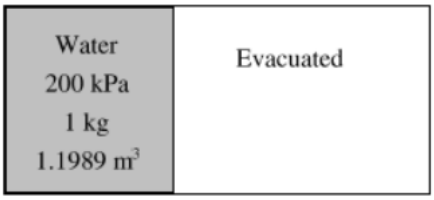
**1(A).** One kilogram of water vapour at 200 kPa fills the 1.1989-$m^3$ left chamber of a partitioned system. The right chamber has twice the volume of the left chamber and is initially evacuated. Determine the pressure in the chamber after the partition has been removed and enough heat has been transferred so that the water temperature is 5°C.

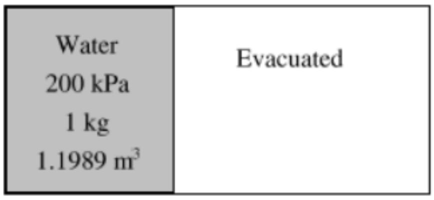
**6 Marks.**




## Solution:

**3-37** Left chamber of a partitioned system contains water at a specified state while the right chamber is evacuated. The partition is now ruptured and heat is transferred from the water. The pressure at the final state is to be determined.

***Analysis*** The initial specific volume is




$$v_1 = \frac{V_1}{m} = \frac{1.1989 \text{ m}^3}{1 \text{ kg}} = 1.1989 \text{ m}^3/\text{kg}$$

At the final state, the water occupies three times the initial volume. Then,

$$v_2 = 3v_1 = 3(1.1989 \text{ m}^3/\text{kg}) = 3.5967 \text{ m}^3/\text{kg}$$

Based on this specific volume and the final temperature, the final state is a saturated mixture and the pressure is

$$P_2 = \boxed{\text{Psat@5C = 0.8725}} \text{ (Table A-4)}$$

**1(B).** A person cooks a meal (predominantly watery) in a 30-cm diameter pot and then covers it with a well-fitting lid. The food cools to the room temperature of 20°C at mean sea level. At 20°C, the contents of the vessel are in a saturated state. The total mass of the food and the pot is 8 kg. Now, the person tries to open the pan by lifting the lid, which has negligible weight. Assuming no air has leaked into the pan during cooling, determine analytically if the lid will open or if the pan will move up together with the lid.

**7 Marks**.

## Solution

**3-46** A person cooks a meal in a pot that is covered with a well-fitting lid, and leaves the food to cool to the room temperature. It is to be determined if the lid will open or the pan will move up together with the lid when the person attempts to open the pan by lifting the lid up.

***Assumptions*** **1** The local atmospheric pressure is 1 atm = 101.325 kPa. **2** The weight of the lid is small and thus its effect on the boiling pressure and temperature is negligible. **3** No air has leaked into the pan during cooling.

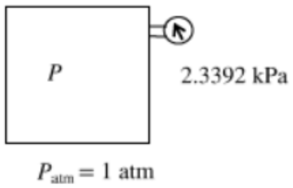
***Properties*** The saturation pressure of water at 20°C is 2.3392 kPa (Table A-4).

***Analysis*** Noting that the weight of the lid is negligible, the reaction force $F$ on the lid after cooling at the pan-lid interface can be determined from a force balance on the lid in the vertical direction to be

$$PA + F = P_{atm}A$$

or,

$$F = A(P_{atm} - P) = (\pi D^2/4)(P_{atm} - P)$$
$$= \frac{\pi(0.3\text{ m})^2}{4}(101{,}325 - 2339.2)\text{ Pa}$$
$$= 6997\text{ m}^2\,\text{Pa} = \mathbf{6997\ N} \quad (\text{since } 1\text{ Pa} = 1\text{ N/m}^2)$$




The weight of the pan and its contents is

$$W = mg = (8\text{ kg})(9.81\text{ m/s}^2) = \mathbf{78.5\ N}$$

which is much less than the reaction force of 6997 N at the pan-lid interface. Therefore, the pan will **move up** together with the lid when the person attempts to open the pan by lifting the lid up. In fact, it looks like the lid will not open even if the mass of the pan and its contents is several hundred kg.

**1(C).** A piston-cylinder device initially contains 1.4 kg saturated water at 200°C. The heat is transferred to the water until the volume quadruples (4 times) and the cylinder contains saturated vapour only. Determine (*a*) the volume of the cylinder, (*b*) the final temperature and pressure, and (*c*) the internal energy change of the water. **7 Marks.**

## Solution

**3-59** Heat is supplied to a piston-cylinder device that contains water at a specified state. The volume of the tank, the final temperature and pressure, and the internal energy change of water are to be determined.

