Quiz #2

MEMS 0051 - Introduction to Thermodynamics

Assigned: February 15^{th}, 2021
Due: February 19^{th}, 2021, 9:00 pm

Intermediate Problem #1

(1 pt) A frictionless piston-cylinder devices contains 0.2 [kg] of liquid water. Heat is added, in a constant-pressure process of 100 [kPa], until the completely water vaporizes. Determine the change of volume between the initial and final states.

At 100 [kPa], the saturated liquid and saturated vapor specific volumes are found from Table B.1.2:

$$\nu_f = 0.001\,043\,[\mathrm{m}^3/\mathrm{kg}]$$

$$\nu_g = 1.694\,00\,[\mathrm{m}^3/\mathrm{kg}]$$

Thus, the change of volume is:

$$d\forall = m(\nu_g - \nu_f) = (0.2\,[\mathrm{kg}])(1.69296\,[\mathrm{m}^3/\mathrm{kg}]) = 0.339\,[\mathrm{m}^3]$$

Intermediate Problem #2

(1 pt) A rigid, non-deformable tank contains 10 [kg] of water at 90 °C. If 8 [kg] of the 10 is a liquid, while the remainder is a vapor, determine the volume of the tank.

Pulling the saturated liquid and saturated vapor specific volumes from Table B.1.1:

$$\nu_f = 0.001\,036\,[\mathrm{m}^3/\mathrm{kg}]$$

$$\nu_g = 2.360\,56\,[\mathrm{m}^3/\mathrm{kg}]$$

Thus, the total volume is:

$$\forall = m_f\nu_f + m_g\nu_g = (8\,[\mathrm{kg}])(0.001\,036\,[\mathrm{m}^3/\mathrm{kg}]) + (2\,[\mathrm{kg}])(2.360\,56\,[\mathrm{m}^3/\mathrm{kg}]) = 4.73\,[\mathrm{m}^3]$$

Intermediate Problem #3

(1 pt) Consider water vapor existing at 350 °C and a specific volume of 0.029 95 [m^3/kg]. Determine the pressure this substance is existing at using a) the steam tables and b) the Ideal Gas law.

a) Since the substance is existing as a superheated vapor (confirmed that $\nu > \nu_g$ at 350 °C using Table B.1.1), we will consult Table B.1.3 on page 788:

$$P = 8,000\,[\mathrm{kPa}]$$

b) Using the Ideal Gas law in conjunction with the values supplied on Table A.5:

$$P = \frac{mRT}{\forall} = \frac{(0.4615\,[\mathrm{kJ/kg\text{-}K}])(623.15\,[\mathrm{K}])}{(0.029\,95\,[\mathrm{m}^3/\mathrm{kg}])} = 9,602\,[\mathrm{kPa}]$$

Challenge Problem #1

(2 pt) Consider a situation where you have a rigid, non-deformable tank that is separated into two equal volumes by a membrane. One side of the tank contains 5 [kg] of water at a temperature of 25 °C and a pressure of 200 [kPa]. The other side is a vacuum. Then, the membrane is broken, allowing the water to fill the entirety of the tank. After sufficient time has passed, the temperature of the water has returned to 25 °C. Determine:

1. The complete volume of the tank (i.e. considering both partitions);
2. The final pressure within the tank;
3. The heat transferred during this process.

1. We will first determine the volume of the water constrained by the membrane. To do such, we recognize the fluid is existing as a compressed liquid, and will use Table B.1.1 to determine the specific volume:

$$\nu_1 \approx \nu_f(25\,^\circ\mathrm{C}) = 0.001\,003\,[\mathrm{m}^3/\mathrm{kg}]$$

The total volume of the tank is simply twice the volume the water occupies:

$$\forall_{\text{total}} = 2\forall_1 = 2(5\,[\mathrm{kg}])(0.001\,003\,[\mathrm{m}^3/\mathrm{kg}]) = 0.010\,03\,[\mathrm{m}^3]$$

2. Now we will break the membrane and allow the temperature to reach 25 °C. The specific volume of the fluid at the final state (occupying the entire volume) is:

$$\nu_2 = \frac{\forall_{\text{total}}}{m} = \frac{0.010\,03\,[\mathrm{m}^3]}{5\,[\mathrm{kg}]} = 0.002\,006\,[\mathrm{m}^3/\mathrm{kg}]$$

This value is between ν_f and ν_g at 25 °C, meaning it is existing as a saturated mixture. Thus, the pressure is the saturation pressure at 25 °C:

$$P_2 = P_{\text{sat}}(25\,^\circ\mathrm{C}) = 3.169\,[\mathrm{kPa}]$$

3. We will apply the Conservation of Energy equation. There are changes in kinetic and potential energy, and work is zero (we will define the C.S. around the rigid, non-deformable tank). Thus, the CoE equation reduces to:

$$m(u_2 - u_1) = Q_{1\to 2}$$

The specific internal energy at State 1 is found via:

$$u_1 \approx u_f(25\,^\circ\mathrm{C}) = 104.86\,[\mathrm{kJ/kg}]$$

The specific internal energy at State 2 is found via interpolation of the specific volume:

$$\left.\frac{\nu_2 - \nu_f}{\nu_g - \nu_f}\right|_{25\,^\circ\mathrm{C}} = \left.\frac{u_2 - u_f}{u_g - u_f}\right|_{25\,^\circ\mathrm{C}}$$

$$\implies u_2 = \left(\frac{(0.002\,006 - 0.001\,003)\,[\mathrm{m}^3/\mathrm{kg}]}{(43.3593 - 0.001\,003)\,[\mathrm{m}^3/\mathrm{kg}]}\right)(2,409.76 - 104.86)\,[\mathrm{kJ/kg}] + 104.86\,[\mathrm{kJ/kg}] = 104.91\,[\mathrm{kJ/kg}]$$

Therefore, the heat is found as:

$$Q_{1\to 2} = (5\,[\mathrm{kg}])(104.91 - 104.86)\,[\mathrm{kJ/kg}] = +0.25\,[\mathrm{kJ}]$$

Academic Integrity Statement:

I hereby attest that I have received no assistance (from a friend, from another student, from an on-line resource, such as Chegg, etc.), and that I have provided no assistance to another student, during this examination. All the work presented within is solely my own work.

Signature: ______________________________________

Date: ________________________