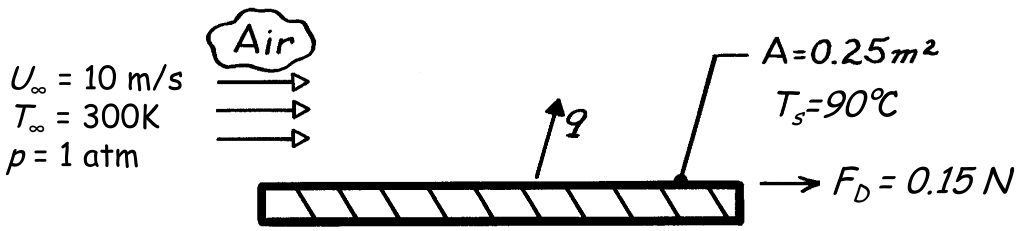
PROBLEM 6.37

KNOWN: Air flow conditions and drag force associated with a heater of prescribed surface temperature and area.

FIND: Required heater power.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Reynolds analogy is applicable, (3) Bottom surface is adiabatic.

PROPERTIES: *Table A-4*, Air (T_f = 325K, 1atm): $\rho = 1.078\ \text{kg/m}^3$, $c_p = 1008\ \text{J/kg·K}$, Pr = 0.704.

ANALYSIS: The average shear stress and friction coefficient are

$$\bar{\tau}_s = \frac{F_D}{A} = \frac{0.15\ \text{N}}{0.25\ \text{m}^2} = 0.6\ \text{N/m}^2$$

$$\bar{C}_f = \frac{\bar{\tau}_s}{\rho\, u_\infty^2/2} = \frac{0.6\ \text{N/m}^2}{1.078\ \text{kg/m}^3 (10\text{m/s})^2/2} = 11.1\times10^{-3}.$$

From the Reynolds analogy,

$$\overline{\text{St}} = \frac{\bar{h}}{\rho\, u_\infty c_p} = \frac{\bar{C}_f}{2}\text{Pr}^{-2/3}.$$

Solving for $\bar{h}$ and substituting numerical values, find

$$\bar{h} = 1.078\ \text{kg/m}^3 (10\text{m/s})\ 1008\ \text{J/kg}\cdot\text{K}\ \left(11.1\times10^{-3}/2\right)\ (0.704)^{-2/3}$$

$$\bar{h} = 76.5\ \text{W/m}^2\cdot\text{K}.$$

Hence, the heat rate is

$$q = \bar{h}\,A\,(T_s - T_\infty) = 76.5\text{W/m}^2\cdot\text{K}\ \left(0.25\text{m}^2\right)\ (90-15)^\circ\ \text{C}$$

$$q = 1.43\ \text{kW}.$$ <

COMMENTS: Due to bottom heat losses, which have been assumed negligible, the actual power requirement would exceed 1.43 kW.