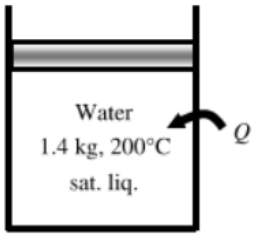
***Properties*** The saturated liquid properties of water at 200°C are: $v_f = 0.001157$ m³/kg and $u_f = 850.46$ kJ/kg (Table A-4).

***Analysis*** (*a*) The cylinder initially contains saturated liquid water. The volume of the cylinder at the initial state is

$$V_1 = m v_1 = (1.4\text{ kg})(0.001157\text{ m}^3/\text{kg}) = 0.001619\text{ m}^3$$

The volume at the final state is

$$V = 4(0.001619) = \mathbf{0.006476\ m^3}$$




(*b*) The final state properties are

$$v_2 = \frac{V}{m} = \frac{0.006476\text{ m}^3}{1.4\text{ kg}} = 0.004626\text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} v_2 = 0.004626\text{ m}^3/\text{kg} \\ x_2 = 1 \end{array}\right\} \begin{array}{l} T_2 = \mathbf{371.3°C} \\ P_2 = \mathbf{21{,}367\ kPa} \\ u_2 = 2201.5\text{ kJ/kg} \end{array} \qquad \text{(Table A-4 or A-5 or EES)}$$

(*c*) The total internal energy change is determined from

$$\Delta U = m(u_2 - u_1) = (1.4\text{ kg})(2201.5\text{-}850.46)\text{ kJ/kg} = \mathbf{1892\ kJ}$$

**2(A).** A piston-cylinder device initially contains 0.6 m³ of saturated water vapour at 250 kPa. At this state, the piston rests on a set of stops, and the mass of the piston is such that a pressure of 300 kPa is required to move it. Heat is now slowly transferred to the steam until the volume doubles. Show the process on a *P-v* diagram with respect to saturation lines and determine (*a*) the final temperature, (*b*) the work done during this process, and (*c*) the total heat transfer. **12 Marks.**

Solution:

**4-41** A cylinder equipped with a set of stops for the piston to rest on is initially filled with saturated water vapor at a specified pressure. Heat is transferred to water until the volume doubles. The final temperature, the boundary work done by the steam, and the amount of heat transfer are to be determined, and the process is to be shown on a *P-v* diagram.

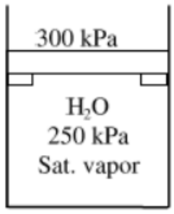
***Assumptions*** **1** The cylinder is stationary and thus the kinetic and potential energy changes are zero. **2** There are no work interactions involved other than the boundary work. **3** The thermal energy stored in the cylinder itself is negligible. **4** The compression or expansion process is quasi-equilibrium.

***Analysis*** We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as

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

$$Q_{in} - W_{b,out} = \Delta U = m(u_3 - u_1) \quad \text{(since KE = PE = 0)}$$

$$Q_{in} = m(u_3 - u_1) + W_{b,out}$$



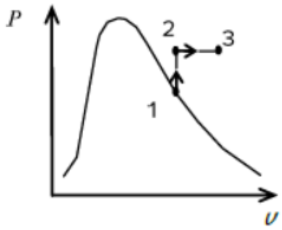

The properties of steam are (Tables A-4 through A-6)

$$\left.\begin{array}{l} P_1 = 250 \text{ kPa} \\ sat.vapor \end{array}\right\} \begin{array}{l} v_1 = v_{g@250 \text{ kPa}} = 0.71873 \text{ m}^3/\text{kg} \\ u_1 = u_{g@250 \text{ kPa}} = 2536.8 \text{ kJ/kg} \end{array}$$

$$m = \frac{V_1}{v_1} = \frac{0.6 \text{ m}^3}{0.71873 \text{ m}^3/\text{kg}} = 0.8348 \text{ kg}$$

$$v_3 = \frac{V_3}{m} = \frac{1.2 \text{ m}^3}{0.8348 \text{ kg}} = 1.4375 \text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} P_3 = 300 \text{ kPa} \\ v_3 = 1.4375 \text{ m}^3/\text{kg} \end{array}\right\} \begin{array}{l} T_3 = \mathbf{662^\circ C} \\ u_3 = 3411.4 \text{ kJ/kg} \end{array}$$




