12-49 A car travels at a velocity of 80 km/h. The rate of heat transfer from the bottom surface of the hot automotive engine block is to be determined.

Assumptions 1 Steady operating conditions exist. **2** The critical Reynolds number is $Re_{cr} = 5 \times 10^5$. **3** Air is an ideal gas with constant properties. **4** The flow is turbulent over the entire surface because of the constant agitation of the engine block.

Properties The properties of air at 1 atm and the film temperature of $(T_s + T_\infty)/2 = (100+20)/2 = 60°C$ are (Table A-22)

$k = 0.02808$ W/m.°C

$\nu = 1.896 \times 10^{-5}$ m²/s

$Pr = 0.7202$

Analysis Air flows parallel to the 0.4 m side. The Reynolds number in this case is

$$Re_L = \frac{V_\infty L}{\nu} = \frac{[(80 \times 1000 / 3600) \text{ m/s}](0.8 \text{ m})}{1.896 \times 10^{-5} \text{ m}^2/\text{s}} = 9.376 \times 10^5$$

which is greater than the critical Reynolds number and thus the flow is laminar + turbulent. But the flow is assumed to be turbulent over the entire surface because of the constant agitation of the engine block. Using the proper relations, the Nusselt number, the heat transfer coefficient, and the heat transfer rate are determined to be

$$Nu = \frac{hL}{k} = 0.037 \, Re_L^{0.8} \, Pr^{1/3} = 0.037(9.376 \times 10^5)^{0.8}(0.7202)^{1/3} = 1988$$

$$h = \frac{k}{L} Nu = \frac{0.02808 \text{ W/m.°C}}{0.8 \text{ m}} (1988) = 69.78 \text{ W/m}^2.°C$$

$$A_s = wL = (0.8 \text{ m})(0.4 \text{ m}) = 0.32 \text{ m}^2$$

$$\dot{Q}_{conv} = hA_s(T_\infty - T_s) = (69.78 \text{ W/m}^2.°C)(0.32 \text{ m}^2)(100 - 20)°C = \textbf{1786 W}$$

The radiation heat transfer from the same surface is

$$\dot{Q}_{rad} = \varepsilon A_s \sigma (T_s^4 - T_{surr}^4)$$
$$= (0.95)(0.32 \text{ m}^2)(5.67 \times 10^{-8} \text{ W/m}^2.K^4)[(100 + 273 \text{ K})^4 - (25 + 273 \text{ K})^4] = \textbf{198 W}$$

Then the total rate of heat transfer from that surface becomes

$$\dot{Q}_{total} = \dot{Q}_{conv} + \dot{Q}_{rad} = (1786 + 198) \text{W} = \textbf{1984 W}$$