Problem Set 10, PS10 due Friday June 11

PS10-1 Saturated water vapor at 250 F is contained in a 4 ft^3 rigid tank which is connected by a valve to a supply pipe line which carries steam at 160 psia and 400 F. The valve is opened. The tank temperature is maintained at 250 F by heat transfer to the surroundings. When the tank is half filled with liquid water the valve is closed. Determine a) the final temperature in the tank, b) the amount of steam that enters the tank, and c) the amount of heat transfer.

PS10-2 Saturated water vapor at a pressure of 100 kPa fills a .05 m^3 piston-cylinder device having a .1 m^2 piston area. The cylinder is cooled until the temperature inside the cylinder drops to 30 C. Determine the force required to keep the piston from moving and the amount of heat transferred.

PS10-3 An insulated piston cylinder device initially contains .2 m^3 of air at 200 kPa and 22 C. At this state a linear spring touches the piston but exerts no force on it. The cylinder is connected by a valve that supplies air at 800 kPa and 22 C. The valve opens and air from the high pressure line is allowed to enter the piston cylinder. The valve is turned off when the pressure inside the cylinder reaches 600 kPa. If the enclosed volume inside the cylinder doubles during the process, determine a) the mass of air that entered the cylinder and b) the temperature of the air inside the cylinder.

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system - final mass m_2

@ $160\ \text{psia},\ 400^\circ\text{F}$

$h_o = 1217.8\ \text{BTU/lb}$

@ 250°F

$u_1 = u_g = 1087.9\ \text{BTU/lb}$

$U_2 = m_{f2} \times u_f + m_{g2} \times u_g$

$U_2 = 117.64 \times 218.49 + .1447 \times 1087.9$

$U_2 = 225860.\ \text{BTU}$

$$m_1 = \frac{4\ \text{ft}^3}{13.826\ \text{ft}^3/\text{lb}} = .2893\ \text{lb}$$

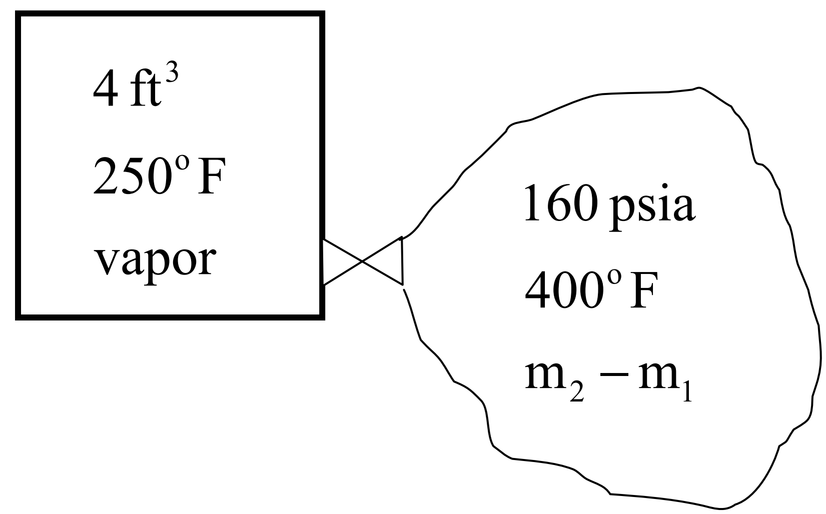
$$m_2 = \frac{2\ \text{ft}^3}{.017001} + \frac{2\ \text{ft}^3}{13.826} = 117.64\ \text{lb}$$

