

*Solution:* (a) For air at 20°C and 1 atm, take  $\rho = 1.2 \text{ kg/m}^3$  and  $\mu = 1.8 \times 10^{-5} \text{ kg/m-s}$ . First, find, in order, the Reynolds number, the skin friction coefficient, and the wall shear stress:

- P7.27 Consider flow at 2 m/s past a thin flat plate. At a position 40 cm downstream from the leading edge, estimate the wall shear stress for (a) air, and (b) water at 20°C and 1 atm. (c) How can you quickly show why the result for (b) is so much (215 times) larger than (a)?

(a) air  $\rho = 1.2 \text{ kg/m}^3 \quad \mu = 1.8 \times 10^{-5} \text{ kg/m-s}$

Re<sub>x</sub> =  $\frac{\rho U x}{\mu} = \frac{1.2 \times 10^3 \text{ kg/m}^3 \times 2 \text{ m/s} \times 0.4 \text{ m}}{1.8 \times 10^{-5} \text{ kg/m-s}}$  in order, the  
Reynolds number, the skin friction coefficient, and the wall shear stress

$$Re_x = \frac{\rho U x}{\mu} = 53,300 \text{ laminar}$$

$$C_f = 0.664 / Re_x^{1/2} = 0.00288$$

$$\tau_w = \frac{1}{2} \rho U^2 C_f = 0.0069 \text{ Pa}$$

$$\tau_w = C_f \frac{\rho U^2}{2} = (0.00288) \frac{998 \text{ kg/m}^3}{2} (2 \text{ m/s})^2 = 1.48 \text{ Pa} \quad \text{Ans (b)}$$

(b) water  $\rho = 998 \text{ kg/m}^3 \quad \mu = 0.001 \text{ kg/m-s} \quad \frac{\mu_w}{\mu_a} = 56$

$$Re_x = 798,000 \text{ laminar}$$

$$C_f = 0.000743$$

$$\tau_w = 1.48 \text{ Pa} \quad \tau_{w,\text{water}} / \tau_{w,\text{air}} = 215$$

(c)  $\tau_w = 0.332 \rho^{1/2} \mu^{1/2} U^{1.5} x^{-1/2}$

$$\tau_{w,\text{water}} / \tau_{w,\text{air}} = \left( \frac{\rho_w}{\rho_a} \right)^{1/2} \left( \frac{\mu_w}{\mu_a} \right)^{1/2} = 215$$

Recall laminar pipe flow:

$$\tau_w = \frac{8 \mu T}{D} \propto U \text{ at independent } x$$