CBE 30355 TRANSPORT PHENOMENA I

First Hour Exam
10/2/07

This test is closed books and closed notes

Problem 1. (15 pts) A mass M is sitting on a plate as depicted below, balanced on a vertical jet of water. If the volumetric flow rate of the jet is Q and the cross-sectional area of the nozzle is A, we can do a force balance on the plate. Don't forget that the jet slows down and spreads out as it travels upwards! For a jet like this, Bernoulli's equation (resulting from a mechanical energy balance in the absence of friction) provides a good relationship between velocity and height:

$$\frac{1}{2}\rho u_1^2 + P_1 + \rho g h_1 = \frac{1}{2}\rho u_2^2 + P_2 + \rho g h_2$$

Given all this, calculate the steady-state height H of the plate, and determine the minimum jet flow rate Q necessary to support the plate.
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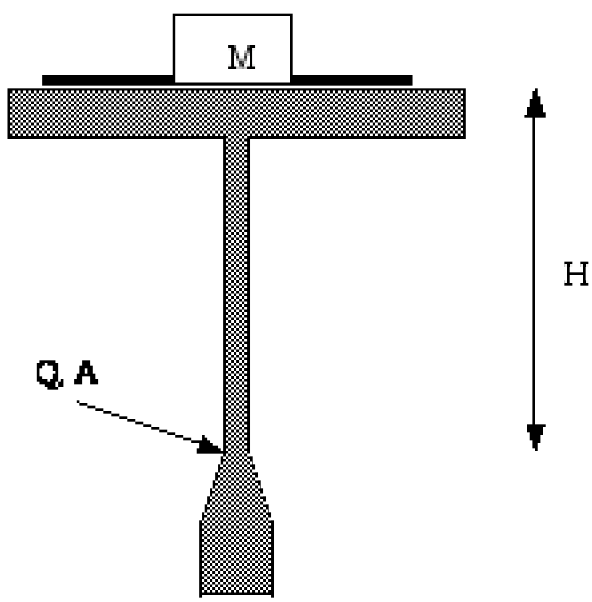
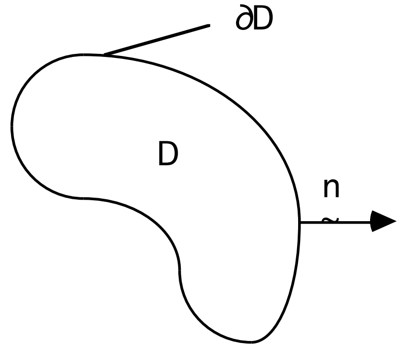
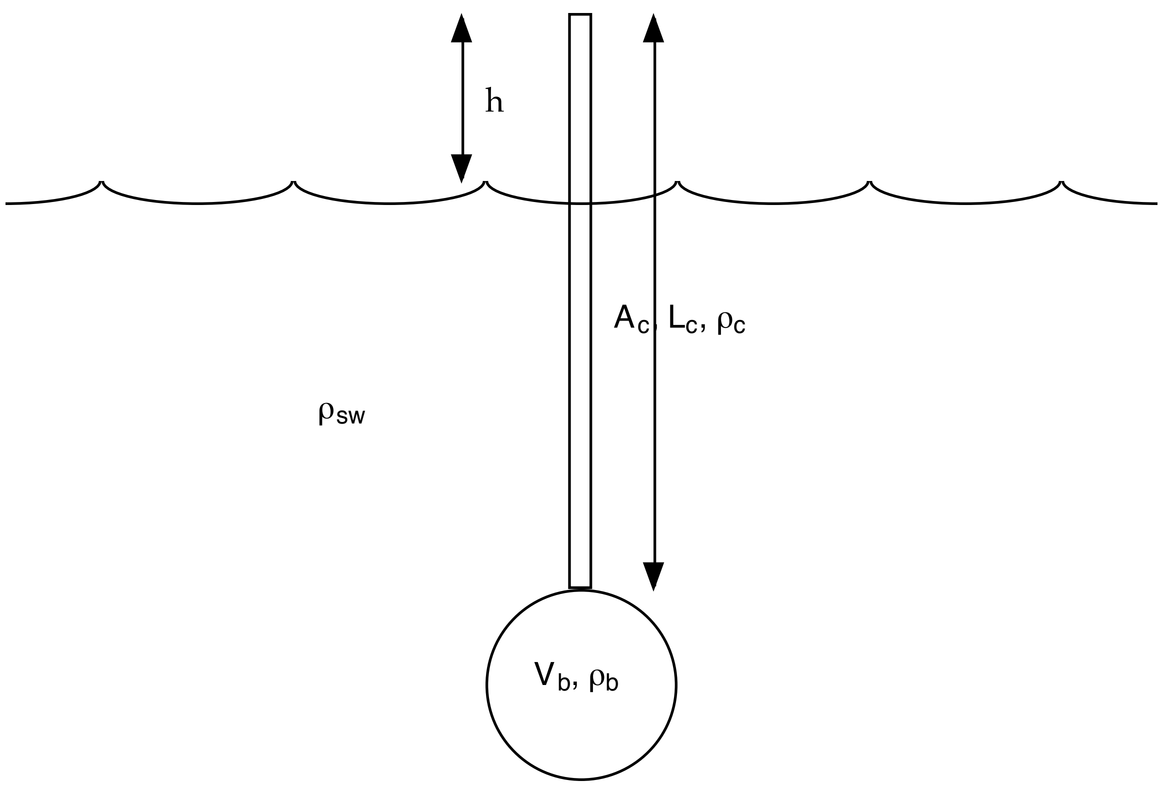


