GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

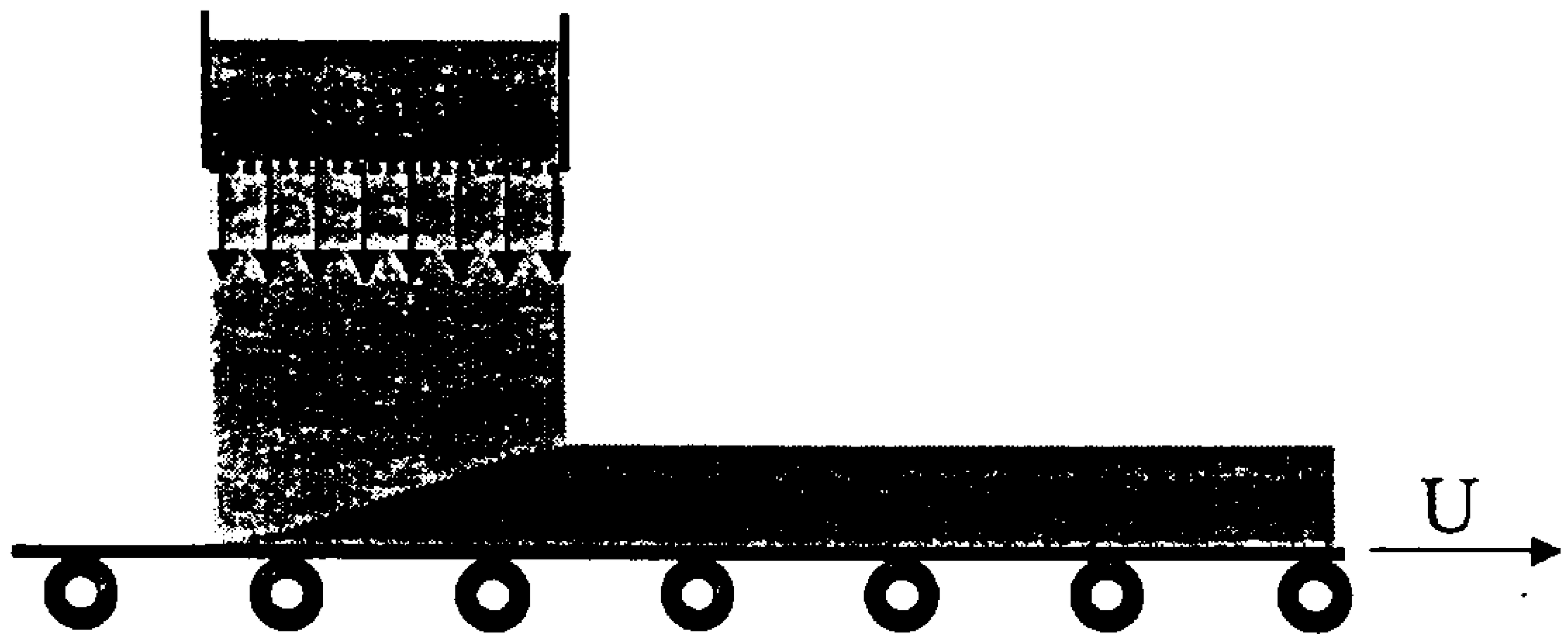
Ph.D. Qualifiers Exam - Fall Semester 2000

