12-51 The top surface of the passenger car of a train in motion is absorbing solar radiation. The equilibrium temperature of the top surface is to be determined.

Assumptions **1** Steady operating conditions exist. **2** The critical Reynolds number is $Re_{cr} = 5 \times 10^5$. **3** Radiation heat exchange with the surroundings is negligible. **4** Air is an ideal gas with constant properties.

Properties The properties of air at 30°C are (Table A-22)

$$k = 0.02588 \text{ W/m.°C}$$

$$\nu = 1.608 \times 10^{-5} \text{ m}^2/\text{s}$$

$$Pr = 0.7282$$

Air   200 W/m²

$V = 70$ km/h

$T_\infty = 30°C$

Analysis The rate of convection heat transfer from the top surface of the car to the air must be equal to the solar radiation absorbed by the same surface in order to reach steady operation conditions. The Reynolds number is

$$Re_L = \frac{VL}{\nu} = \frac{[70 \times 1000/3600) \text{ m/s}](8 \text{ m})}{1.608 \times 10^{-5} \text{ m}^2/\text{s}} = 9.674 \times 10^6$$

which is greater than the critical Reynolds number. Thus we have combined laminar and turbulent flow. Using the proper relation for Nusselt number, the average heat transfer coefficient and the heat transfer rate are determined to be

$$Nu = \frac{hL}{k} = (0.037 \, Re_L^{0.8} - 871) \, Pr^{1/3} = [0.037(9.674 \times 10^6)^{0.8} - 871](0.7282)^{1/3} = 1.212 \times 10^4$$

$$h = \frac{k}{L} Nu = \frac{0.02588 \text{ W/m.°C}}{8 \text{ m}} (1.212 \times 10^4) = 39.21 \text{ W/m}^2\text{.°C}$$

The equilibrium temperature of the top surface is then determined by taking convection and radiation heat fluxes to be equal to each other

$$\dot{q}_{rad} = \dot{q}_{conv} = h(T_s - T_\infty) \longrightarrow T_s = T_\infty + \frac{\dot{q}_{conv}}{h} = 30°C + \frac{200 \text{ W/m}^2}{39.21 \text{ W/m}^2\text{.°C}} = \mathbf{35.1°C}$$