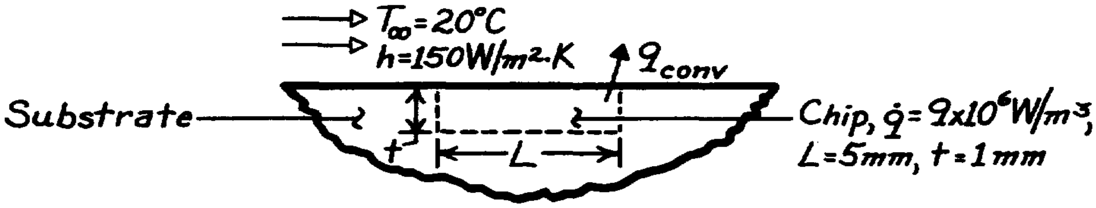
PROBLEM 5.27

KNOWN: Dimensions and operating conditions of an integrated circuit.

FIND: Steady-state temperature and time to come within 1°C of steady-state.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties, (2) Negligible heat transfer from chip to substrate.

PROPERTIES: Chip material (given): $\rho = 2000\ kg/m^3$, $c = 700\ J/kg\cdot K$.

ANALYSIS: At steady-state, conservation of energy yields

$$-\dot{E}_{out} + \dot{E}_g = 0$$

$$-h\left(L^2\right)\left(T_f - T_\infty\right) + \dot{q}\left(L^2 \cdot t\right) = 0$$

$$T_f = T_\infty + \frac{\dot{q}t}{h}$$

$$T_f = 20^\circ C + \frac{9\times10^6\ W/m^3 \times 0.001\ m}{150\ W/m^2\cdot K} = 80^\circ C.$$ <

From the general lumped capacitance analysis, Equation 5.15 reduces to

$$\rho\left(L^2 \cdot t\right)c\frac{dT}{dt} = \dot{q}\left(L^2 \cdot t\right) - h\left(T - T_\infty\right)L^2.$$

With

$$a \equiv \frac{h}{\rho tc} = \frac{150\ W/m^2\cdot K}{\left(2000\ kg/m^3\right)\left(0.001\ m\right)\left(700\ J/kg\cdot K\right)} = 0.107\ s^{-1}$$

$$b \equiv \frac{\dot{q}}{\rho c} = \frac{9\times10^6\ W/m^3}{\left(2000\ kg/m^3\right)\left(700\ J/kg\cdot K\right)} = 6.429\ K/s.$$

From Equation 5.24,

$$\exp\left(-at\right) = \frac{T - T_\infty - b/a}{T_i - T_\infty - b/a} = \frac{\left(79 - 20 - 60\right)K}{\left(20 - 20 - 60\right)K} = 0.01667$$

$$t = -\frac{\ln\left(0.01667\right)}{0.107\ s^{-1}} = 38.3\ s.$$ <

COMMENTS: Due to additional heat transfer from the chip to the substrate, the actual values of T_f and t are less than those which have been computed.