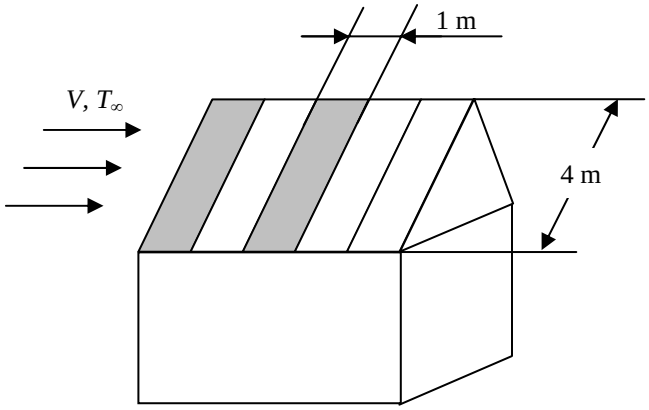
12-48 Ambient air flows over parallel plates of a solar collector that is maintained at a specified temperature. The rates of convection heat transfer from the first and third plate are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The critical Reynolds number is $\text{Re}_{cr} = 5\times10^5$. **3** Radiation effects are negligible. **4** Atmospheric pressure is taken 1 atm.



Properties The properties of air at the film temperature of (15+10)/2=12.5°C are (Table A-22)

$$k = 0.02458\ \text{W/m.°C}$$
$$\nu = 1.448\times10^{-5}\ \text{m}^2/\text{s}$$
$$\text{Pr} = 0.7330$$

Analysis (*a*) The critical length of the plate is first determined to be

$$x_{cr} = \frac{\text{Re}_{cr}\,\nu}{V} = \frac{(5\times10^5)(1.448\times10^{-5}\ \text{m}^2/\text{s})}{2\ \text{m/s}} = 3.62\ \text{m}$$

Therefore, both plates are under laminar flow. The Reynolds number for the first plate is

$$\text{Re}_1 = \frac{VL_1}{\nu} = \frac{(2\ \text{m/s})(1\,\text{m})}{1.448\times10^{-5}\ \text{m}^2/\text{s}} = 1.381\times10^5$$

Using the relation for Nusselt number, the average heat transfer coefficient and the heat transfer rate are determined to be

$$\text{Nu}_1 = 0.664\,\text{Re}_1^{\,1/2}\,\text{Pr}^{1/3} = 0.664(1.381\times10^5)^{1/2}(0.7330)^{1/3} = 222.5$$
$$h_1 = \frac{k}{L_1}Nu = \frac{0.02458\ \text{W/m.°C}}{1\,\text{m}}(222.5) = 5.47\ \text{W/m}^2.\text{°C}$$
$$A = wL = (4\,\text{m})(1\,\text{m}) = 4\,\text{m}^2$$
$$\dot{Q} = hA(T_s - T_\infty) = (5.47\ \text{W/m}^2.\text{°C})(4\,\text{m}^2)(15-10)\text{°C} = \mathbf{109\ W}$$

(*b*) Repeating the calculations for the second and third plates,

$$\text{Re}_2 = \frac{VL_2}{\nu} = \frac{(2\ \text{m/s})(2\,\text{m})}{1.448\times10^{-5}\ \text{m}^2/\text{s}} = 2.762\times10^5$$
$$\text{Nu}_2 = 0.664\,\text{Re}_2^{\,1/2}\,\text{Pr}^{1/3} = 0.664(2.762\times10^5)^{1/2}(0.7330)^{1/3} = 314.7$$
$$h_2 = \frac{k}{L_2}Nu = \frac{0.02458\ \text{W/m.°C}}{2\,\text{m}}(314.7) = 3.87\ \text{W/m}^2.\text{°C}$$
$$\text{Re}_3 = \frac{VL_3}{\nu} = \frac{(2\ \text{m/s})(3\,\text{m})}{1.448\times10^{-5}\ \text{m}^2/\text{s}} = 4.144\times10^5$$
$$\text{Nu}_3 = 0.664\,\text{Re}_3^{\,1/2}\,\text{Pr}^{1/3} = 0.664(4.144\times10^5)^{1/2}(0.7330)^{1/3} = 385.4$$
$$h_3 = \frac{k}{L_3}Nu = \frac{0.02458\ \text{W/m.°C}}{3\,\text{m}}(385.4) = 3.16\ \text{W/m}^2.\text{°C}$$

Then

$$h_{2-3} = \frac{h_3L_3 - h_2L_2}{L_3 - L_2} = \frac{3.16\times3 - 3.87\times2}{3-2} = 1.74\ \text{W/m}^2.\text{°C}$$

The rate of heat loss from the third plate is

$$\dot{Q} = hA(T_s - T_\infty) = (1.74\ \text{W/m}^2.\text{°C})(4\ \text{m}^2)(15-10)\text{°C} = \mathbf{34.8\ W}$$

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