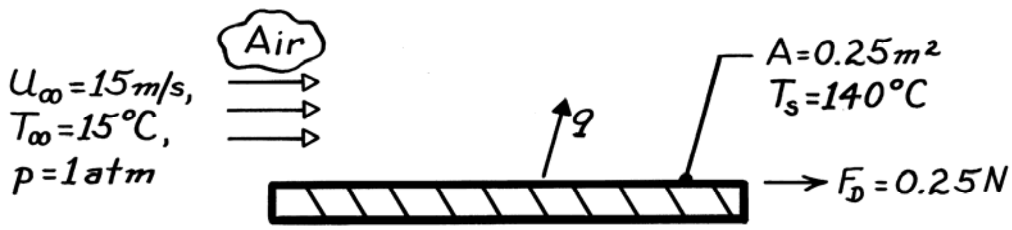
PROBLEM 6.46

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 = 350K, 1atm): ρ = 0.995 kg/m^3, c_p = 1009 J/kg·K, Pr = 0.700.

ANALYSIS: The average shear stress and friction coefficient are

$$\overline{\tau}_s = \frac{F_D}{A} = \frac{0.25\text{ N}}{0.25\text{ m}^2} = 1\text{ N/m}^2$$

$$\overline{C}_f = \frac{\overline{\tau}_s}{\rho u_\infty^2/2} = \frac{1\text{ N/m}^2}{0.995\text{ kg/m}^3(15\text{m/s})^2/2} = 8.93\times10^{-3}.$$

From the Reynolds analogy,

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

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

$$\overline{h} = 0.995\text{ kg/m}^3(15\text{m/s})\ 1009\text{ J/kg}\cdot\text{K}\left(8.93\times10^{-3}/2\right)\ (0.7)^{-2/3}$$

$$\overline{h} = 85\text{ W/m}^2\cdot\text{K}.$$

Hence, the heat rate is

$$q = \overline{h}\,A\,(T_s - T_\infty) = 85\text{W/m}^2\cdot\text{K}\left(0.25\text{m}^2\right)\ (140-15)^\circ\text{C}$$

$$q = 2.66\text{ kW}.$$ <

COMMENTS: Due to bottom heat losses, which have been assumed negligible, the actual power requirement would exceed 2.66 kW.