تعداد سؤالات: تستی: تشریحی: ۵   زمان آزمون (دقیقه): تستی: -- تشریحی: ۱۲۰

نام درس: ترمودینامیک، ترمودینامیک۱

رشته تحصیلی /کد درس : مهندسی پزشکی بیومتریال مهندسی خودرو-۱۳۱۵۱۳۵-هوافضا- مکانیکها حرارت وسیالات-جامدات-ساخت وتولید- راه آهن جریه ۱۳۱۵۰۱۹

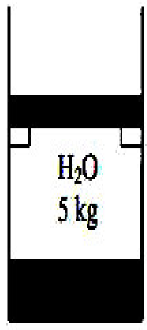
بارم نمره هرسوال۲/۸۰ می باشد.

۱-

$$T_1 = T_{sat@125\ kPa} = 106.0°C$$

The total initial volume is

$$V_1 = m_f v_f + m_g v_g = 2\times 0.001048 + 3\times 1.3750 = 4.127\ m^3$$



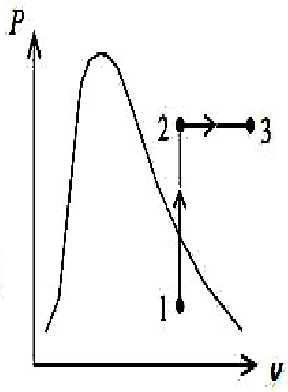
Then the total and specific volumes at the final state are

$$V_3 = 1.2V_1 = 1.2\times 4.127 = 4.953\ m^3$$

$$v_3 = \frac{V_3}{m} = \frac{4.953\ m^3}{5\ kg} = 0.9905\ m^3/kg$$

Thus,

$$\left.\begin{array}{l} P_3 = 300\ kPa \\ v_3 = 0.9905\ m^3/kg \end{array}\right\} T_3 = 373.6°C$$



(*b*) When the piston first starts moving, $P_2 = 300$ kPa and $V_2 = V_1 = 4.127$ m^3. The specific volume at this state is

$$v_2 = \frac{V_2}{m} = \frac{4.127\ m^3}{5\ kg} = 0.8254\ m^3/kg$$

which is greater than $v_g = 0.60582$ m^3/kg at 300 kPa. Thus **no liquid** is left in the cylinder when the piston starts moving.

(*c*) No work is done during process 1-2 since $V_1 = V_2$. The pressure remains constant during process 2-3 and the work done during this process is

$$W_b = \int_2^3 P\,dV = P_2(V_3 - V_2) = (300\ kPa)(4.953 - 4.127)m^3\left(\frac{1\ kJ}{1\ kPa\cdot m^3}\right) = 247.6\ kJ$$

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رشته تحصیلی /کد درس : مهندسی پزشکی بیومتریال مهندسی خودرو-۱۳۱۵۱۳۵-هوافضا- مکانیکها حرارت وسیالات-جامدات-ساخت وتولید- راه آهن جریه ۱۳۱۵۰۱۹

۲ -

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

$$-Q_{out} = \Delta U_A + \Delta U_B = [m(u_2 - u_1)]_A + [m(u_2 - u_1)]_B \quad (\text{since } W = \text{KE} = \text{PE} = 0)$$

The properties of steam in both tanks at the initial state are (Tables A-4 through A-6)

$$\left.\begin{array}{l} P_{1,A} = 1000 \text{ kPa} \\ T_{1,A} = 300°\text{C} \end{array}\right\} \begin{array}{l} v_{1,A} = 0.25799 \text{ m}^3/\text{kg} \\ u_{1,A} = 2793.7 \text{ kJ/kg} \end{array}$$

$$\left.\begin{array}{l} T_{1,B} = 150°\text{C} \\ x_1 = 0.50 \end{array}\right\} \begin{array}{ll} v_f = 0.001091, & v_g = 0.39248 \text{ m}^3/\text{kg} \\ u_f = 631.66, & u_{fg} = 1927.4 \text{ kJ/kg} \end{array}$$

$$v_{1,B} = v_f + x_1 v_{fg} = 0.001091 + [0.50 \times (0.39248 - 0.001091)] = 0.19679 \text{ m}^3/\text{kg}$$

$$u_{1,B} = u_f + x_1 u_{fg} = 631.66 + (0.50 \times 1927.4) = 1595.4 \text{ kJ/kg}$$

