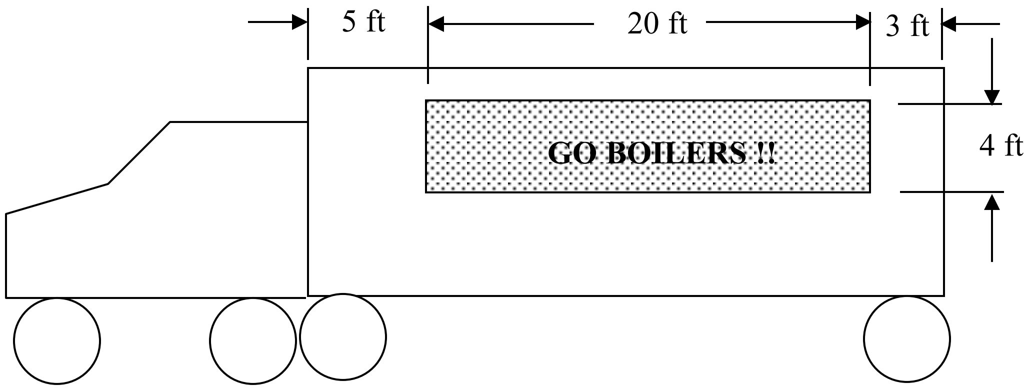
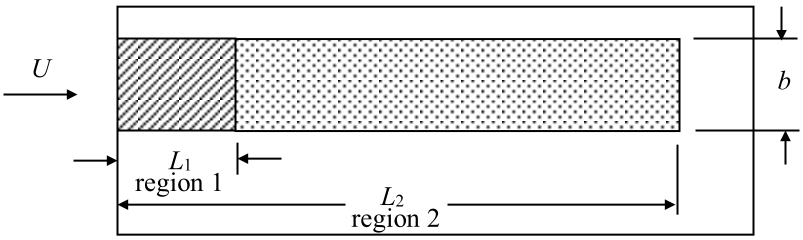
A thin smooth sign is attached to the side of a truck as shown. Estimate the skin friction drag on the sign when the truck speed is 55 mph.



SOLUTION:

Assume that the boundary layer forms at the front of the trailer.



$L_1 = 5$ ft
$L_2 = 25$ ft
$b = 4$ ft
$U = 55$ mph $= 80.7$ ft/s
$\nu_{air} = 1.57*10^{-4}$ ft^2/s
$\rho_{air} = 2.38*10^{-3}$ slugs/ft^3

To find the drag on the sign, determine the drag on region 2 and subtract the drag from region 1.

$$D_{\text{sign}} = D_2 - D_1 \tag{1}$$

where

$$D_i = c_{Di}\tfrac{1}{2}\rho U^2 L_i b \quad (i = 1 \text{ or } 2) \tag{2}$$

Substitute and simplify.

$$D_{\text{sign}} = \tfrac{1}{2}\rho U^2 b\left(c_{D2}L_2 - c_{D1}L_1\right) \tag{3}$$

The drag coefficients are determined from the Reynolds numbers at each region's trailing edge.

$$\text{Re}_1 = \frac{UL_1}{\nu} = \frac{(80.7 \text{ ft/s})(5 \text{ ft})}{\left(1.57*10^{-4} \text{ ft}^2\text{/s}\right)} = 2.6*10^6 \quad \text{(turbulent!)} \tag{4}$$

$$\text{Re}_2 = \frac{UL_2}{\nu} = \frac{(80.7 \text{ ft/s})(25 \text{ ft})}{\left(1.57*10^{-4} \text{ ft}^2\text{/s}\right)} = 1.3*10^7 \quad \text{(turbulent!)} \tag{5}$$

Assume that the flow is fully turbulent throughout regions 1 and 2 (neglect any laminar flow contribution) so that:

$$c_{D1} = \frac{0.0742}{\text{Re}_1^{1/5}} = \frac{0.0742}{\left(2.6*10^6\right)^{1/5}} = 3.87*10^{-3} \tag{6}$$

$$c_{D2} = \frac{0.0742}{\text{Re}_2^{1/5}} = \frac{0.0742}{\left(1.3*10^7\right)^{1/5}} = 2.80*10^{-3} \tag{7}$$

Substitute into Eqn. (3) and evaluate.

$$D_{\text{sign}} = \tfrac{1}{2}\left(2.38*10^{-3} \text{ slugs/ft}^3\right)(80.7 \text{ ft/s})^2(4 \text{ ft})\left[\left(2.80*10^{-3}\right)(25 \text{ ft}) - \left(3.87*10^{-3}\right)(5 \text{ ft})\right]$$

$$\boxed{\therefore D_{\text{sign}} = 1.57 \text{ lb}_\text{f}} \tag{8}$$