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 $\rho = 1.2\ kg/m^3$ $\mu = 1.8E{-5}\ kg/m\text{-}s$

$Re = \rho U x/\mu = 53{,}300$ laminar

$c_f = .664/Re_x^{1/2} = .00288$

$\tau_w = \frac{1}{2}\rho U^2 c_f = .0069\ Pa$

$\frac{\rho_w}{\rho_a} = 832$

(b) Water $\rho = 998\ kg/m^3$ $\mu = .001\ kg/m\text{-}s$ $\frac{\mu_w}{\mu_a} = 56$

$Re = 798{,}000$ laminar

$c_f = .000743$

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

(c) $\tau_w = .332\,\rho^{1/2}\mu^{1/2}U^{1.5}x^{-1/2}$

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

Recall laminar pipe flow:

$\tau_w = \frac{8\mu U}{D} \propto U$ and independent x