The total volume and total mass of the system are

$$V = V_A + V_B = m_A v_{1,A} + m_B v_{1,B} = (2 \text{ kg})(0.25799 \text{ m}^3/\text{kg}) + (3 \text{ kg})(0.19679 \text{ m}^3/\text{kg}) = 1.106 \text{ m}^3$$

$$m = m_A + m_B = 3 + 2 = 5 \text{ kg}$$

Now, the specific volume at the final state may be determined

$$v_2 = \frac{V}{m} = \frac{1.106 \text{ m}^3}{5 \text{ kg}} = 0.22127 \text{ m}^3/\text{kg}$$

which fixes the final state and we can determine other properties

$$\left.\begin{array}{l} P_2 = 300 \text{ kPa} \\ v_2 = 0.22127 \text{ m}^3/\text{kg} \end{array}\right\} \begin{array}{l} T_2 = T_{sat@300 \text{ kPa}} = \mathbf{133.5°C} \\ x_2 = \dfrac{v_2 - v_f}{v_g - v_f} = \dfrac{0.22127 - 0.001073}{0.60582 - 0.001073} = \mathbf{0.3641} \\ u_2 = u_f + x_2 u_{fg} = 561.11 + (0.3641 \times 1982.1) = 1282.8 \text{ kJ/kg} \end{array}$$

(*b*) Substituting,

$$-Q_{out} = \Delta U_A + \Delta U_B = [m(u_2 - u_1)]_A + [m(u_2 - u_1)]_B$$
$$= (2 \text{ kg})(1282.8 - 2793.7)\text{kJ/kg} + (3 \text{ kg})(1282.8 - 1595.4)\text{kJ/kg} = -3959 \text{ kJ}$$

or

$$Q_{out} = \mathbf{3959 \text{ kJ}}$$

۳-

$$\dot{Q}_{C.V.} + \sum m_i\left(h_i + \frac{V_i^2}{2} + gZ_i\right)$$

$$= \sum m_e\left(h_e + \frac{V_e^2}{2} + gZ_e\right)$$

$$+ \left[m_2\left(u_2 + \frac{V_2^2}{2} + gZ_2\right) - m_1\left(u_1 + \frac{V_1^2}{2} + gZ_1\right)\right]_{C.V.} + W_{C.V.}$$

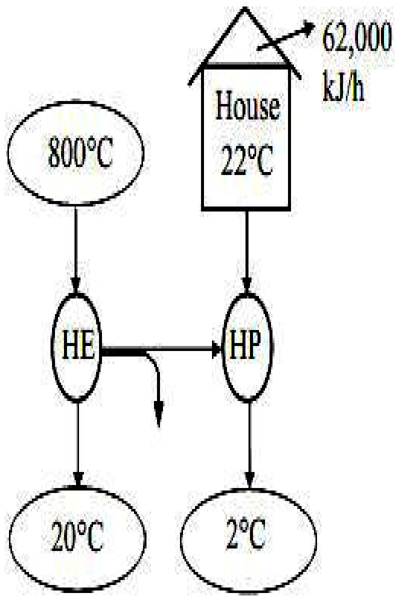
$$Q_{C.V.} = 0,\ W_{C.V.} = 0,\ m_e = 0,\ \text{and}\ (m_1)_{C.V.} = 0.$$

$$m_i h_i = m_2 u_2 \qquad m_2 = m_i \qquad h_i = u_2 \qquad h_i = u_2 = 3040.4\ \text{kJ/kg}$$

Since the final pressure is given as 1.4 MPa, we know two properties at the final state and therefore the final state is determined. The temperature corresponding to a pressure of 1.4 MPa and an internal energy of 3040.4 kJ/kg is found to be 452°C.

۴-

Analysis The coefficient of performance of the Carnot heat pump is



$$\mathrm{COP_{HP,C}} = \frac{1}{1-(T_L/T_H)} = \frac{1}{1-(2+273\ \mathrm{K})/(22+273\ \mathrm{K})} = 14.75$$

Then power input to the heat pump, which is supplying heat to the house at the same rate as the rate of heat loss, becomes

$$\dot{W}_{\mathrm{net,in}} = \frac{\dot{Q}_H}{\mathrm{COP_{HP,C}}} = \frac{62{,}000\ \mathrm{kJ/h}}{14.75} = 4203\ \mathrm{kJ/h}$$

which is half the power produced by the heat engine. Thus the power output of the heat engine is

$$\dot{W}_{\mathrm{net,out}} = 2\dot{W}_{\mathrm{net,in}} = 2(4203\ \mathrm{kJ/h}) = 8406\ \mathrm{kJ/h}$$

