FINAL EXAM CHEE 210 A.

WINTER 2010

(Q1) ARASH

Problem #1

5

Convert to correct units to be able to look up closest values in steam tables in back of text.

a) 10 MPa 0.003 m^3/kg = 3 cm^3/s

wet steam 1

b) 200°C 0.1 m^3/kg = 100 cm^3/s

wet steam 1

c) 2200 kPa 3134 kJ/kg

Superheated steam 1

d) 300°C 10 MPa

subcooled liquid 1

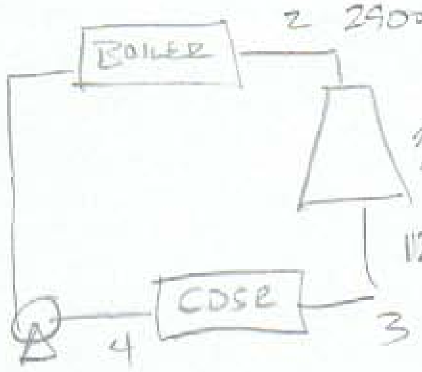
e) 5°C, 147.2 m^3/kg

saturated vapour. 1

7 minutes

Q2) ARASH

10:35 / 24 min



1

25

Consider Turbine

$H_2 = 3457.3$ kJ/kg 2

$S_2 = 7.2512$ kJ/kg K

Isentropic

$S_3 = S_2 = 7.2512$ kJ/kg K 1

125 kPa

$H^L_{125} = 444.356$ kJ/kg $\qquad H^V_{125} = 2685.2$ kJ/kg 3

$S^L_{125} = 1.3740$ kJ/kg K $\qquad S^V_{125} = 7.2847$ kJ/kg K

$$(x_3)_s = \frac{7.2512 - 1.3740}{7.2847 - 1.3740} = 0.994$$ 3

$$H_3 = 3457.3 + 0.85\left([0.994 \cdot 2685.2] + (1-0.994)(444.356) - 3457.3\right)$$

$$= 3457.3 + 0.85(-786.8)$$

$$= 2788.5 \text{ kJ/kg}$$ 1

$$\boxed{W_t = \Delta H_t = -668.8 \text{ kJ/kg}}$$ 3

Q2)

Consider Pump.

$H_4 = H^L_{125kPa} = 444.356$ kJ/kg.

$(\Delta H)_s = W_p = V\Delta P = 1.049 (L/kg)(2900 - 125)$ kPa 1

$= 2,911$ J/kg $= 2.91$ kJ/kg

$\Delta H = \frac{(\Delta H)_s}{\eta} =$ 3.43 kJ/kg. $= W_p$ 3

$H_1 = H_4 + \Delta H = 444.356 + 3.43$ 1

$= 447.78$ kJ/kg

Consider Boiler

$\Delta H = Q_H = H_2 - H_1 = (3457.3 - 447.78)$ 2

$Q_H = 3009.52$ kJ/kg.

Plant Efficiency

$$\eta = \frac{|W_t| - |W_p|}{Q_H} = \frac{668.8 - 3.43}{3009.52}$$ 1

$= 0.221$ 3

The plant is 22.1% efficient.

Q3 / PROSHAD

19 marks

(i) Energy content of fuel

$$E_{Fuel} = 171{,}000 \text{ L} \times 34.8 \text{ MJ/L}$$
$$= 5{,}950{,}800 \text{ MJ}$$

(ii)

$$\eta = \frac{\eta_t \eta_c (T_C/T_A)(1 - 1/\alpha) - (\alpha - 1)}{\eta_c (T_C/T_A - 1) - (\alpha - 1)}$$

$$\alpha = \left(\frac{P_B}{P_A}\right)^{\frac{\gamma - 1}{\gamma}} = 34.4^{\left(\frac{1.4-1}{1.4}\right)} = 2.748$$

$$T_C/T_A = \frac{(1700 + 273.15)}{(-54 + 273.15)} = 9.004$$

$$\eta = \frac{(0.85)(0.9)(9.004)(1 - 1/2.748) - (2.748 - 1)}{[0.9(9.004 - 1) - (2.748 - 1)]}$$

$$= 0.483$$

(iii) Time in air $= \dfrac{14{,}260 \text{ km}}{900 \text{ km/h}} = 15.84$ hrs

$= 57{,}040$ s.

$$\text{Power per Engine} = \frac{(0.483)(5{,}950{,}800) \text{ MJ}}{2 \, (57{,}040 \text{ s})}$$

$$= 25.2 \text{ MW}$$

Q4) If a 40 L tank of hydrogen is pressurized to 5000 psi (1 bar = 14.5038 psia) at 25°C how many kilograms of hydrogen are stored in the tank? Use the appropriate equation of state. According to the IGL how many kilograms would be stored?

