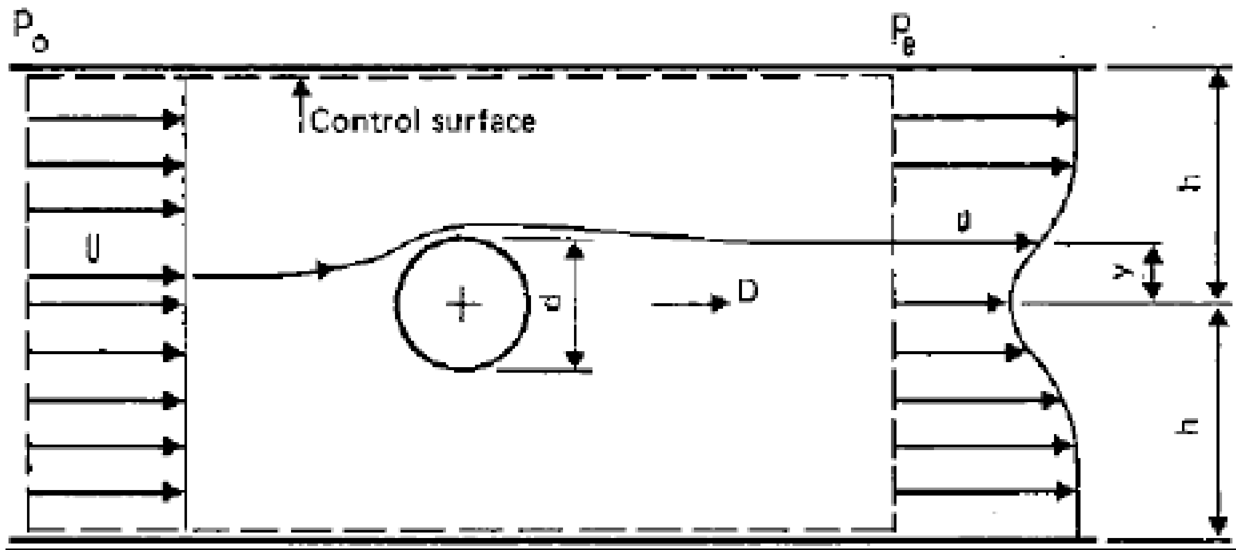
CBE 30355 TRANSPORT PHENOMENA I

First Hour Exam
10/3/06

This test is closed books and closed notes

Problem 1). (20 pts) In Senior Laboratory one of the experiments used to be measuring the drag on a cylinder at high Re. One of the techniques used is called a "wake traverse", in which we measure both the uniform velocity U upstream of the cylinder, and the non-uniform velocity u(y) downstream of the cylinder. We also measure the upstream pressure p_0 and the downstream pressure p_e. The diagram from the lab manual is given below.



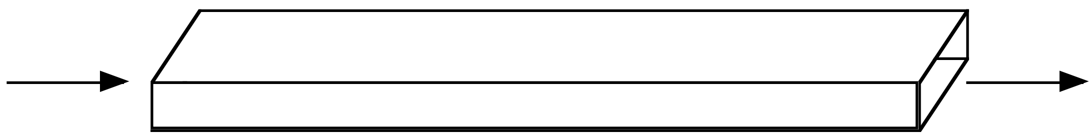
a. Write down in words the integral momentum balance around the control surface depicted above.

b. Is there more momentum convected into or out of the control volume (e.g., upstream vs. downstream)?

c. Given that we can neglect any drag on the side walls of the control surface, develop an explicit integral expression for the drag per unit length (into the paper) D exerted by the fluid on the cylinder in terms of p_0, p_e, U and u. Both p_0 and p_e may be taken to be constant over the inlet and outlet, respectively, and they are *not* equal!

Hint: This problem is pretty much identical to the sluice gate problem you solved for homework, except here the upstream and downstream pressures are measured (no gravity), and the downstream velocity profile is non-uniform, and thus must be left in integral form in the momentum balance. In lab it's this downstream velocity measurement that's the tricky part of the experiment...

Problem 2). (20 points) Plane Poiseuille Flow: A problem which is currently being investigated in bioengineering laboratories is the phenomenon of cell adhesion to surfaces in the presence of hydrodynamic stresses. This is very important in the design of biocompatible materials, for example. To study this, a researcher has built a rectangular flow cell which is 100μm deep, 2mm wide, and 2cm long. The objective is to have a wall shear stress (e.g., stress at the lower wall - the 2mm x 2cm surface - where cell adhesion is being studied) of 10 dyne/cm^2. Due to the ratio of length scales, you can assume unidirectional plane-Poiseuille flow. If the working fluid has the same viscosity as water (~1 cP), what should the flow rate of the pump supplying the fluid be?

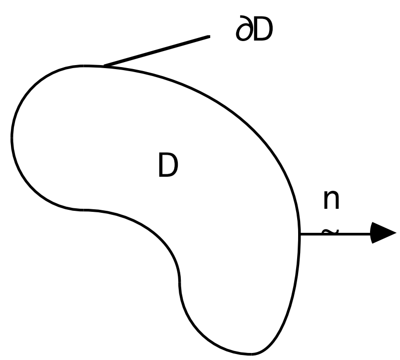


Problem 3). (20 pts) One of the key aspects of our research over the years has been developing equations governing particle concentration distributions in suspensions of particles in fluids. Here we look at the evolution of the particle volume fraction (the fraction of the local volume occupied by the particles) given by the variable ϕ. The particle flux may be modelled as the sum of two terms: the convective flux vector $u_i\phi$ due to the local fluid velocity vector u, and an additional diffusive flux specified by a flux vector N_i. It's closing the problem by relating N_i back to the velocity and concentration profile which is the tricky part of all the research, but we won't worry about that here. Starting from the arbitrary stationary control volume depicted below, derive the conservation equation for the particle volume fraction.

a. Write down the conservation relationship in words. Don't forget accumulation!

b. Write down the conservation relationship in integral form.

c. Complete the problem by deriving the differential form of the conservation law.



Problem 4). (20 pts total) Index notation / Additional Readings / Multimedia CD questions

a. (6pts) Briefly identify the physical mechanism described by each of the following terms:

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

2.. $\dfrac{\partial u_i}{\partial x_i} = 0$

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

b. (4 pts) Match the name up with an item for which they achieved recognition:

1. Pneumatics	A. Osbourne Reynolds
2. Couette Instability	B. Hero of Alexandria
3. Stress-Strain Relationship	C. G. I. Taylor
4. Turbulent Pipe Flow	D. Sir Isaac Newton

c. (2pts) Using index notation, show how you can decompose the rate of strain tensor into symmetric and anti-symmetric parts.

d. (2 pts) Crooke's Radiometer works because of:
- A. The momentum of light
- B. Thermal transpiration
- C. Maxwell said it should
- D. Hot gas on the black face of the vane

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

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

f. (2 pts) The vorticity is defined as the curl of the velocity. Write down this defining relation using index notation.

g. (2pts) What is the most general second order **pseudo** tensor characterized by a single director p_i? (Hint: this is the one we used to show that rotation of a body of revolution with fore-and-aft symmetry was zero)