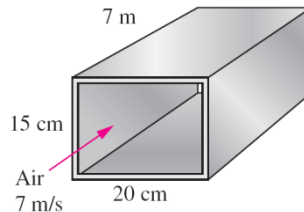


1. Air enters a 7-m-long section of a rectangular duct of cross section 15 cm x 20 cm made of commercial steel ($\epsilon=0.045\text{mm}$) at 1 atm and 35°C at an average velocity of 7 m/s. Disregarding the entrance effects, determine the fan power needed to overcome the pressure losses in this section of the duct. (Air at 35°C : $\rho_{\text{air}}= 1.145 \text{ kg/m}^3$, $\nu_{\text{air}}= 1.655\text{E-}5 \text{ m}^2/\text{s}$)



2. Air at 20°C flows through a 14-cm-diameter smooth tube under fully developed conditions. The shear stress on the wall is $\tau_w=0.062 \text{ Pa}$. Find: (a) Friction velocity. (b) Velocity at the edge of inner layer. (c) Centerline velocity (V at $r=0$). Assume that the pipe roughness is not negligible and it is 0.005 m , (d) what would be centerline velocity for the rough pipe? (Air at 20°C : $\rho_{\text{air}}= 1.205 \text{ kg/m}^3$, $\nu_{\text{air}}= 1.51\text{E-}5 \text{ m}^2/\text{s}$)
3. A boundary layer develops along the walls of a rectangular wind tunnel. The air is at 20°C and atmospheric pressure. The boundary layer starts upstream of the contraction and grows into the test section, as shown in Fig. a. By the time it reaches the test section, the boundary layer is fully turbulent. The boundary layer profile and its thickness are measured at both the beginning ($x = x_1$) and the end ($x = x_2$) of the bottom wall of the wind tunnel test section, as shown in Fig. b. The test section is 1.8 m long and 0.50 m wide (into the page in figure) and wind tunnel velocity is $V=10 \text{ m/s}$. The following measurements are made:

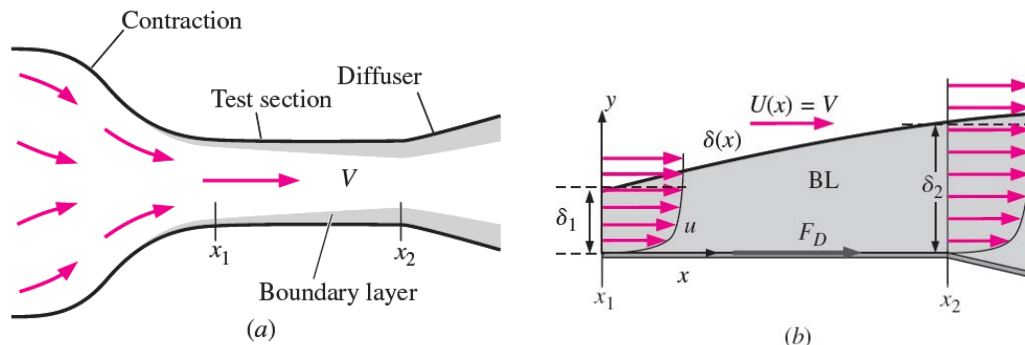
$$\delta_1 = 4.2 \text{ cm} \quad \delta_2 = 7.7 \text{ cm}$$

At both locations the boundary layer profile fits better to a one-eighth-power law approximation:

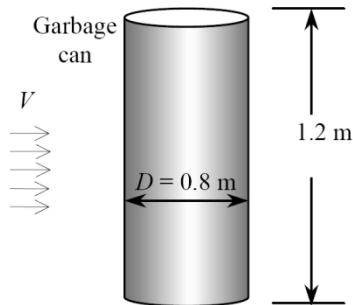
$$\frac{u}{U} \cong \left(\frac{y}{\delta} \right)^{1/8} \quad y \leq \delta$$

$$\frac{u}{U} = 1 \quad y \geq \delta$$

Estimate (a) momentum thickness in term of boundary layer thickness δ . (b) Use momentum thickness to find local shear stress τ_w in term of boundary layer thickness δ . (c) Integrate the local shear stress τ_w and compute the total skin friction drag force F_D acting on the bottom wall of the wind tunnel test section. (Air at 20°C : $\rho_{\text{air}}= 1.205 \text{ kg/m}^3$, $\nu_{\text{air}}= 1.51\text{E-}5 \text{ m}^2/\text{s}$)



4. A 0.80-m-diameter, 1.2-m-high garbage can is found in the morning tipped over due to high winds during the night. Assuming the average density of the garbage inside to be 150 kg/m^3 and taking the air density to be 1.25 kg/m^3 , estimate the wind velocity during the night when the can was tipped over. Take the drag coefficient of the can to be 0.7.



5. Consider the flow of air into the floor attachment nozzle of a typical household vacuum cleaner. The width of the nozzle inlet slot is $w = 2.0 \text{ mm}$, and its length is $L = 35.0 \text{ cm}$. The slot is held a distance $b = 2.0 \text{ cm}$ above the floor, as shown in Fig a. The total volume flow rate through the vacuum hose is $Q = 0.110 \text{ m}^3/\text{s}$. Consider the flow field in the center plane of the attachment (the xy -plane in Fig a) as a 2D sink line flow near a wall, as shown in Fig b. The strength of the sink (m) can be estimated by $m = (Q/L)/(2\pi)$. Calculate (a) the velocity and (b) gage pressure distribution along the x axis. (c) What is the maximum magnitude of speed along the floor, and where does it occur? (The vacuum cleaner should be most effective where speed is maximum or pressure is minimum)

