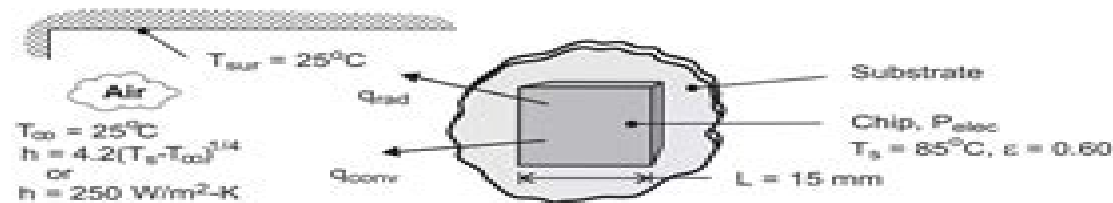


PROBLEM 1.31

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,

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

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

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

<

(b) If heat transfer is by forced convection,

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

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

<

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.

Incropera Principles Of Heat Transfer Solution Manual

D.P. Dewitt



Incropera Principles Of Heat Transfer Solution Manual:

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