Concordia University
Faculty of Engineering and Computer Science

Date: **March 16, 2018**

Course and No.: **Thermodynamics I ENGR 251 W**

Exam: **Midterm**

Total no. of pages: **9 including the cover sheet and tables in the appendix (Note: Page #9 is blank as a scratch sheet if needed)**

Professor: **Dr. Zhibin Ye**

Time: **11:45 a.m. – 1:15 p.m.**

Location: **MB S2.401, MB S1.430**

~~23~~ 38

SPECIAL INSTRUCTIONS:

(1) **Closed book, closed notes**
(2) **Faculty approved calculators allowed**
(3) **Write everything on this exam paper**
(4) **Answer all 3 questions**
(5) **State your assumptions clearly wherever necessary**
(6) **Do not tear out any page**

1. (a) Demonstrate that for an ideal gas: $C_p - C_v = R$. [2 marks]

(b) For an ideal gas undergoing a process, what does the area under a C_v vs. T graph represent? [2 marks]

(c) For an ideal gas undergoing a process, what does the area under a C_p vs. T graph represent? [2 marks]

b) The area under the graph represents the ~~enthalpy~~ $= \Delta U$

c) The area under the graph represente the ~~entropy~~ $= \Delta h$

$P \cdot V = \cancel{m} R_s T.$

a) $V = m C_v \Delta T$

$H = m C_v \Delta T + W = m C_p \Delta T$

$W = m C_p \Delta T - m C_v \Delta T.$

$P \cdot \Delta V = m \Delta T (C_p - C_v)$

$$C_p - C_v = \frac{P \Delta V}{m \Delta T} = R_s$$

2

$$(Y-Y_1) = \frac{Y_2-Y_1}{X_2-Y_1}(X-Y_1).$$ $$v = \frac{V}{m}.$$

2. Ammonia, NH_3, is contained in a sealed rigid tank at 0 °C, x = 50% and is then heated to 100 °C. Find the final state P_2, u_2, and the specific work and specific heat transfer involved in the heating process. (Thermodynamic tables of NH_3 are attached, page 5~8.) [18 marks]

$T_1 = 0°C = 273.15 k$ $\quad T_2 = 100°c$ $\quad \boxed{V_1 = V_2}$

$x = 0.5$ $\quad = 373.15 k$

$P_{1\,@T_{sat}0°c} = 429,6 kPa$

$v_{f1} = 0,001566 \, m^3/kg$

$v_{g1} = 0,28920 \, m^3/kg$

$v_{fg1} = 0,28763 \, m^3/kg$

$$\left.\begin{array}{l} v_1 = 0,145381 \, m^3/kg. \\ u_1 = 748,84 \, kJ/kg. \end{array}\right\}$$

$$\left.\begin{array}{l} V_1 = V_2, \quad V_1 = v_1 \cdot m \\ \qquad\qquad V_2 = v_2 \cdot m. \end{array}\right\} \Rightarrow v_1 = v_2.$$

$\underline{v_2 = 0,145381 \, m^3/kg.}$

Ⓑ $T_{sat}\,100°C$:

$$\left.\begin{array}{l} v_f = 0,002188 \\ v_g = 0,01784 \end{array}\right\} \left.\begin{array}{l} v_2 > v_f \\ v_2 > v_g \end{array}\right\} \Rightarrow \underline{\text{Superheated.}}$$

$P_1 = 500 kPa.$ $\quad u_1 = 1501,7$

$P_2 = 600 kPa$ $\quad u_2 = 1499,5$

$P = 586,74 kPa.$ $\quad u = ?.$

$$u - u_1 = \frac{u_2-u_1}{P_2-P_1}(P-P_1)$$

1485.83 kJ/kg

$$u = \frac{u_2-u_1}{P_2-P_1}(P-P_1) + u_1 = 1499,79 \, kJ/kg.$$

$P \cdot v = R_s T.$

$$\frac{P_1 \cdot v_1}{T_1} = R_s$$

$R_s = 0,2286$

$P_2 v_2 = R_s T_2 \Rightarrow P_2 = 586,74 \, kPa.$

9

$\Delta u = \underline{u_2 - u_1} = 750,95 \, kJ/kg$

$w = P_1 \Delta v$ {sealed rigid tank).

✓ $\boxed{= 0.}$

$q = w + \Delta u$

$q = \underline{\Delta u} = 750,95 \, kJ/kg.$

(heat into the system)

[illegible] 12

$$W = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{mR_s(T_2-T_1)}{1-n}$$

$P \cdot V = m R_S T.$

0.18

0.11 0.149

0.026

3. Consider a **gas** whose molecular weight is **33 g/mol**, initially at **3 bar** and **300 K**, and occupying a volume of **0.1 m^3**. The gas undergoes a polytropic expansion during which the pressure-volume relation is $PV^{1.3}$ = ***constant*** and the energy transfer by **heat to the gas** is **3.84 kJ**. Assume the **ideal gas model** with constant C$_v$ = 0.6 kJ/(kg K). Neglecting kinetic and potential energy effects, determine

24

- (a) the **final temperature**, in K. [12 marks]
- (b) the **final pressure**, in bar. [5 marks]
- (c) the **final volume**, in m^3. [4 marks]
- (d) the **work**, in kJ. [5 marks]

$M = 33 g/mol.$ $R_s = R_u/M = 0.251$

$P_1 = 3$ bar $= 300$ kPa

$T_1 = 300$K. $T_2 = 259,58$K

$V_1 = 0,1 m^3.$

$Q = 3.84$ kJ.

$n = 1.3$

$c_v = 0.6$ kJ/kgK.

$$v_1 = \frac{T_1 R_S}{P_1} = 0,25 m^3/kg$$

$$m = \frac{V_1}{v_1} = 0,4 kg.$$

$\Delta U = m C_v \Delta T$

9

a) $Q = W + \Delta U$

$$= \frac{P_2V_2}{1-n} - \frac{P_1V_1}{1-n} + mC_v(T_2-T_1). = 3,84kJ.$$

$$= \frac{mR_S(T_2-T_1)}{1-n} + mC_v(T_2-T_1) = 3,84kJ.$$

$$(T_2-T_1)\left(\frac{mR_s}{1-n} + mC_v\right) = 3,84kJ.$$

$$(T_2-T_1)\cdot\left(m\left(\frac{R_S}{1-n} + C_v\right)\right) = 3,84kJ.$$

$$(T_2-T_1)(-0,095) = 3,84kJ.$$

$$\boxed{T_2 = 259,58K}$$

$P_1V_1^n = P_2V_2^n$

d) $W = \frac{mR_S\Delta T}{1-n} = 13,5$ kJ. (work done by the gas it has to be positive).

b) $P_1\left(\frac{T_1}{P_1}\right)^n = P_2\left(\frac{T_2}{P_2}\right)^n.$

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

$P_1^{(1-n)} \cdot T_1^n = P_2^{1-n} \cdot T_2^n. \rightarrow P_2^{1-n} = P_1^{(1-n)} \cdot \left(\frac{T_1}{T_2}\right)^n$

$P_2 = 570$ kPa.

$P_2 = 5,7$ bar.

−2

c) $P_1V_1^n = P_2V_2^n$

$$V_2^n = \frac{P_1}{P_2} \cdot V_1^n = 0,06 m^3$$