Problem 1: Given: Closed rigid tank containing water

Initial state 1: water at critical point

Final state 2: $T_2 = 100$ °C

To find: Final quality

Solution: Critical constants for water are, $T_c = 374.15$ °C,

$P_c = 22.12$ kPa,

$V_c = 0.00315$ m$^3$/kg

Since it is a closed rigid tank the volume and mass are constant. Hence the specific volume $v_c$, is constant throughout the process.

At $T_2 = 100$ °C, $v = v_c$, $v_f = 0.001044$ m$^3$/kg and $v_g = 1.67290$ m$^3$/kg

And $v_f < v < v_g$. Hence saturated state.

$\text{Quality } x = \left( \frac{v - v_f}{v_g} \right) = \left( \frac{0.00315 - 0.001044}{1.67185} \right) = 0.001255$

Problem 2: Given: Piston-cylinder assembly with air.

State 1: $P_1 = 100$ kPa

$V_1 = 1$ L ($= 1 \times 10^{-3}$ m$^3$)

$T_1 = 300$ K

State 2: $V_2 = 2$ L ($= 2 \times 10^{-3}$ m$^3$); Piston hits the stops

State 3: $T_3 = 900$ K

Solution: The external pressure throughout the process is constant and is the sum of the atmospheric pressure and the pressure due to the piston’s weight. During the process 1-2, there is free motion of the piston and hence the pressure of air is constant while the temperature and volume change. During the process 2-3 the stops restrict further motion of the piston. Hence the volume is constant and the temperature and pressure change.

Assumption: Air is a perfect gas
1-2 is a constant pressure process. Therefore, \( \frac{V_1}{T_1} = \frac{V_2}{T_2} \) or, \( T_2 = \frac{V_2T_1}{V_1} \)

Hence \( T_2 = \frac{(2\times10^{-3})(300)}{(1\times10^{-3})} = 600 \text{ K} \)  

(a)

3-4 is a constant volume process. Therefore, \( \frac{P_2}{T_2} = \frac{P_3}{T_3} \) or, \( P_3 = \frac{P_2T_3}{T_2} \)

Hence \( P_3 = \frac{(100)(900)}{(600)} = 150 \text{ kPa} \)  

(b)

Total work done is during the process is \( W_{1-3} \)

\[ W_{1-3} = W_{1-2} + W_{2-3} \]

Since 2-3 is a constant volume process, \( dV_{2-3} = 0 \). Hence \( W_{2-3} = 0 \)

\[ W_{1-3} = W_{1-2} = (100)(2\times10^{-3} - 1\times10^{-3}) = 0.1 \text{ kJ} \] (work done by the system)  

(c)

Problem 3: Given: Rigid, insulated tank divide by an un-insulated rigid divider, into two parts A and B, containing water.

State 1: Part A: \( m_{A1} = 0.1 \text{ kg} \)  
\( T_{A1} = 200 \text{ °C} (= 473.15 \text{ K}) \)  
\( P_{A1} = 100 \text{ kPa} \)

Part B: \( m_{B1} = 0.2 \text{ kg} \)  
\( T_{B1} = 80 \text{ °C} (= 353.15 \text{ K}) \)  
quality \( x_{B1} = 0.8 \)

State 2:  
\( T_{A2} = 150 \text{ °C} (= 423.15 \text{ K}) \)  
\( T_{B2} = 90 \text{ °C} (= 363.15 \text{ K}) \)  
\( P_{A2} = 50 \text{ kPa} \)

Heat transferred from A to B

Solution:
First law for the whole system, $\Delta U = Q_{12} - W_{12}$

where $Q_{12} = 0$ (insulated), and $W_{12} = 0$ (rigid; dV = 0)

Hence the First law for the whole system is, $\Delta U = 0$ or $\Delta U_A + \Delta U_B = 0$-------------------------(a)

The divider between A and B being rigid, dV=0 and hence $(W_{12})_A = 0$ and $(W_{12})_B = 0$. But is not insulated. Hence there is heat transfer. Also $(Q_{12})_A = -(Q_{12})_B$

First law for part A is, $\Delta U_A = (Q_{12})_A$ i.e., $U_{A2} - U_{A1} = (Q_{12})_A$-------------------------(a)

First law for part B is, $\Delta U_B = (Q_{12})_B$ i.e., $U_{B2} - U_{B1} = (Q_{12})_B = U_{A1} - U_{A2}$-------------------------(a)

From first law for A, $U_{A2} - U_{A1} = (Q_{12})_A = m_A (u_{A2} - u_{A1})$

Tables for water show that A in states 1 and 2 is in superheated state. Hence from Table B.1.3, we get $u_{A1} = 2658.05 \text{ kJ/kg}$ and $u_{A2} = 2585.61 \text{ kJ/kg}$.

Hence $(Q_{12})_A = m_A (u_{A2} - u_{A1}) = (0.1)(2585.61-2658.01) = -7.244 \text{ kJ}$ (heat removed from A) ---(b)

From table B.1.1, at $T_{B1} = 80 ^\circ \text{C}$ and quality $x_{B1} = 0.8$, $u_f = 334.84 \text{ kJ/kg}$ and $u_{fg} = 2147.36 \text{ kJ/kg}$.

Therefore, $u_{B1} = u_f + x_{B1} u_{fg} = 334.84 + 0.8*2147.36 = 2052.728 \text{ kJ/kg}$

$\frac{(Q_{12})_B}{m_B} = U_{B2} - U_{B1} = 7.244 \text{ kJ}$

Hence $u_{B2} = \frac{(Q_{12})_B}{m_B} + u_{B1} = \frac{7.244}{0.2} + 2052.728 = 2088.948 \text{ kJ/kg}$

From Table B.1.1 at $T_{B2} = 90 ^\circ \text{C}$, $u_f = 376.82 \text{ kJ/kg}$, $u_g = 2494.52$ and $u_{fg} = 2117.70 \text{ kJ/kg}$

Since $u_f < u_{B2} < u_g$, it is in saturated state.

The quality $x_{B2} = \frac{u_{B2} - u_f}{u_{fg}} = \frac{2088.948 - 376.82}{2117.70} = 0.8085$-------------------------(c)