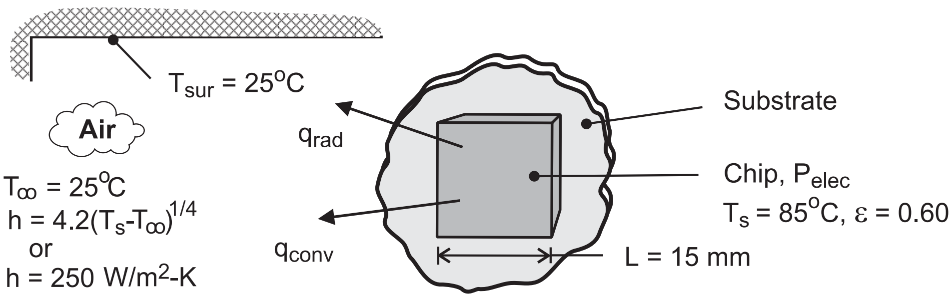
PROBLEM 1.40

KNOWN: Width, surface emissivity and maximum allowable temperature of an electronic chip. Temperature of air and surroundings. Convection coefficient.

FIND: (a) Maximum power dissipation for free convection with $h(W/m^2 \cdot K) = 4.2(T - T_\infty)^{1/4}$, (b) Maximum power dissipation for forced convection with $h = 250\ W/m^2 \cdot K$.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Radiation exchange between a small surface and a large enclosure, (3) Negligible heat transfer from sides of chip or from back of chip by conduction through the substrate.

ANALYSIS: Subject to the foregoing assumptions, electric power dissipation by the chip must be balanced by convection and radiation heat transfer from the chip. Hence, from Eq. (1.10),

$$P_{elec} = q_{conv} + q_{rad} = hA\left(T_s - T_\infty\right) + \varepsilon A\sigma\left(T_s^4 - T_{sur}^4\right)$$

where $A = L^2 = \left(0.015m\right)^2 = 2.25\times10^{-4}m^2$.

(a) If heat transfer is by natural convection,

$$q_{conv} = C\ A\left(T_s - T_\infty\right)^{5/4} = 4.2\ W/m^2 \cdot K^{5/4}\left(2.25\times10^{-4}m^2\right)\left(60K\right)^{5/4} = 0.158\ W$$

$$q_{rad} = 0.60\left(2.25\times10^{-4}m^2\right)5.67\times10^{-8}\ W/m^2 \cdot K^4\left(358^4 - 298^4\right)K^4 = 0.065\ W$$

$$P_{elec} = 0.158\ W + 0.065\ W = 0.223\ W \qquad <$$

(b) If heat transfer is by forced convection,

$$q_{conv} = hA\left(T_s - T_\infty\right) = 250\ W/m^2 \cdot K\left(2.25\times10^{-4}m^2\right)\left(60K\right) = 3.375\ W$$

$$P_{elec} = 3.375\ W + 0.065\ W = 3.44\ W \qquad <$$

COMMENTS: Clearly, radiation and natural convection are inefficient mechanisms for transferring heat from the chip. For $T_s = 85°C$ and $T_\infty = 25°C$, the natural convection coefficient is $11.7\ W/m^2 \cdot K$. Even for forced convection with $h = 250\ W/m^2 \cdot K$, the power dissipation is well below that associated with many of today's processors. To provide acceptable cooling, it is often necessary to attach the chip to a highly conducting substrate and to thereby provide an additional heat transfer mechanism due to conduction from the back surface.