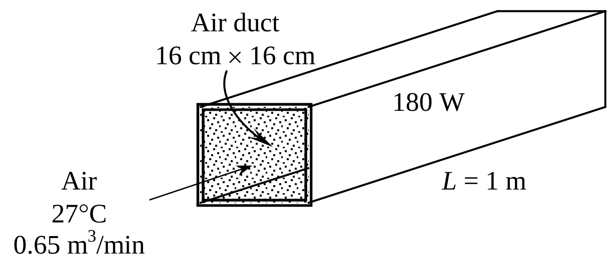
13-59 The components of an electronic system located in a rectangular horizontal duct are cooled by forced air. The exit temperature of the air and the highest component surface temperature are to be determined.

Assumptions **1** Steady flow conditions exist. **2** The inner surfaces of the duct are smooth. **3** The thermal resistance of the duct is negligible. **4** Air is an ideal gas with constant properties. **5** The pressure of air is 1 atm.

Properties We assume the bulk mean temperature for air to be 35°C since the mean temperature of air at the inlet will rise somewhat as a result of heat gain through the duct whose surface is exposed to a constant heat flux. The properties of air at 1 atm and this temperature are (Table A-22)

$$\rho = 1.145\ \text{kg/m}^3$$
$$k = 0.02625\ \text{W/m.°C}$$
$$\nu = 1.655\times10^{-5}\ \text{m}^2/\text{s}$$
$$c_p = 1007\ \text{J/kg.°C}$$
$$\text{Pr} = 0.7268$$



Analysis (*a*) The mass flow rate of air and the exit temperature are determined from

$$\dot{m} = \rho\dot{V} = (1.145\ \text{kg/m}^3)(0.65\ \text{m}^3/\text{min}) = 0.7443\ \text{kg/min} = 0.0124\ \text{kg/s}$$

$$\dot{Q} = \dot{m}c_p(T_e - T_i) \rightarrow T_e = T_i + \frac{\dot{Q}}{\dot{m}c_p} = 27°\text{C} + \frac{(0.85)(180\ \text{W})}{(0.0124\ \text{kg/s})(1007\ \text{J/kg.°C})} = \mathbf{39.3°C}$$

(*b*) The mean fluid velocity and hydraulic diameter are

$$V_m = \frac{\dot{V}}{A_c} = \frac{0.65\ \text{m/min}}{(0.16\ \text{m})(0.16\ \text{m})} = 25.4\ \text{m/min} = 0.4232\ \text{m/s}$$

$$D_h = \frac{4A_c}{p} = \frac{4(0.16\ \text{m})(0.16\ \text{m})}{4(0.16\ \text{m})} = 0.16\ \text{m}$$

Then

$$\text{Re} = \frac{V_{\text{avg}}D_h}{\nu} = \frac{(0.4232\ \text{m/s})(0.16\ \text{m})}{1.655\times10^{-5}\ \text{m}^2/\text{s}} = 4091$$

which is not greater than 10,000 but the components will cause turbulence and thus we can assume fully developed turbulent flow in the entire duct, and determine the Nusselt number from

$$Nu = \frac{hD_h}{k} = 0.023\,\text{Re}^{0.8}\,\text{Pr}^{0.4} = 0.023(4091)^{0.8}(0.7268)^{0.4} = 15.69$$

and

$$h = \frac{k}{D_h}Nu = \frac{0.02625\ \text{W/m.°C}}{0.16\ \text{m}}(15.69) = 2.574\ \text{W/m}^2.°\text{C}$$

The highest component surface temperature will occur at the exit of the duct. Assuming uniform surface heat flux, its value is determined from

$$\dot{Q}/A_s = h(T_{s,highest} - T_e)$$

$$T_{s,highest} = T_e + \frac{\dot{Q}/A_s}{h} = 39.2°\text{C} + \frac{(0.85)(180\ \text{W})/[4(0.16\ \text{m})(1\ \text{m})]}{2.574\ \text{W/m}^2.°\text{C}} = \mathbf{132°C}$$