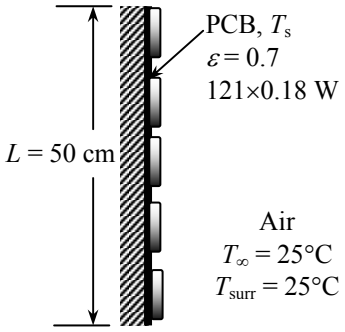
14-42 A circuit board containing square chips is mounted on a vertical wall in a room. The surface temperature of the chips is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Air is an ideal gas with constant properties. **3** The local atmospheric pressure is 1 atm. **4** The heat transfer from the back side of the circuit board is negligible.



Properties The properties of air at 1 atm and the anticipated film temperature of $(T_s+T_\infty)/2 = (35+25)/2 = 30°C$ are (Table A-22)

$$k = 0.02588 \text{ W/m.°C}$$

$$\nu = 1.608\times10^{-5} \text{ m}^2/\text{s}$$

$$\Pr = 0.7282$$

$$\beta = \frac{1}{T_f} = \frac{1}{(30+273)\text{K}} = 0.0033 \text{ K}^{-1}$$

Analysis The solution of this problem requires a trial-and-error approach since the determination of the Rayleigh number and thus the Nusselt number depends on the surface temperature which is unknown. We start the solution process by "guessing" the surface temperature to be 35°C for the evaluation of the properties and h. We will check the accuracy of this guess later and repeat the calculations if necessary. The characteristic length in this case is the height of the board, $L_c = L = 0.5$ m. Then,

$$Ra = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2}\Pr = \frac{(9.81 \text{ m/s}^2)(0.0033 \text{ K}^{-1})(35-25 \text{ K})(0.5 \text{ m})^3}{(1.608\times10^{-5} \text{ m}^2/\text{s})^2}(0.7282) = 1.140\times10^8$$

$$Nu = \left\{0.825 + \frac{0.387\text{Ra}^{1/6}}{\left[1+\left(\frac{0.492}{\Pr}\right)^{9/16}\right]^{8/27}}\right\}^2 = \left\{0.825 + \frac{0.387(1.140\times10^8)^{1/6}}{\left[1+\left(\frac{0.492}{0.7282}\right)^{9/16}\right]^{8/27}}\right\}^2 = 63.72$$

$$h = \frac{k}{L}Nu = \frac{0.02588 \text{ W/m.°C}}{0.5 \text{ m}}(63.72) = 3.30 \text{ W/m}^2\text{.°C}$$

$$A_s = (0.5 \text{ m})^2 = 0.25 \text{ m}^2$$

Considering both natural convection and radiation, the total rate of heat loss can be expressed as

$$\dot{Q} = hA_s(T_s - T_\infty) + \varepsilon A_s\sigma({T_s}^4 - {T_{surr}}^4)$$

$$(121\times0.18) \text{ W} = (3.30 \text{ W/m}^2\text{.°C})(0.25 \text{ m}^2)(T_s - 25)°C + (0.7)(0.25 \text{ m}^2)(5.67\times10^{-8} \text{ W/m}^2\text{.K}^4)[(T_s + 273 \text{ K})^4 - (25+273 \text{ K})^4]$$

Its solution is

$$T_s = \mathbf{36.2°C}$$

which is sufficiently close to the assumed value in the evaluation of properties and h. Therefore, there is no need to repeat calculations by reevaluating the properties and h at the new film temperature.

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