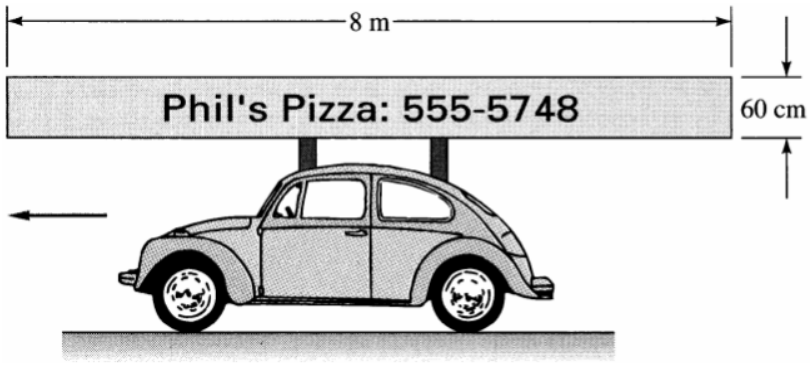
December 2, 2016

NAME

Quiz 14. A delivery vehicle carries a long sign on top, as shown in Figure. If the sign is very thin and the vehicle moves at 29.06 m/s, calculate (a) the boundary layer thickness at 6m from the leading edge and (b) the force on the sign. ($\rho = 1.23\,\mathrm{kg/m^3}$, $\mu = 1.8 \times 10^{-5}\mathrm{kg/ms}$)



Note: Attendance (+2 points), format (+1 point)

Reynolds number:

$$Re_L = \frac{\rho UL}{\mu}, Re_x = \frac{\rho Ux}{\mu}, Re_{critical} \approx 5 \times 10^5$$

Boundary layer thickness:

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

Friction drag coefficient:

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

Solution:

$$Re_x = \frac{\rho Ux}{\mu} = \frac{1.23\times29.06\times6}{1.8\times10^{-5}} = 1.19 \times 10^7 \Rightarrow \text{Turbulent flow (+2)}$$

$$\delta = x\frac{0.16}{Re_x^{\frac{1}{7}}} = 6\frac{0.16}{(1.19\times10^7)^{1/7}} = 0.0936\,m \text{ (+1)}$$

$$Re_L = \frac{\rho UL}{\mu} = \frac{1.2\times29.06\times8}{1.8\times10^{-5}} = 1.55 \times 10^7 \Rightarrow \text{Turbulent flow (+2)}$$

$$C_f = \frac{0.031}{Re_L^{1/7}} = \frac{0.031}{(1.55\times10^7)^{1/7}} = 0.00291 \text{ (+1)}$$

$$D_f = \frac{1}{2}C_f U^2 A = \frac{1}{2}0.00291 \times 1.2 \times 29.06^2 \times (8 \times 0.6 \times 2) = 14N \text{ (+1)}$$