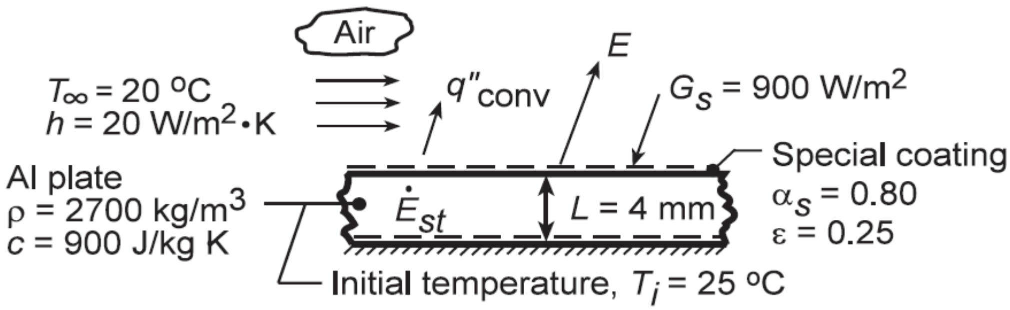
## PROBLEM 1.40

**KNOWN:** Thickness and initial temperature of an aluminum plate whose thermal environment is changed.

**FIND:** (a) Initial rate of temperature change, (b) Steady-state temperature of plate.

**SCHEMATIC:**




**ASSUMPTIONS:** (1) Negligible end effects, (2) Uniform plate temperature at any instant, (3) Constant properties, (4) Adiabatic bottom surface, (5) Negligible radiation from surroundings, (6) No internal heat generation.

**ANALYSIS:** (a) Applying an energy balance, Eq. 1.12c, at an instant of time to a control volume about the plate, $\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st}$, it follows for a unit surface area.

$$\alpha_S G_S \left(1\,m^2\right) - E\left(1\,m^2\right) - q''_{conv}\left(1\,m^2\right) = \left(d/dt\right)\left(McT\right) = \rho\left(1\,m^2 \times L\right)c\left(dT/dt\right).$$

Rearranging and substituting from Eqs. 1.3 and 1.7, we obtain

$$dT/dt = \left(1/\rho Lc\right)\left[\alpha_S G_S - \varepsilon\sigma T_i^4 - h\left(T_i - T_\infty\right)\right].$$

$$dT/dt = \left(2700\,kg/m^3 \times 0.004\,m \times 900\,J/kg\cdot K\right)^{-1} \times$$

$$\left[0.8 \times 900\,W/m^2 - 0.25 \times 5.67 \times 10^{-8}\,W/m^2\cdot K^4\left(298\,K\right)^4 - 20\,W/m^2\cdot K\left(25-20\right)^\circ C\right]$$

$$dT/dt = 0.052^\circ\,C/s\,.$$ <

(b) Under steady-state conditions, $\dot{E}_{st}$ = 0, and the energy balance reduces to

$$\alpha_S G_S = \varepsilon\sigma T^4 + h\left(T - T_\infty\right) \qquad (2)$$

$$0.8 \times 900\,W/m^2 = 0.25 \times 5.67 \times 10^{-8}\,W/m^2\cdot K^4 \times T^4 + 20\,W/m^2\cdot K\left(T - 293\,K\right)$$

The solution yields T = 321.4 K = 48.4°C. <

**COMMENTS:** The surface radiative properties have a significant effect on the plate temperature, which would decrease with increasing ε and decreasing $\alpha_S$. If a low temperature is desired, the plate coating should be characterized by a large value of $\varepsilon/\alpha_S$. The temperature would also decrease with increasing h.