GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2002

Fluids

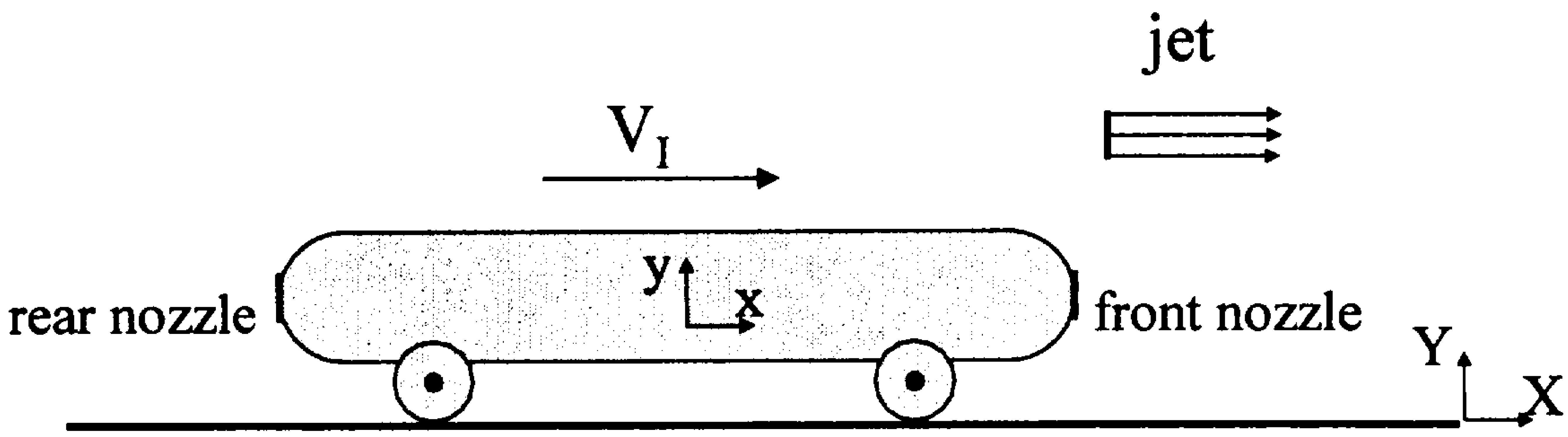
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

1. A cart of mass M is moving to the right on a frictionless surface with constant velocity V_I (relative to the frame X-Y) as shown in the sketch below. Built-in horizontal air jets installed at the front and rear ends (i.e., on the left and right) control the speed of the cart and can be turned on and off remotely. Each jet is uniform and emanates out of a round nozzle of area A_N with constant velocity V_J *relative to the cart* (i.e., in a frame X-Y that is attached to the cart). It may be assumed that all friction forces (including aerodynamic drag) are negligible, the mass of the cart M remains unchanged, the pressure at the exit plane of each of the jets is atmospheric, and that transient effects (when the jets are turned on and off) are negligible.

It is desired to reduce the speed of the cart using *one* of the air jets so that the cart continues to move to the right with constant velocity $V_F < V_I$. Using a control-volume analysis, determine how long the jet should be active.

