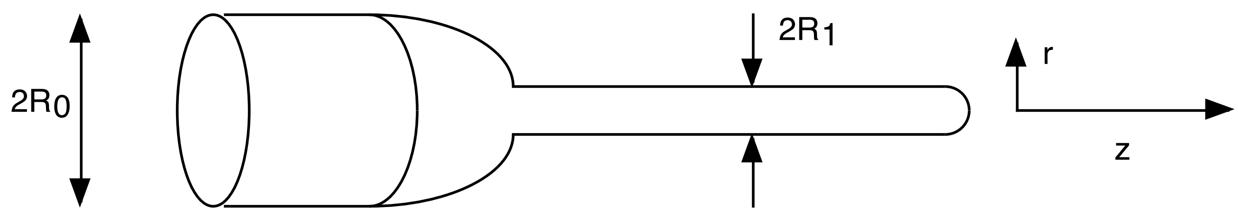
PROBLEM SET 3 CHEG 355 DUE 9/16/03

1). A classic "Honorable Mention" on the Darwin Awards website is the saga of "Lawn Chair Larry" who decided to go flying by attaching 42 helium filled 33 ft^3 weather balloons to his lawn chair. Instead of leveling off at around 30ft of altitude, he wound up at 16,000ft and actually was cited for violating LAX airspace. I'd like you to analyze this problem in hydrostatics and determine how many balloons Larry should have used - and if it is possible to control elevation with any precision. Make any approximations you find necessary to get the answer in a reasonable amount of time - although I'd certainly want more careful ones before -I- got in the lawnchair! One (of many) url's for the Lawn Chair Larry story is:

http://www.darwinawards.com/stupid/stupid1997-11.html

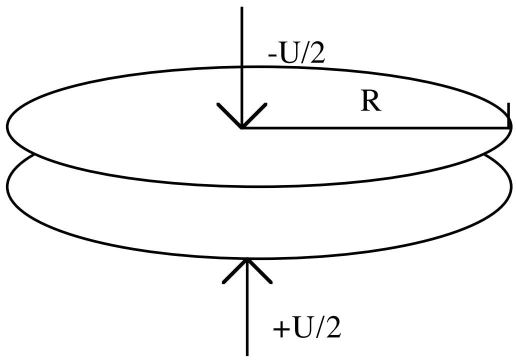
2). Fluid is flowing through the pipe contraction depicted below. If the velocity profile in the first section is parabolic, e.g., $u_z = D(1-r^2/R_0^2)$ where R_0 is the radius of the pipe in the first section and r is the radial coordinate, answer the following:

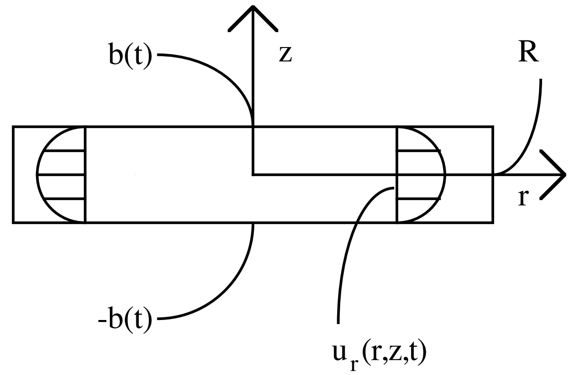
a. What is the flow rate in the first section?
b. What is the flow rate in the second section?
c. What is the average velocity in the first section?
d. What is the average velocity in the second section?



3). A 100 liter tank is initially filled with fresh water. If it is continuously stirred (a CSTR) and salt water at a concentration of 10g/liter is added to it at a rate of 2 liters/minute (mixed water flows out the bottom to keep the total volume at 100 liters), derive an expression for the total amount of salt in the tank. At what time does the salt concentration reach 90% of its equilibrium value?

4). The results of this problem are very useful in *lubrication theory*, the study of flow in very thin films (we will discuss this in more detail later on this semester). Consider the geometry depicted below:





The two disks of radius R are approaching each other with velocity U (e.g., the upper disk moves with velocity -U/2 and the lower with velocity +U/2 in the z direction). As the disks approach each other, the fluid between the disks will be squeezed out.

a. Using the continuity equation, calculate the average radial velocity (the average of the velocity over z) as a function of the dimensionless variable r/R. Note that the radial velocity is zero at r/R = 0.

b. Invoking the quasi-parallel flow approximation (a fancy way of saying that the velocity is a parabolic function of z -- e.g. $u_r = u_{r,max}(1\text{-}z^2/b^2)$ where $u_{r,max}$ is a function of r/R and b is a function of time) explicitly determine the velocity profile as a function of r/R and z/b(t). What is b(t)? Later on we'll use the momentum equations to determine the force required for this motion!

5). Index Notation: Using the concept of symmetry, isotropy and index notation, evaluate the following integrals over a spherical surface:

a. $\displaystyle\int_{r=a} x_i\, x_j\, x_k\, x_l\, dA$

b. $\displaystyle\int_{r=a} x_i\, x_j\, x_k\, dA$