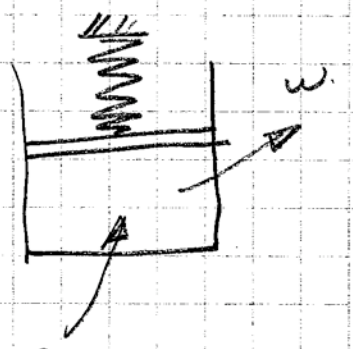
CHE 260-MID-TERM EXAM
2010

(1)

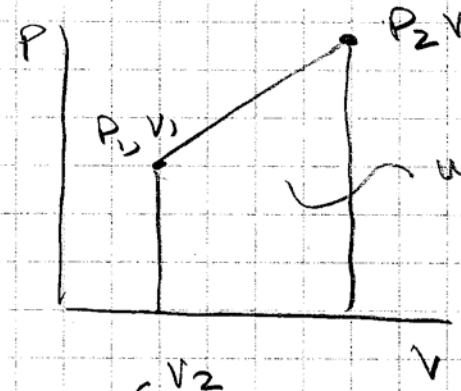


$P_1 = 150$ kPa

$V_1 = 10^{-3}$ m^3

$P_2 = 800$ kPa

$V_2 = 1.5 \times 10^{-3}$ m^3



$$W_{12} = -\int_{V_1}^{V_2} P\,dV$$

$$W_{12} = -\int_{V_1}^{V_2} P\,dV = -\left(\frac{P_1+P_2}{2}\right)\left(V_2 - V_1\right)$$

$$= -\frac{1}{2}\left(150+800\right)\left(1.5\times10^{-3} - 1\times10^{-3}\right)$$

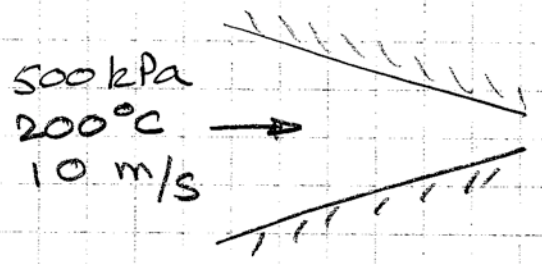
$$= -0.2375 \text{ kJ}$$

$$\therefore \Delta U = Q + W$$

$$\Delta U = 1 \text{ kJ} - 0.2375 \text{ kJ}$$

$$= 0.7625 \text{ kJ}$$

(2)



$\dot{m} = 0.15$ kg/s

$$\cancel{\dot{Q}}^{0} + \cancel{\dot{W}}^{0} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$\Rightarrow \quad h_2 - h_1 = C_p (T_2 - T_1) = \frac{V_1^2 - V_2^2}{2}$$

$$1.042 \text{ kg/s}\left[T_2 - 200^\circ C\right] = \frac{10^2 - 300^2}{2 \times 1000}$$

$$T_2 = 156.9^\circ C = 430 \text{ K}.$$

For isentropic process

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad P_2 = P_1\left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}} = 500\left(\frac{430\text{K}}{473\text{K}}\right)^{\frac{1.4}{0.4}}$$

$$P_2 = 358 \text{ kPa}$$

$$v_2 = \frac{RT_2}{P} = \frac{0.2968 \times 430}{358} = 0.356 \text{ m}^3/\text{kg}$$

$$\dot{m} = \frac{A_2 V_2}{v_2}$$

$$\Rightarrow A_2 = \frac{\dot{m} v_2}{V_2} = \frac{0.15 \times 0.356}{300}$$

$$= 1.78 \times 10^{-4} \text{ m}^2$$

(3)

A	B
200 kPa $x = 0.8$	2 MPa 400°C

$V_A = V_B = 1\ m^3$

$P_2 = 1$ MPa.

At 200 kPa

$v_f = 0.001061\ m^3/kg$ $\quad v_g = 0.88578\ m^3/kg$

$u_f = 504.50\ kJ/kg$ $\quad u_{fg} = 2024.6\ kJ/kg$

$u_{A,1} = 504.50 + 0.8 \times 2024.6 = 2124.18\ kJ/kg$

$v_{A,1} = 0.001061 + 0.8 \times (0.88578 - 0.001061)$

$= 0.70884\ m^3/kg.$

At 2 MPa, 400°C

$v_{B,1} = 0.15122\ m^3/kg$, $u_{B,1} = 2945.9\ kJ/kg$

$m_A = \frac{1}{v_{A,1}} = \frac{1}{0.70884} = 1.411\ kg$

$m_B = \frac{1}{v_{B,1}} = \frac{1}{0.15122} = 6.613\ kg$

$m = m_A + m_B = 1.411 + 6.613 = 8.024\ kg$

$v_2 = \frac{2\ m^3}{8.024} = 0.24925$; $P_2 = 1$ MPa

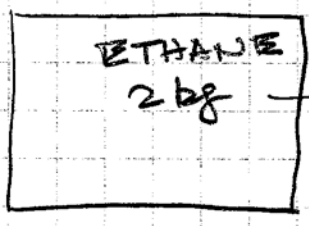
$\frac{T_2 - 250}{300 - 250} = \frac{0.24925 - 0.23275}{0.25799 - 0.23275} \Rightarrow T_2 = 289.2°C$

