GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

TRIBOLOGY
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

Question #1

Consider a disc-brake system for an automobile with all wheels having identical disc brakes.

a) Derive an expression for the pad normal force (W) that provides the maximum deceleration of the vehicle, assuming 2 pads per wheel. (To do this you will have to introduce certain other parameters.)

b) Taking the mass of the car to be 2,500 kg, calculate the pad normal force (W) required to stop the vehicle with the maximum possible deceleration. (Make reasonable assumptions for the relevant coefficients of friction.)

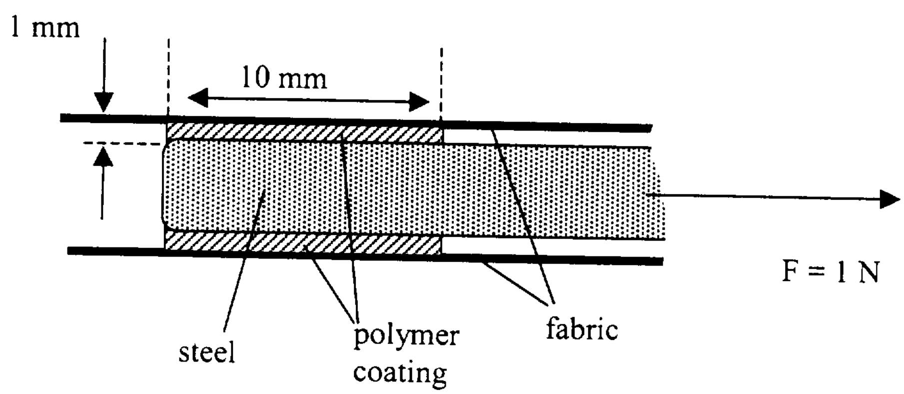
c) In "hydroplaning" on a wet road, it is often thought that the tires go into full-film lubrication. Assuming Couette flow with a uniform film thickness, estimate the water film thickness (h) that would provide a deceleration rate of 0.1 m/s^2 for a 2,500-kg car initially traveling at 20 m/s. For this purpose, take the viscosity of water to be 1.0 mPa-s, and the tire pressure to be 200 kPa.

d) Based on the results of Part c) comment on whether or not a full film of water actually develops when a car skids on a wet road.

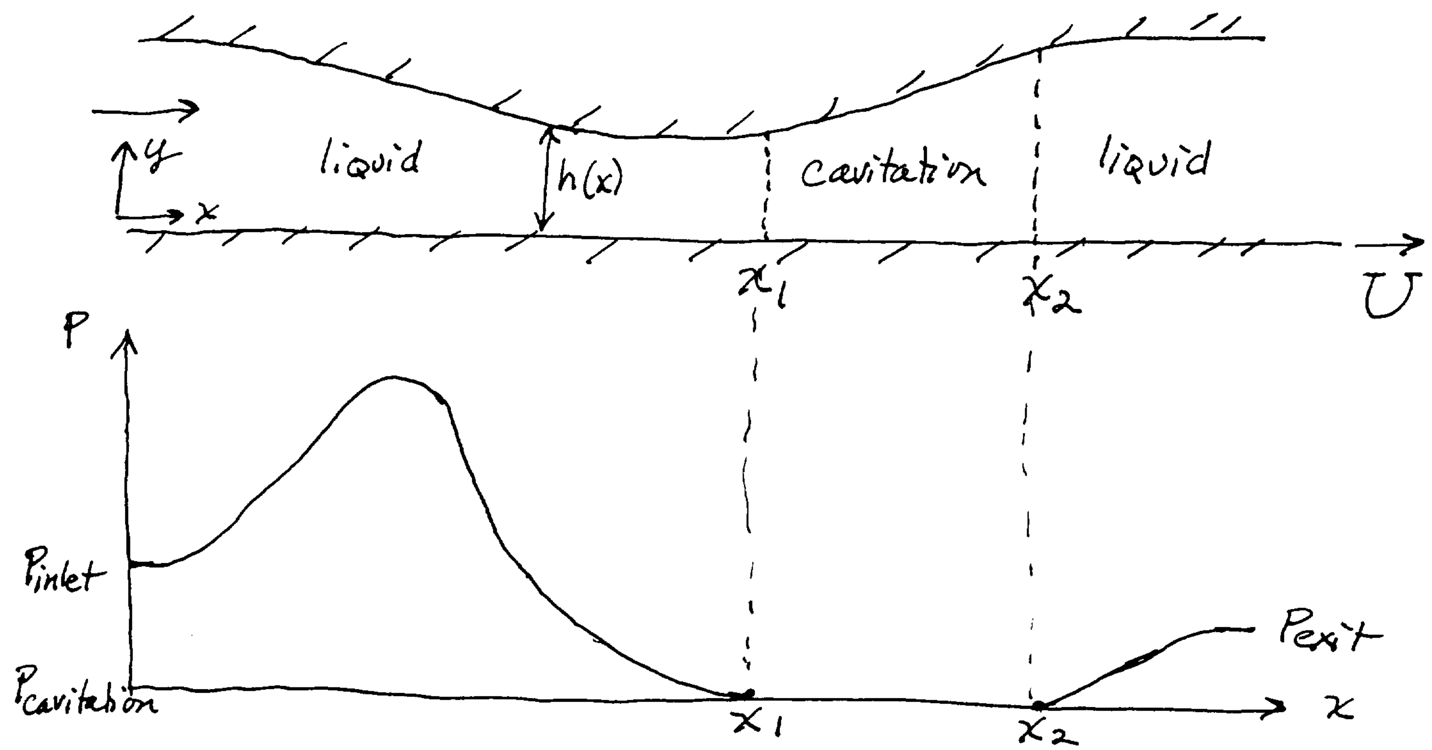
Question #2

A steel member with polymer coating slides between two swatches of fabric as shown below. It is found that the friction force is 1.0 N. Assuming Archard's Wear Law and using the following data, estimate the length of travel to wear away the coating.

$H = 100\ kg_f/mm^2$
$K = 0.5\times10^{-3}$
$\mu = 0.3$
coating length = 10 mm
coating width (into page) = 10 mm
coating thickness = 1 mm



Question #3



Consider the two-dimensional flow, above, in which the lower surface moves to the right with speed U and the upper surface is stationary. The film thickness h is small enough so that the usual lubrication approximations are valid.

At $x<x_1$ liquid flows between the two surfaces; at $x=x_1$ the pressure falls to the cavitation pressure, and gas comes out of solution so that in the cavitation region $x_1<x<x_2$ the fluid is a mixture of liquid and gas with an average density ρ. The density is a function of x. At $x=x_2$ the liquid film reforms.

a) Express the velocity profile in the liquid regions ($x<x_1$ and $x>x_2$) as a function of y, h, U, μ, $\frac{dp}{dx}$.

b) Express the velocity profile in the cavitation region ($x_1<x<x_2$) as a function of the parameters mentioned in part a.

c) Write down an equation governing the pressure in the liquid regions.

d) Write down an equation governing the density in the cavitation region.

e) The boundary conditions on the equations of parts c and d, at the boundaries of the cavitation region, are at $x = x_1$: $\frac{dp}{dx} = 0 \quad \theta = 1$

at $x = x_2$: $(1-\theta)\frac{Uh}{2} - \frac{h^3}{12\mu}\frac{dp}{dx} = 0$

where $\theta = \rho/\rho_{liquid}$

(note: There is a discontinuity in density at $x = x_2$)

Describe a solution scheme to solve the equations of parts c and d for p and ρ, subject to the appropriate boundary conditions.