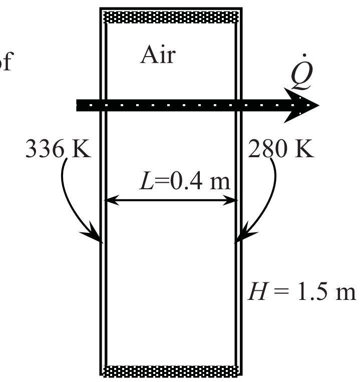
14-67 Two glasses of a double pane window are maintained at specified temperatures. The fraction of heat transferred through the enclosure by radiation is to be determined.



Assumptions **1** Steady operating conditions exist. **2** Air is an ideal gas with constant properties. **3** The air pressure in the enclosure is 1 atm.

Properties The properties of air at 1 atm and the average temperature of $(T_1+T_2)/2$ = (280+336)/2 = 308 K = 35°C are (Table A-22E)

$$k = 0.02625 \text{ W/m.°C}$$

$$\nu = 1.655\times10^{-5} \text{ m}^2\text{/s}$$

$$\text{Pr} = 0.7268$$

$$\beta = \frac{1}{T_f} = \frac{1}{308 \text{ K}} = 0.003247 \text{ K}^{-1}$$

Analysis The characteristic length in this case is the distance between the two glasses, $L_c = L$ = 0.4 m. Then,

$$Ra_L = \frac{g\beta(T_1-T_2)L_c^3}{\nu^2}\text{Pr} = \frac{(9.81 \text{ m/s}^2)(0.003247 \text{ K}^{-1})(336-280 \text{ K})(0.4 \text{ m})^3}{(1.655\times10^{-5} \text{ m}^2\text{/s})^2}(0.7268) = 3.029\times10^8$$

The aspect ratio of the geometry is H/L = 1.5/0.4 = 3.75. For this value of H/L the Nusselt number can be determined from

$$Nu = 0.22\left(\frac{\text{Pr}}{0.2+\text{Pr}}Ra\right)^{0.28}\left(\frac{H}{L}\right)^{-1/4} = 0.22\left(\frac{0.7268}{0.2+0.7268}(3.029\times10^8)\right)^{0.28}\left(\frac{1.5}{0.4}\right)^{-1/4} = 35.00$$

Then,

$$A_s = H\times W = (1.5 \text{ m})(3 \text{ m}) = 4.5 \text{ m}^2$$

$$\dot{Q}_{\text{conv}} = kNuA_s\frac{T_1-T_2}{L} = (0.02625 \text{ W/m.°C})(35.00)(4.5 \text{ ft}^2)\frac{(336-280)\text{K}}{0.4 \text{ m}} = 578.9 \text{ W}$$

The effective emissivity is

$$\frac{1}{\varepsilon_{\text{eff}}} = \frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1 = \frac{1}{0.15}+\frac{1}{0.90}-1 = 6.778 \longrightarrow \varepsilon_{eff} = 0.1475$$

The rate of heat transfer by radiation is

$$\dot{Q}_{\text{rad}} = \varepsilon_{\text{eff}}A_s\sigma(T_1^4-T_2^4)$$
$$= (0.1475)(4.5 \text{ m}^2)(5.67\times10^{-8} \text{ W/m}^2\text{.K}^4)[(336 \text{ K})^4-(280 \text{ K})^4] = 248.4 \text{ W}$$

Then the fraction of heat transferred through the enclosure by radiation becomes

$$f_{\text{rad}} = \frac{\dot{Q}_{\text{rad}}}{\dot{Q}_{\text{conv}}+\dot{Q}_{\text{rad}}} = \frac{248.4}{578.9+248.4} = \mathbf{0.30}$$