Homework #3

MEMS 0051 - Introduction to Thermodynamics

Assigned: May 21$^{\text{th}}$, 2020
Due: May 28$^{\text{st}}$, 2020

Problem #1

A person decides they want a cup of tea. They bring 0.5 [L] of water to a boil using an electric tea kettle. The water is initially at a temperature and pressure of 20 °C and 101.3 [kPa]. If the average cost of electricity is 13 cents per kilowatt-hour, determine the following:

a) How much did it cost to heat the water to its boiling point? Assume the process is isobaric and that no heat is lost to the surroundings during heating.
b) Say this person forgets they were making tea and all of the water is turned to vapor. Starting at the boiling point, how much did it cost to transform all the water to saturated vapor? Assume again the process is isobaric and that no heat is lost to the surroundings during heating.

Problem #2

Consider a piston-cylinder device containing 5 [L] of air at a temperature and pressure of 50 °C and 150 [kPa]. The piston begins to rise upward, allowing the initial volume to double, and reducing the temperature of air to 15 °C. Assuming the air behaves as an ideal gas, determine the following:

a) The pressure at State 2, P_2;
b) The work performed during the process. Assume a linear relationship between pressure and volume;
c) The amount of heat transferred into or out of the system given $u_1 = 231$ [kJ/kg] and $u_2 = 205.86$ [kJ/kg];
d) If the air should be treated as an ideal gas. Use $T_c = 132.41$ [K] and $P_c = 3{,}774$ [kPa];

Problem #3

A piston-cylinder device contains 10 [kg] of ammonia at 150 [kPa] and 40 °C. The system is first cooled at constant pressure, reducing the volume and causing the piston to move downwards until the piston comes to rest on some stops. At this point, the volume in the cylinder is only 25% of the original volume. The system is now cooled at constant volume until the temperature reaches -50 °C. Determine the following:

a) The quality, x, at States 1, 2, and 3, if applicable;
b) The net work performed on or by the system moving from State 1 to 3;
c) The net heat transferred into or out of the system moving from State 1 to 3;

Problem #4

Consider a well-insulated vessel that is divided into two sections by a thin liner, with each section containing water. The liner begins to fail and allows the two sections to mix until the vessel reaches thermodynamic equilibrium. All that is known about the first section before mixing occurred is that its initial pressure was 1,000 [kPa] and initial specific internal energy was 740.16 [kJ/kg]. The only thing known about the second section before mixing occurred is that it occupied most of the volume of the vessel at 4.982 [m^3]. After the vessel reaches equilibrium, the pressure is now 1,600 [kPa] and the specific internal energy is 2,692.26 [kJ/kg]. If no heat is transferred into or out of the system, and the total volume of the vessel is 5 [m^3], determine the following:

a) The specific volume, ν, specific internal energy, u, volume, $\forall$, and mass, m, for both sections before mixing (State 1) and for the vessel after mixing (State 2).
b) Is this system open, closed, or isolated? Explain why;