$\frac{u_2 - 2710.4}{2793.7 - 2710.4} = \frac{0.24925 - 0.23275}{0.25799 - 0.23275} \Rightarrow u_2 = 2764.9\ \frac{kJ}{kg}$

$Q = m\Delta u = m\left[u_2 - (u_{A,1} + u_{B,1})\right]$

$= 8.024\left[2764.9 - (2124.18 + 2945.9)\right] = -18.50\ MJ$

4)



$$Q + W = \Delta U = m c_v (T_2 - T_1)$$

$$\Delta S = \frac{Q}{T_{surr}} + S_{gen}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{and} \quad P_1 V_1^{1.3} = P_2 V_2^{1.3}$$

$$\Rightarrow \quad P_2 = P_1 \left(\frac{T_2}{T_1} \right)^{\frac{1.3}{0.3}}$$

$$= 500\ kPa \left(\frac{293\ K}{373\ K} \right)^{\frac{1.3}{0.3}} = 175.7\ kPa$$

$$W = \frac{P_2 V_2 - P_1 V_1}{n-1} = \frac{R(T_2 - T_1)}{n-1}$$

$$= \frac{0.276\ (293 - 373)}{1.3 - 1} = -73.6\ kJ/kg$$

$$q = c_v (T_2 - T_1) - w = 1.490\ (293 - 373) + 73.6 = -45.6\ \frac{kJ}{kg}$$

$$\Delta s = c_p \ln \left(\frac{T_2}{T_1} \right) - R \ln \frac{P_2}{P_1}$$

$$= 1.766 \ln \left(\frac{293}{373} \right) - 0.276 \ln \left(\frac{175.7}{500} \right)$$

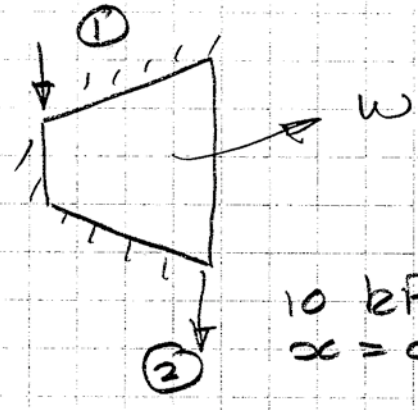
$$= -0.1376\ kJ/kg\,K$$

$$\Delta S = m \Delta s = 2\ kg \times (-0.1376)\ \frac{kJ}{kg\,K} = -0.2753\ \frac{kJ}{K}$$

$$S_{gen} = \Delta S - \frac{Q}{T_{surr}} = -0.2753 - \frac{(2 \times (-45.6))}{293}$$

$$= 0.0360\ \frac{kJ}{K}$$

(5) 400°C
2 MPa



10 kPa.
$x = 0.95$

a) $w = \frac{\dot{W}}{\dot{m}} = h_2 - h_1$

at 400°C, 2 MPa, $h_1 = 3468.3 \frac{kJ}{kg}$, $s_1 = 7.4337 \frac{kJ}{kg K}$

at 10 kPa, $h_f = 191.81 \frac{kJ}{kg}$ $h_{fg} = 2392.1 \frac{kJ}{kg}$.

$h_2 = 191.81 + 0.95 \times 2392.1 = 2464.3 \ kJ/kg$

$w = 2464.3 - 3468.3 = -1004.0 \ kJ/kg$

b) For isentropic expansion $s_2 = s_1 = 7.4337 \frac{kJ}{kg K}$.

at 10 kPa $s_f = 0.6492 \frac{kJ}{kg K}$ $s_{fg} = 7.4996 \frac{kJ}{kg K}$

$x_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{7.4337 - 0.6492}{7.4996} = 0.9046$

$h_2 = h_f + x_2 h_{fg}$

$= 191.81 + 0.9046 \times 2392.1 = 2355.7 \frac{kJ}{kg}$.

$w = h_2 - h_1 = 2355.7 - 3468.3$

$= -1112.6 \ kJ/kg$.