(*b*) The work done during process 1-2 is zero (since *V* = const) and the work done during the constant pressure process 2-3 is

$$W_{b,out} = \int_2^3 P\,dV = P(V_3 - V_2) = (300 \text{ kPa})(1.2 - 0.6) \text{ m}^3 \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3}\right) = \mathbf{180 \text{ kJ}}$$

(*c*) Heat transfer is determined from the energy balance,

$$\begin{aligned} Q_{in} &= m(u_3 - u_1) + W_{b,out} \\ &= (0.8348 \text{ kg})(3411.4 - 2536.8) \text{ kJ/kg} + 180 \text{ kJ} \\ &= \mathbf{910 \text{ kJ}} \end{aligned}$$

**2(B).** A commercial refrigerator with refrigerant-134a as the working fluid is used to keep the refrigerated space at -35°C by rejecting waste heat to cooling water that enters the condenser at 18°C at a rate of 0.25 kg/s and leaves at 26°C. The refrigerant enters the condenser at 1.2 MPa and 50°C and leaves at the same pressure subcooled by 5°C. The properties of the subcooled refrigerant at the exit from the condenser can be taken from the R-134a temperature-based table. If the compressor consumes 3.3 kW of power, determine (*a*) the mass flow rate of the refrigerant, (*b*) the refrigeration load, (*c*) the COP, and (*d*) the minimum power input to the compressor for the same refrigeration load.
**13 Marks.**

## Solution

**6-107** A commercial refrigerator with R-134a as the working fluid is considered. The condenser inlet and exit states are specified. The mass flow rate of the refrigerant, the refrigeration load, the COP, and the minimum power input to the compressor are to be determined.

***Assumptions*** **1** The refrigerator operates steadily. **2** The kinetic and potential energy changes are zero.

***Properties*** The properties of R-134a and water are (Steam and R-134a tables)

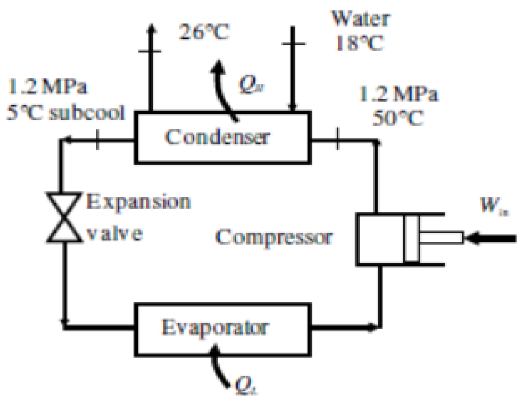
$$\left.\begin{array}{l} P_1 = 1.2\text{ MPa} \\ T_1 = 50^\circ\text{C} \end{array}\right\} h_1 = 278.28\text{ kJ/kg}$$

$$T_2 = T_{sat@1.2\text{ MPa}} + \Delta T_{subcool} = 46.3 - 5 = 41.3^\circ\text{C}$$

$$\left.\begin{array}{l} P_2 = 1.2\text{ MPa} \\ T_2 = 41.3^\circ\text{C} \end{array}\right\} h_2 = 110.19\text{ kJ/kg}$$

$$\left.\begin{array}{l} T_{w,1} = 18^\circ\text{C} \\ x_{w,1} = 0 \end{array}\right\} h_{w,1} = 75.54\text{ kJ/kg}$$

$$\left.\begin{array}{l} T_{w,2} = 26^\circ\text{C} \\ x_{w,2} = 0 \end{array}\right\} h_{w,2} = 109.01\text{ kJ/kg}$$




***Analysis*** (*a*) The rate of heat transferred to the water is the energy change of the water from inlet to exit

$$\dot{Q}_H = \dot{m}_w (h_{w,2} - h_{w,1}) = (0.25\text{ kg/s})(109.01 - 75.54)\text{ kJ/kg} = 8.367\text{ kW}$$

The energy decrease of the refrigerant is equal to the energy increase of the water in the condenser. That is,

$$\dot{Q}_H = \dot{m}_R (h_1 - h_2) \longrightarrow \dot{m}_R = \frac{\dot{Q}_H}{h_1 - h_2} = \frac{8.367\text{ kW}}{(278.28 - 110.19)\text{ kJ/kg}} = \mathbf{0.0498\text{ kg/s}}$$