Fluids
EXAM AREA

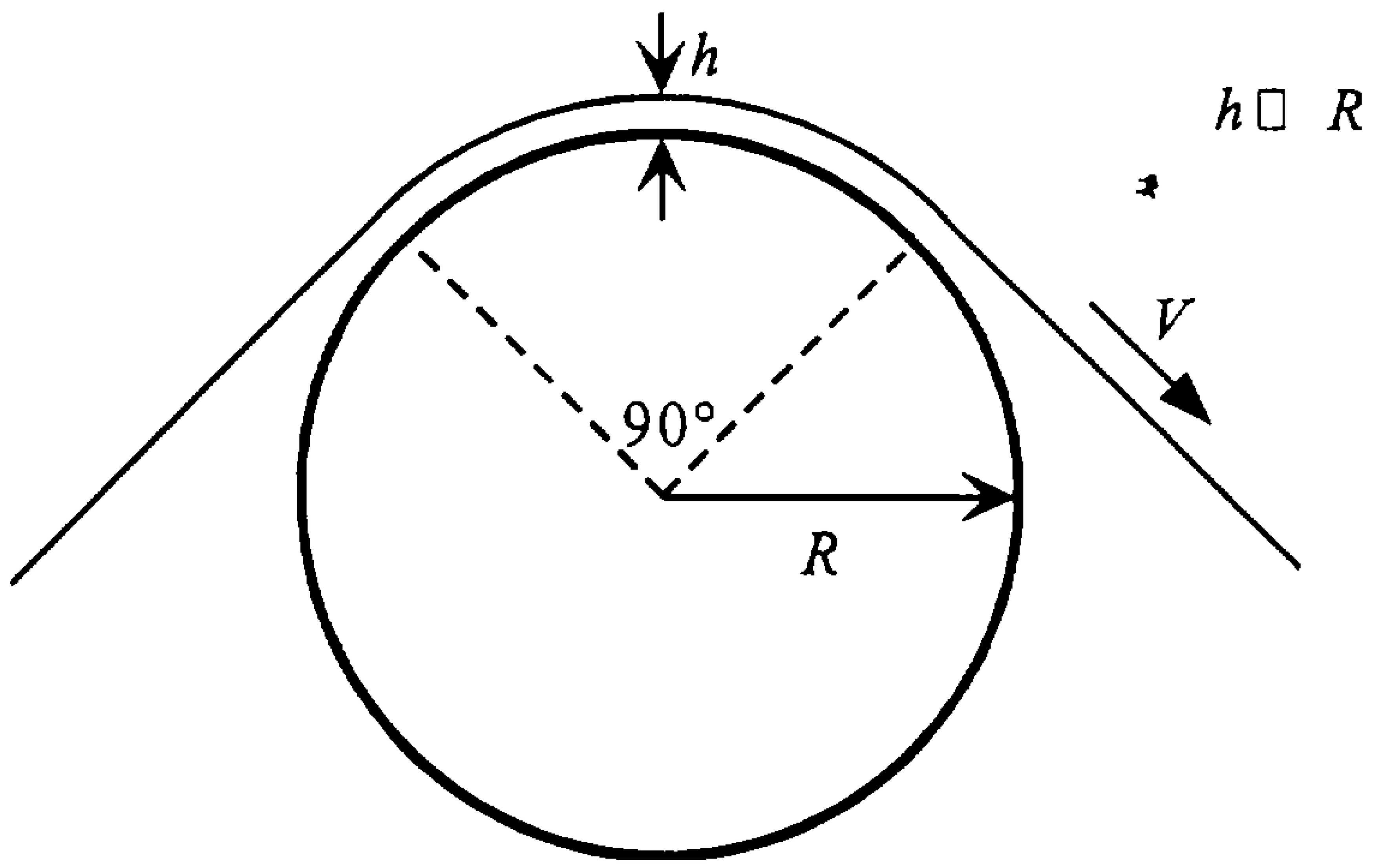
Assigned Number **(DO NOT SIGN YOUR NAME)**

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

1) Consider a conveyor belt that is moving to the right on frictionless rollers at constant velocity U [m/sec] as shown in the figure below (it is assumed that the belt does not sag or bend between the rollers). Sand is continuously dumped onto the belt at a rate that results in a layer of uniform thickness of M Kg per meter of belt. Using control volume analysis and subject to the assumptions given determine what force, if any, is required to drive the belt. Explain why.



2) A thin sheet of steel is pulled over a large cylindrical roller (radius R, length L) as shown below. A thin film of lubricant of thickness h and viscosity μ is between the sheet and the roller over a 90° arc. Find the force F required to move the sheet at a speed V if the roller is held stationary.



Now the roller is allowed to rotate about its center. The roller has a frictional torque $T = C\omega$, where C is a constant and ω is the angular velocity of the roller. Find the force F required to move the sheet at the speed V. Find the angular velocity ω, and comment on the limits when $C \to 0$ and $C \to \infty$.

3) Consider inviscid and steady flows on Earth where pressure gradient effects are negligible. Write the local form of the momentum equation for this type of flow, and nondimensionalize this equation using characteristic scales. What is the important dimensionless group that characterizes these flows? Show that this group (call it Π), derived using the momentum equation, also describes the relative importance of the potential and kinetic energies of the flow.

It is known that the propagation speed of surface waves in channels, including tidal waves or tsunami, are described by the equation $\Pi \approx 1$, where the characteristic length is the channel depth. The largest recorded tsunami, due to an earthquake in Chile in 1960, crossed the Pacific Ocean and struck the coast of Japan 23 hours later. If the average depth of the Pacific is about 4.6 km, estimate the distance between (the coasts of) Japan and Chile.

4) A gate with a mass m and length $2L$ is suspended at one end by a hinge at the free surface of a reservoir. The bottom of the gate is free to move. The gate is at an angle θ with respect to the vertical. The reservoir contains two layers of different liquids:

- the upper liquid layer of depth L has a specific weight γ; and
- the lower liquid layer, also of depth L, has a specific weight $C\gamma$, where C is a constant ($C > 1$).

Assume that everything has a unit dimension normal to the page.

a) What is the net pressure force $\vec{\mathbf{F}}_p$ due to these two liquids on the gate? Assume that atmospheric pressure P_{atm} acts upon the other side of the gate.

b) Determine an expression for θ, the equilibrium angle for the gate. Note that you are NOT required to solve for θ.

c) Now consider the more general case where a positive gauge pressure P_g acts upon the other side of the gate. Will θ_g, the angle of the gate in this case, be larger or smaller than θ, the angle of the gate when $P_g = 0$? Please explain your answer.