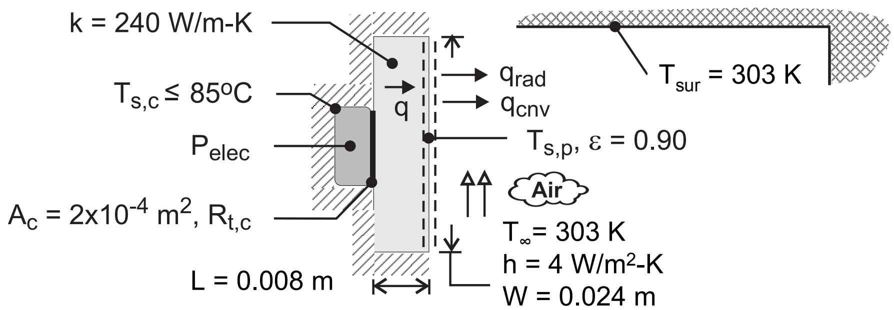
PROBLEM 3.33

KNOWN: Dimensions, thermal conductivity and emissivity of base plate. Temperature and convection coefficient of adjoining air. Temperature of surroundings. Maximum allowable temperature of transistor case. Case-plate interface conditions.

FIND: (a) Maximum allowable power dissipation for an air-filled interface, (b) Effect of convection coefficient on maximum allowable power dissipation.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) Negligible heat transfer from the enclosure, to the surroundings. (3) One-dimensional conduction in the base plate, (4) Radiation exchange at surface of base plate is with large surroundings, (5) Constant thermal conductivity.

PROPERTIES: Aluminum-aluminum interface, air-filled, 10 μm roughness, 10^5 N/m^2 contact pressure (Table 3.1): $R''_{t,c} = 2.75 \times 10^{-4}\ m^2 \cdot K/W$.

ANALYSIS: (a) With all of the heat dissipation transferred through the base plate,

$$P_{elec} = q = \frac{T_{s,c} - T_\infty}{R_{tot}} \qquad (1)$$

where $R_{tot} = R_{t,c} + R_{cnd} + \left[(1/R_{cnv}) + (1/R_{rad})\right]^{-1}$

$$R_{tot} = \frac{R''_{t,c}}{A_c} + \frac{L}{kW^2} + \frac{1}{W^2}\left(\frac{1}{h + h_r}\right) \qquad (2)$$

and $$h_r = \varepsilon\sigma\left(T_{s,p} + T_{sur}\right)\left(T_{s,p}^2 + T_{sur}^2\right) \qquad (3)$$

To obtain $T_{s,p}$, the following energy balance must be performed on the plate surface,

$$q = \frac{T_{s,c} - T_{s,p}}{R_{t,c} + R_{cnd}} = q_{cnv} + q_{rad} = hW^2\left(T_{s,p} - T_\infty\right) + h_r\, W^2\left(T_{s,p} - T_{sur}\right) \qquad (4)$$

With $R_{t,c} = 2.75 \times 10^{-4}\ m^2 \cdot K/W / 2\times10^{-4}\ m^2 = 1.375$ K/W, $R_{cnd} = 0.008\ m/(240\ W/m \cdot K \times 5.76 \times 10^{-4}\ m^2) = 0.0579$ K/W, and the prescribed values of h, W, $T_\infty = T_{sur}$ and ε, Eq. (4) yields a surface temperature of $T_{s,p} = 357.5$ K = 84.5°C and a power dissipation of

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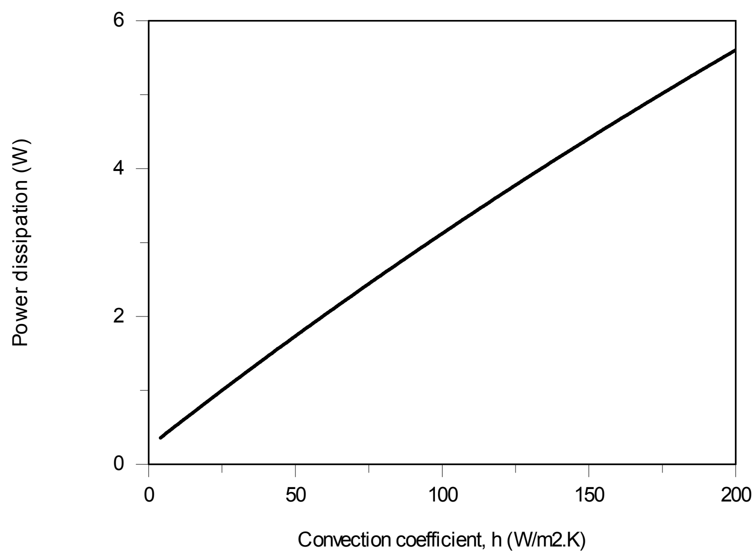
$$P_{elec} = q = 0.358\ W$$ <

The convection and radiation resistances are R_{cnv} = 434 K/W and R_{rad} = 235 K/W, where h_r = 7.40 $W/m^2 \cdot K$.

(b) With the major contribution to the total resistance made by convection, significant benefit may be derived by increasing the value of h.



For h = 200 $W/m^2 \cdot K$, R_{cnv} = 8.68 K/W and $T_{s,p}$ = 350 K, yielding R_{rad} = 243 K/W. The effect of radiation is then negligible.

COMMENTS: (1) The plate conduction resistance is negligible, and even for h = 200 $W/m^2 \cdot K$, the contact resistance is small relative to the convection resistance. However, $R_{t,c}$ could be rendered negligible by using indium foil, instead of an air gap, at the interface. From Table 3.1, $R''_{t,c} = 0.07 \times 10^{-4}\ m^2 \cdot K / W$, in which case $R_{t,c}$ = 0.035 m·K/W.

(2) Because $A_c < W^2$, heat transfer by conduction in the plate is actually two-dimensional, rendering the conduction resistance even smaller.