6-94 Two streams of cold and warm air are mixed in a chamber. If the ratio of hot to cold air is 1.6, the mixture temperature and the rate of heat gain of the room are to be determined.

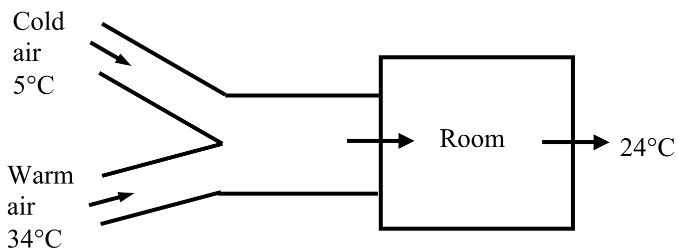
Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** The device is adiabatic and thus heat transfer is negligible.

Properties The gas constant of air is $R = 0.287$ kPa.m^3/kg.K. The enthalpies of air are obtained from air table (Table A-21) as

$$h_1 = h_{@278\text{ K}} = 278.13 \text{ kJ/kg}$$

$$h_2 = h_{@\,307\text{ K}} = 307.23 \text{ kJ/kg}$$

$$h_{\text{room}} = h_{@\,297\text{ K}} = 297.18 \text{ kJ/kg}$$



Analysis (*a*) We take the mixing chamber as the system, which is a control volume since mass crosses the boundary. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance:

$$\dot m_{\text{in}} - \dot m_{\text{out}} = \Delta \dot m_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \rightarrow \dot m_{\text{in}} = \dot m_{\text{out}} \rightarrow \dot m_1 + 1.6\dot m_1 = \dot m_3 = 2.6\dot m_1 \quad \text{since} \quad \dot m_2 = 1.6\dot m_1$$

Energy balance:

$$\underbrace{\dot E_{\text{in}} - \dot E_{\text{out}}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot E_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\ \text{potential, etc. energies}}} = 0$$

$$\dot E_{\text{in}} = \dot E_{\text{out}}$$

$$\dot m_1 h_1 + \dot m_2 h_2 = \dot m_3 h_3 \quad (\text{since } \dot Q \cong \dot W \cong \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two gives $\dot m_1 h_1 + 1.6\dot m_1 h_2 = 2.6\dot m_1 h_3$ *or* $h_3 = (h_1 + 1.6h_2)/2.6$

Substituting,

$$h_3 = (278.13 + 1.6\times 307.23)/2.6 = 296.04 \text{ kJ/kg}$$

From air table at this enthalpy, the mixture temperature is

$$T_3 = T_{@\,h = 296.04 \text{ kJ/kg}} = 295.9 \text{ K} = \mathbf{22.9°C}$$

(*b*) The mass flow rates are determined as follows

$$v_1 = \frac{RT_1}{P} = \frac{(0.287 \text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(5+273 \text{ K})}{105 \text{ kPa}} = 0.7599 \text{ m}^3/\text{kg}$$

$$\dot m_1 = \frac{\dot V_1}{v_1} = \frac{1.25 \text{ m}^3/\text{s}}{0.7599 \text{ m}^3/\text{kg}} = 1.645 \text{ kg/s}$$

$$\dot m_3 = 2.6\dot m_1 = 2.6(1.645 \text{ kg/s}) = 4.277 \text{ kg/s}$$

The rate of heat gain of the room is determined from

$$\dot Q_{\text{cool}} = \dot m_3 (h_{\text{room}} - h_3) = (4.277 \text{ kg/s})(297.18 - 296.04) \text{ kJ/kg} = \mathbf{4.88 \text{ kW}}$$