

9.21 A smooth, flat plate of length  $\ell = 6$  m and width  $b = 4$  m is placed in water with an upstream velocity of  $U = 0.5$  m/s. Determine the boundary layer thickness and the wall shear stress at the center and the trailing edge of the plate. Assume a laminar boundary layer.

$$\delta = 5 \sqrt{\frac{\nu x}{U}} = 5 \sqrt{\frac{(1.12 \times 10^{-6} \frac{\text{m}^2}{\text{s}}) x}{0.5 \frac{\text{m}}{\text{s}}}} = 7.48 \times 10^{-3} \sqrt{x} \text{ m, where } x \sim \text{m}$$

and

$$\tau_w = 0.332 U^{3/2} \sqrt{\frac{\rho \mu}{x}} = 0.332 (0.5 \frac{\text{m}}{\text{s}})^{3/2} \sqrt{\frac{(999 \frac{\text{kg}}{\text{m}^3})(1.12 \times 10^{-3} \frac{\text{N}\cdot\text{s}}{\text{m}^2})}{x}}$$

$$= \frac{0.124}{\sqrt{x}} \frac{\text{N}}{\text{m}^2}, \text{ where } x \sim \text{m}$$

Thus, at  $x = 3$  m

$$\delta = 7.48 \times 10^{-3} \sqrt{3} = \underline{\underline{0.0130 \text{ m}}}$$

$$\tau_w = \frac{0.124}{\sqrt{3}} = \underline{\underline{0.0716 \frac{\text{N}}{\text{m}^2}}}$$

while at  $x = 6$  m

$$\delta = 7.48 \times 10^{-3} \sqrt{6} = \underline{\underline{0.0183 \text{ m}}}$$

$$\tau_w = \frac{0.124}{\sqrt{6}} = \underline{\underline{0.0506 \frac{\text{N}}{\text{m}^2}}}$$