15 min.

H_2 molar mass = 2.016

$\omega = -0.216$

$T_c = 33.19$ K

$P_c = 13.13$ bar

Given: $V^{tot} = 40$ L

$P = 5000$ psi $= 344.7$ bar

$T = 25°C = 298.15$ K

Since $T_r > 4.0$ use Pitzer correlations 2

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}} \quad B' = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$Z = 1 + B^0 \frac{P_r}{T_r} + \omega B' \frac{P_r}{T_r}$$

$$P_r = \frac{344.7}{13.13} = 26.26 \quad T_r = \frac{298}{33.19} = 8.98$$ 2

$B' = 0.1390$

$B^0 = 0.07041$

$$Z = 1 + 0.7041\left(\frac{26.26}{(8.98)^{1.6}}\right) + (-0.216)\left(\frac{26.26}{(8.98)^{1.6}}\right)$$

Q4

$Z = 1.181$ 2

$PV = ZRT$

$$V = \frac{ZRT}{P} = \frac{(1.181)\left(8.314 \frac{L \cdot kPa}{mol\,K}\right)(299\,K)}{34,474\,kPa}$$

$$= 0.0804 \quad L/mol$$ 2

$$n = \frac{V^{tot}}{V} = \frac{40\,L}{0.0804\,L/mol} = 497.8\,mol$$

$$m = 2.0179\,\frac{g}{mol} \times 497.8\,mol = 1003.5\,g$$

$$= 1.004\,kg$$

b) IGL

$PV = nRT$

$PV = \frac{m}{M}RT$

$$m = \frac{MPV}{RT} = \frac{(2.017\,g/mol)(34473\,kPa)(40\,L)}{\left(8.314\,\frac{L \cdot kPa}{mol\,K}\right)(298\,K)}$$

$$= 1.12\,kg$$

CHEE 210 WINTER 2010

Q5) PROSHAD

$C_p = \frac{11}{2} R$ $\quad C_v = C_p - R = \frac{9}{2} R$

$\gamma = \frac{11}{9} = 1.222$

Reversible Adiabatic.

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{R}{C_p}}$ $\quad T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{R}{C_p}}$

$T_2 = (300)\left(\frac{8}{1.1}\right)^{\frac{2}{11}} = 430.3 \text{ K}$

$(\Delta H)_s = \frac{11}{2} R (430.3 - 300) = 5959 \text{ kJ}$

$\Delta H = \frac{11}{2} R (480 - 300) = 8231 \text{ kJ}$

$\eta = \frac{5959}{8231} = 0.724$

CHEE 210 WINTER 2010

Q6) Prosthad

a) $P = 101.3\ kPa + 110.2\ kPa$

$= 211.5\ kPa$

b) From steam table at 211.5 kPa water boils at 122°C

c) At atmosphere pressure water boils at 100°C

Q.7 BAP CHEE210 WINTER 2010

From steam tables.

@ 11400 kPa 650 °C $V^V = 35.733$ L/kg

$$V^R = V - V^{IG}$$

for one mole of steam from IGL

$$V = \frac{RT}{P} = \frac{(8.314)(923.15)}{11400} = 0.673 \text{ L/mol}$$

$$1 \text{ kg} = \frac{1000 \text{ g}}{18.02 \text{ g/mol}} = 37.36$$

$$V^R = 35.73 - 37.36$$
$$= -1.631 \text{ L/kg}$$

Q18) BAP 20 min p1

Energy Balance

$$m_1 H_1 + m_2 H_2 - m_3 H_3 = 0$$

Mass Balance $m_1 = m_2 = \frac{1}{2} m_3 = m$

$$\therefore \quad mH_1 + mH_2 - 2mH_3 = 0$$

$$H_1 + H_2 - 2H_3 = 0$$

$$(H_1 - H_3) + (H_2 - H_3) = 0$$

$$C_p(T - T_1) + C_p(T - T_2) = 0$$

$$\boxed{T = \frac{T_1 + T_2}{2}}$$

$$\Delta S = mC_p \ln\left(\frac{T}{T_1}\right) + mC_p \ln\left(\frac{T}{T_2}\right)$$

$$= mC_p\left(\ln\left(\frac{T^2}{T_1 T_2}\right)\right)$$

Q8

~~$\Delta S^t = 2 m C_p \ln\left(\frac{T}{2\sqrt{T_1 T_2}}\right)$~~

$$= m C_p \ln\left(\frac{\left(\frac{T_1 + T_2}{2}\right)^2}{T_1 T_2}\right)$$