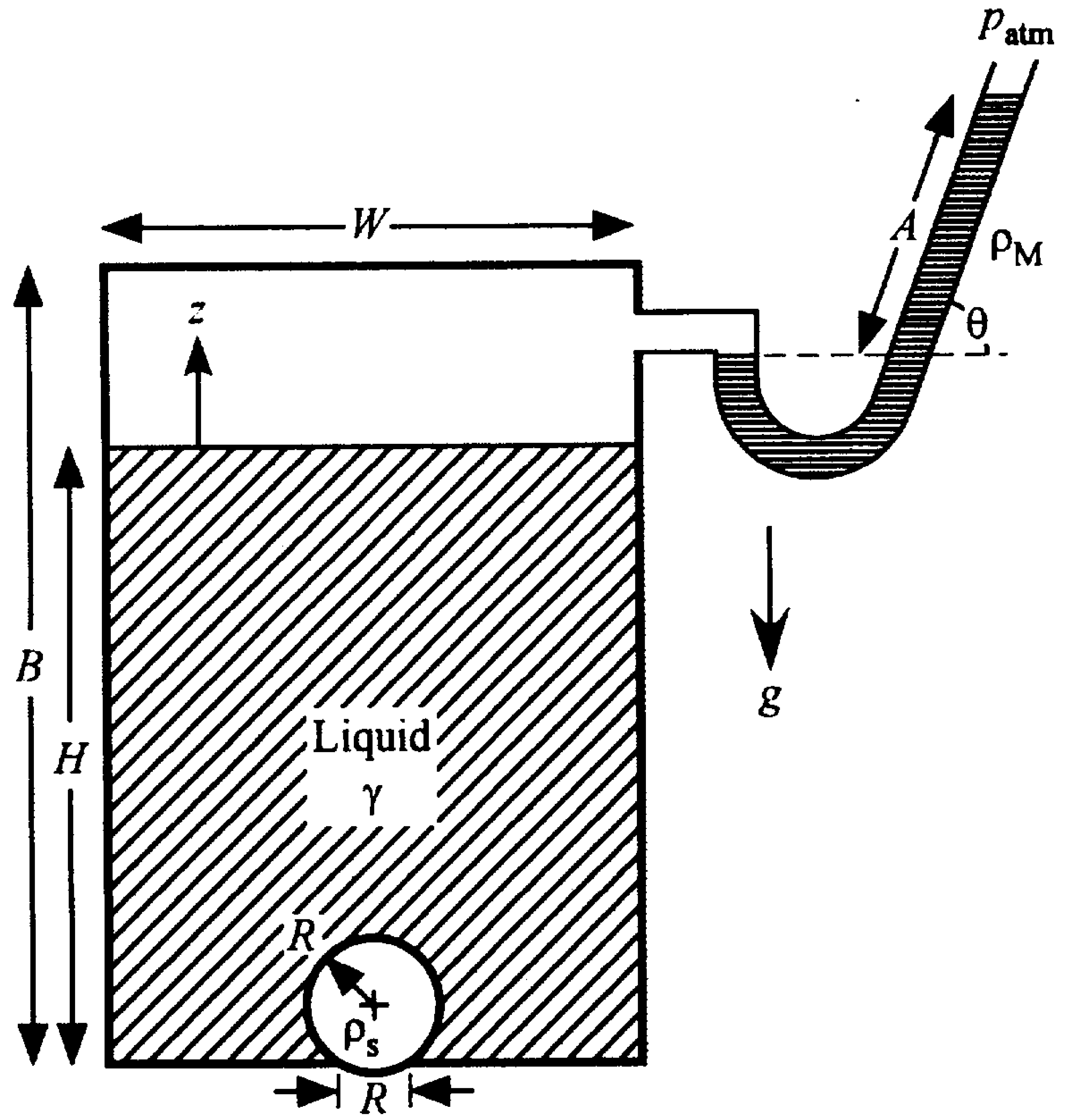


2. A cylinder of radius R, axial length L and density ρ_s is used to plug a rectangular hole (dimensions $R \times L$) in the bottom of a rectangular tank. The closed tank, with dimensions as shown in the figure below, is filled to a depth H with a liquid of specific weight γ. A manometer inclined at an angle of θ and filled with a liquid of density ρ_M, measures the pressure of the air above the tank free surface. The air surrounding the tank is at atmospheric pressure p_{atm}.

a) What is the gage pressure distribution in the liquid as a function of z, $p_g(z)$? Note that z starts at the tank free surface.

b) What is the force **F** due to the liquid and air <u>in the tank</u> acting on the cylinder? What is the line of action of this force?

c) What is then the minimum force **D** required to dislodge the cylindrical "plug" at the bottom of the tank?



3. Consider a 2-D, steady, planar, incompressible, fully developed flow between two stationary parallel plates placed $2H$ distance apart. The fluid is allowed to slip by the walls at a slip velocity given by $u_w = -\frac{1}{B}(\tau_{xy})$, where B is a slip coefficient.

Analyze this flow to obtain:

a) the velocity profile between the two walls,

b) a relationship between volume flow rate and pressure drop, and

c) condition(s) under which your solution reduces to that for classical Poiseuille flow.

4. A point source of momentum flux produces a 2-D laminar jet as shown below. At some point x downstream the jet centerline velocity u_c and half-width δ depend on the following parameters: distance to the point source x, fluid density ρ, kinematic viscosity ν, and the source momentum flux strength M^*.

a) Find all appropriate dimensionless groups for this problem. (Finding or knowing the units of momentum flux is part of this problem).

b) The flow in the jet satisfies a horizontal momentum equation of boundary-layer form $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2}$, and the horizontal momentum flux of the jet remains constant.
Using this information, determine how the jet centerline velocity and half-width vary with x. Rewrite the dimensionless forms of u_c and δ using this scaling on x to determine dimensionless *constants* for these parameters. Note: You will not find the values of the constants only the forms.