Homework #2

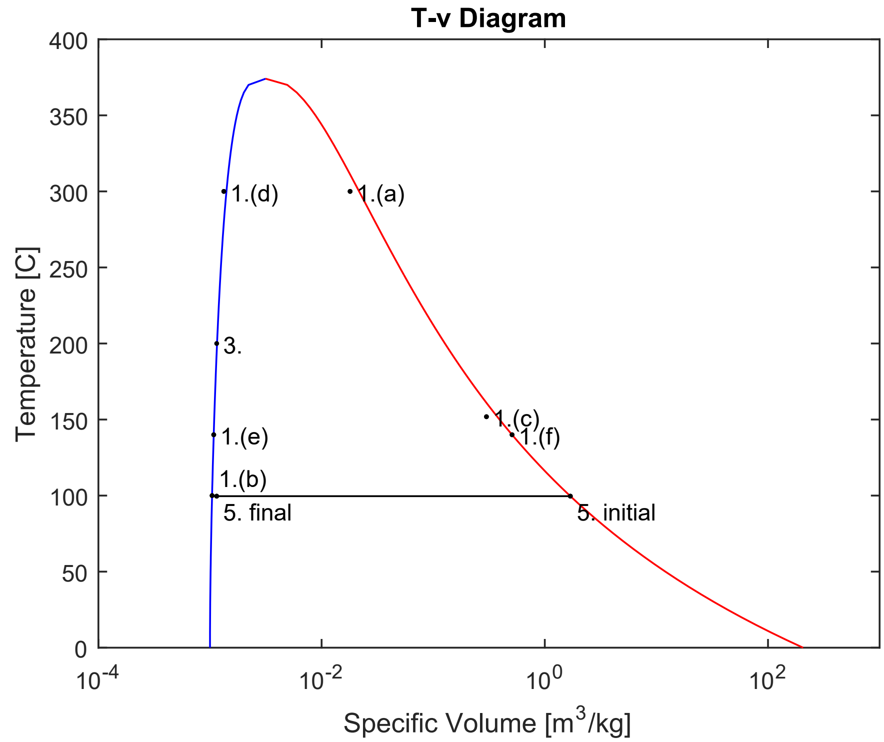
MEMS 0051 - Introduction to Thermodynamics

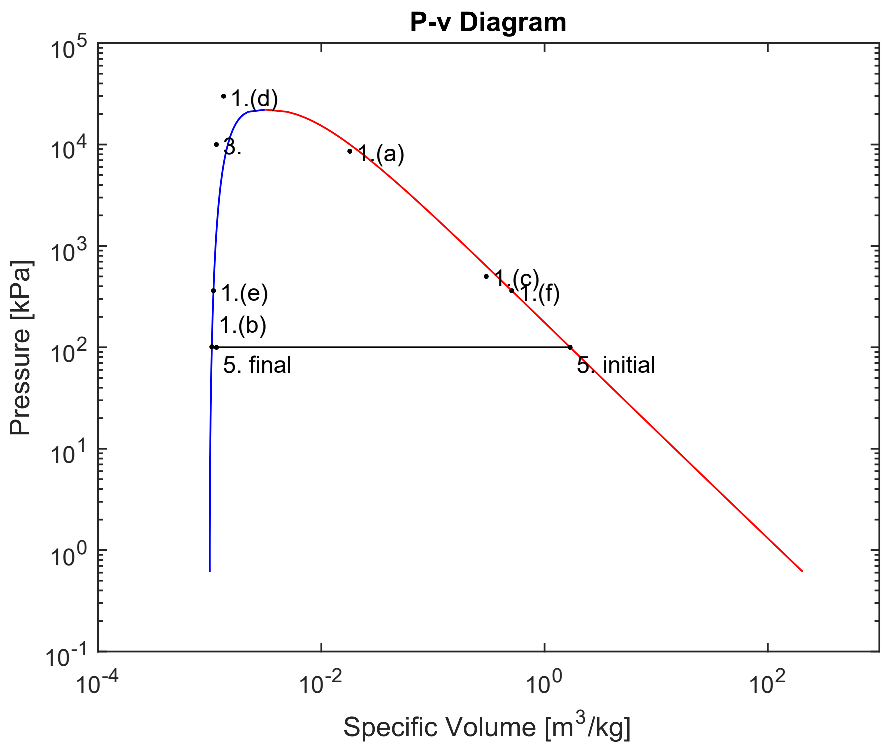
Assigned January 18th, 2019
Due January 25th, 2019

