University of California
Dept. of Mechanical Engineering
ME 105, Thermodynamics

Name________________

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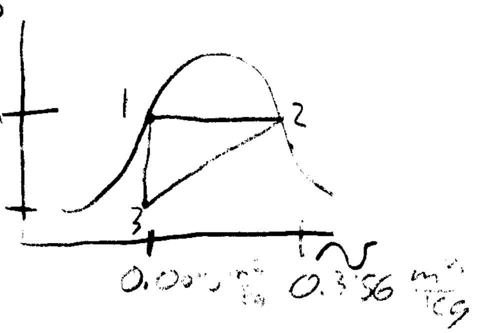
Closed Book, No Notes

MIDTERM #1

1. (50 pts.) The control mass cycle described below is considered for power production. Saturated water at 600 kPa is heated from state 1 at constant pressure until state 2 when the quality equals 1. Then work and heat are added/subtracted such that the specific volume decreases linearly with pressure to state 3 where the pressureis 100 kPa and the specific volume is equal to that of state 1. Finally, the mass is heated at constant volume until the pressure equals 600 kPa.

a. Draw the process on a P-v diagram.
b. Calculate the work for each part of the cycle.
c. Calculate the heat transfer for each heating or cooling phase.
d. What is the efficiency (net work divided by the heat added) of this cycle?

a.



From Table 105:

$v_1 = v_3 = 0.001101 \frac{m^3}{kg}$

$v_2 = 0.3156 \frac{m^3}{kg}$

$u_1 = 670.05 \frac{kJ}{kg}$

$u_2 = 2567.3 \frac{kJ}{kg}$

b) $w_{1-2} = P(v_2 - v_1) = 600kPa(0.3156 - 0.001101)\frac{m^3}{kg} = 188.7 \frac{kJ}{kg}$

$W_{2-3} = 100kPa(0.001101 - 0.3156)\frac{m^3}{kg} + \frac{1}{2}500kPa(0.001101 - 0.3156)\frac{m^3}{kg}$

$= -110.1 \frac{kJ}{kg}$

$\boxed{W_{3-1} = 0}$

c) $X_3 = \frac{v - v_L}{v_v - v_L} = \frac{0.001101 - 0.001043}{1.6943 - 0.001043} = 3.43 \times 10^{-5}$

$u_3 = (1 - X_3)u_L + X_3 u_v = 417.5 \frac{kJ}{kg}$

$Q_{1-2} = \Delta U_{12} + W_{12} = 2086 \frac{kJ}{kg}$

$Q_{2-3} = \Delta U_{23} + W_{23} = -2259.9 \frac{kJ}{kg}$

$Q_{3-1} = \Delta U_{31} + \underbrace{\cancel{W_{31}}}_{0} = 252.6 \frac{kJ}{kg}$

d) $\eta = \frac{188.7 - 110.1}{2086 + 252.6}$

$\boxed{= 3.4\%}$

relation of P and v during the process 2-3 is obtained

$\rightarrow$ $P = a + bv$ with (P_2, v_2) and (P_3, v_3)

$$\therefore P_{2-3} = P_2 + \left(\frac{P_2 - P_3}{v_2 - v_3}\right)(v - v_2) \equiv P_2 + A(v - v_2) = Av + (P_2 - Av_2)$$

$$\therefore W_{2-3} = \int P dv = \int_{v_2}^{v_3} (Av + (P_2 - Av_2)) dv = \frac{A}{2} v^2 + (P_2 - Av_2) v \Big|_{v_2}^{v_3}$$

$$= \frac{1}{2}\left(\frac{P_2 - P_3}{v_2 - v_3}\right)(v_3^2 - v_2^2) + \left(P_2 - \frac{P_2 - P_3}{v_2 - v_3} v_2\right)(v_3 - v_2)$$

$$= \frac{-1}{2}(P_2 - P_3)(v_2 + v_3) + P_2(v_3 - v_2) + v_2(P_2 - P_3)$$

$$= \frac{-1}{2}(P_2 - P_3)(v_2 + v_3) + P_2 v_3 - P_3 v_2$$

$$= \frac{-1}{2}\left[P_2 v_2 + P_2 v_3 - P_3 v_2 - P_3 v_3 - 2 P_2 v_3 + 2 P_3 v_2\right]$$

$$= \frac{-1}{2}\left[P_2 v_2 - P_2 v_3 + P_3 v_2 - P_3 v_3\right]$$

$$= \frac{-1}{2}(P_2 + P_3)(v_2 - v_3)$$

$$= \frac{-1}{2}(700 \times 10^3)(0.3156 - 0.001101) = -110.1 \,(\mathrm{kJ/kg})$$

200 kPa and temperature of 500 K (negligible velocity) that exhausts to a pressure of 50 kPa and a temperature of 250 K.

$$\cancel{\dot{m}}(h_1 + \cancel{\frac{V_1^2}{2g_c}}) = \cancel{\dot{m}}(h_2 + \frac{V_2^2}{2g_c})$$

$$V_2 = \sqrt{2(\Delta h)}$$

$$\Delta h = C_p \Delta T$$

$$C_p = C_v + R = 1 \frac{kJ}{kg \cdot K}$$

$$\Delta h = 250 \frac{kJ}{kg}$$

$$V_2 = \sqrt{2(250{,}000 \frac{J}{kg})} = \boxed{707.1 \text{ m/s}}$$

MPa. What is the temperature in the small tank when its pressure reaches 1 MPa.

$$m_2 u_2 - \cancel{m_1 u_1}^{\,0} = m_{in} h_{in} \qquad m_{in} = m_2 - \cancel{m_1}^{\,0}$$

$$\cancel{m_2} u_2 = \cancel{m_2} h_{in}$$

$$u_2 = C_v(T_2 - 0K) \qquad h_{in} = C_p(T_{in} - 0K)$$

$$C_v T_2 = C_p(293K)$$

$$T_2 = \frac{C_p}{C_v}(293 K) = \frac{1 \frac{kJ}{kg \cdot K}}{0.72 \frac{kJ}{kg \cdot K}}(293K) = \boxed{407 K}$$

$$= 134\,°C$$

4. $w_{in} = h_2 - h_1 = \Delta h$

$$dh = d\cancel{u} + v\,dP + \cancel{P\,dv}$$

$$\Delta h = v(P_2 - P_1) = 0.001 \frac{m^3}{kg}(1100 - 100)\frac{kN}{m^2}$$

$$\Delta h = w_{in} = \boxed{1.0 \frac{kJ}{kg}}$$