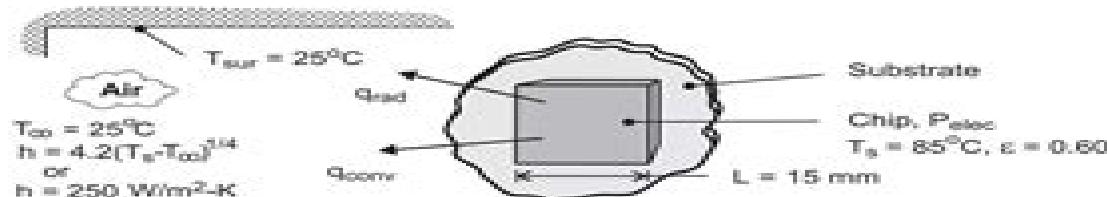


### PROBLEM 1.31

**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),

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

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

(a) If heat transfer is by natural convection,

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

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

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

<

(b) If heat transfer is by forced convection,

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

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

<

**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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