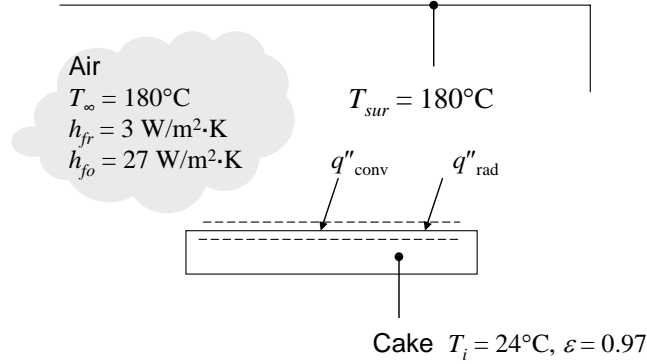


PROBLEM 1.54

KNOWN: Temperatures of small cake as well as oven air and walls. Convection heat transfer coefficient under free and forced convection conditions. Emissivity of cake batter and pan.

FIND: Heat flux to cake under free and forced convection conditions.

SCHEMATIC:



ASSUMPTIONS: (1) Large surroundings.

ANALYSIS: The heat flux to the cake pan and batter is due to convection and radiation. With the surface temperature equal to T_i , when the convection feature is disabled,

$$\begin{aligned}
 q''_{fr} &= (q''_{conv} + q''_{rad}) = h_{fr}(T_{\infty} - T_i) + \varepsilon\sigma(T_{sur}^4 - T_i^4) \\
 &= 3 \text{ W/m}^2 \cdot \text{K}(180^{\circ}\text{C} - 24^{\circ}\text{C}) + 0.97 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 \left((180 + 273 \text{ K})^4 - (24 + 273 \text{ K})^4 \right) < \\
 &= 470 \text{ W/m}^2 + 1890 \text{ W/m}^2 = 2360 \text{ W/m}^2
 \end{aligned}$$

When the convection feature is activated, the heat flux is

$$\begin{aligned}
 q''_{fo} &= (q''_{conv} + q''_{rad}) = h_{fo}(T_{\infty} - T_i) + \varepsilon\sigma(T_{sur}^4 - T_i^4) \\
 &= 27 \text{ W/m}^2 \cdot \text{K}(180^{\circ}\text{C} - 24^{\circ}\text{C}) + 0.97 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 \left((180 + 273 \text{ K})^4 - (24 + 273 \text{ K})^4 \right) < \\
 &= 4210 \text{ W/m}^2 + 1890 \text{ W/m}^2 = 6100 \text{ W/m}^2
 \end{aligned}$$

COMMENTS: Under free convection conditions, the convection contribution is about 20% of the total heat flux. When forced convection is activated, convection becomes larger than radiation, accounting for 69% of the total heat flux. The cake will bake faster under forced convection conditions.