1. Two immiscible, incompressible, viscous fluids having the same densities but different viscosities are contained between two infinite, horizontal, parallel plates (Fig.1). The bottom plate is fixed and the upper plate moves with a constant velocity U. Determine the velocity at the interface. Express your answer in terms of U, μ_1, μ_2. The motion of the fluid is caused entirely by the movement of the upper plate; that is, there is no pressure gradient in the x direction. The fluid velocity and shearing stress are continuous across the interface between the two fluids. Assume laminar flow.

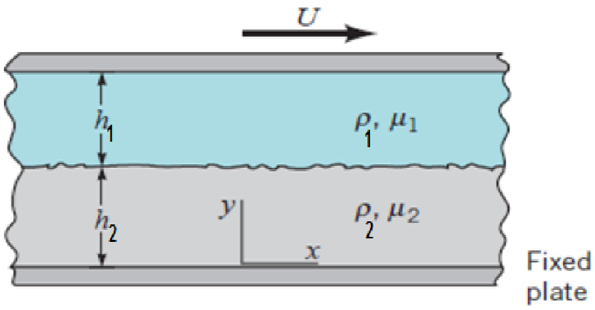

Fig. 1

2. An incompressible Newtonian fluid flows steadily between two infinitely long, concentric cylinders as shown in Fig. 2. The outer cylinder is fixed, but the inner cylinder moves with a longitudinal velocity V_0 as shown. The pressure gradient in the axial direction is $(-\Delta p/l)$. For what value of V_0 will the drag on the inner cylinder be zero? Assume that the flow is laminar, axisymmetric, and fully developed.

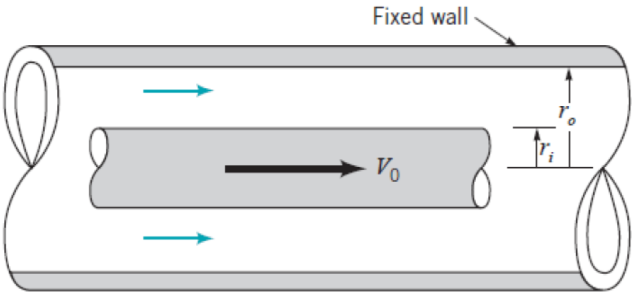

Fig. 2

3. Consider a viscous film of liquid draining uniformly down the side of a vertical rod of radius a, as in Fig. 3. At some distance down the rod the film will approach a terminal or fully developed draining flow of constant outer radius b, with $v_z = v_z(\theta)$, $v_\theta = v_r = 0$. Assume that the atmosphere offers no shear resistance to the film motion. Derive a differential equation for v_z, state the proper boundary conditions, and solve for the film velocity distribution. How does the film radius b relate to the total film volume flow rate Q?

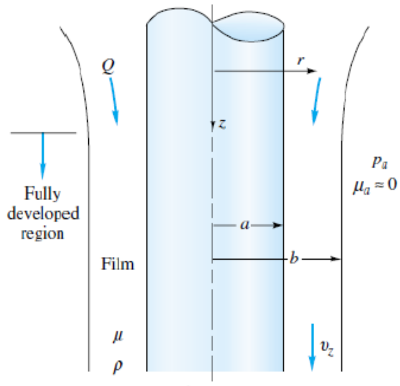

Fig. 3

4. A solid circular cylinder of radius R rotates at angular velocity Ω in a viscous incompressible fluid which is at rest far from the cylinder, as in Fig. 4. Make simplifying assumptions and derive the governing differential equation and boundary conditions for the velocity field v_θ in the fluid. Do not solve unless you are obsessed with this problem. What is the steady-state flow field for this problem?

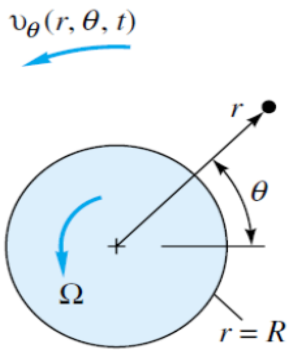

Fig. 4

5. The velocity profile for laminar flow between two plates, as in Fig.5 is:

$u = 6u_{max}(h-y)h_2$, $v = w = 0$. If the wall temperature is T_w at both walls, use the incompressible flow energy equation to solve for the temperature distribution $T(y)$ between the walls for steady flow.

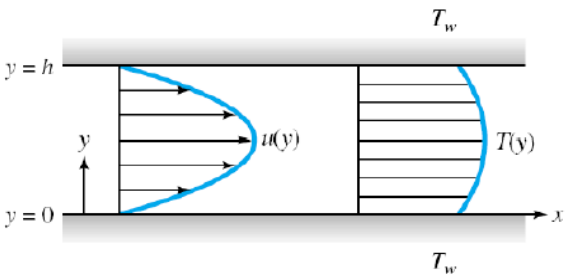

Fig. 5