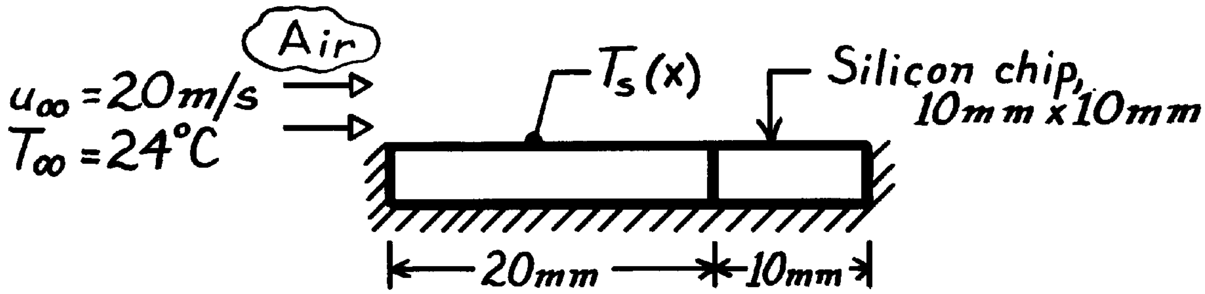
PROBLEM 7.33

KNOWN: Dimensions and maximum allowable temperature of a silicon chip. Air flow conditions.

FIND: Maximum allowable power with or without unheated starting length.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) $T_f = 52°C$, (3) Negligible radiation, (4) Negligible heat loss through insulation, (5) Uniform heat flux at chip-air interface, (6) $Re_{x,c} = 5 \times 10^5$.

PROPERTIES: *Table A-4*, Air (T_f = 325K, 1 atm): $\nu = 18.41 \times 10^{-6}$ m^2/s, k = 0.0282 W/m·K, Pr = 0.703.

ANALYSIS: For uniform heat flux, maximum T_s corresponds to minimum h_x. Without unheated starting length,

$$Re_L = \frac{u_\infty L}{\nu} = \frac{20 \text{ m/s} \times 0.01 \text{ m}}{18.41 \times 10^{-6} \text{ m}^2/\text{s}} = 10,864.$$

With the unheated starting length, L = 0.03 m, Re_L = 32,591. Hence, the flow is laminar in both cases and the minimum h_x occurs at the trailing edge (x = L).

Without unheated starting length,

$$h_L = \frac{k}{L} 0.453 Re_L^{1/2} Pr^{1/3} = \frac{0.0282 \text{ W/m} \cdot \text{K}}{0.01 \text{ m}} 0.453 (10,864)^{1/2} (0.703)^{1/3}$$

$$h_L = 118 \text{ W/m}^2 \cdot \text{K}$$

$$q''(L) = h_L (T_s - T_\infty) = 118 \text{ W/m}^2 \cdot \text{K} (80 - 24)^\circ \text{C} = 6630 \text{ W/m}^2$$

$$q_{max} = A_s q'' = \left(10^{-2} \text{m}\right)^2 6630 \text{ W/m}^2 = 0.66 \text{ W}. \qquad <$$

With the unheated starting length,

$$h_L = \frac{k}{L} 0.453 \frac{Re_L^{1/2} Pr^{1/3}}{\left[1 - (\xi/L)^{3/4}\right]^{1/3}} = \frac{0.0282 \text{ W/m} \cdot \text{K}}{0.03 \text{ m}} 0.453 \frac{(32,951)^{1/2} (0.703)^{1/3}}{\left[1 - (0.02/0.03)^{3/4}\right]^{1/3}}$$

$$h_L = 107 \text{ W/m}^2 \cdot \text{K}$$

$$q''(L) = h_L (T_s - T_\infty) = 107 \text{ W/m}^2 \cdot \text{K} \ (80 - 24)^\circ \text{C} = 6013 \text{ W/m}^2$$

$$q_{max} = A_s q'' = 10^{-4} \text{m}^2 \times 6013 \text{ W/m}^2 = 0.60 \text{ W}. \qquad <$$

COMMENTS: Prior velocity boundary layer development on the unheated starting section decreases h_x, although the effect diminishes with increasing x.