

NAME

Fluids-ID

Quiz 11.

SAE 30 oil at 20°C flows at $U = 10$ ft/s over the upper side of a flat plate of which width $b = 2$ ft and length $L = 5$ ft and area $A = bL = 10$ ft². (a) What is the boundary layer thickness at the middle of the plate and (b) what is the friction drag D_f acting on the plate? Transition to turbulent flow may occur at $Re = 5 \times 10^5$. ($\rho = 1.73$ slug/ft³; $\mu = 0.00607$ slug/ft·s)

Boundary layer thickness:

$$\frac{\delta}{x} = \begin{cases} \frac{5}{\sqrt{Re_x}} & \text{(laminar)} \\ \frac{0.16}{Re_x^{1/7}} & \text{(turbulent)} \end{cases}$$

Friction drag coefficient:

$$C_f = \frac{D_f}{\frac{1}{2}\rho U^2 A} = \begin{cases} \frac{1.328}{\sqrt{Re_L}} & \text{(laminar)} \\ \frac{0.031}{Re_L^{1/7}} & \text{(turbulent)} \end{cases}$$

Solution:

(a)

$$Re_x = \frac{\rho U x}{\mu} \Big|_{x=L/2} = \frac{(1.73)(10)(5/2)}{0.00607} = 7.125 \times 10^3 \quad \text{(Laminar)} \quad (+2 \text{ points})$$

$$\frac{\delta}{x} = \frac{5}{\sqrt{Re_x}} = \frac{5}{\sqrt{1.425 \times 10^4}} = 0.059$$

$$\therefore \delta = 0.059 \left(\frac{L}{2}\right) = (0.059) \left(\frac{5 \text{ ft}}{2}\right) = 0.148 \text{ ft} \quad (+3 \text{ points})$$

(b)

$$Re_L = \frac{\rho U L}{\mu} = \frac{(1.73)(10)(5)}{0.00607} = 1.425 \times 10^4 \quad \text{(Laminar)} \quad (+2 \text{ points})$$

$$C_f = \frac{1.328}{\sqrt{Re_L}} = \frac{1.328}{\sqrt{1.425 \times 10^4}} = 0.0111$$

$$\therefore D_f = \frac{1}{2} \rho U^2 A C_f = \left(\frac{1}{2}\right) (1.73)(10)^2 (10)(0.0111) = 9.6 \text{ lb} \quad (+3 \text{ points})$$