Final exam

(8:00-11:00 am on December 9, 2009)

Problem 1 (20). A racer rests his coffee mug on a horizontal tray while accelerating at 7 $\mathrm{m/s^2}$ as shown in figure 1. The mug is 10 cm deep and 6 cm in diameter and contains coffee 7 cm deep when at rest. **Hint:** You must take into account the total acceleration vector which has gravity **g** and acceleration **a** as components.

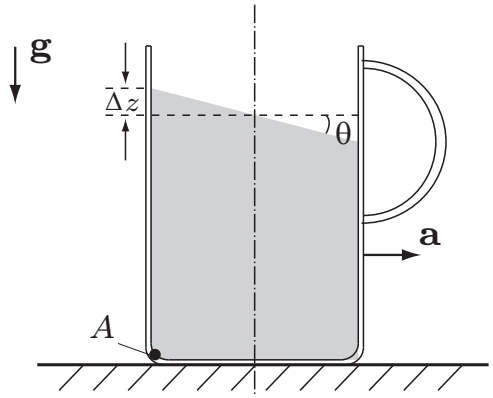

Figure 1: The coffee tilted during the acceleration $\mathbf{a} = 7\,\mathrm{m/s^2}$.

(a:10) Assuming rigid-body acceleration of the coffee, determine whether it will spill out of the mug.

(b:10) Calculate the gage pressure in the corner at point A if the density of coffee is 1010 $\mathrm{kg/m^3}$.

Problem 2 (25). A 10 cm fire hose with a 3 cm nozzle discharges water at 1.5 $\mathrm{m^3/min}$ to the atmosphere. Assuming frictionless flow and using Bernoulli's equation, find the force F_B exerted by the flange bolts to hold the nozzle on the hose.

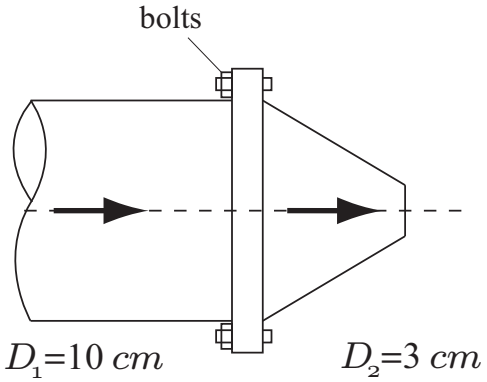

Figure 2: Fire hose with a nozzle. D_1 and D_2 are the diameters of the hose and the nozzle, respectively.

Problem 3 (35). Consider the plate of width b and length L parallel to the flow, as shown in figure 3. The oncoming flow is of uniform velocity $\mathbf{V} = U_0\mathbf{i}$. The pressure is assumed uniform, so it has no net force on the plate. The no-slip condition at the wall brings the fluid there at a halt, and these slowly moving particles retard their neighbors above, so that at the end of the plate there is a significant retarded shear layer (or boundary layer) of thickness δ. The viscous stresses along the wall can sum to a finite drag force on the plate. Using the integral control volume analysis and the control volume in figure 3, find the drag force D in terms of the flow properties ρ, U_0, δ, velocity profile $u(y)$ at $x = L$, and the plate dimensions.

Hints: (1) This particular control volume has streamlines as its top and bottom boundaries (in other words, the control volume is a streamtube). (2) Leave your final answer as an integral.

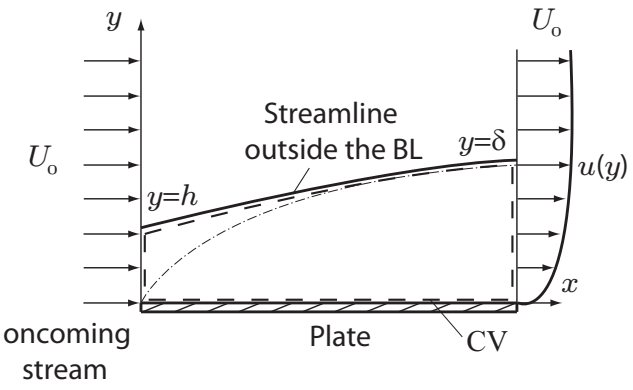

Figure 3: Drag force on a flat plate. Control volume (CV) is shown with a dashed line.