Problem #1

Answer the following questions based on the steam tables (Tables B.1.1-B.1.5) provided. Short answers are fine. For all parts (1-5), indicate the location of the state(s) on both $T-\nu$ and $P-\nu$ diagrams, and if applicable, the process between said states. Be sure to distinguish your points and draw the curves the state(s) are on. Illustrate neatly!

1. What phase(s) of H_2O are present at the following conditions?
   (a) 300 °C, 0.018 [m^3/kg] Saturated mixture, P = 8.581 [MPa]
   (b) 100 °C, 0.001044 [m^3/kg] Saturated liquid, P = 101.3 [kPa]
   (c) 0.5 [MPa], 0.3 [m^3/kg] Saturated mixture, T = 151.86 [°C]
   (d) 30 [MPa], 300 °C Compressed Liquid, v = 0.001330 [m^3/kg]
   (e) 140 °C, 0.001080 [m^3/kg] Saturated Liquid, P = 361.3 [kPa]
   (f) 140 °C, 0.50885 [m^3/kg] Saturated Vapor, P = 361.3 [kPa]
2. What phase change is occurring for a mass of H_2O going from (e)→(f)? Liquid to gas. Evaporation process
3. Let's say that we know the pressure and temperature of some mass of H_2O are 10 [MPa] and 200 °C respectively. Can we determine the specific volume of this sample? If so, what is it? If not, why not?
   The specific volume can be found because the conditions make the sample a compressed liquid. Looking at Table B.1.4, it can be found that the specific volume is 0.001 148 [m^3/kg]
4. Let's say that we know the temperature and pressure of a mass of H_2O are 1 [MPa] and 179.9 °C. Can we determine the specific volume of this sample? If so, what is it? If not, why not?
   The specific volume can not be determined. All that can be said is that it is in the saturated mixture region
5. Consider saturated vapor enclosed in a piston-cylinder. The water is cooled, causing an isobaric compression at a constant pressure of 0.1 [MPa] until all of the water is a saturated liquid. What is the final specific volume of the water? What is the saturation temperature at the final state?
   The process brings the sample from an initial specific volume of 1.694 [m^3/kg] to a final specific volume of 0.001 148 [m^3/kg]. During this isobaric process, the saturation temperature is 99.62 °C.


T-v Diagram
Temperature [C]
Specific Volume [m^3/kg]
1.(d)
1.(a)
3.
1.(c)
1.(f)
1.(e)
1.(b)
5. final
5. initial


P-v Diagram
Pressure [kPa]
Specific Volume [m^3/kg]
1.(d)
3.
1.(a)
1.(c)
1.(f)
1.(e)
1.(b)
5. final
5. initial

Problem #2

Answer the following questions based on the P-T diagram for CO_2 given below. (Short answers are fine, no need to re-draw the diagram on your solution)

1. What phase is CO_2 in at the following temperature and pressure combinations?
   (a) 250 K, 10^4 [kPa] Liquid
   (b) 170 K, 10^5 [kPa] Solid
   (c) 190 K, 10^1 [kPa] Vapor
   (d) 330 K, 10^2 [kPa] Supercritical phase
2. Consider a piece of dry ice that is dropped into a room at 20 °C and 1 atm (101.3 [kPa]). What phase change(s) will the dry ice undergo?
   Solid to vapor transition. Sublimation process.

3. Consider CO_2 gas enclosed in an isothermal chamber fixed at 220 K. More CO_2 is injected into the chamber, causing the internal pressure to rise from 100 [kPa] to 10^4 [kPa]. What phase change(s) will the CO_2 undergo? Be sure to indicate the phase change process?
   Vapor to liquid transition. Condensation process.

