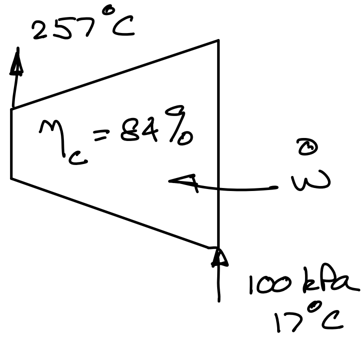
CHE 260 MID TERM SOLUTION - 2021

1)



$$\eta_c = \frac{T_{2s} - T_1}{T_2 - T_1}$$

$$\frac{P_{2s}}{P_1} = \left(\frac{T_{2s}}{T_1}\right)^{\gamma/\gamma-1}$$

$$T_2 = 257^\circ C = 530\ K$$

$$T_{2s} = T_1 + \eta_c (T_2 - T_1)$$

$$= 290\ K + 0.84(530 - 290)\ K = 491.6\ K.$$

$$C_v = C_p - R = 1.004 - 0.287 = 0.717\ kJ/kgK$$

$$\gamma = \frac{C_p}{C_v} = \frac{1.004\ kJ/kgK}{0.717\ kJ/kgK} = 1.400$$

$$P_{2s} = P_1 \left(\frac{T_{2s}}{T_1}\right)^{\gamma/\gamma-1} = 100\ kPa \left(\frac{491.6\ K}{290\ K}\right)^{\frac{1.4}{0.4}} = 634.2\ kPa$$

Density of air at inlet

$$\rho = \frac{P}{RT} = \frac{100\ kPa}{0.287\ kJ/kgK \times 290\ K} = 1.201\ kg/m^3$$

$$\dot{m} = \rho \dot{V} = 1.201\ kg/m^3 \times 2.4\ \frac{m^3}{s} = 2.88\ kg/s$$

$$\dot{W} = \dot{m}(h_2 - h_1) = \dot{m}\, C_p (T_2 - T_1)$$

$$= 2.88\ kg/s \times 1.004\ \frac{kJ}{kg\,K} (530 - 290)\ K$$

$$\dot{W} = 694.0\ kW$$

②

$$\cancel{Q}_{0} + \cancel{W}_{0} = \Delta U = 0$$

$$\Rightarrow \frac{m}{2} c (T_f - T_1) + \frac{m}{2} c (T_f - T_2) = 0$$

$$\Rightarrow T_f = \frac{T_1 + T_2}{2}$$

$$S_{gen} = m s_f - \left[\frac{m}{2} s_1 + \frac{m}{2} s_2 \right]$$

$$= \frac{m}{2}(s_f - s_1) + \frac{m}{2}(s_f - s_2)$$

For water
$$s_f - s_1 = c \ln \frac{T_f}{T_1}$$
$$s_f - s_2 = c \ln \frac{T_f}{T_2}$$

$$S_{gen} = \frac{m}{2} c \left[\ln \frac{T_f}{T_1} + \ln \frac{T_f}{T_2} \right]$$

$$= m c \ln \left(\frac{T_f^2}{T_1 T_2} \right)^{1/2}$$

$$= m c \ln \frac{T_f}{\sqrt{T_1 T_2}}$$

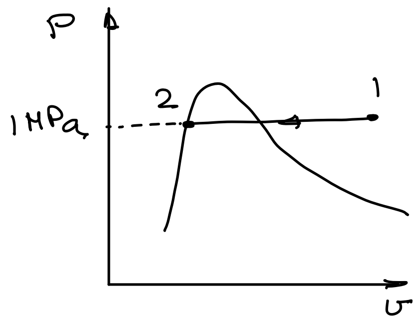
$$S_{gen} = m c \ln \left[\frac{T_1 + T_2}{2\sqrt{T_1 T_2}} \right]$$

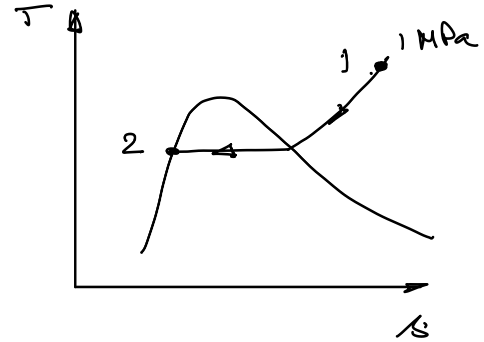
(3)

