P7.43 In the flow of air at 20°C and 1 atm past a flat plate in Fig. P7.43, the wall shear is to be determined at position x by a *floating element* (a small area connected to a strain-gage force measurement). At $x = 2$ m, the element indicates a shear stress of 2.1 Pa. Assuming turbulent flow from the leading edge, estimate (a) the stream velocity U, (b) the boundary layer thickness δ at the element, and (c) the boundary-layer velocity u, in m/s, at 5 mm above the element.

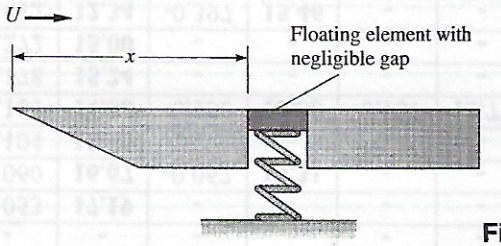

Fig. P7.43

(a) $c_f = .027 / Re_x^{1/7} = \dfrac{\tau_w}{\frac{1}{2}\rho U^2}$

$\tau_w = 2.1\ Pa = c_f \times \frac{1}{2}\rho U^2$

$\rho = 1.2\ kg/m^3$

$\mu = 1.8E-5\ kg/m\cdot s$

$= \dfrac{.027}{\left(\frac{\rho U x}{\mu}\right)^{1/7}} \times \frac{1}{2}\rho U^2$

Solve $U = 34\ m/s$ $\quad Re_x = 4.54E6$

OK turbulent

(b) $\delta = \dfrac{.16x}{Re_x^{1/7}} = 36\ mm$

(c) $u/u^* = \frac{1}{\kappa} \ln \dfrac{y u^*}{\nu} + B \qquad y = 5\ mm$

$u/1.32 = \dfrac{1}{.41} \ln \dfrac{.005 \times 1.32}{1.5E-5} + 5 \qquad u^* = \sqrt{\dfrac{\tau_w}{\rho}} = 1.32\ \dfrac{m}{s}$

$u = 26.3\ m/s$

$\nu = \mu/\rho$

$\kappa = .41$

$B = 5$