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ENME 3770 Engineering Thermodynamics  
Test # 1, Summer 2010

Part 1: Closed Books and Notes (63 points, Recommended Time: 40 minutes) Name: Nicholas March

1. Define or explain the following terms:

Newton (2%)  
~~a unit of force~~  
~~1 Newton =  $kg \cdot \frac{m}{s^2}$~~

Btu (2%)  
~~British Thermal Unit~~  
~~1 Btu = 1.06 kJ~~

$C_v$  (2%)  
~~constant volume specific heat~~

k (2%)  
~~a constant~~

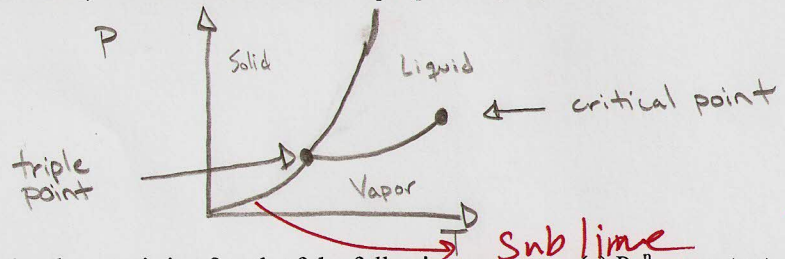
Quality of two-phase mixtures (2%)  
 $x = \frac{\text{vapor mass}}{\text{total mass}} =$  ~~liquid vapor mixture~~

Specific Volume and its unit (3%)  
 $\frac{m^3}{kg}$  ~~volume divided by mass~~  
~~represented as  $v$~~

Relationship between  $C_p$  and  $C_v$ : (3%)  
 $n = \frac{C_p}{C_v} - 1$

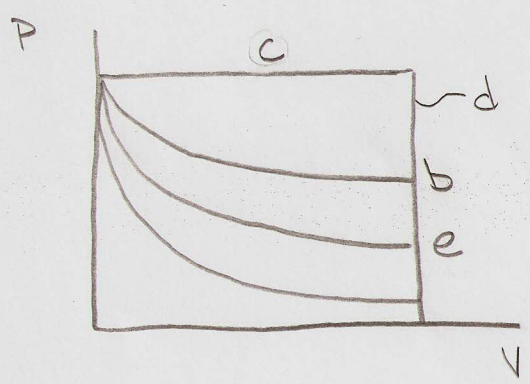
Thermodynamic First Law: (3%)  
Closed System:  ~~$\oint \delta W = \int \delta Q$~~   
Open System:  ~~$\Delta Q - \Delta W = \Delta E$~~

2. Qualitatively plot a P-T phase diagram for a substance that contracts on freezing and identify the melting, vaporization and sublimation lines, and the critical and the triple points. (6%)



3. Describe the characteristic of each of the following processes. (a)  $Pv^n = \text{constant}$ , (b)  $n = 1$ , (c)  $n = 0$ , (d)  $n = \infty$ , (e)  $n = k = C_p/C_v$ . Plot (b), (c), (d), (e) on a P-v diagram. (6%)

- a) polytropic
- b) isothermal (constant temperature)
- c) isobaric (constant pressure)
- d) isometric (constant volume)
- e) isentropic (constant entropy)



4. What are the assumptions for ideal gas model? What are the effects of high pressure, low pressure, high temperature and low temperature on ideal gas model (15%)

$PV = RT$      $PV = nRT$      $PV = mRT$   
 $h = h(T) = u(T) + PV = u(T) + RT$   
 assume:  $z = 1$  for ideal gas  
 $z > 1$  for real gas

high & low pressure = no condensation (unclear)

high temperature = high enthalpy  
 low temperature = low enthalpy

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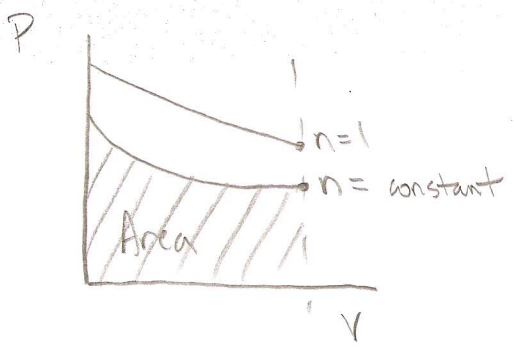
5. Derive the general equation of the work performed in a closed system via the process.  $Pv^n = \text{Constant}$ , for  $n = 1.3$ , respectively. Show the area that is represented by the work in the P-v diagram. (10%)

$$W = \int P dv = \int_{V_1}^{V_2} \frac{\text{constant}}{v^n} dv = \frac{(\text{constant}) V_2^{1-n} - (\text{constant}) V_1^{1-n}}{1-n}$$

$$= \frac{(P_2 V_2^n) V_2^{1-n} - (P_1 V_1^n) V_1^{1-n}}{1-n} = \frac{P_2 V_2 - P_1 V_1}{1-n}$$

(if  $n \neq 1$ )  $W = \frac{P_2 V_2 - P_1 V_1}{1-n}$       put  $n = 1.3$       -2

(if  $n = 1$ )  ~~$W = (\text{constant}) \int_{V_1}^{V_2} \frac{dv}{v} = (\text{constant}) \ln \frac{V_2}{V_1} = (P_1 V_1) \ln \frac{V_2}{V_1}$~~



6. Fill in the blanks for the blank places in the steam table provided. Use all your thermodynamic relations for fill-up. Show all the calculations in the space provided in this page. (7%) [Interpolation is not allowed]

