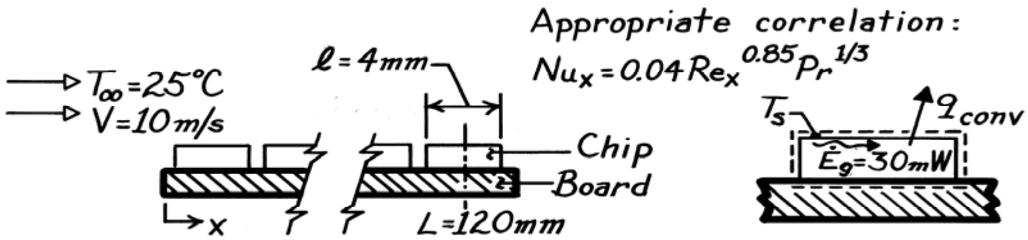
PROBLEM 6.39

KNOWN: Expression for the local heat transfer coefficient of air at prescribed velocity and temperature flowing over electronic elements on a circuit board and heat dissipation rate for a 4 × 4 mm chip located 120mm from the leading edge.

FIND: Surface temperature of the chip surface, T_s.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Power dissipated within chip is lost by convection across the upper surface only, (3) Chip surface is isothermal, (4) The average heat transfer coefficient for the chip surface is equivalent to the local value at x = L, (5) Negligible radiation.

PROPERTIES: *Table A-4*, Air (assume T_s = 45°C, T_f = (45 + 25)/2 = 35°C = 308K, 1atm): ν = 16.69 × 10^{-6} m^2/s, k = 26.9 × 10^{-3} W/m·K, Pr = 0.703.

ANALYSIS: From an energy balance on the chip (see above),

$$q_{conv} = \dot{E}_g = 30W. \tag{1}$$

Newton's law of cooling for the upper chip surface can be written as

$$T_s = T_\infty + q_{conv} / \bar{h} A_{chip} \tag{2}$$

where $A_{chip} = \ell^2$. Assume that the *average* heat transfer coefficient $(\bar{h})$ over the chip surface is equivalent to the *local* coefficient evaluated at x = L. That is, $\bar{h}_{chip} \approx h_x(L)$ where the local coefficient can be evaluated from the special correlation for this situation,

$$Nu_x = \frac{h_x x}{k} = 0.04\left[\frac{Vx}{\nu}\right]^{0.85} Pr^{1/3}$$

and substituting numerical values with x = L, find

$$h_x = 0.04\frac{k}{L}\left[\frac{VL}{\nu}\right]^{0.85} Pr^{1/3}$$

$$h_x = 0.04\left[\frac{0.0269 \text{ W/m}\cdot\text{K}}{0.120 \text{ m}}\right]\left[\frac{10 \text{ m/s} \times 0.120 \text{ m}}{16.69 \times 10^{-6} \text{ m}^2/\text{s}}\right]^{0.85}(0.703)^{1/3} = 107 \text{ W/m}^2\cdot\text{K}.$$

The surface temperature of the chip is from Eq. (2),

$$T_s = 25°C + 30 \times 10^{-3} \text{ W}/\left[107 \text{ W/m}^2\cdot\text{K} \times (0.004\text{m})^2\right] = 42.5°C.$$ <

COMMENTS: (1) Note that the estimated value for T_f used to evaluate the air properties was reasonable. (2) Alternatively, we could have evaluated $\bar{h}_{chip}$ by performing the integration of the local value, h(x).