$m = 2\ \text{kg}$

$P_1 = 1\ \text{MPa}$ $\qquad x_2 = 0$

$T_1 = 250^\circ C$





At 1 MPa, 250°C $\left.\right\}$ $v_1 = 0.23275\ \text{m}^3/\text{kg}$

$u_1 = 2710.4\ \text{kJ/kg}$

At 1MPa $\quad v_2 = v_f = 0.001127\ \text{m}^3/\text{kg}$

$u_2 = u_f = 761.39\ \text{kJ/kg}$

$$W_{12} = -mP(v_2 - v_1)$$

$$= -2\,\text{kg} \times 10^3\,\text{kPa} \times (0.001127 - 0.23275)\,\frac{\text{m}^3}{\text{kg}}$$

$$W_{12} = 463.1\ \text{kJ}$$

$$Q_{12} = m(u_2 - u_1) - W_{12}$$

$$= 2\,\text{kg}\,(761.39 - 2710.4)\,\frac{\text{kJ}}{\text{kg}} - 463.1\ \text{kJ}$$

$$Q_{12} = -4361.1\ \text{kJ}$$

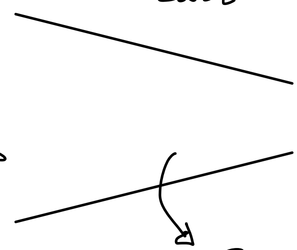
(4)

$T_{surr} = 20^\circ C.$

$P_1 = 280$ kPa

$T_1 = 77^\circ C$

$V_1 = 50$ m/s



$P_2 = 85$ kPa

$V_2 = 320$ m/s

$q = -3.2$ kJ/kg

<u>Energy Balance</u>

$$\dot{Q} + \dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right)$$

$$\Rightarrow \quad c_p (T_2 - T_1) = \frac{V_1^2 - V_2^2}{2} + q.$$

$$\Rightarrow \quad T_2 = T_1 + \frac{V_1^2 - V_2^2}{2 c_p} + \frac{q}{c_p}$$

$$T_2 = 77^\circ C + \frac{(50\,m/s)^2 - (320\,m/s)^2}{2 \times 1.004\,\frac{kJ}{kg\,K} \times 10^3\,J/kJ} - \frac{3.2\,kJ/kg}{1.004\,\frac{kJ}{kg\,K}}$$

$$T_2 = 24.1^\circ C = 297.3\,K.$$

$$\Delta s_{air} = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

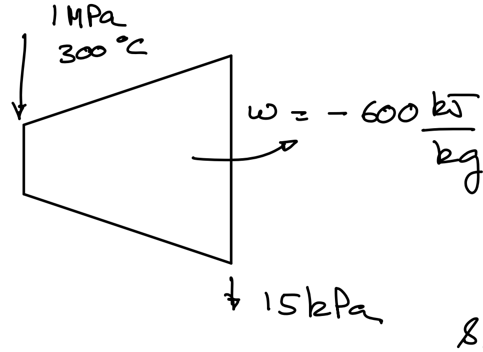
$$= 1.004\,\frac{kJ}{kg\,K} \ln \frac{297.1\,K}{350.2\,K} - 0.287\,\frac{kJ}{kg\,K} \ln \frac{85\,kPa}{280\,kPa}$$

$$\Delta s_{air} = 0.1770\ kJ/kg\,K.$$

$$\Delta s_{surr} = \frac{q}{T_{surr}} = \frac{3.2\,kJ/kg}{293.2\,K} = 0.0109\,\frac{kJ}{kg\,K}$$

$$\Delta s_{TOTAL} = \Delta s_{air} + \Delta s_{surr} = 0.1879\ kJ/kg\,K$$

(5)



1 MPa, 300°C: $h_1 = 3051.6$ kJ/kg, $s_1 = 7.1246$ kJ/kgK

at 15 kPa

$h_f = 225.94\ \frac{kJ}{kg}$, $h_g = 2598.3\ \frac{kJ}{kg}$

$s_f = 0.7549\ \frac{kJ}{kgK}$, $s_g = 8.0071\ \frac{kJ}{kgK}$

For an isentropic process $s_2 = s_1$

$$x_{2,s} = \frac{s_{2,s} - s_f}{s_g - s_f} = \frac{7.1246 - 0.7549}{8.0071 - 0.7549} = 0.8783$$

$$h_{2s} = h_f + x_{2,s}(h_g - h_f)$$
$$= 225.94 + 0.8783(2598.3 - 225.94)$$
$$= 2309.6 \text{ kJ/kg.}$$

$$w_s = h_1 - h_{2s} = 3051.6 - 2309.6 = 742.0 \text{ kJ/kg}$$

a) $$\eta_t = \frac{w_a}{w_s} = \frac{600 \text{ kJ/kg}}{742 \text{ kJ/kg}} = 80.9\%$$

$$h_2 = h_1 - w_a = 3051.6 - 600 = 2451.6 \text{ kJ/kg.}$$

$$x_2 = \frac{h_2 - h_f}{h_g - h_f} = \frac{2451.6 - 225.94}{2598.3 - 225.94}$$

b) $x_2 = 0.938$