Temperature (°C)	Saturation Pressure (kPa)	$V_f$ (m <sup>3</sup> /kg)	$V_g$ (m <sup>3</sup> /kg)	$u_f$ (kJ/kg)	$u_g$ (kJ/kg)	$h_f$ (kJ/kg)	$h_g$ (kJ/kg)
85	57.83	0.00103	2.828	355.84	2488.4	355.9	2652.1
90	70.14	0.00104	2.361	376.86	2494.5	376.92	2660.1
95	84.55	0.00104	1.982	397.88	2500.6	397.96	2668.1
100	101.35	0.00104	1.6729	418.94	2506.5	419.00	2676.1
105	120.82	0.00105	1.4194	440.02	2512.4	440.15	2684.1
110	143.27	0.00105	1.1823	461.14	2518.1	461.3	2691.5

$$PV = RT$$

$$h = u(T) + Pv = u(T) + RT$$

$$v = v(T)$$

$$h_f = u_f + RT @ 90^\circ C$$

$$376.92 = u_f + R(90^\circ C)$$

$$\Delta E = \Delta Q - \Delta W$$

$$\Delta E = \Delta U + \Delta KE + \Delta PE$$

$$= m(u) + \Delta KE + \Delta PE$$

$$376.92 - 8.314(363.14) = u_f = 376.86 \text{ kJ/kg}$$

$$h_g = u_g + RT @ 85^\circ C$$

$$h_g = 2488.4 + 8.314(358.14) = 2652.1 \text{ kJ/kg}$$

$$PV = RT @ 95^\circ C$$

$$84.55 (v_f) = 8.314(368.14) \Rightarrow v_f = \frac{8.314(368.14)}{84.55} = 0.00104$$

$$h_f = u_f + RT @ 100^\circ C$$

$$h_f = 418.94 + 8.314(373.14) = 419.00 \text{ kJ/kg}$$

$$h_g = u_g + RT @ 105^\circ C$$

$$h_g = 2512.4 + 8.314(378.14) = 2684.1 \text{ kJ/kg}$$

$$PV = RT @ 110^\circ C$$

$$v = \frac{RT}{P} = \frac{8.314(383.14)}{143.27} = 1.1823 \text{ m}^3/\text{kg}$$

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Part 2: Open Books and Notes (37 points, Recommended Time: 35 minutes)

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7. A system consists of 2 kg of water undergoes a three-process cycle. Determine the net work and net heat transfer for each process and the entire cycle, in kJ. Neglect KE and PE. Qualitatively plot this cycle on a P-v diagram including the vapor dome.

- 1-2: Adiabatic compression from 2 MPa, 90% quality to 5 MPa and 700K.
- 2-3: Isothermal process with  $W = 1000$  kJ to  $P_3 = 2$  MPa.
- 3-1: Isobaric process.

$m = 2 \text{ kg}$  Find  $\Delta W$  &  $\Delta Q$

$$x = \frac{u_1 - u_f}{u_g - u_f} \Rightarrow u_1 = x(u_g - u_f) + u_f$$

$$u_1 = 0.9(2600.3 - 906.44) + 906.44$$

$$u_1 = 2430.91$$

1-2: Adiabatic,  $Q_{1-2} = 0 \text{ kJ}$

$P_1 = 2 \text{ MPa} = 20 \text{ bar}$   $x_1 = 90\%$

$P_2 = 5 \text{ MPa} = 50 \text{ bar}$   $T_2 = 700 \text{ K}$

$u_1 = 2430.91 \frac{\text{kJ}}{\text{kg}}$

$u_2 = 2597.1 \frac{\text{kJ}}{\text{kg}}$

$$\Delta E = \Delta U + \Delta KE + \Delta PE$$

$$\Delta E = \Delta Q - \Delta W \Rightarrow \Delta U = -\Delta W$$

$$\Delta W = -\Delta U = -m(u_2 - u_1) = -2(2597.1 - 2430.91) = -332.38 \text{ kJ}$$

$Q_{1-2} = 0$        $W_{1-2} = -332.38 \text{ kJ}$

2-3: Isothermal,  $T = 700 \text{ K}$   $W = 1000 \text{ kJ}$

$P_2 = 50 \text{ bar}$   $u_2 = 2597.1 \frac{\text{kJ}}{\text{kg}}$

$P_3 = 2 \text{ MPa} = 20 \text{ bar}$   $u_3 = 2600.3 \frac{\text{kJ}}{\text{kg}}$

$$\Delta E = \Delta Q - \Delta W \Rightarrow \Delta U + \Delta W = \Delta Q \Rightarrow Q_{2-3} = m(u_3 - u_2) + 1000 \text{ kJ}$$

$$Q_{2-3} = 2(2600.3 - 2597.1) + 1000 = 1006.4 \text{ kJ}$$

$Q_{2-3} = 1006.4 \text{ kJ}$        $W_{2-3} = 1000 \text{ kJ}$

3-1: Isobaric  $P = 20 \text{ bar}$

$u_1 = 2430.91 \frac{\text{kJ}}{\text{kg}}$

$u_3 = 2600.3 \frac{\text{kJ}}{\text{kg}}$

$$x = \frac{v_1 - v_f}{v_g - v_f} \Rightarrow v_1 = x(v_g - v_f) + v_f$$

$$= 0.9(0.09963 - 1.1767) + 1.1767$$

$$= 0.207337$$

$v_1 = 0.207337$

$v_3 = 0.09963 \frac{\text{m}^3}{\text{kg}}$

$$W_{1-3} = m P_3 (v_1 - v_3) = 2(20 \text{ bar})(0.207337 - 0.09963)$$

$$m(u_1 - u_3) = Q_{1-3} - W_{1-3}$$

$$2(2430.91 - 2600.3) = Q_{1-3} - 4.30828 \text{ kJ}$$

$W_{1-3} = -4.30828 \text{ kJ}$   
 $Q_{1-3} = -334.472 \text{ kJ}$

Q cycle



W cycle