To minimize the rate of heat supply, we must use a Carnot heat engine whose thermal efficiency is determined from

$$\eta_{\mathrm{th,C}} = 1 - \frac{T_L}{T_H} = 1 - \frac{293\ \mathrm{K}}{1073\ \mathrm{K}} = 0.727$$

Then the rate of heat supply to this heat engine is determined from the definition of thermal efficiency to be

$$\dot{Q}_{H,\mathrm{HE}} = \frac{\dot{W}_{\mathrm{net,out}}}{\eta_{\mathrm{th,HE}}} = \frac{8406\ \mathrm{kJ/h}}{0.727} = \mathbf{11{,}560\ \ kJ/h}$$

۵ –

Analysis (a) The steam in tank A undergoes a reversible, adiabatic process, and thus $s_2 = s_1$. From the steam tables (Tables A-4 through A-6),

$$\left.\begin{array}{l} P_1 = 350 \text{ kPa} \\ \textit{sat.vapor} \end{array}\right\} \begin{array}{l} v_1 = v_{g@350\text{ kPa}} = 0.52422 \text{ m}^3/\text{kg} \\ u_1 = u_{g@350\text{ kPa}} = 2548.5 \text{ kJ/kg} \\ s_1 = s_{g@350\text{ kPa}} = 6.9402 \text{ kJ/kg}\cdot\text{K} \end{array}$$

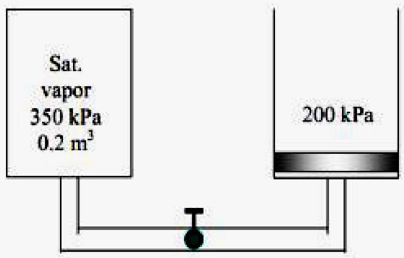
$$\left.\begin{array}{l} P_2 = 200 \text{ kPa} \\ s_2 = s_1 \\ (\textit{sat.mixture}) \end{array}\right\} \begin{array}{l} T_{2,A} = T_{\text{sat@200 kPa}} = \mathbf{120.2°C} \\ x_{2,A} = \dfrac{s_{2,A} - s_f}{s_{fg}} = \dfrac{6.9402 - 1.5302}{5.5968} = 0.9666 \\ v_{2,A} = v_f + x_{2,A} v_{fg} = 0.001061 + (0.9666)(0.88578 - 0.001061) = 0.85626 \text{ m}^3/\text{kg} \\ u_{2,A} = u_f + x_{2,A} u_{fg} = 504.50 + (0.9666)(2024.6 \text{ kJ/kg}) = 2461.5 \text{ kJ/kg} \end{array}$$

The initial and the final masses are

$$m_{1,A} = \frac{V_A}{v_{1,A}} = \frac{0.2 \text{ m}^3}{0.52422 \text{ m}^3/\text{kg}} = 0.3815 \text{ kg}$$

$$m_{2,A} = \frac{V_A}{v_{2,A}} = \frac{0.2 \text{ m}^3}{0.85626 \text{ m}^3/\text{kg}} = 0.2336 \text{ kg}$$

$$m_{2,B} = m_{1,A} - m_{2,A} = 0.3815 - 0.2336 = 0.1479 \text{ kg}$$



(*b*) The boundary work done during this process is

$$W_{b,out} = \int_1^2 P dV = P_B\left(V_{2,B} - 0\right) = P_B m_{2,B} v_{2,B}$$

Taking the contents of both the tank and the cylinder to be the system, the energy balance for this closed system can be expressed as

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

$$-W_{b,out} = \Delta U = (\Delta U)_A + (\Delta U)_B$$

$$W_{b,out} + (\Delta U)_A + (\Delta U)_B = 0$$

or,

$$P_B m_{2,B} v_{2,B} + (m_2 u_2 - m_1 u_1)_A + (m_2 u_2)_B = 0$$

$$m_{2,B} h_{2,B} + (m_2 u_2 - m_1 u_1)_A = 0$$

Thus,

$$h_{2,B} = \frac{(m_1 u_1 - m_2 u_2)_A}{m_{2,B}} = \frac{(0.3815)(2548.5) - (0.2336)(2461.5)}{0.1479} = 2685.8 \text{ kJ/kg}$$

At 200 kPa, $h_f = 504.71$ and $h_g = 2706.3$ kJ/kg. Thus at the final state, the cylinder will contain a saturated liquid-vapor mixture since $h_f < h_2 < h_g$. Therefore,

$$T_{2,B} = T_{\text{sat@200 kPa}} = \mathbf{120.25°C}$$