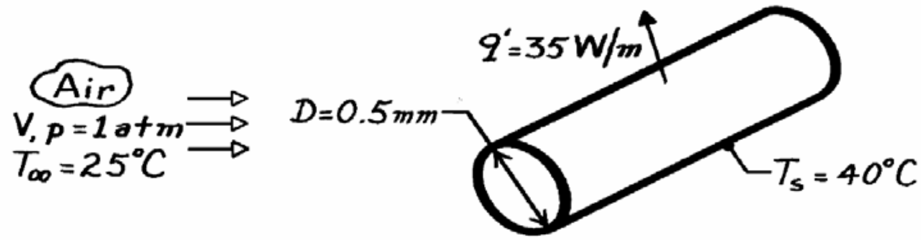
PROBLEM 7.49

KNOWN: Temperature and heat dissipation in a wire of diameter D.

FIND: (a) Expression for flow velocity over wire, (b) Velocity of airstream for prescribed conditions.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Uniform wire temperature, (3) Negligible radiation.

PROPERTIES: *Table A-4*, Air (T_∞ = 298 K, 1 atm): $\nu = 15.8 \times 10^{-6}$ m^2/s, k = 0.0262 W/m·K, Pr = 0.71; (T_s = 313 K, 1 atm): Pr = 0.705.

ANALYSIS: (a) The rate of heat transfer per unit cylinder length is

$$q' = (q/L) = \overline{h}(\pi D)\ (T_s - T_\infty)$$

where, from the Zhukauskas relation, with $Pr \approx Pr_s$,

$$\overline{h} = \frac{k}{D} C\, Re_D^m\, Pr^n = \frac{k}{D}\, C \left(\frac{VD}{\nu}\right)^m Pr^n$$

Hence,

$$V = \left[\frac{q'}{(k/D) C\, Pr^n (\pi D)\ (T_s - T_\infty)}\right]^{1/m} \left(\frac{\nu}{D}\right). \quad <$$

(b) Assuming ($10^3 < Re_D < 2 \times 10^5$), C = 0.26, m = 0.6 from Table 7.3. Hence,

$$V = \left[\frac{35\text{ W/m}}{0.0262\text{ W/m}\cdot\text{K} \times 0.26(0.71)^{0.37}\,\pi(40-25)^\circ\text{C}}\right]^{1/0.6} \left(\frac{15.8 \times 10^{-6}\text{m}^2/\text{s}}{5 \times 10^{-4}\text{m}}\right)$$

$$V = 97\text{ m/s}. \quad <$$

To verify the assumption of the Reynolds number range, calculate

$$Re_D = \frac{VD}{\nu} = \frac{97\text{ m/s}\left(5 \times 10^{-4}\text{m}\right)}{15.8 \times 10^{-6}\text{m}^2/\text{s}} = 3074.$$

Hence the assumption was correct.

COMMENTS: The major uncertainty associated with using this method to determine V is that associated with use of the correlation for $\overline{Nu}_D$.