ENGR 2010: Exam I

Allowable materials: 4 formula pages and the property tables in the text.

In Accordance with those virtues of Honesty and Truthfulness set forth in the Auburn Creed, I, as a student and fellow member of the Auburn Family, do hereby pledge that all work is my own, achieved through personal merit and without any unauthorized aid. In the promotion of integrity, and for the betterment of Auburn, I give honor to this, my oath and obligation.

1. Provide **BRIEF** answers to the following questions.

   (a) Will knowledge of the temperature and pressure of a substance always be sufficient to specify the state of the substance? Explain in a sentence or two; a simple yes or no will not suffice.

   (b) What is the unique characteristic of water that prevents the ocean depths from freezing solid?

   (c) Briefly explain under what conditions can a substance be treated as an ideal gas.

   (d) A coffee cup cools during a lecture. Can the energy transferred from the cup during this process be considered work? Explain in a sentence or two.

   (e) A system containing water is initially at state 1, illustrated in the $T-v$ diagram at right. The system now undergoes a constant pressure process, and ends up as a saturated liquid. Sketch the process path on the diagram.
2. A piston cylinder device, having an initial volume 0.2 m$^3$, contains water at an initial temperature and pressure of 300°C and 2 MPa. The system is now cooled, during which the piston maintains a constant pressure in the system. At the end of the process a total of 3000 kJ of heat has been removed from the system. Determine the final temperature and total volume of the system.

state 1 superheated:

\[ v_1 = 0.125 \, \text{m}^3/\text{kg}, \quad h_1 = 3023.5 \, \text{kJ/kg} \]
\[ m = \frac{V}{v_1} = 1.59 \, \text{kg} \]
\[ h_2 = h_1 + \frac{Q}{m} = 1141.6 \, \text{kJ/kg} \]

\( P \) and \( h_2 \) fix state 2: state is a saturated mix at 212°C, \( x_2 = 0.123, \quad v_2 = 0.0133 \, \text{m}^3/\text{kg}, \) and
\[ V_2 = m \, v_2 = 0.0212 \, \text{m}^3 \]

3. Air is contained in a piston cylinder apparatus. Initial total volume, temperature, and pressure are 0.5 m$^3$, 80°C, and 100 kPa. The air is now compressed, and during the process the system is cooled so that the temperature remains constant. At the end of the process the volume is half of the original volume. Calculate

(a) The final pressure.
(b) The total work done on the system during the process, and
(c) The total heat transfer from the system during the process.

Assume air to be an ideal gas with a constant specific heat of \( C_p = 1.005 \, \text{kJ/kg K} \).

\[ P_2 = \frac{V_1}{V_2} P_1 = 200 \, \text{kPa} \]

For the isothermal, ideal gas process,
\[ W_{1-2} = P_1 V_1 \ln \left( \frac{V_2}{V_1} \right) = -34.7 \, \text{kJ} \]

and since the temperature is constant \( \Delta u = 0 \), and \( Q = W \).

4. Refrigerant R-134 enters an adiabatic air conditioner compressor as a saturated vapor at -10°C. The volumetric flow rate of the refrigerant entering the compressor is 1.6 Liters/s, and the inlet pipe diameter is 2 cm. The flow exits at 600 kPa and 50°C. Determine:

(a) the mass averaged velocity at the inlet and the mass flow rate.
(b) the power input to the compressor.

state 1 is a saturated vapor at -10°C:

\[ v_1 = 0.1 \, \text{m}^3/\text{kg}, \quad h_1 = 245 \, \text{kJ/kg} \]
\[ V_1 = \frac{V_1}{\pi D^2/4} = 5.1 \, \text{m/s} \]
\[ \dot{m} = \frac{V_1}{v_1} = 0.016 \, \text{kg/s} \]

State 2 is superheated, with \( h_2 = 290.3 \, \text{kJ/kg} \)
\[ \dot{W} = \dot{m} (h_1 - h_2) = -0.725 \, \text{kW} \]