(*b*) The refrigeration load is

$$\dot{Q}_L = \dot{Q}_H - \dot{W}_{in} = 8.37 - 3.30 = \mathbf{5.07\text{ kW}}$$

(*c*) The COP of the refrigerator is determined from its definition,

$$\text{COP} = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{5.07\text{ kW}}{3.3\text{ kW}} = \mathbf{1.54}$$

(*d*) The COP of a reversible refrigerator operating between the same temperature limits is

$$\text{COP}_{max} = \frac{1}{T_H / T_L - 1} = \frac{1}{(18 + 273)/(-35 + 273) - 1} = 4.49$$

Then, the minimum power input to the compressor for the same refrigeration load would be

$$\dot{W}_{in,min} = \frac{\dot{Q}_L}{\text{COP}_{max}} = \frac{5.07\text{ kW}}{4.49} = \mathbf{1.13\text{ kW}}$$

**3(A).** An electronic device dissipating 25 W has a mass of 20 g and a specific heat of 850 J/kg°C. The device is lightly used, and it is on for 5 minutes and then off for several hours, during which it cools to the ambient temperature of 25°C. Determine the highest possible temperature of the device at the end of the 5-minute operating period. What would your answer be if the device were attached to a 0.5 kg aluminium heat sink? The specific heat of aluminium is 902 J/kg°C. **8 Marks.**

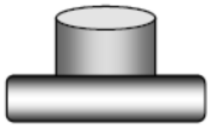
Solution:

**4-88** An electronic device is on for 5 minutes, and off for several hours. The temperature of the device at the end of the 5-min operating period is to be determined for the cases of operation with and without a heat sink.

***Assumptions*** **1** The device and the heat sink are isothermal. **2** The thermal properties of the device and of the sink are constant. **3** Heat loss from the device during on time is disregarded since the highest possible temperature is to be determined.

***Properties*** The specific heat of the device is given to be $c_p = 850$ J/kg.°C. The specific heat of aluminum at room temperature of 300 K is 902 J/kg.°C (Table A-3).

***Analysis*** We take the device to be the system. Noting that electrical energy is supplied, the energy balance for this closed system can be expressed as




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

$$W_{e,\,in} = \Delta U_{device} = m(u_2 - u_1)$$

$$\dot{W}_{e,\,in}\Delta t = mc(T_2 - T_1)$$

Substituting, the temperature of the device at the end of the process is determined to be

$$(25\text{ J/s})(5\times 60\text{ s}) = (0.020\text{ kg})(850\text{ J/kg.°C})(T_2 - 25)\text{°C} \rightarrow T_2 = \mathbf{466°C} \text{ (without the heat sink)}$$

**Case 2** When a heat sink is attached, the energy balance can be expressed as

$$W_{e,in} = \Delta U_{device} + \Delta U_{heat\ sink}$$

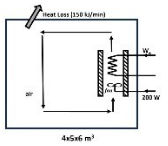
$$\dot{W}_{e,in}\Delta t = mc(T_2 - T_1)_{device} + mc(T_2 - T_1)_{heat\ sink}$$

Substituting, the temperature of the device-heat sink combination is determined to be

$$(25\text{ J/s})(5\times 60\text{ s}) = (0.020\text{ kg})(850\text{ J/kg.°C})(T_2 - 25)\text{°C} + (0.500\text{ kg})(902\text{ J/kg.°C})(T_2 - 25)\text{°C}$$

$$T_2 = \mathbf{41.0°C} \text{ (with heat sink)}$$

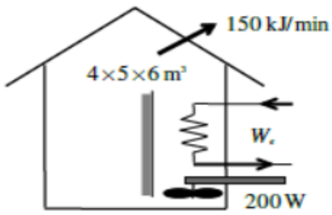
**3(B).** A 4 m × 5 m × 6 m room is to be heated by an electric resistance heater placed in a short duct in the room. Initially, the room is at 15°C, and the local atmospheric pressure is 98 kPa. The room is losing heat steadily to the outside at a rate of 150 kJ/min. A 200 W fan recirculates the room air steadily through the duct and the electric heater at an average mass flow rate of 40 kg/min. The duct can be assumed to be adiabatic, and no air leaks in or out of the room. If it takes 25 min for the room air to reach an average temperature of 25°C, find (*a*) the power rating of the electric heater and (*b*) the temperature rise that the air experiences each time it passes through the duct.
$C_p$: 1.005 kJ/kg-K, $C_v$: 0.718 kJ/kg-K **17 Marks.**



***Assumptions*** **1** Steady operating conditions exist. **2** Air is an ideal gas with constant specific heats at room temperature. **3** Kinetic and potential energy changes are negligible. **4** The heating duct is adiabatic, and thus heat transfer through it is negligible. **5** No air leaks in and out of the room.

