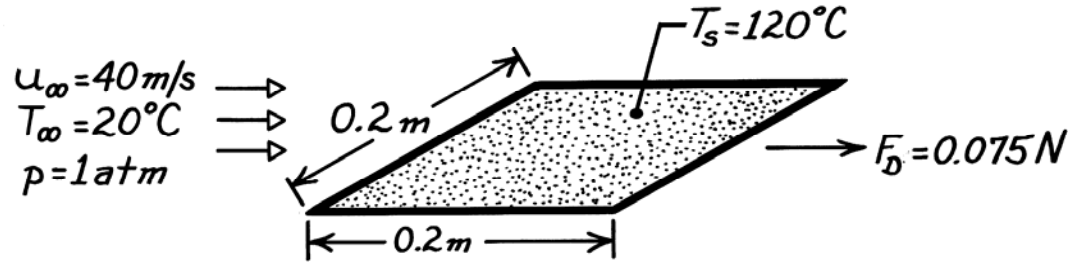
PROBLEM 6.34

KNOWN: Drag force and air flow conditions associated with a flat plate.

FIND: Rate of heat transfer from the plate.

SCHEMATIC:



ASSUMPTIONS: (1) Chilton-Colburn analogy is applicable.

PROPERTIES: *Table A-4,* Air (70°C,1 atm): $\rho = 1.018$ kg/m^3, $c_p = 1009$ J/kg·K, Pr = 0.70, $\nu = 20.22 \times 10^{-6}$ m^2/s.

ANALYSIS: The rate of heat transfer from the plate is

$$q = 2\bar{h}\left(L^2\right)\left(T_s - T_\infty\right)$$

where $\bar{h}$ may be obtained from the Chilton-Colburn analogy,

$$\bar{j}_H = \frac{\bar{C}_f}{2} = \bar{St}\,Pr^{2/3} = \frac{\bar{h}}{\rho\, u_\infty\, c_p} Pr^{2/3}$$

$$\frac{\bar{C}_f}{2} = \frac{1}{2}\frac{\bar{\tau}_s}{\rho\, u_\infty^2/2} = \frac{1}{2}\frac{(0.075\text{ N}/2)/(0.2\text{m})^2}{1.018\text{ kg/m}^3(40\text{ m/s})^2/2} = 5.76\times10^{-4}.$$

Hence,

$$\bar{h} = \frac{C_f}{2}\rho\, u_\infty\, c_p\, Pr^{-2/3}$$

$$\bar{h} = 5.76\times10^{-4}\left(1.018\text{kg/m}^3\right)40\text{m/s}\,(1009\text{J/kg}\cdot\text{K})\,(0.70)^{-2/3}$$

$$\bar{h} = 30\text{ W/m}^2\cdot\text{K}.$$

The heat rate is

$$q = 2\left(30\text{ W/m}^2\cdot\text{K}\right)(0.2\text{m})^2\,(120-20)^\circ\text{C}$$

$$q = 240\text{ W}. \qquad <$$

COMMENTS: Although the flow is laminar over the entire surface ($Re_L = u_\infty L/\nu = 40$ m/s $\times$ 0.2m/20.22×10^{-6} m^2/s $= 4.0 \times 10^5$), the pressure gradient is zero and the Chilton-Colburn analogy is applicable to *average,* as well as *local,* surface conditions. Note that the only contribution to the drag force is made by the surface shear stress.