ME 40

Thermodynamics

Spring 2009

Quiz #2

February 23, 2009

Name:____________________________________

SID: ____________________________________

Instructions:

Read each question carefully. Take into consideration the point values for each question. **Write your name and SID on each page**. You have roughly 45 minutes.

One double-sided reference sheet is permitted.

Good luck!

Name: ____________________________
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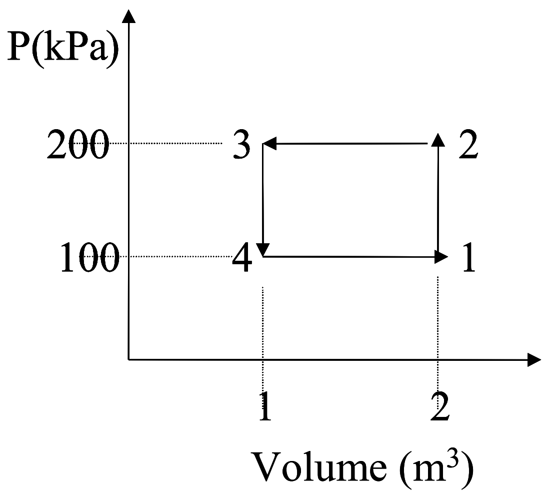
Question 1: [10 points]

A closed system undergoes a *cycle* consisting of processes 1→2, 2→3, 3→4, and 4→1 as sketched in the P-V diagram below. Determine the amount of net heat transfer between the system and the surroundings during this cycle. Note: net heat transfer is negative when the closed system loses heat to the surroundings.



E_{in}-E_{out}=ΔEcycle

Q-W=0
Q=W=Pdv work

$W_{23} = P_2(v_3-v_2) = 200*(1-2) = -200$
$W_{41} = P_4(v_1-v_4) = 100*(2-1) = 100$

W = Q = -200 + 100 = -100

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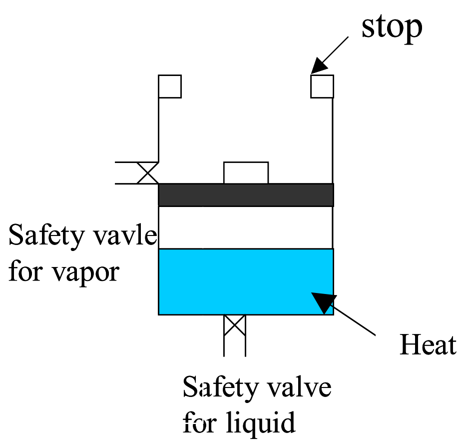
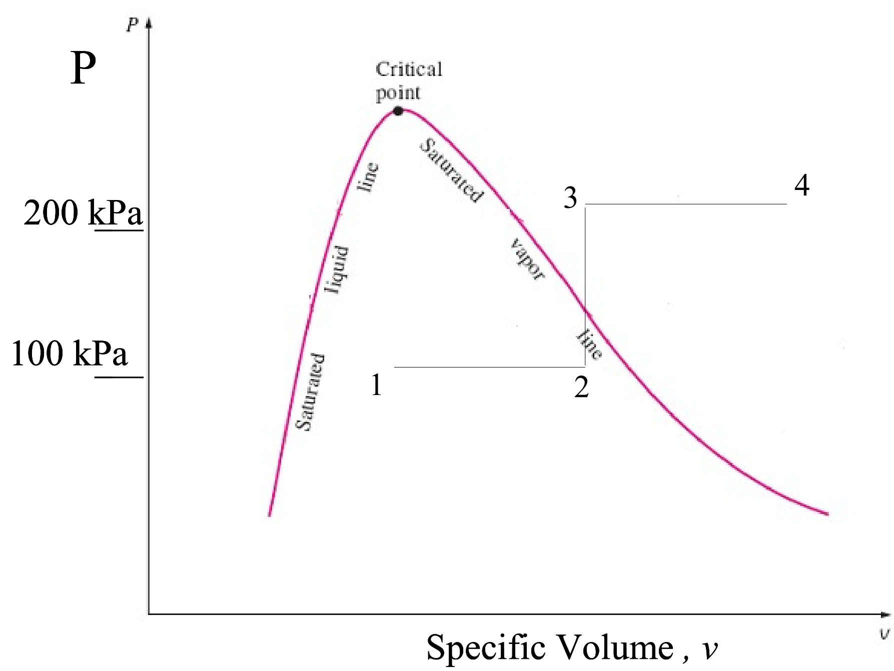
Question 2: [10 points]