$m_2 - m_1 = 117.5\ \text{lb}$

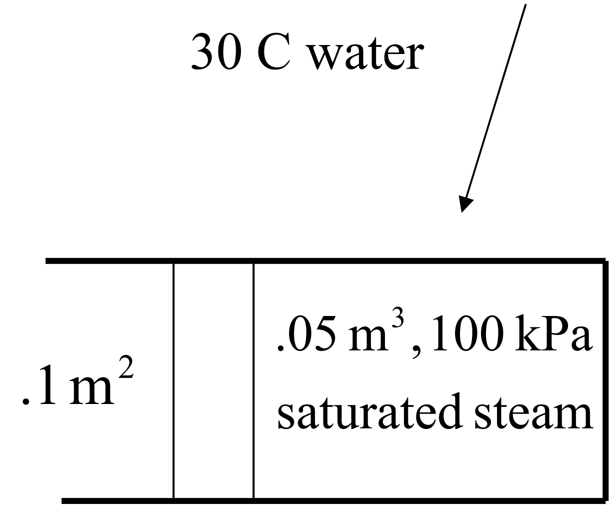
$Q = U_2 - m_1 u_1 - (m_2 - m_1) h_o$

$Q = 25{,}860 - .2893 \times 1087.9 - 117.5 \times 1217.8$

$Q = 117{,}545\ \text{BTU}$



PS10-2



$$v_1 = v_g @\ 100\,\text{kPa} = 1.694\,\text{m}^3/\text{kg}$$

$$u_1 = u_g @\,100\,\text{kPa} = 2506.1\,\text{kJ/kg}$$

$$m_1 = m_2 = \frac{.05\,\text{m}^3}{1.694\,\text{m}^3/\text{kg}} = .0295\,\text{kg}$$

$$@30^\circ\text{C}\ \ p_g = 4.246\,\text{kPa}$$

$$v_f = .001004\,\text{m}^3/\text{kg},\quad v_g = 32.89\,\text{m}^3/\text{kg}$$

$$u_f = 125.78\ \ \text{kJ/kg},\quad u_{fg} = 2290.8\,\text{kJ/kg}$$

$$v_2 = v_1 = 1.694\,\text{m}^3/\text{kg}$$

$$x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{1.694 - .001004}{32.89 - .001004}$$

$$x_2 = .05148$$

$$u_2 = u_f + x \times u_{fg}$$

$$u_2 = 125.78 + .05148 \times 2290.8$$

$$u_2 = 243.7\ \ \text{kJ/kg}$$

$$F = A \times \left(p_{baro} - p_2\right)$$

$$F = .05\,\text{m}^2 \times \left(100\,\text{kPa} - 4.246\,\text{kPa}\right) \times \left(\frac{1000\,\text{N/m}^2}{\text{kPa}}\right)$$

$$F = 9575\text{N}$$

$$Q_{out} = m\Delta u$$

$$Q_{out} = .029\,\text{kg} \times \left(2506.1\,\text{kJ/kg} - 243.7\,\text{kJ/kg}\right)$$

$$Q_{out} = 66.7\,\text{kJ}$$

PS10-3

$$m_1 = \frac{pV}{RT} = \frac{200\,\text{kPa} \times .2\text{m}^3}{.286\left(273.15 + 22\right)} = .4739\,\text{kg}$$

$$m_2 = \frac{pV}{RT} = \frac{600 \times .4}{.287 \times T_2} = \frac{839.2}{T_2}$$

$$W_b = p_{ave}(V_1 - V_2) = \frac{200 + 600}{2} \times .2 = 80\,\text{kJ}$$

$$Q = 0$$

$$m_2 u_2 + W_b = m_1 u_1 + (m_2 - m_1)\,h_o$$

$$\frac{839.2}{T_2} \times .718 T_2 + W_b = .4739 \times 211.92 + \left(\frac{839.2}{T_2} - .4739\right) \times 296.63$$

$$602.5 + 80 = 100.43 + \frac{248{,}932}{T_2} - 104.57$$

$$722.2 T_2 = 248{,}932.$$

$$T_2 = 344.5^{\circ}\,\text{K}$$

$$m_2 = \frac{839.2}{T_2} = \frac{839.2}{344.5} = 2.43\,\text{kg}$$

$$\left(m_2 - m_1\right) = 2.43 - .4739 = 1.95\,\text{kg}$$