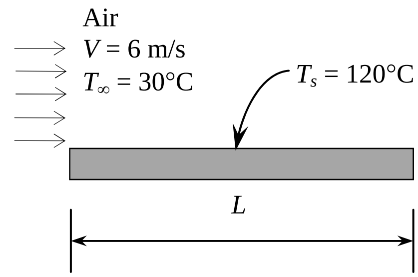
12-40 The top surface of a hot block is to be cooled by forced air. The rate of heat transfer is to be determined for two cases.

Assumptions **1** Steady operating conditions exist. **2** The critical Reynolds number is $\mathrm{Re}_{cr} = 5\times10^5$. **3** Radiation effects are negligible. **4** Air is an ideal gas with constant properties.

Properties The atmospheric pressure in atm is

$$P = (83.4\ \mathrm{kPa})\frac{1\ \mathrm{atm}}{101.325\ \mathrm{kPa}} = 0.823\ \mathrm{atm}$$



For an ideal gas, the thermal conductivity and the Prandtl number are independent of pressure, but the kinematic viscosity is inversely proportional to the pressure. With these considerations, the properties of air at 0.823 atm and at the film temperature of (120+30)/2=75°C are (Table A-22)

$$k = 0.02917\ \mathrm{W/m.°C}$$

$$\nu = \nu_{@1atm} / P_{atm} = (2.046\times10^{-5}\ \mathrm{m^2/s}) / 0.823 = 2.486\times10^{-5}\ \mathrm{m^2/s}$$

$$\mathrm{Pr} = 0.7166$$

Analysis (*a*) If the air flows parallel to the 8 m side, the Reynolds number in this case becomes

$$\mathrm{Re}_L = \frac{VL}{\nu} = \frac{(6\ \mathrm{m/s})(8\ \mathrm{m})}{2.486\times10^{-5}\ \mathrm{m^2/s}} = 1.931\times10^6$$

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

$$Nu = \frac{hL}{k} = (0.037\,\mathrm{Re}_L^{\ 0.8} - 871)\,\mathrm{Pr}^{1/3} = [0.037(1.931\times10^6)^{0.8} - 871](0.7166)^{1/3} = 2757$$

$$h = \frac{k}{L}Nu = \frac{0.02917\ \mathrm{W/m.°C}}{8\ \mathrm{m}}(2757) = 10.05\ \mathrm{W/m^2.°C}$$

$$A_s = wL = (2.5\ \mathrm{m})(8\ \mathrm{m}) = 20\ \mathrm{m}^2$$

$$\dot{Q} = hA_s(T_\infty - T_s) = (10.05\ \mathrm{W/m^2.°C})(20\ \mathrm{m^2})(120-30)\mathrm{°C} = 18{,}100\ \mathrm{W} = \mathbf{18.10\ kW}$$

(*b*) If the air flows parallel to the 2.5 m side, the Reynolds number is

$$\mathrm{Re}_L = \frac{VL}{\nu} = \frac{(6\ \mathrm{m/s})(2.5\ \mathrm{m})}{2.486\times10^{-5}\ \mathrm{m^2/s}} = 6.034\times10^5$$

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

$$Nu = \frac{hL}{k} = (0.037\,\mathrm{Re}_L^{\ 0.8} - 871)\,\mathrm{Pr}^{1/3} = [0.037(6.034\times10^5)^{0.8} - 871](0.7166)^{1/3} = 615.1$$

$$h = \frac{k}{L}Nu = \frac{0.02917\ \mathrm{W/m.°C}}{2.5\ \mathrm{m}}(615.1) = 7.177\ \mathrm{W/m^2.°C}$$

$$\dot{Q} = hA_s(T_\infty - T_s) = (7.177\ \mathrm{W/m^2.°C})(20\ \mathrm{m^2})(120-30)\mathrm{°C} = 12{,}920\ \mathrm{W} = \mathbf{12.92\ kW}$$