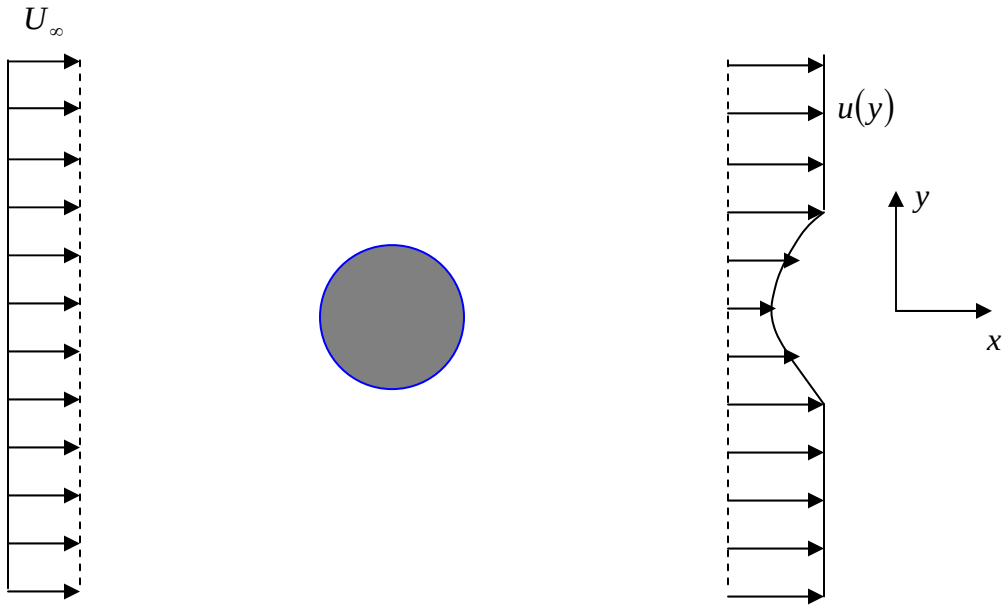
EXAM #1 58:160

1. Consider an experiment in which the drag on a two-dimensional body immersed in a steady incompressible flow can be determined from measurement of the velocity distributions far upstream and downstream of the body (figure below). Velocity far upstream is the uniform flow U_∞, and that in the wake of the body is measured to be $u(y)$, which is less than U_∞ due to the drag of the body. Find the drag force D per unit length of the body.



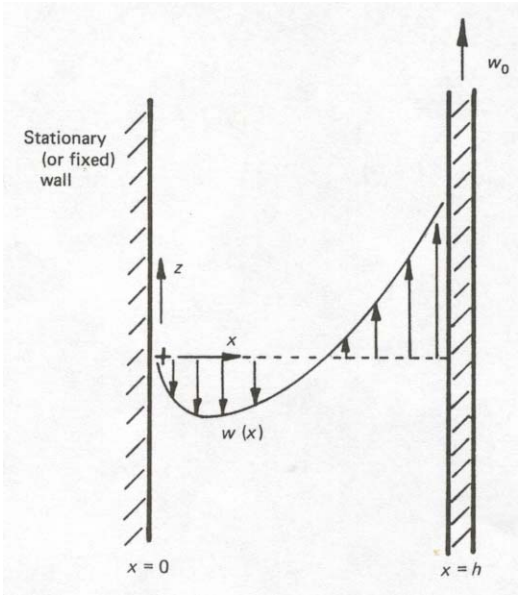
2. Consider a steady, low-speed flow of a viscous fluid between two infinitely long, parallel, vertical plates, spaced a distance *h* apart. As shown in Figure below, the velocity variations take place in the x, z plane. The flow is completely independent of *y*. Because the flow is confined between parallel plates that are infinitely long, the velocity components do not vary in the z direction. Hence, this flow is fully developed in the z (or vertical) direction.

   The wall on the left ($x = 0$) is stationary; the wall on the right ($x = h$) is moving upward at a constant speed, w_0. Assume that all pressure gradients are negligible, but that we cannot neglect the effects of gravity, which acts in the negative z direction.

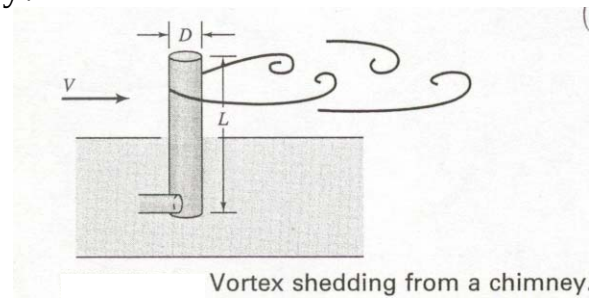
   (a). Find expressions for *u*, *v*, and *w*.

   (b). What is the value of *w* at the midpoint of the channel, that is, at $x = h/2$?

   (c). Develop relation between w_0, g, h, ρ, and μ so that there is zero net mass flow across any horizontal plane, that is, any plane for which $z =$ constant.



3. When wind blows over a chimney, vortices are shedding in the wake, as shown in the figure. The non-dimensionless shedding frequency f depends on chimney diameter D, chimney length L, velocity V, and kinematic viscosity ν.
   (a). Find dimensionless f which depends on dimensionless groups.
   (b). If a $\frac{1}{10}$ scale model were to be tested in a wind tunnel and full dynamic similarity was required:
      (i) What air velocity would be necessary in the wind tunnel compared to the wind velocity experienced by the full scale chimney?
      (ii) What shedding frequency would be observed in the wind tunnel compared to the shedding frequency generated by the full scale chimney?



Vortex shedding from a chimney

4. Water (density ρ=1,000 kg/m^3, kinematic viscosity ν=10^{-6} m^2/s) flows with the average velocity of V=10 m/s in a smooth pipe of diameter D=10 cm.
   (a). Find the thickness of the laminar sublayer.
   (b). Where does the turbulent core begin?
   (c). Write the equations of the velocity distribution in the pipe
   (d). What are the velocities at the edge of the laminar sublayer, at the beginning of the turbulent core, and at the pipe centerline?