ME 24-221
THERMODYNAMICS I

Solution to First Mid-Term Exam
October 5, 2000
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Problem 1: Given: Closed rigid tank containing water

Initial state 1: water at critical point

Final state 2: $T_2 = 100\ ^oC$

To find: Final quality

Solution: Critical constants for water are, $T_c = 374.15\ ^oC$,

$P_c = 22.12$ 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 $T_2 = 100\ ^oC$, $v = v_c$, $v_f = 0.001044\ m^3/kg$ and $v_g = 1.67290\ m^3/kg$

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

Quality $x = \dfrac{(v - v_f)}{v_{fg}} = \dfrac{(0.00315 - 0.001044)}{1.67185} =$ **0.001255 ---**(1)

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

State 1: $P_1 = 100$ kPa

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

$T_1 = 300$ K

State 2: $V_2 = 2$ L $(= 2*10^{-3}\ m^3)$; 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, $T_2 = \frac{V_2 T_1}{V_1}$

Hence $\mathbf{T_2}$ = $\frac{(2*10^{-3})(300)}{(1*10^{-3})}$ = **600 K** ---(a)

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

Hence $\mathbf{P_3}$ = $\frac{(100)(900)}{(600)}$ = **150 kPa** ---(b)

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

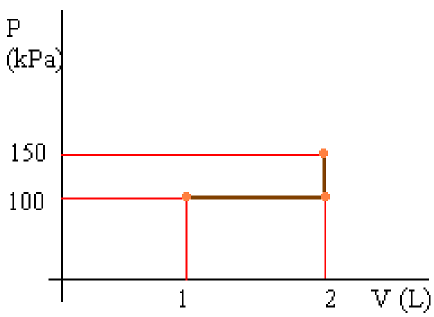
$W_{1-3} = W_{1-2} + W_{2-3}$

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

$\mathbf{W_{1-3}}$= W_{1-2} = $P_1(V_2 - V_1)$ (1-2 is a constant pressure process)

= $(100)(2*10^{-3} - 1*10^{-3})$ = **0.1 kJ** (work done by the system)------------------------------------(c)

(d)



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 kg — Part B: m_{B1} = 0.2 kg

T_{A1} = 200 °C (= 473.15 K) — T_{B1} = 80 °C (= 353.15 K)

P_{A1} = 100 kPa — quality x_{B1} = 0.8

State 2: T_{A2} = 150 °C (= 423.15 K) — T_{B2} = 90 °C (= 363.15 K)

P_{A2} = 50 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., $U_{A2} - U_{A1} = (Q_{1-2})_A$---------------------------------------(a)

First law for part B is, $\Delta U_B = (Q_{12})_B$ i.e., $U_{B2} - U_{B1} = (Q_{1-2})_B = U_{A1} - U_{A2}$ ---------------------(a)

From first law for A, $U_{A2} - U_{A1} = (Q_{1-2})_A = m_A(u_{A2} - u_{A1})$

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

Hence $(Q_{1-2})_A = m_A(u_{A2} - u_{A1})$ = (0.1)(2585.61-2658.01) = **-7.244 kJ** (heat removed from A) --(b)

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

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

$(Q_{1-2})_B = -(Q_{1-2})_A = U_{B2} - U_{B1} = 7.244$ kJ

Hence $u_{B2} = \frac{(Q_{1-2})_B}{m_B} + u_{B1} = \frac{7.244}{0.2} + 2052.728 = 2088.948$ kJ/kg

From Table B.1.1 at T_{B2} = 90 °C, u_f = 376.82 kJ/kg, u_g = 2494.52 and u_{fg} = 2117.70 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)