Homework #1

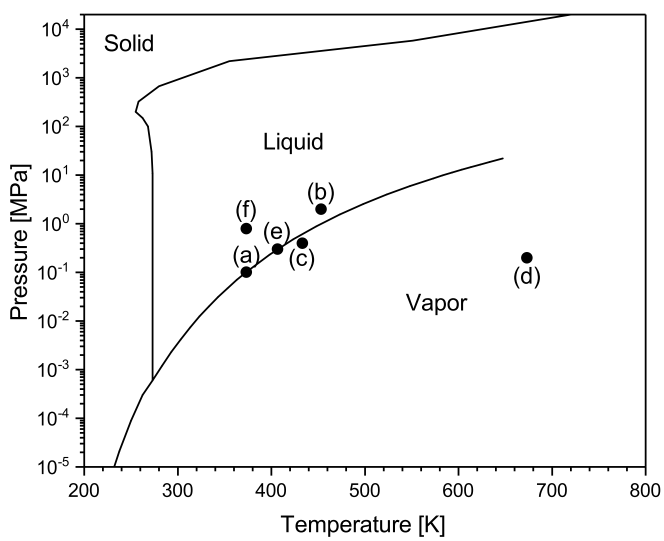
MEMS 0051 - Introduction to Thermodynamics

Assigned May 8$^{\text{th}}$, 2018
Due: May 14$^{\text{th}}$, 2018

Problem #1

Use the phase diagram of water (Fig. 3.7 on page 54 of Sonntag 7e) to determine the *phase* of water at the following conditions. Sketch the phase diagram, including axis and region labels, and indicate where points (a)-(f) lie.

(a) 100 °C, 101.3 [kPa] liquid+vapor
(b) 180 °C, 2,000 [kPa] liquid
(c) 160 °C, 400 [kPa] vapor
(d) 400 °C, 200 [kPa] vapor
(e) 133.5 °C, 300 [kPa] liquid+vapor
(f) 100 °C, 800 [kPa] liquid



Problem #2

Water vapor at 200 [kPa], which has a specific volume of 0.88573 [m^3/kg], is contained in a piston-cylinder device. At this initial state, the piston is 0.1 [m] from the bottom of the cylinder. The water vapor is then cooled in a constant pressure process such that final volume occupies half the initial. Determine:

(a) the final specific volume; The final volume is one half of the initial volume. The specific volume is defined as the volume per unit mass:

$$\nu = \frac{\forall}{m}$$

Since this is a control mass, the mass at the initial and final state is the same. Thus, the specific volume at the final state is:

$$\nu_2 = \frac{\nu_1}{2} = \frac{0.88573\,[\text{m}^3/\text{kg}]}{2} = 0.442865\,[\text{m}^3/\text{kg}]$$

(b) the final mass; The final mass is the same as the initial mass:

$$m = \frac{\forall}{\nu} = \frac{\pi D^2 L}{4(0.88573\,[\mathrm{m}^3/\mathrm{kg}])}$$

(c) specify if this system is a open or closed, a control mass and/or isolated. The system depicted is a control mass. It is not open because there is no mass crossing the control surface. It is not isolated because heat is removed (i.e. it is cooled).

Problem #3

There exists a container with a volume of 10 [m^3]. This container is filled with 8 [m^3] of coarse stone, which has a density of 1,600 [kg/m^3], 1 [m^3] of sand, which has a density of 1,442 [kg/m^3], and the rest is filled with water, which has a density of 998 [kg/m^3]. Determine:

(a) the average specific volume; Specific volume is defined as the volume per mass of the system. To determine the average specific volume, we must sum the volumes of each material per the sum of the mass of each material. The mass of each material is simply the density of that material times the volume that material occupies. The average specific volume is then:

$$\nu_{avg} = \frac{\sum \forall}{\sum m} = \frac{10\,[\mathrm{m}^3]}{(8\,[\mathrm{m}^3])(1,600\,[\mathrm{kg/m}^3]) + (1\,[\mathrm{m}^3])(1,442\,[\mathrm{kg/m}^3]) + (1\,[\mathrm{m}^3])(998\,[\mathrm{kg/m}^3])}$$

Therefore

$$\nu_{avg} = 0.000\,656\,[\mathrm{m}^3/\mathrm{kg}]$$

The average density is the inverse of the average specific volume:

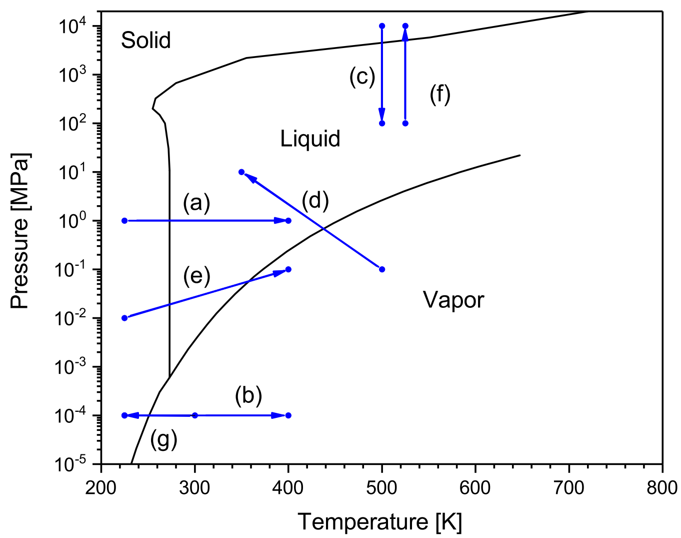
$$\rho_{avg} = \frac{1}{\nu_{avg}} = \frac{1}{0.000\,656\,[\mathrm{m}^3/\mathrm{kg}]} = 1,524\,[\mathrm{kg/m}^3]$$

(b) the average density.

Problem #4

Using the phase diagram of water (Fig. 3.7 on page 54 of Sonntag 7e), indicate which of the following processes occur (melting, solidification, vaporization, condensation, sublimation and/or deposition) when going from the specified initial to final state. Sketch the phase diagram, including axis and region labels, and indicate the initial and final states connected by a straight line for parts (a)-(g).

(a) 225 [K] and 1 [MPa] → 400 [K] and 1 [MPa] melting
(b) 225 [K] and 0.0001 [MPa] → 400 [K] and 0.0001 [MPa] sublimation
(c) 500 [K] and 10,000 [MPa] → 500 [K] and 100 [MPa] melting
(d) 500 [K] and 0.1 [MPa] → 350 [K] and 10 [MPa] condensation
(e) 225 [K] and 0.01 [MPa] → 400 [K] and 0.1 [MPa] melting and vaporization
(f) 525 [K] and 100 [MPa] → 525 [K] and 10,000 [MPa] freezing
(g) 300 [K] and 0.0001 [MPa] → 225 [K] and 0.0001 [MPa] deposition


Solid
Liquid
Vapor
(a)
(b)
(c)
(d)
(e)
(f)
(g)
Pressure [MPa]
Temperature [K]
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
200
300
400
500
600
700
800