1. A propeller-driven airplane cruises at speed V . The airplane is equipped with a single propeller of diameter d that develops a thrust T when operating at N revolutions per minute. It is given that the air density and viscosity at the cruise altitude are ρ . and μ, respectively.

    a. Using dimensional analysis, determine the relevant dimensionless groups for this problem. Use N, V, and ρ as the repeating parameters..

    b. The single propeller system described above is replaced a two-propeller system where the new propellers are geometrically-similar to the single propeller, and together produce the same total thrust so that the airplane can fly at the same cruise speed and altitude. Determine the diameter d_2 and the rotational speed N_2 of each of the replacement propellers.

    c. What change in power, if any, is required to operate the two propellers?

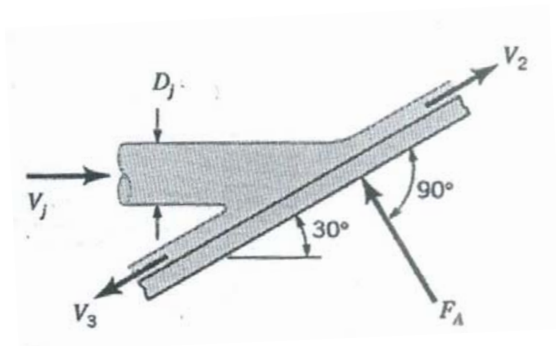
    d. Based on your dimensional analysis, determine whether the viscous effects are the same for the propellers in each of the systems. Explain briefly

2. A horizontal circular air jet strikes a stationary flat plate as shown in the figure below. The jet velocity and diameter are V_j and D_j, respectively. Assume that the air velocity magnitude remains constant as the air flows over the plate surface in the direction shown, (Hint: this means that $V_j = V_2 = V_3$, and the shear force acting along the plate is zero)

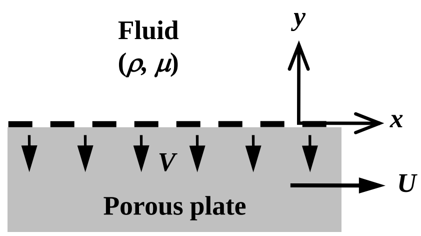
   a. Determine the magnitude of F_A, the anchoring force required to hold the plate stationary.

   b. Determine the magnitude of F_A, the anchoring force required to allow the plate to move to the right at a constant speed V_p.

   c. If the plate is held stationary, determine the fraction of mass flow along the plate surface in each of the two directions shown.



3. A porous horizontal plate moves to the right with a constant velocity U through a still viscous Newtonian fluid of constant density ρ and constant viscosity μ. Suction is applied through the plate so that the fluid has a speed V normal to the surface of the plate. You may assume that: the flow is steady and laminar, body forces and pressure gradients are negligible, the flow is one-dimensional, and there is no flow normal to the page.



a. What are the boundary conditions on the velocity field $\vec{\mathbf{V}}$ for this flow?

b. Find the velocity field $\vec{\mathbf{V}}$.

c. What happens to $\vec{\mathbf{V}}$ if fluid is injected at a constant speed V instead of suctioned through the porous plate?

4) A 2-m-diameter circular tank open at the top and partially filled with water rotates about its vertical axis at a constant rate of rotation, ω. When the tank is at rest, the height of the water in the tank is 1 m.

   a. Describe the motion of the water after the tank has been rotating at a constant ω for a long time.

   b. What is ω_m at which the bottom surface of the tank is first exposed to air? (no water spills out of the tank)

   c. Determine the maximum water height when the tank is rotating at $\omega = \omega_m$.