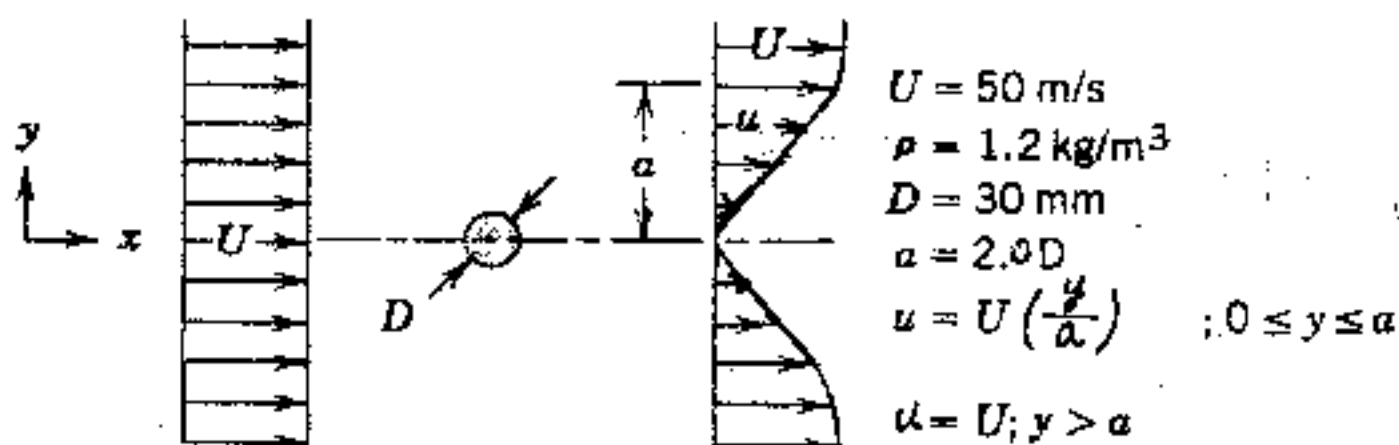


- (15%)1. The drag force of a device is to be predicted, based on wind tunnel test data. The prototype of the device, a 200 mm diameter sphere, is to be towed at 3 m/s in water. Determine the required test speed of the model in the air for simulating the behavior between the prototype and model. If the drag of the model at test condition is 20 N, estimate the drag of the prototype in Newtons.

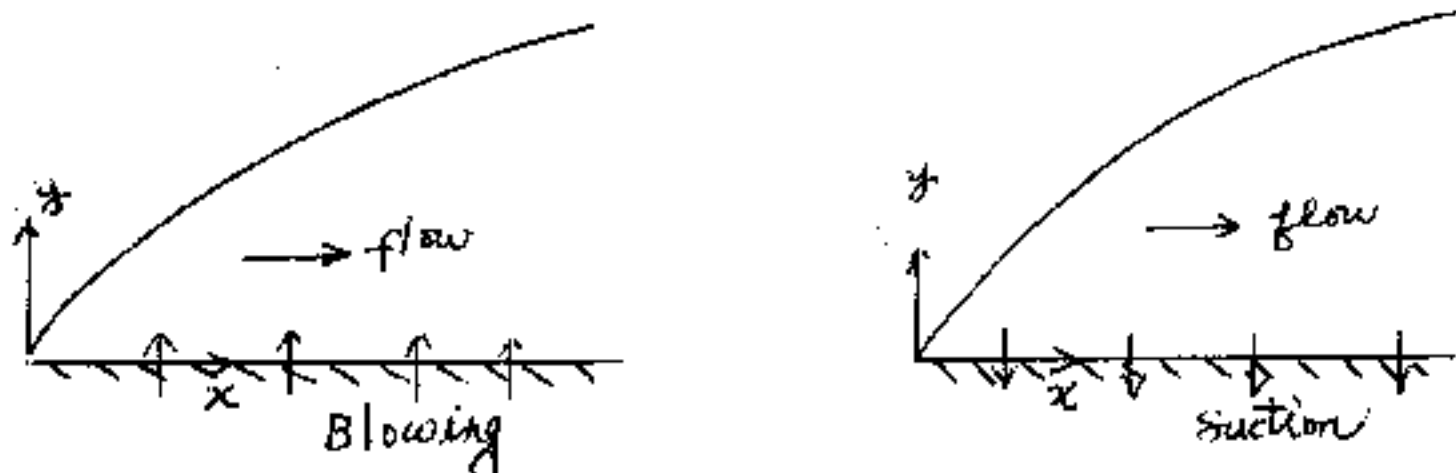
$$\rho_{\text{water}} : 1000 \text{ kg/m}^3, \quad \rho_{\text{air}} : 1 \text{ kg/m}^3, \quad \nu_{\text{water}} : 1.5 \times 10^{-6} \text{ m}^2/\text{s}, \quad \nu_{\text{air}} : 1.5 \times 10^{-5} \text{ m}^2/\text{s}$$

[Hint: Use dimension analysis method]

- (15%)2. Experimental measurements are made in a low-speed air jet to determine the drag force in the x direction on a cylinder. Results from velocity measurements at two sections, where the pressure is uniform and equal, are shown in the figure below. Evaluate the drag force on the cylinder per unit width. The flow is steady and the body force is neglected.

