Example: A flat plate 1.2 ft long and 6 ft wide is placed in a seawater flow of 40 ft/s, with ρ = 1.99 slugs/ft^3 and ν = 0.000011 ft^2/s. (a) Estimate the boundary layer thickness at the end of the plate. Estimate the friction drag for (b) turbulent smooth-wall flow from the leading edge, (c) laminar turbulent flow with $Re_{trsans} = 5 \times 10^5$.

Part (a): The Reynolds number is

$$Re_L = \frac{U_\infty L}{\nu} = \frac{(40\ \text{ft/s})(1.2\ \text{ft})}{0.000011\ \ \text{ft}^2/\text{s}} = 4.36 \times 10^6$$

Thus the trailing-edge flow is certainly turbulent. The maximum boundary layer thickness would occur for turbulent flow starting at the leading edge. The boundary layer thickness is

$$\delta = \left.\frac{0.37x}{Re_x^{\frac{1}{5}}}\right)_{x=L} = \frac{(0.37)(1.2\ \text{ft})}{(4.36 \times 10^6)^{\frac{1}{5}}} = 0.021\ \text{ft} \quad (\approx 0.25\ \text{in})$$

This is about 7.5 times thicker than a fully laminar boundary layer at the same Reynolds number:

$$\delta_{laminar} = \left.\frac{5x}{\sqrt{Re_x}}\right)_{x=L} = \frac{(5)(1.2\ \text{ft})}{\sqrt{4.36 \times 10^6}} = 0.0029\ \text{ft} \quad (\approx 0.034\ \text{in})$$

Part (b): For fully turbulent smooth-wall flow, the friction drag coefficient on one side of the plate is

$$C_f = \frac{0.074}{Re_L^{\frac{1}{5}}} = \frac{0.074}{(4.36 \times 10^6)^{\frac{1}{5}}} = 0.00348$$

Then the friction drag on both sides of the foil is approximately

$$D_f = 2 \times C_f \cdot \frac{1}{2}\rho U_\infty^2 A = 2(0.00348)\left(\frac{1}{2}\right)(1.99)(40)^2(6 \times 1.2) = 80\ \text{lbf}$$

Part (c): With a laminar leading edge and $Re_{trnas} = 5 \times 10^5$,

$$C_f = \frac{0.074}{Re_L^{\frac{1}{5}}} - \frac{1700}{Re_L} = 0.00348 - \frac{1700}{4.36 \times 10^6} = 0.0031$$

The friction drag can be recomputed for this lower friction drag coefficient:

$$D_f = 2 \times C_f \cdot \frac{1}{2}\rho U_\infty^2 A = 71\ \text{lbf}$$