Problem #3

Answer the following questions using Tables B.1.1.-B.1.5.

(a) Determine the saturation pressure corresponding to a temperature of 283.6 °C.
Using Table B.1.1 on pg. 778:

$$\frac{(283.6 - 280)\,[^\circ\text{C}]}{(285 - 280)\,[^\circ\text{C}]} = \frac{(P_{sat} - 6,411.7)\,[\text{kPa}]}{(6,909.4 - 6,411.7)\,[\text{kPa}]} \implies \boxed{P_{sat} = 6,770.0\,[\text{kPa}]}$$

(b) Determine the saturation temperature corresponding to a pressure of 5,387 [kPa].
Using Table B.1.2 on pg. 782:

$$\frac{(5,387 - 5,000)\,[\text{kPa}]}{(6,000 - 5,000)\,[\text{kPa}]} = \frac{(T_{sat} - 263.99)\,[^\circ\text{C}]}{(275.64 - 263.99)\,[^\circ\text{C}]} \implies \boxed{T_{sat} = 264.89\,[^\circ\text{C}]}$$

(c) Determine the saturated liquid specific volume corresponding to a temperature of 102.89 °C.
Using Table B.1.1 on pg. 776:

$$\frac{(102.89 - 100)\,[^\circ\text{C}]}{(105 - 100)\,[^\circ\text{C}]} = \frac{(\nu_f - 0.001\,044)\,[\text{m}^3/\text{kg}]}{(0.001\,047 - 0.001\,044)\,[\text{m}^3/\text{kg}]} \implies \boxed{\nu_f = 0.001\,046\,[\text{m}^3/\text{kg}]}$$

(d) Determine the saturated vapor specific volume corresponding to a pressure of 20,089 [kPa].
Using Table B.1.2 on pg. 782:

$$\frac{(20,089 - 20,000)\,[\text{kPa}]}{(21,000 - 20,000)\,[\text{kPa}]} = \frac{(\nu_g - 0.005\,83)\,[\text{m}^3/\text{kg}]}{(0.004\,95 - 0.005\,83)\,[\text{m}^3/\text{kg}]} \implies \boxed{\nu_g = 0.005\,752\,[\text{m}^3/\text{kg}]}$$

(e) Determine the specific volume corresponding to water at a pressure of 128.5 [kPa] and a temperature of 485.3 [°C].
Using Table B.1.3 on pg. 784, we first interpolate to get $\nu(485.3\,[°\text{C}])$ at 100 [kPa]:

$$\frac{(485.3 - 400)\,[°\text{C}]}{(500 - 400)\,[°\text{C}]} = \frac{(\nu - 3.102\,63)\,[\text{m}^3/\text{kg}]}{(3.565\,47 - 3.102\,63)\,[\text{m}^3/\text{kg}]} \implies \nu(485.3\,[°\text{C}], 100\,[\text{kPa}]) = 3.497\,433\,[\text{m}^3/\text{kg}]$$

Next , we interpolate to get $\nu(485.3\,[°\text{C}])$ at 200 [kPa]:

$$\frac{(485.3 - 400)\,[°\text{C}]}{(500 - 400)\,[°\text{C}]} = \frac{(\nu - 1.549\,30)\,[\text{m}^3/\text{kg}]}{(1.781\,39 - 1.549\,30)\,[\text{m}^3/\text{kg}]} \implies \nu(485.3\,[°\text{C}], 200\,[\text{kPa}]) = 1.747\,273\,[\text{m}^3/\text{kg}]$$

Lastly, we interpolate between 100 [kPa] and 200 [kPa] at 485.3 [°C]:

$$\frac{(128.5 - 100)\,[\text{kPa}]}{(200 - 100)\,[\text{kPa}]} = \frac{(\nu - 3.497\,433)\,[\text{m}^3/\text{kg}]}{(1.747\,273 - 3.497\,433)\,[\text{m}^3/\text{kg}]} \implies \boxed{\nu = 2.998\,637\,[\text{m}^3/\text{kg}]}$$