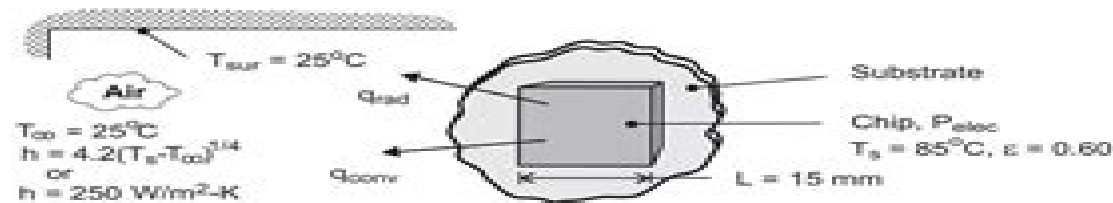


PROBLEM 1.31

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

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),

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

where $A = L^2 = (0.015 \text{ m})^2 = 2.25 \times 10^{-4} \text{ m}^2$.

(a) If heat transfer is by natural convection,

$$q_{\text{conv}} = C A (T_s - T_\infty)^{5/4} = 4.2 \text{ W/m}^2 \cdot \text{K}^{5/4} \left(2.25 \times 10^{-4} \text{ m}^2 \right) (60 \text{ K})^{5/4} = 0.158 \text{ W}$$

$$q_{\text{rad}} = 0.60 \left(2.25 \times 10^{-4} \text{ m}^2 \right) 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 \left(358^4 - 298^4 \right) \text{ K}^4 = 0.065 \text{ W}$$

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

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(b) If heat transfer is by forced convection,

$$q_{\text{conv}} = hA(T_s - T_\infty) = 250 \text{ W/m}^2 \cdot \text{K} \left(2.25 \times 10^{-4} \text{ m}^2 \right) (60 \text{ K}) = 3.375 \text{ W}$$

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

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COMMENTS: Clearly, radiation and natural convection are inefficient mechanisms for transferring heat from the chip. For $T_s = 85^\circ\text{C}$ and $T_\infty = 25^\circ\text{C}$, the natural convection coefficient is $11.7 \text{ W/m}^2\cdot\text{K}$. Even for forced convection with $h = 250 \text{ W/m}^2\cdot\text{K}$, 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.

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