9.21

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.

$$\delta = 5\sqrt{\frac{\nu x}{U}} = 5\sqrt{\frac{(1.12\times10^{-6}\,\frac{m^2}{s})\,x}{0.5\,\frac{m}{s}}} = 7.48\times10^{-3}\sqrt{x}\ \text{m, where } x\sim\text{m}$$

and

$$\tau_w = 0.332\,U^{3/2}\sqrt{\frac{\rho\mu}{x}} = 0.332\,(0.5\tfrac{m}{s})^{3/2}\sqrt{\frac{(999\,\frac{kg}{m^3})(1.12\times10^{-3}\,\frac{N\cdot s}{m^2})}{x}}$$

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

Thus, at $x = 3$ m $\quad \delta = 7.48\times10^{-3}\sqrt{3} = \underline{\underline{0.0130\ \text{m}}}$

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

while at $x = 6$ m $\quad \delta = 7.48\times10^{-3}\sqrt{6} = \underline{\underline{0.0183\ \text{m}}}$

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