CBE 30355 TRANSPORT PHENOMENA I

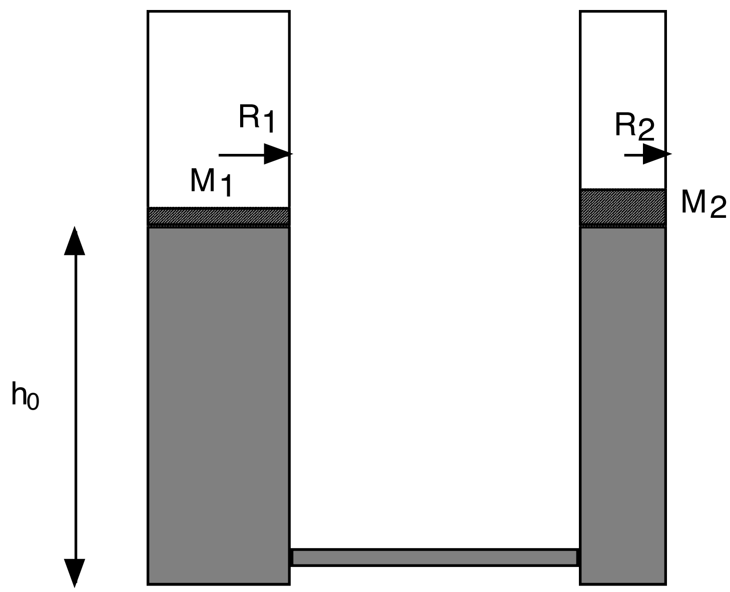
First Hour Exam
10/4/11

This test is closed books and closed notes

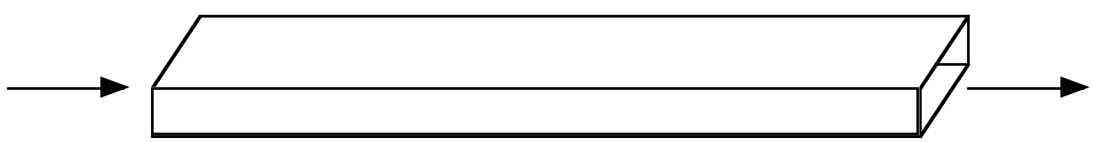
Problem 1. (15 pts) Hydrostatics: Consider the system depicted below. Two tubes, filled with a fluid of density ρ, are connected at the bottom. The tube radii are R_1 and R_2, respectively. A piston (ignore friction!) sits on the top of the fluid in each tube. The mass of the piston in tube 1 is M_1, and the mass of the piston in tube 2 is M_2. Initially both pistons are at a height h_0, and then they equilibrate to different heights h_1 and h_2.

a. Calculate the equilibrium height difference h_2-h_1.

b. Determine both h_2 and h_1 in terms of the initial height h_0.



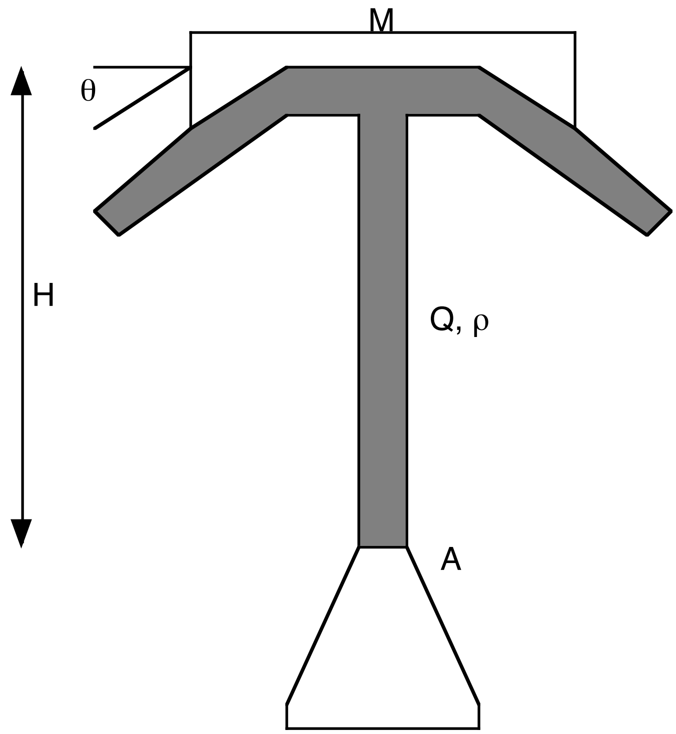
Problem 2. (15 pts) Plane-Poiseuille Flow: It is desired to pump fluid of viscosity μ through a microchannel of length L, width W, and depth 2b with volumetric flow rate Q as depicted below. The aspect ratios are such that L>>W>>b.



a. Making any reasonable approximations, develop an equation for the pressure drop required for the flow rate Q.

b. If L=10cm, W=0.1cm, and b=0.001cm (e.g., 2b=20μm), Q=0.1 μl/s (e.g., the channel processes 1ml in a bit under 3 hours), and the working fluid is water, what is the numerical value of the pressure drop in cgs units? In atmospheres? In cm H_2O (e.g., if you used a water manometer to measure it)?

Problem 3. (15 pts) Conservation of Momentum: Consider the plate and mass depicted below. The mass M is supported by the deflection of a jet of water of volumetric flow rate Q and density ρ. The jet emerges from a nozzle of cross-sectional area A, yielding some initial velocity U_0. The curvature of the plate deflects the stream backwards by some angle θ. Using all this (and an integral momentum balance!) calculate the equilibrium height of the plate. Note that the jet slows down as it moves upwards: think of Bernoulli's Equation!



Problem 4. (15 pts) Short Answer / Index notation / Additional Readings

Identify the physical mechanism behind the following terms:

1. $\rho \underset{\sim}{u}$ (two interpretations!)

2. $\mu \dfrac{\partial^2 u_x}{\partial y^2}$

3. $\rho \dfrac{v_r v_\theta}{r}$

4. $\rho u_x \dfrac{\partial u_y}{\partial x}$

5. $\dfrac{D\rho}{Dt}$

Briefly answer the following (2 pts each):

6. What is the most general relationship for the velocity of a body of revolution falling under some force F_j in terms of its orientation vector p_j at zero Re? Use index notation.

7. What is the corresponding expression for its angular velocity.

8. Write down the continuity equation for an incompressible fluid using index notation.

9. The "legs of wine" phenomenon is driven by ethanol's evaporation affecting what material property?

10. Cookie dough climbs up the shaft of a mixer (the Weissenberg Effect). Why?