GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2004

Fluid Mechanics

EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

* Please sign your **name** on the back of this page —

WORK ALL PROBLEMS!

All problems are of equal weight.

GWW School of Mechanical Engineering Fluid Mechanics Qualifying Examination
Spring, 2004

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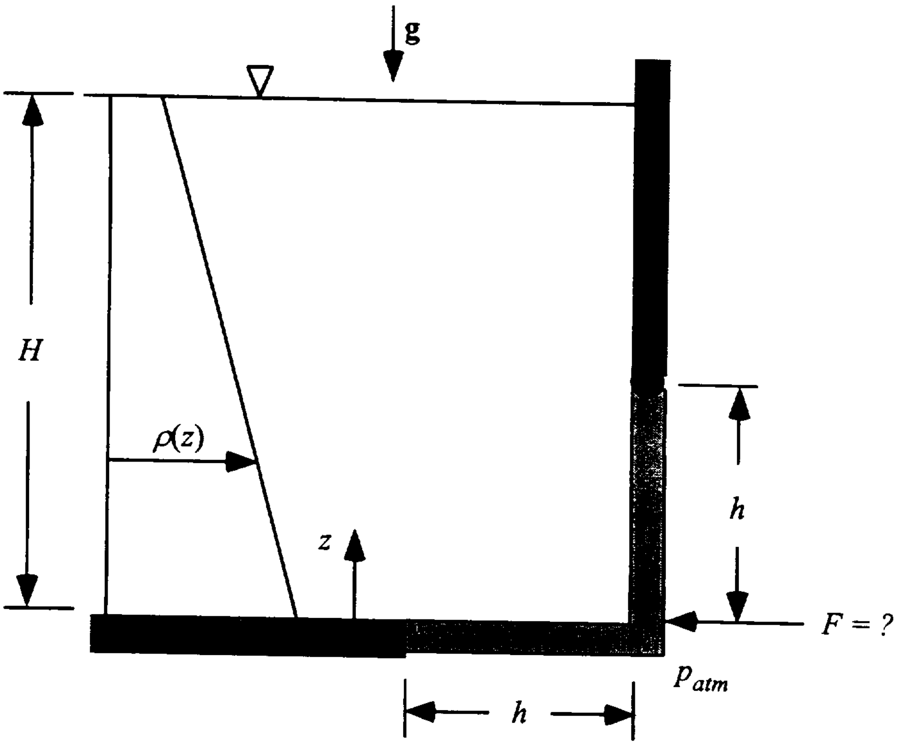


1. An L-shaped gate of weight W (per unit distance normal to the plane of the figure) is attached to a hinge on a vertical wall. The back side of the gate is exposed to air at atmospheric pressure and the other side to a *stratified* liquid with density profile

$$\rho(z) = \rho_0 - \alpha(z - H),$$

where $\alpha > 0$ is a constant and the coordinate origin is indicted on the figure. What force F (per unit distance normal to the figure) would need to be applied in the horizontal direction indicated at the bottom of the gate to keep the gate closed, as shown?

You may neglect the wall thickness of the gate material in performing your calculation. It is not necessary to do all the algebra at the end of the calculations!

2. Consider a fluid flow problem of red blood cells traveling in capillary tube. Red blood cells are disc shaped objects with a diameter D1. The capillary tube as a diameter D2. The moving blood fluid has a viscosity μ, density ρ, and a pulsatile frequency of f.

A. Using dimensional analysis, describe the dimensionless parameters which are relevant to this problem.

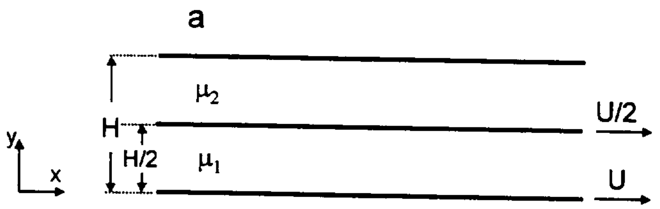
B. If you wanted to create an experiment to model this microscopic flow on a macroscopic level where the model tube was 1000 X the diameter of the capillary tube, what single fluid property should be changed in the model to achieve a similar balance of fluid forces with a reasonable fluid velocity? How would you change this property in the model to achieve this objective?

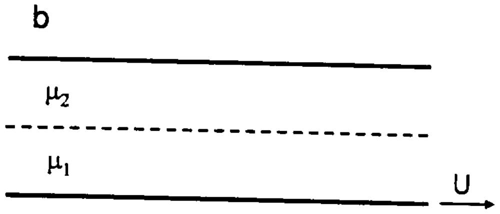
C. Derive the relationship between the model frequency of pulsatility (dimensional variable) in relation to the actual capillary frequency in terms of the dimensional parameters of the problem.

D. Is it proper to treat this fluid as a continuum for a given D2?

3. Two incompressible, immiscible fluids having the same density ρ but different viscosities μ_1 and μ_2 ($\mu_1 > \mu_2$) are transported within a long horizontal channel of height H as shown schematically in Figure 3a) below (the channel's length and width are much greater than H). The fluids are separated by a thin, massless horizontal partition at $y = H/2$, and are transported to the right by moving the bottom surface and the partition at fixed speeds U and $U/2$, respectively. In order to improve the efficiency of the system, it is proposed to remove the partition and transport the two fluids by the motion of the bottom surface alone (as shown in Figure 3b). Assuming that the motion within the channel remains two-dimensional and streamwise-invariant (i.e., independent of x), determine whether the volume flow rate of each fluid in the proposed configuration (Figure 3b) remains unchanged.

Along with your answer, please explain WHY the flow fields in Figures 3a and 3b are or aren't the same.





The 2-D, incompressible Navier-Stokes and continuity equations, in Cartesian coordinates, are:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+g_x$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+g_y$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

4. A cylindrical tank with cross-sectional area A and mass m filled to a level H with water (density ρ) sits on a flat horizontal surface. As shown below, a jet discharges through a small orifice of diameter δ on the side of the tank near its bottom.

   a) Assuming a quasi-steady model valid at the instant shown in the figure below, what is the coefficient of friction μ required for the tank to slide on the surface? Is this the minimum or maximum coefficient of friction?

   b) Simplify your expression for μ for the case when the mass of the tank is small compared with that of the water and the orifice area is small compared that of the tank cross-section.