient damper!). Calculate the velocity distribution and force on the plate for this case.

Problem 4). (10 pts) Dimensional Analysis: Under some conditions (slow drips seeping from the underside of a porous plate) the radius R of a drop detaching from the surface is the result of a balance between the surface tension Γ (units Force/Length) and gravitational forces. If it's slow enough, velocity and viscosity don't matter.

a. Form the dimensional matrix of the parameters governing this problem, and determine the number of dimensionless groups involved.

b. Using the results of part (a) give a **rough estimate** of the radius R of a drop of water (Γ = 70 dynes/cm) dripping off of a plate and calculate its volume.