6-51 Air is compressed at a rate of 10 L/s by a compressor. The work required per unit mass and the power required 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** Air is an ideal gas with constant specific heats.

Properties The constant pressure specific heat of air at the average temperature of (20+300)/2=160°C=433 K is c_p = 1.018 kJ/kg·K (Table A-2b). The gas constant of air is R = 0.287 kPa·m^3/kg·K (Table A-1).

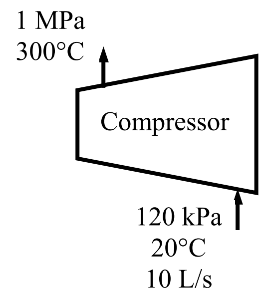
Analysis (a) There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the compressor as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

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

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{in} + \dot{m}h_1 = \dot{m}h_2 \quad (\text{since } \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot{W}_{in} = \dot{m}(h_2 - h_1) = \dot{m}c_p(T_2 - T_1)$$



Thus,

$$w_{in} = c_p(T_2 - T_1) = (1.018\text{ kJ/kg}\cdot\text{K})(300 - 20)\text{K} = \mathbf{285.0\ kJ/kg}$$

(b) The specific volume of air at the inlet and the mass flow rate are

$$\boldsymbol{v}_1 = \frac{RT_1}{P_1} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(20 + 273\text{ K})}{120\text{ kPa}} = 0.7008\text{ m}^3/\text{kg}$$

$$\dot{m} = \frac{\dot{\boldsymbol{V}}_1}{\boldsymbol{v}_1} = \frac{0.010\text{ m}^3/\text{s}}{0.7008\text{ m}^3/\text{kg}} = 0.01427\text{ kg/s}$$

Then the power input is determined from the energy balance equation to be

$$\dot{W}_{in} = \dot{m}c_p(T_2 - T_1) = (0.01427\text{ kg/s})(1.018\text{ kJ/kg}\cdot\text{K})(300 - 20)\text{K} = \mathbf{4.068\ kW}$$