CBE 30355 TRANSPORT PHENOMENA I

First Hour Exam
10/8/19

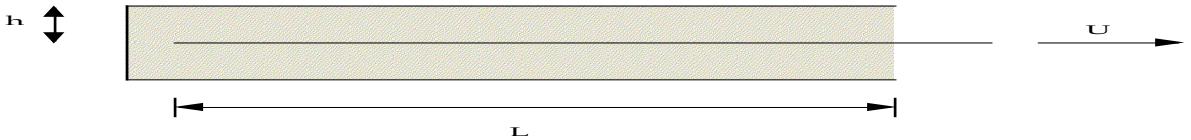
This test is closed books and closed notes

Problem 1. (20 points) Unidirectional Flow: A viscous damper uses viscous dissipation (e.g., the stress on a plate) to damp vibrations. The geometry is depicted below. The plate at the center has a velocity U, and because the end is closed there is no net flow of the fluid – which produces a pressure gradient. Assuming steady unidirectional flow, we want to calculate the force on the plate as a function of the viscosity of the fluid, the plate velocity U, the length L, the fluid gap width h, and the width (into the paper) W.

a. Write down the equations governing the velocity distribution with these assumptions as well as the boundary conditions (and the integral no-flux condition!). The sides are mirror images, so you can just work with one side of the plate.

b. Solve for the velocity distribution.

c. Get the force on the plate. Note that the force is just double what you get for one side.



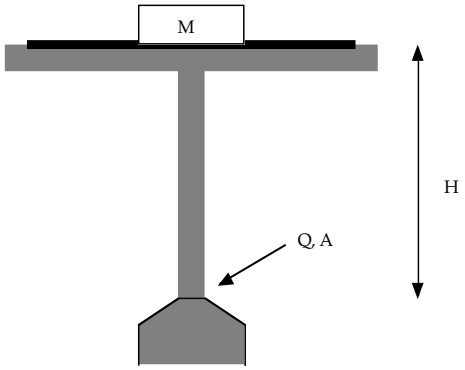
Problem 2. (20 pts) Hydrostatics. For the following, assume that the fluid is at rest and gravity is constant.

a. Using an integral force balance (such as was done in class!) derive Archimedes Law.

b. Using the divergence theorem, use this to obtain the equation governing the pressure distribution in a fluid at rest.

c. A friend picked up a gold chain at an estate sale "on spec," which the vendor said was "pure gold". Now jewelry is almost never pure gold (e.g., 24 karat – 24/24 parts by weight gold) as it is really too soft to use. The value of the chain depends on just how much gold is in it, and your friend turned to you as an expert in hydrostatics to see how much it is actually worth. You fill a beaker with water and measure a mass of 350.0g. You ball the chain up, tie a thread around it, and then suspend it in the water just above the bottom: the scale now reads 360.0. You then let the thread go and allow the chain to rest on the bottom and get a third reading of 470.0g. If the density of gold is 19.3g/cm^3, the density of the metal alloy is 9.6 g/cm^3 (this depends on the composition, but is a typical value for the mixture of silver, copper, and zinc used in yellow gold) and the cost of gold is $48 per gram, how much is the chain worth?

Problem 3. (20 pts) Integral Momentum Balances: A mass M is sitting on a flat plate as depicted below, balanced on a vertical jet of water. If the volumetric flow rate of the water jet is Q and the area of the jet nozzle is A, we can do a force balance on the plate. Don't forget that the water slows down and spreads out as it travels upwards, but the flow rate is the same! Neglecting all losses (e.g., use Bernoulli's Equation!), calculate the steady-state height H of the plate, and determine the minimum flow rate for which the plate can be supported.



Problem 4. (10 pts) Short answer questions:

1. Provide two physical interpretations for the vector ρu_i .

2. You put a sheet of rubber of thickness 2mm on a hot surface. The rubber has a thermal diffusivity of about 0.001 in cgs units. About how long would you have to wait before the top of the sheet warms up? Show the basis of your calculation.

3. Provide a physical interpretation for each term in Bernoulli's equation.

4. Write down the Navier-Stokes equation in index notation.

5. Karo syrup has a dynamic viscosity of 40 poise. Glycerin has a dynamic viscosity of 14 poise. You prepare a mixture consisting of 75ml of Karo syrup and 25ml of glycerin (they are miscible fluids, and nothing weird happens when you mix them). About what would you expect the viscosity of this mixture to be?