Solution to First Examination, Thursday, 2011 February 17

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Statistics

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<table>
<thead>
<tr>
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</thead>
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<tr>
<td>High</td>
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<td>Average</td>
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<tr>
<td>Median</td>
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<tr>
<td>Standard Deviation</td>
<td>17.4</td>
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Problem 1.0

Because you live in Park City, Utah, at an elevation of 2000 m, you do most of your cooking with a pressure cooker. The atmospheric pressure in Park City is 79.5 kPa. Your pressure cooker is designed to operate at 95.0 kPa (gage).

Estimate the temperature of operation (°C) if you use your cooker with refrigerant-134a instead of water. Assume that the cooker contains only r-134a and that liquid and vapor phases are present.

The absolute pressure is 95 kPa + 79.5 kPa = 174.5 kPa. The saturation pressure is 174.5 kPa. Interpolate in Table A-12 to find the saturation temperature:

\[ T_{sat} = -15.60 + \frac{-12.73 - (-15.60)}{180 - 160}(174.5 - 160) = -13.5°C \]

Problem 2.0

A 27-ft³, compressed-air storage tank is at 80°F and 100 psig. The atmospheric pressure is 14.7 psia. Calculate the mass of air in the tank (in lbm) using the ideal gas equation. You may assume that the air is dry.

Model the air using the ideal gas equation:

\[ m = \frac{PV}{RT} = \frac{114.7 \text{ psia}(27 \text{ ft}^3)}{\left(\frac{10.73 \text{ psia ft}^3}{29 \text{ lbm R}}\right)(80 + 460) \text{ R}} = 15.5 \text{ lbm} \]
Problem 3.0
A 1.00-liter, rigid vessel contains 1.00 g of water and nothing else at 25°C. The system is brought to equilibrium at 80°C. Find the phase description, pressure, quality (if defined), and internal energy (U, kJ) of the water.

The specific volume is

\[ \nu = \frac{V}{m} = \frac{0.001 \text{ m}^3}{0.001 \text{ kg}} = 1.00 \text{ m}^3/\text{kg} \]

From Table A-4 at 80°C, \( v_f = 0.001029 \) and \( v_g = 3.4053 \text{ m}^3/\text{kg} \). Because \( v \) is between \( v_f \) and \( v_g \), we have a saturated mixture of liquid and vapor and the pressure of the system is \( P_{\text{sat}} = 47.416 \text{ kPa} \).

The quality is

\[ x = \frac{\nu - v_f}{v_g - v_f} = \frac{1.0 - 0.001029}{3.4053 - 0.001029} = 0.2934 \]

The internal energy is

\[ U = m(u_f + xu_g) = 0.001 \text{ kg} \left( 334.97 \frac{\text{kJ}}{\text{kg}} + 0.2934 \left( 2146.6 \frac{\text{kJ}}{\text{kg}} \right) \right) = 0.9649 \text{ kJ} \]

Problem 4.0
Fifty grams of dry air are compressed from 300 K and 100 kPa to 500 kPa in a piston-cylinder device. The process is polytropic with \( n = 1.30 \). Calculate the work performed on the air (\( W_{\text{in}}, \text{kJ} \)) and the heat transferred to the air (\( Q_{\text{in}}, \text{kJ} \)). Sketch the process on a P-v diagram.

Model the air using the ideal gas equation. Solving for \( T_2 \) gives

\[ T_2 = T_1 \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} = 300 \text{ K} \left( \frac{5}{1.3} \right)^{0.7} = 434.9 \text{ K} \]

The work performed on the air is

\[ W_{\text{in}} = mR \frac{T_2 - T_1}{n-1} = 0.05 \text{ kg} \left( \frac{8.314 \text{ kJ/kgK}}{29 \text{ kgK}} \right) \frac{(434.9 - 300) \text{ K}}{0.3} = 6.45 \text{ kJ} \]

The heat transferred to the air is obtained from an energy balance:
\[ \Delta U = Q_{in} + W_{in} \]
\[ Q_{in} = \Delta U - W_{in} = mc_v (T_2 - T_1) - W_{in} \]
\[ Q_{in} = 0.05 \, \text{kg} \left( 0.718 \frac{\text{kJ}}{\text{kgK}} \right) (435 - 300) \text{K} - 6.45 \, \text{kJ} = -1.60 \, \text{kJ} \]