A frictionless piston-cylinder device with a set of stops on the top contains initially 1 kg of saturated water at 100 kPa and 20 percent quality (State 1) as sketched below. The weight on the top of piston keeps the pressure inside the cylinder at 100 kPa. The piston can move freely and when the piston reaches the stops, the volume is tripled (State 2). Two safety valves are installed in the cylinder: one is located at the upper portion of the cylinder to vent vapor and the other at the bottom to release liquid. Both valves open at 200 kPa. Heat is transferred to the water inside the cylinder. During this process, the piston reaches the top and the safety valves open (State 3). At the end, the mass of water is 0.75kg (State 4). Sketch the entire process (State 1 → State 4) on the P-v diagram below and carefully mark all states.





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Question 3: [10 points]

The enthalpy of a non-ideal gas is a function of temperature and pressure as represented by

$$h(T, P) = CpT + \alpha P$$

where T is temperature in Kelvin, P is pressure in kPa, C_p=1 kJ/K-kg, and α= 0.1 kJ/kPa-kg. This gas at State 1 (T_1=300 K and P1=100 kPa) passes through a *throttle* device and the pressure is reduced to P_2=10 kPa at State 2. Assuming that the throttling process is adiabatic with negligible changes in kinetic and potential energies, determine the temperature at State 2, T_2.

$h_2(T_2, P_2) = h_1(T_1, P_1)$

1 kJ/kg-K $*T_2 + 0.1 * 10 = 1 * 300 + 0.1 * 100 = 310$ kJ/kg

$\rightarrow$ T_2=309 K.

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Question 4: [10 points]

A frictionless piston-cylinder piston device initially contains 1 kg of **helium** at 100 kPa and 273 K. The device is connected by a valve to a large tank that supplies helium gas at a *constant* state of 150 kPa at 298 K. Now the valve is opened and helium is allowed to enter the piston-cylinder device until pressure equilibrium with the helium supply line is reached. During this process, there is *no* heat transfer and the total amount of work done by the helium through the piston is 1,000 kJ. The final mass of helium in the piston device is 3 kg. Determine the temperature of helium at this final state. Helium is assumed to be an ideal gas with ***constant*** specific heats C_p=5.2 kJ/kg-K, C_v=3.1 kJ/kg-K, respectively. For helium, internal energy is modeled by $u(T)=C_vT(K)$ and enthalpy is $h(T)=C_pT(K)$.

(M_1= 1kg, T_1=273 K, P_1=100kPa) (M_2=3 kg, P_2=150 Kpa, T_2=?)

Solution:

First law → denote state 1 : initial state
2: final state

$$(m_2-m_1)h_{supply} + m_1 u_1 = W + m_2 u_2.$$

With $h_{supply} = C_pT_{supply}$ and $u=C_vT$, we have

$$(m_2-m_1)C_pT_{supply} + m_1 C_v T_1 = W + m_2C_vT_2.$$

Solving for T_2,

$$T_2 = [(m_2-m_1)C_pT_{supply} + m_1 C_v T_1 - W]/m_2C_v$$
$$= [(3-1)\text{x}5.2\text{x}298 + 1 \text{ x } 3.1\text{x } 273 - 1000 \text{ kJ}]/(3\text{X}3.1)=316.72\text{K} =\underline{43.6\ {}^{o}\text{C}}$$