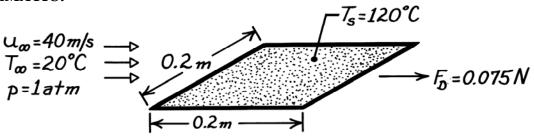
PROBLEM 6.34

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): $\rho = 1.018 \text{ kg/m}^3$, $c_p = 1009 \text{ J/kg·K}$, Pr = 0.70, $v = 20.22 \times 10^{-6} \text{m}^2/\text{s}$.

ANALYSIS: The rate of heat transfer from the plate is

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

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

$$\overline{\mathbf{j}}_{\mathrm{H}} = \frac{\overline{\mathbf{C}}_{\mathrm{f}}}{2} = \overline{\mathbf{S}} \mathbf{t} \operatorname{Pr}^{2/3} = \frac{\mathbf{h}}{\rho \, \mathbf{u}_{\infty} \, \mathbf{c}_{\mathrm{p}}} \operatorname{Pr}^{2/3}$$
$$\frac{\overline{\mathbf{C}}_{\mathrm{f}}}{2} = \frac{1}{2} \frac{\overline{\tau}_{\mathrm{s}}}{\rho \, \mathbf{u}_{\infty}^{2}/2} = \frac{1}{2} \frac{(0.075 \, \mathrm{N}/2)/(0.2 \mathrm{m})^{2}}{1.018 \, \mathrm{kg/m^{3}} \left(40 \, \mathrm{m/s}\right)^{2}/2} = 5.76 \times 10^{-4}.$$

Hence,

$$\overline{h} = \frac{C_{f}}{2} \rho u_{\infty} c_{p} Pr^{-2/3}$$

$$\overline{h} = 5.76 \times 10^{-4} (1.018 \text{kg/m}^{3}) 40 \text{m/s} (1009 \text{J/kg} \cdot \text{K}) (0.70)^{-2/3}$$

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

The heat rate is

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

 $q = 240 \text{ W}.$

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COMMENTS: Although the flow is laminar over the entire surface ($\text{Re}_{\text{L}} = u_{\infty}L/v = 40 \text{ m/s} \times 0.2\text{m}/20.22 \times 10^{-6}\text{m}^2/\text{s} = 4.0 \times 10^5$), 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.

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