***Properties*** The gas constant of air is 0.287 kPa.m³/kg.K (Table A-1). The specific heats of air at room temperature are $c_p$ = 1.005 and $c_v$ = 0.718 kJ/kg·K (Table A-2).

***Analysis*** (*a*) The total mass of air in the room is




$$V = 4\times5\times6 \text{ m}^3 = 120 \text{ m}^3$$

$$m = \frac{P_1V}{RT_1} = \frac{(98 \text{ kPa})(120 \text{ m}^3)}{(0.287 \text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(288 \text{ K})} = 142.3 \text{ kg}$$

We first take the ***entire room*** as our system, which is a closed system since no mass leaks in or out. The power rating of the electric heater is determined by applying the conservation of energy relation to this constant volume closed system:

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

$$W_{\text{e,in}} + W_{\text{fan,in}} - Q_{out} = \Delta U \quad (\text{since } \Delta\text{KE} = \Delta\text{PE} = 0)$$

$$\Delta t\left(\dot W_{\text{e,in}} + \dot W_{\text{fan,in}} - \dot Q_{\text{out}}\right) = mc_{v,\text{avg}}(T_2 - T_1)$$

Solving for the electrical work input gives

$$\begin{aligned}\dot W_{\text{e,in}} &= \dot Q_{\text{out}} - \dot W_{\text{fan,in}} + mc_v(T_2 - T_1)/\Delta t\\ &= (150/60 \text{ kJ/s}) - (0.2 \text{ kJ/s}) + (142.3 \text{ kg})(0.718 \text{ kJ/kg}\cdot{}^\circ\text{C})(25-15)^\circ\text{C}/(25\times60 \text{ s})\\ &= \mathbf{2.981 \text{ kW}}\end{aligned}$$

(*b*) We now take the ***heating duct*** as the system, which is a control volume since mass crosses the boundary. There is only one inlet and one exit, and thus $\dot m_1 = \dot m_2 = \dot m$. The energy balance for this adiabatic steady-flow system can be expressed in the rate form as

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

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

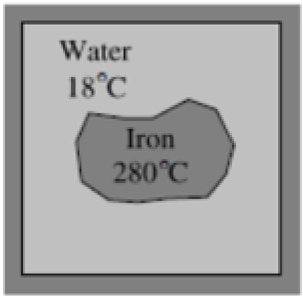
$$\dot W_{\text{e,in}} + \dot W_{\text{fan,in}} + \dot m h_1 = \dot m h_2 \quad (\text{since } \dot Q = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot W_{\text{e,in}} + \dot W_{\text{fan,in}} = \dot m(h_2 - h_1) = \dot m c_p(T_2 - T_1)$$

Thus,

$$\Delta T = T_2 - T_1 = \frac{\dot W_{\text{e,in}} + \dot W_{\text{fan,in}}}{\dot m c_p} = \frac{(2.981+0.2) \text{ kJ/s}}{(40/60 \text{ kg/s})(1.005 \text{ kJ/kg}\cdot\text{K})} = \mathbf{4.75^\circ C}$$

**4(A).** A 25-kg iron block initially at 280°C is quenched in an insulated tank that contains 100 kg of water at 18°C. Assuming the water that vaporizes during the process condenses back into the tank, determine the total entropy change during this process. **10 Marks.**




## Solution

**7-64** A hot iron block is dropped into water in an insulated tank. The total entropy change during this process is to be determined.

***Assumptions*** **1** Both the water and the iron block are incompressible substances with constant specific heats at room temperature. **2** The system is stationary and thus the kinetic and potential energies are negligible. **3** The tank is well-insulated and thus there is no heat transfer. **4** The water that evaporates, condenses back.

***Properties*** The specific heat of water at 25°C is $c_p$ = 4.18 kJ/kg.°C. The specific heat of iron at room temperature is $c_p$ = 0.45 kJ/kg.°C (Table A-3).

