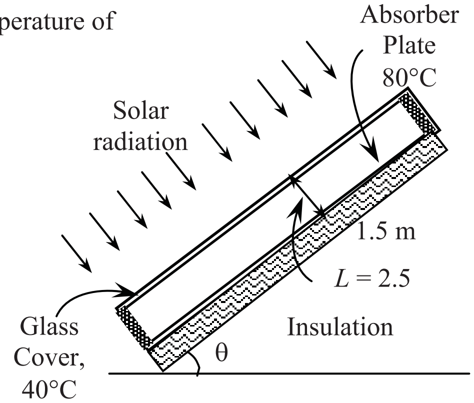
**14-72** The absorber plate and the glass cover of a flat-plate solar collector are maintained at specified temperatures. The rate of heat loss from the absorber plate by natural convection is to be determined.

***Assumptions*** **1** Steady operating conditions exist. **2** Air is an ideal gas with constant properties. **3** Heat loss by radiation is negligible. **4** The air pressure in the enclusure is 1 atm.

***Properties*** The properties of air at 1 atm and the average temperature of $(T_1+T_2)/2 = (80+40)/2 = 60°C$ are (Table A-22)

$$k = 0.02808 \text{ W/m.°C}$$
$$\nu = 1.896\times10^{-5} \text{ m}^2\text{/s}$$
$$\Pr = 0.7202$$
$$\beta = \frac{1}{T_f} = \frac{1}{(60+273)\text{K}} = 0.003003 \text{ K}^{-1}$$




***Analysis*** For $\theta = 0°$, we have horizontal rectangular enclosure. The characteristic length in this case is the distance between the two glasses $L_c = L = 0.025$ m Then,

$$Ra = \frac{g\beta(T_1-T_2)L^3}{\nu^2}\Pr = \frac{(9.81 \text{ m/s}^2)(0.003003 \text{ K}^{-1})(80-40 \text{ K})(0.025 \text{ m})^3}{(1.896\times10^{-5} \text{ m}^2\text{/s})^2}(0.7202) = 3.689\times10^4$$

$$\text{Nu} = 1+1.44\left[1-\frac{1708}{\text{Ra}}\right]^+ + \left[\frac{\text{Ra}^{1/3}}{18}-1\right]^+$$

$$= 1+1.44\left[1-\frac{1708}{3.689\times10^4}\right]^+ + \left[\frac{(3.689\times10^4)^{1/3}}{18}-1\right]^+ = 3.223$$

Then

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

$$\dot{Q} = kNuA_s\frac{T_1-T_2}{L} = (0.02808 \text{ W/m.°C})(3.223)(4.5 \text{ m}^2)\frac{(80-40)\text{°C}}{0.025 \text{ m}} = \mathbf{652\ W}$$

For $\theta = 30°$, we obtain

$$\text{Nu} = 1+1.44\left[1-\frac{1708}{\text{Ra}\cos\theta}\right]^+\left[1-\frac{1708(\sin 1.8\theta)^{1.6}}{\text{Ra}\cos\theta}\right] + \left[\frac{(\text{Ra}\cos\theta)^{1/3}}{18}-1\right]^+$$

$$= 1+1.44\left[1-\frac{1708}{(3.689\times10^4)\cos(30)}\right]^+\left[1-\frac{1708[\sin(1.8\times30)]^{1.6}}{(3.689\times10^4)\cos(30)}\right] + \left[\frac{[(3.689\times10^4)\cos(30)]^{1/3}}{18}-1\right]^+$$

$$= 3.074$$

$$\dot{Q} = kNuA_s\frac{T_1-T_2}{L} = (0.02808 \text{ W/m.°C})(3.074)(4.5 \text{ m}^2)\frac{(80-40)\text{°C}}{0.025 \text{ m}} = \mathbf{621\ W}$$

For $\theta = 90°$, we have vertical rectangular enclosure. The Nusselt number for this geometry and orientation can be determined from ($Ra = 3.689\times10^4$ - same as that for horizontal case)

$$Nu = 0.42Ra^{1/4}\Pr^{0.012}\left(\frac{H}{L}\right)^{-0.3} = 0.42(3.689\times10^4)^{1/4}(0.7202)^{0.012}\left(\frac{2 \text{ m}}{0.025 \text{ m}}\right)^{-0.3} = 1.557$$

$$\dot{Q} = kNuA_s\frac{T_1-T_2}{L} = (0.02808 \text{ W/m.°C})(1.557)(4.5 \text{ m}^2)\frac{(80-40)\text{°C}}{0.025 \text{ m}} = \mathbf{315\ W}$$

***Discussion*** Caution is advised for the vertical case since the condition $H/L < 40$ is not satisfied.