

15-79 The floor and the ceiling of a cubical furnace are maintained at uniform temperatures. The net rate of radiation heat transfer between the floor and the ceiling is to be determined.

Assumptions 1 Steady operating conditions exist 2 The surfaces are opaque, diffuse, and gray. 3 Convection heat transfer is not considered.

Properties The emissivities of all surfaces are $\varepsilon = 1$ since they are black or reradiating.

Analysis We consider the ceiling to be surface 1, the floor to be surface 2 and the side surfaces to be surface 3. The furnace can be considered to be three-surface enclosure. We assume that steady-state conditions exist. Since the side surfaces are reradiating, there is no heat transfer through them, and the entire heat lost by the ceiling must be gained by the floor. The view factor from the ceiling to the floor of the furnace is $F_{12} = 0.2$. Then the rate of heat loss from the ceiling can be determined from

$$\dot{Q}_1 = \frac{E_{b1} - E_{b2}}{\left(\frac{1}{R_{12}} + \frac{1}{R_{13} + R_{23}} \right)^{-1}}$$

where

$$E_{b1} = \sigma T_1^4 = (5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(1100 \text{ K})^4 = 83,015 \text{ W/m}^2$$

$$E_{b2} = \sigma T_2^4 = (5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(550 \text{ K})^4 = 5188 \text{ W/m}^2$$

and

$$A_1 = A_2 = (4 \text{ m})^2 = 16 \text{ m}^2$$

$$R_{12} = \frac{1}{A_1 F_{12}} = \frac{1}{(16 \text{ m}^2)(0.2)} = 0.3125 \text{ m}^{-2}$$

$$R_{13} = R_{23} = \frac{1}{A_1 F_{13}} = \frac{1}{(16 \text{ m}^2)(0.8)} = 0.078125 \text{ m}^{-2}$$

Substituting,

$$\dot{Q}_{12} = \frac{(83,015 - 5188) \text{ W/m}^2}{\left(\frac{1}{0.3125 \text{ m}^{-2}} + \frac{1}{2(0.078125 \text{ m}^{-2})} \right)^{-1}} = 7.47 \times 10^5 \text{ W} = \mathbf{747 \text{ kW}}$$