***Analysis*** We take the entire contents of the tank, water + iron block, 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

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

$$0 = \Delta U$$


or,

$$\Delta U_{iron} + \Delta U_{water} = 0$$

$$[mc(T_2 - T_1)]_{iron} + [mc(T_2 - T_1)]_{water} = 0$$

Substituting,

$$(25 \text{ kg})(0.45 \text{ kJ/kg}\cdot\text{K})(T_2 - 280°\text{C}) + (100 \text{ kg})(4.18 \text{ kJ/kg}\cdot\text{K})(T_2 - 18°\text{C}) = 0$$

$$\rightarrow T_2 = \mathbf{24.9°C} = 297.9 \text{ K}$$

The entropy generated during this process is determined from

$$\Delta S_{iron} = mc_{avg} \ln\left(\frac{T_2}{T_1}\right) = (25 \text{ kg})(0.45 \text{ kJ/kg}\cdot\text{K}) \ln\left(\frac{297.9 \text{ K}}{553 \text{ K}}\right) = -6.961 \text{ kJ/K}$$

$$\Delta S_{water} = mc_{avg} \ln\left(\frac{T_2}{T_1}\right) = (100 \text{ kg})(4.18 \text{ kJ/kg}\cdot\text{K}) \ln\left(\frac{297.9 \text{ K}}{291 \text{ K}}\right) = 9.749 \text{ kJ/K}$$

Thus,

$$S_{gen} = \Delta S_{total} = \Delta S_{iron} + \Delta S_{water} = -6.961 + 9.749 = \mathbf{2.79 \text{ kJ / K}}$$

**4(B).** An insulated piston-cylinder device contains 0.05 m³ of saturated refrigerant R-134a vapour at 0.8-MPa pressure. The refrigerant is now allowed to expand reversibly until the pressure drops to 0.4 MPa. Determine: (*a*) the final temperature in the cylinder, and (*b*) the work done by the refrigerant.

**10 Marks.**

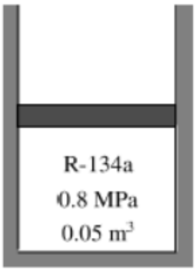
## Solution

**7-36** An insulated cylinder is initially filled with saturated R-134a vapor at a specified pressure. The refrigerant expands in a reversible manner until the pressure drops to a specified value. The final temperature in the cylinder and the work done by the refrigerant are to be determined.

***Assumptions*** **1** The kinetic and potential energy changes are negligible. **2** The cylinder is well-insulated and thus heat transfer is negligible. **3** The thermal energy stored in the cylinder itself is negligible. **4** The process is stated to be reversible.

***Analysis*** (*a*) This is a reversible adiabatic (i.e., isentropic) process, and thus $s_2 = s_1$. From the refrigerant tables (Tables A-11 through A-13),

$$\left.\begin{array}{l} P_1 = 0.8 \text{ MPa} \\ \text{sat. vapor} \end{array}\right\} \begin{array}{l} \upsilon_1 = \upsilon_{g\,@\,0.8\text{ MPa}} = 0.025645 \text{ m}^3/\text{kg} \\ u_1 = u_{g\,@\,0.8\text{ MPa}} = 246.82 \text{ kJ/kg} \\ s_1 = s_{g\,@\,0.8\text{ MPa}} = 0.91853 \text{ kJ/kg}\cdot\text{K} \end{array}$$




Also,

$$m = \frac{V}{\upsilon_1} = \frac{0.05 \text{ m}^3}{0.025645 \text{ m}^3/\text{kg}} = 1.950 \text{ kg}$$

and

$$\left.\begin{array}{l} P_2 = 0.4 \text{ MPa} \\ s_2 = s_1 \end{array}\right\} \begin{array}{l} x_2 = \dfrac{s_2 - s_f}{s_{fg}} = \dfrac{0.91853 - 0.24757}{0.67954} = 0.9874 \\ u_2 = u_f + x_2 u_{fg} = 63.61 + (0.9874)(171.49) = 232.94 \text{ kJ/kg} \end{array}$$

$$T_2 = T_{\text{sat}\,@\,0.4\text{ MPa}} = \mathbf{8.91°C}$$

(*b*) We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this adiabatic closed system can be expressed as

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

$$-W_{b,\text{out}} = \Delta U$$

$$W_{b,\text{out}} = m(u_1 - u_2)$$

Substituting, the work done during this isentropic process is determined to be

$$W_{b,\text{out}} = m(u_1 - u_2) = (1.950 \text{ kg})(246.82 - 232.94) \text{ kJ/kg} = \mathbf{27.1 \text{ kJ}}$$