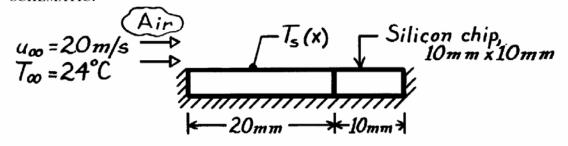
PROBLEM 7.39

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) $\text{Re}_{X,C} = 5 \times 10^5$.

PROPERTIES: Table A-4, Air (T_f = 325K, 1 atm): v = 18.41 × 10⁻⁶ m²/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,

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

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,

$$\begin{split} h_{L} &= \frac{k}{L} 0.453 \text{Re}_{L}^{1/2} \text{Pr}^{1/3} = \frac{0.0282 \text{ W/m} \cdot \text{K}}{0.01 \text{ m}} 0.453 (10,864)^{1/2} (0.703)^{1/3} \\ h_{L} &= 118 \text{ W/m}^{2} \cdot \text{K} \\ q''(L) &= h_{L} (T_{s} - T_{\infty}) = 118 \text{ W/m}^{2} \cdot \text{K} (80 - 24)^{\circ} \text{ C} = 6630 \text{ W/m}^{2} \\ q_{max} &= A_{s} q'' = (10^{-2} \text{m})^{2} 6630 \text{ W/m}^{2} = 0.66 \text{ W}. \end{split}$$

With the unheated starting length,

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

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

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

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

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

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