Problem 2. (10 pts) The lower atmosphere may be regarded as *adiabatic*, thus we have $P \sim \rho^\gamma$ where $\gamma = 1.4$ is the adiabatic exponent of a diatomic gas. Given that the density of the atmosphere at sea level is 1.2 kg/m^3 , the pressure at sea level is 1.01x10 ^{5} N/m^2, and the acceleration due to gravity is 9.8 m/s^2, solve the equation governing hydrostatic pressure variation and calculate the altitude where the density drops to half the value at sea level.

Problem 3. (10 pts) Starting from the arbitrary stationary control volume depicted below, derive the continuity equation for a *compressible* fluid.



Problem 4. (10 pts) In this problem we design a *hydrometer*, a simple device for measuring the density of a liquid, usually used in deterimining the salt concentration. A simplified version is depicted below, and consists of a bulb of volume V_b and density ρ_b, and a column of length L_c, cross sectional area A_c, and density ρ_c. Given this, determine the relation between the height h the column sticks up out of the water as a function of ρ_{sw} (the density of the salt water solution we are interested in) and the other parameters in the problem. What is the range of densities we can measure using this device?



Problem 5. (15 pts) Index notation / Additional Readings / Multimedia CD questions

1. (1 pt) Flow visualization using the time-lapsed photography of a tracer particle technique reveals which of the below for **unsteady** flows?

A. Pathlines
B. Streaklines
C. Streamlines
D. All of the above

2. (1 pt) Flow visualization using the dye release technique (dye ejected from a fixed array of nozzles) reveals which of the below for **steady** flows?

A. Pathlines
B. Streaklines
C. Streamlines
D. All of the above

3. (2 pts) Provide two interpretations of $\underset{\sim}{u}$.

4. (2 pts) Provide two interpretations of $\rho\underset{\sim}{u}$

5. (3 pts) Using index notation, prove that the divergence of the vorticity is zero.

6. (2 pts) Write down the continuity equation for an incompressible fluid using index notation.

7. (2 pt) Using index notation, write down the representation of the symmetric part of the general matrix A_{ij}.

8. (2 pts) Match up the kinematic viscosities of the following materials:

1. Water	A. 650 cSt
2. Air	B. 17.0 cSt
3. Glycerine	C. 1.0 cSt
4. Mercury	D. 0.118 cSt