

7-32C Yes, because an internally reversible, adiabatic process involves no irreversibilities or heat transfer.

7-60 Steam is expanded in an isentropic turbine. The work produced is to be determined.

Assumptions 1 This is a steady-flow process since there is no change with time. 2 The process is isentropic (i.e., reversible-adiabatic).

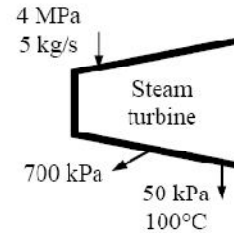
Analysis There is one inlet and two exits. We take the turbine as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{\text{system}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} \stackrel{\text{no (steady)}}{=} 0$$

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

$$\dot{m}_1 h_1 - \dot{m}_2 h_2 + \dot{m}_3 h_3 + \dot{W}_{\text{out}}$$

$$\dot{W}_{\text{out}} = \dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3$$



From a mass balance,

$$\dot{m}_2 = 0.05 \dot{m}_1 = (0.05)(5 \text{ kg/s}) = 0.25 \text{ kg/s}$$

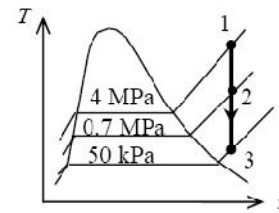
$$\dot{m}_3 = 0.95 \dot{m}_1 = (0.95)(5 \text{ kg/s}) = 4.75 \text{ kg/s}$$

Noting that the expansion process is isentropic, the enthalpies at three states are determined as follows:

$$\left. \begin{array}{l} P_3 = 50 \text{ kPa} \\ T_3 = 100^\circ\text{C} \end{array} \right\} \begin{array}{l} h_3 = 2682.4 \text{ kJ/kg} \\ s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array} \quad (\text{Table A-6})$$

$$\left. \begin{array}{l} P_1 = 4 \text{ MPa} \\ s_1 = s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array} \right\} h_1 = 3979.3 \text{ kJ/kg} \quad (\text{Table A-6})$$

$$\left. \begin{array}{l} P_2 = 700 \text{ kPa} \\ s_2 = s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array} \right\} h_2 = 3309.1 \text{ kJ/kg} \quad (\text{Table A-6})$$



Substituting,

$$\begin{aligned} \dot{W}_{\text{out}} &= \dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3 \\ &= (5 \text{ kg/s})(3979.3 \text{ kJ/kg}) - (0.25 \text{ kg/s})(3309.1 \text{ kJ/kg}) - (4.75 \text{ kg/s})(2682.4 \text{ kJ/kg}) \\ &= \mathbf{-6328 \text{ kW}} \end{aligned}$$

7-72 An iron block and a copper block are dropped into a large lake. The total amount of entropy change when both blocks cool to the lake temperature is to be determined.

Assumptions 1 Both the water and the iron block are incompressible substances with constant specific heats at room temperature. 2 Kinetic and potential energies are negligible.

Properties The specific heats of iron and copper at room temperature are $c_{\text{iron}} = 0.45 \text{ kJ/kg} \cdot ^\circ\text{C}$ and $c_{\text{copper}} = 0.386 \text{ kJ/kg} \cdot ^\circ\text{C}$ (Table A-3).

Analysis The thermal-energy capacity of the lake is very large, and thus the temperatures of both the iron and the copper blocks will drop to the lake temperature (15°C) when the thermal equilibrium is established. Then the entropy changes of the blocks become

$$\Delta S_{\text{iron}} = mc_{\text{avg}} \ln\left(\frac{T_2}{T_1}\right) = (50 \text{ kg})(0.45 \text{ kJ/kg} \cdot \text{K}) \ln\left(\frac{288 \text{ K}}{353 \text{ K}}\right) = -4.579 \text{ kJ/K}$$

$$\Delta S_{\text{copper}} = mc_{\text{avg}} \ln\left(\frac{T_2}{T_1}\right) = (20 \text{ kg})(0.386 \text{ kJ/kg} \cdot \text{K}) \ln\left(\frac{288 \text{ K}}{353 \text{ K}}\right) = -1.571 \text{ kJ/K}$$

We take both the iron and the copper blocks, as the *system*. This is a *closed system* since no mass crosses the system boundary during the process. The energy balance for this system can be expressed as

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc. energies}}} \\ -Q_{\text{out}} = \Delta U = \Delta U_{\text{iron}} + \Delta U_{\text{copper}}$$

or,

$$Q_{\text{out}} = [mc(T_1 - T_2)]_{\text{iron}} + [mc(T_1 - T_2)]_{\text{copper}}$$

