GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2004

FLUID MECHANICS

EXAM AREA

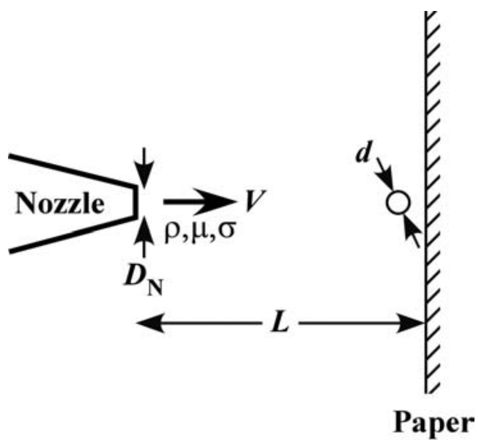
Assigned Number (DO NOT SIGN YOUR NAME)

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

1) In an inkjet printer, the diameter *d* of the dots made by the printer depends on the viscosity μ and density ρ of the ink, the ink-air surface tension σ, the diameter of the inkjet nozzle D_N, and the distance between the nozzle exit and the surface of the paper *L*.

a) Determine the number of Π groups required to characterize the behavior of the inkjet printer, and find these Π groups.

b) The size of the dots made by the printer determines the printer resolution (measured in dots per inch, for example). Based upon your dimensional analysis, give at least three suggestions for reducing *d*. Briefly discuss how an inkjet printer might be modified to implement your suggestions



2) A hydraulic system is comprised of two adjoining chambers as shown in the side and top views in Figures 2(a) and 2(b) below. Initially, the chamber on the left is completely filled with a Newtonian liquid (of constant density ρ_L and viscosity μ_L) while the chamber on the right contains pressurized gas (density ρ_g and viscosity μ_g). The system is equipped with two massless round pistons, denoted "1" and "2", which are mounted in frictionless sleeves and have diameters D_1 and D_2, respectively. Both compartments are surrounded by air at atmospheric pressure p_{atm}.

a) Given the information in Figures 2(a) and 2(b), determine the absolute pressure p_A that is necessary to hold pistons "1" and "2" stationary when a force F_1 is applied to piston "1".

b) At some later time, the partition separating the two adjoining chambers develops a small leak at the top so that the gas originally in the right compartment forms a very thin film above the liquid as shown in the side view given in Figure 2(c). Determine the absolute pressure p_B required to hold pistons "1" and "2" stationary. Note that there is still a force F_1 applied to piston "1".

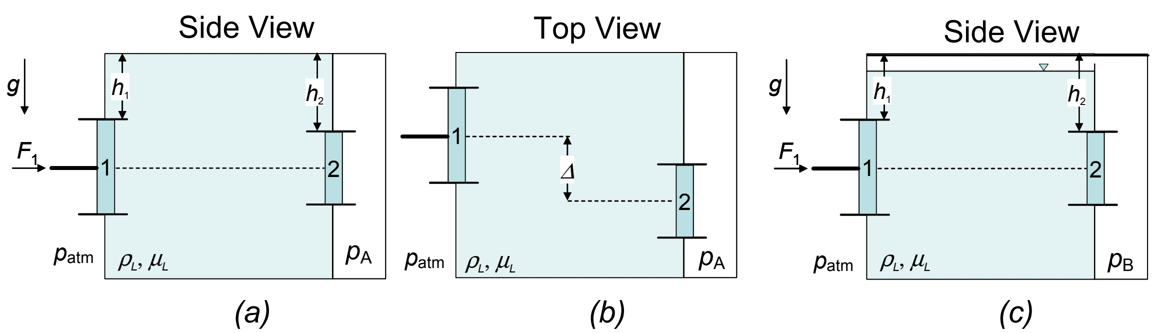


Figure 2: Sketches for Problem 2

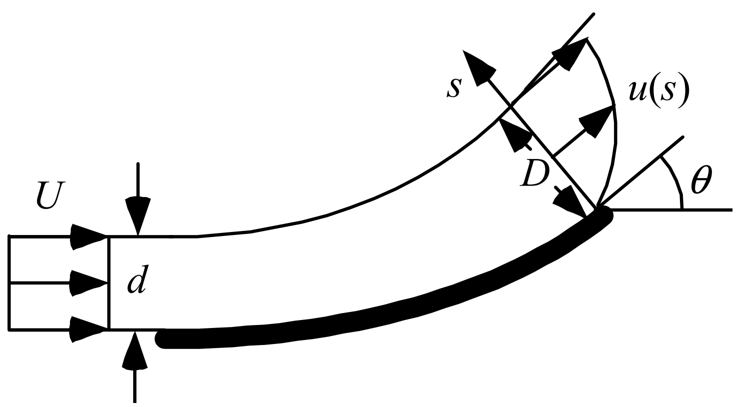
3) A sheet of liquid of thickness d strikes a curved plate with uniform speed U. The plate deflects the liquid through an angle θ, while viscous action causes the liquid to develop a parabolic velocity profile

$$u(s) = U\frac{s}{D}\left(2 - \frac{s}{D}\right)$$

(where s is the local coordinate indicated on the figure) at the point where the liquid leaves the plate in a sheet of thickness D.

a) Determine D.

b) Determine the total force required to hold the plate stationary.



4) Consider a
are a distance h_1 and h_0, respectively, from the surface of the substrate, the blade thickness is L, and the substrate moves at velocity, U. Note that the surface of the substrate is flat and smooth and the coating liquid can be treated as an incompressible Newtonian fluid with viscosity, μ. Assume that h_0, $h_1 << L$, and the effects from the upstream and downstream ends of the gap can be neglected.

a) Simplify the Navier-Stokes equation and solve for the velocity components, u and w, in terms of pressure gradients, $\frac{\partial p}{\partial x}$ and $\frac{\partial p}{\partial z}$.

b) Assuming that $\frac{\partial p}{\partial z} = 0$, find the relation for the pressure profile as a function of gap height, h, under the blade using Reynolds lubrication equation, given by

$$\frac{d}{dx}\left(h^3 \frac{dp}{dx}\right) = 6\mu U \frac{dh}{dx}$$

Assume that $p = p_0$ at $x = 0$ and at $x = L$.

c) Find the functional form of the velocity profile at the location under the blade where pressure is at a maximum value.

Use reasonable assumptions when solving this problem.