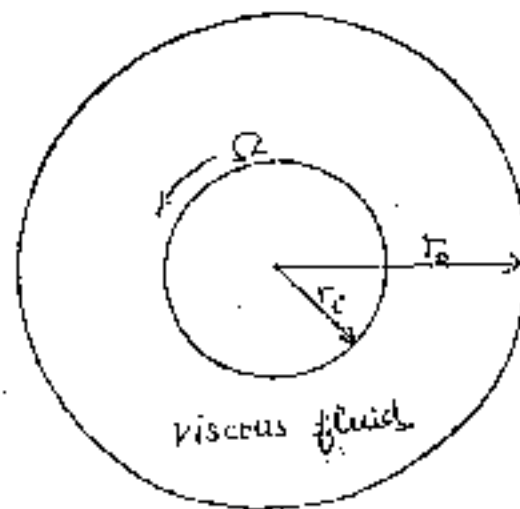


- (10%)3. Consider a laminar boundary layer flow over a flat plate. The flow will undergo a transition to a turbulent state at a certain critical Reynolds number. Now a flow of the same fluid is blowing into or sucking out of the boundary layer. Will the flow transition become earlier or later? Justify your answer according to the momentum transport in the flow.



(20%) 4. Consider steady laminar viscous flow between two concentric long cylinder.

- If the inner cylinder rotates counterclockwise at angular velocity Ω and the outer cylinder is fixed, derive an expression for the tangential velocity $V_\theta(r)$ for the fluid between the cylinders.
- If the inner cylinder moves axially at speed V and the outer cylinder is fixed, derive an expression for the axial velocity $V_z(r)$ in the fluid.
- If the inner cylinder is both rotating and moves axially, can the velocity field in the fluid be obtained by simply adding the solutions in parts (a) and (b) linearly.
- When V or Ω is relatively high, what do you expect to happen in the fluid?



5. A thermocouple is used to measure the temperature of flame in combustion research. Due to the heat loss from the bead of thermocouple, the measurement of temperature directly from the signal of the thermocouple must be corrected in order to obtain the correct temperature of the flame. Please develop a mathematical model for correcting the measurement. Explain your physical model and be sure that you list all your assumptions associated with the physical model. (15%)

6. In various manufacturing processes a wide sheet of thin material is drawn out steadily from a slot (as shown in Fig. a). Assume that the flow of air in the neighborhood of the sheet remains steady and laminar. The problem may then be expressed as that shown in Fig. b. Formulate the problem and determine the temperature distribution, θ . The convective heat transfer coefficient h is assumed constant. (25%)

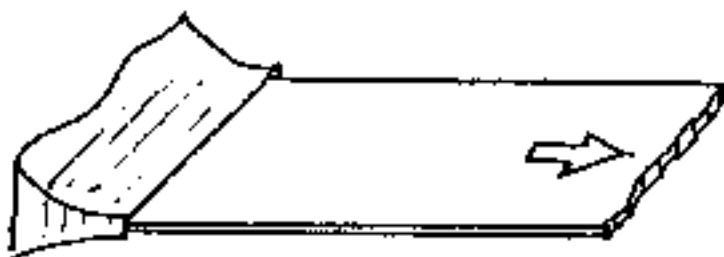


Fig. a

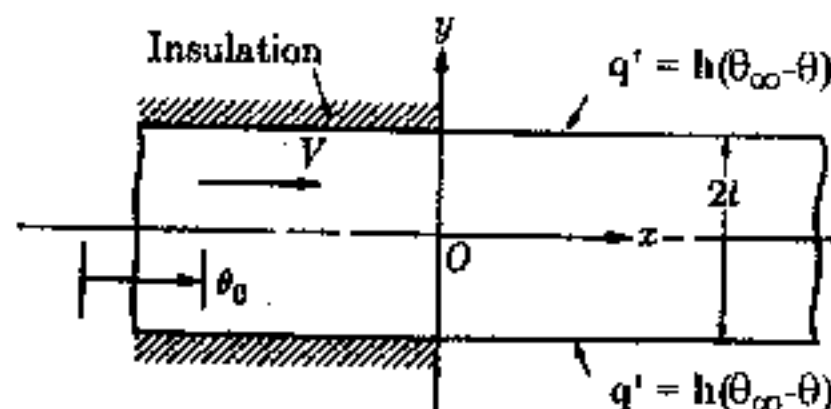


Fig. b