Substituting,

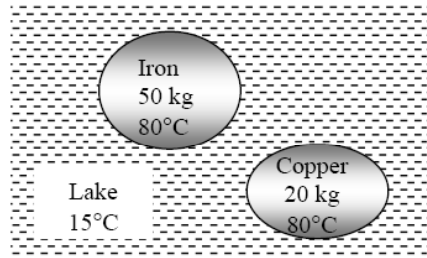
$$Q_{\text{out}} = (50 \text{ kg})(0.45 \text{ kJ/kg} \cdot \text{K})(353 - 288)\text{K} + (20 \text{ kg})(0.386 \text{ kJ/kg} \cdot \text{K})(353 - 288)\text{K} \\ = 1964 \text{ kJ}$$

Thus,

$$\Delta S_{\text{lake}} = \frac{Q_{\text{lake, in}}}{T_{\text{lake}}} = \frac{1964 \text{ kJ}}{288 \text{ K}} = 6.820 \text{ kJ/K}$$

Then the total entropy change for this process is

$$\Delta S_{\text{total}} = \Delta S_{\text{iron}} + \Delta S_{\text{copper}} + \Delta S_{\text{lake}} = -4.579 - 1.571 + 6.820 = \mathbf{0.670 \text{ kJ/K}}$$



7-75C For an ideal gas, $dh = c_p dT$ and $v = RT/P$. From the second Tds relation,

$$ds = \frac{dh}{T} - \frac{vdP}{T} = \frac{c_p dT}{T} - \frac{RT}{P} \frac{dP}{T} = c_p \frac{dT}{T} - R \frac{dP}{P}$$

Integrating,

$$s_2 - s_1 = c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

Since c_p is assumed to be constant.

7-80C The entropy change relations of an ideal gas simplify to

$$\Delta s = c_p \ln(T_2/T_1) \text{ for a constant pressure process}$$

and $\Delta s = c_v \ln(T_2/T_1)$ for a constant volume process.

Noting that $c_p > c_v$, the entropy change will be larger for a constant pressure process.

7-95 An insulated rigid tank contains argon gas at a specified pressure and temperature. A valve is opened, and argon escapes until the pressure drops to a specified value. The final mass in the tank is to be determined.

Assumptions 1 At specified conditions, argon can be treated as an ideal gas. 2 The process is given to be reversible and adiabatic, and thus isentropic. Therefore, isentropic relations of ideal gases apply.

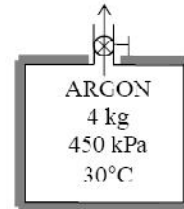
Properties The specific heat ratio of argon is $k = 1.667$ (Table A-2).

Analysis From the ideal gas isentropic relations,

$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{(k-1)/k} = (303 \text{ K}) \left(\frac{200 \text{ kPa}}{450 \text{ kPa}} \right)^{0.667/1.667} = 219.0 \text{ K}$$

The final mass in the tank is determined from the ideal gas relation,

$$\frac{P_1 \mathcal{V}}{P_2 \mathcal{V}} = \frac{m_1 R T_1}{m_2 R T_2} \longrightarrow m_2 = \frac{P_2 T_1}{P_1 T_2} m_1 = \frac{(200 \text{ kPa})(303 \text{ K})}{(450 \text{ kPa})(219 \text{ K})} (4 \text{ kg}) = \mathbf{2.46 \text{ kg}}$$



7-101 Air is expanded in an adiabatic nozzle by a polytropic process. The temperature and velocity at the exit are to be determined.

Assumptions 1 This is a steady-flow process since there is no change with time. 2 There is no heat transfer or shaft work associated with the process. 3 Air is an ideal gas with constant specific heats.

Properties The properties of air at room temperature are $c_p = 1.005 \text{ kJ/kg}\cdot\text{K}$ and $k = 1.4$ (Table A-2a).

Analysis For the polytropic process of an ideal gas, $Pv^n = \text{Constant}$, and the exit temperature is given by

$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{(n-1)/n} = (373 \text{ K}) \left(\frac{200 \text{ kPa}}{700 \text{ kPa}} \right)^{0.3/1.3} = \mathbf{279 \text{ K}}$$

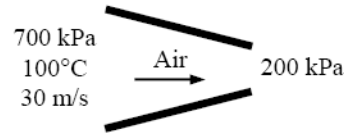
There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take nozzle as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{\text{system}}^{\text{no (steady)}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} = 0$$

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

$$\dot{m} \left(h_1 + \frac{V_1^2}{2} \right) = \dot{m} \left(h_2 + \frac{V_2^2}{2} \right)$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$



Solving for the exit velocity,

$$\begin{aligned} V_2 &= \left[V_1^2 + 2(h_1 - h_2) \right]^{0.5} \\ &= \left[V_1^2 + 2c_p(T_1 - T_2) \right]^{0.5} \\ &= \left[(30 \text{ m/s})^2 + 2(1.005 \text{ kJ/kg}\cdot\text{K})(373 - 279)\text{K} \left(\frac{1000 \text{ m}^2/\text{s}^2}{1 \text{ kJ/kg}} \right) \right]^{0.5} \\ &= \mathbf{436 \text{ m/s}} \end{aligned}$$