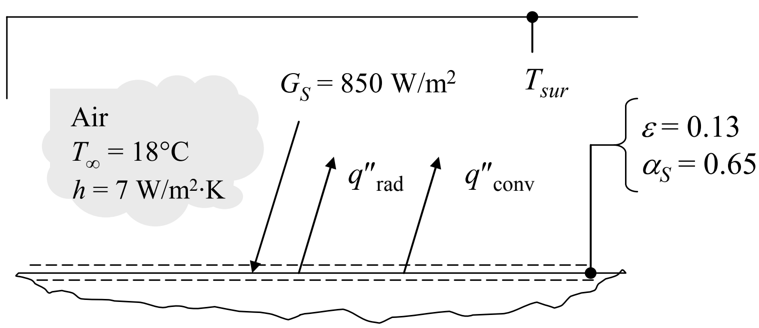
PROBLEM 1.50

KNOWN: Emissivity and solar absorptivity of steel sheet. Solar irradiation, air temperature and convection coefficient.

FIND: Temperature of the steel sheet to determine cat comfort.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Bottom surface of steel is insulated, (3) Radiation from the environment can be treated as radiation from large surroundings, with $\alpha = \varepsilon$, (4) $T_{sur} = T_\infty$.

ANALYSIS: Performing a control surface energy balance on the top surface of the steel sheet gives (on a per unit area basis)

$$\alpha_S G_S - q''_{\text{rad}} - q''_{\text{conv}} = 0$$

$$\alpha_S G_S - \varepsilon\sigma(T_s^4 - T_{\text{sur}}^4) - h(T_s - T_\infty) = 0$$

$$0.65 \times 850 \text{ W/m}^2 - 0.13 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 (T_s^4 - (291 \text{ K})^4) - 7 \text{ W/m}^2 \cdot \text{K}(T_s - 291 \text{ K}) = 0$$

Solving this equation for T_s using IHT or other software results in T_s = 360 K = 87°C. A temperature of 60°C is typically safe to touch without being burned. The steel sheet would be uncomfortably hot or even cause burning. <

COMMENTS: The individual heat flux terms are

$$\alpha_s G_s = 553 \text{ W/m}^2$$

$$q''_{\text{rad}} = \varepsilon\sigma(T_s^4 - T_{\text{sur}}^4) = 70 \text{ W/m}^2$$

$$q''_{\text{conv}} = h(T_s - T_\infty) = 483 \text{ W/m}^2$$

None of these is negligible, although the radiation exchange with the surroundings is smaller than the solar radiation and convection terms.