ME 371 Thermodynamics –I-
Second Semester, 1428-1429H
1^{st} Midterm Exam Solutions

Problem 1

a. (True or False) If the compressibility factor (Z) is less than 1, the fluid is not considered an ideal gas.

   TRUE

b. (True or False) For ideal gases, $h = u + RT$.

   TRUE

c. When a rigid tank is heated, boundary work is:
   (i) positive (ii) negative **(iii) zero**

d. Specific volume is:
   (i) an intensive property (ii) an extensive property (iii) not a property

e. What are the three mechanisms of energy transfer to and from a system?

   1. **HEAT**
   2. **WORK**
   3. **MASS**

Problem 2

Complete the following table for H_2O

T, ºC	P, kPa	u, kJ/kg	x	Phase Description
120	**198.53**	2100	**0.788**	**Saturated liquid-vapor mixture**
151.86	500	**1408.32**	0.4	**Saturated liquid-vapor mixture**
1200	400	4467	**--**	**Superheated vapor**
180	2000	**762.09**	**--**	**Compressed liquid**

Problem 3

A rigid tank whose volume is 1 m^3 initially contains refrigerant 134a at a pressure of 800 kPa and a temperature of 50ºC. The tank is now cooled to a final temperature of 20ºC.

a. Determine the mass of refrigerant 134a.
b. Determine the final phase of refrigerant 134a (show your work)
c. Determine the change in specific internal energy during the process (Δu)
d. Show the process on the *T*-*v* diagram with respect to saturation lines.

Given: $V = 1\ m^3$, $P_1 = 800$ kPa, $T_1 = 50$ºC, $T_2 = 20$ºC

Part (a)

$m = V / v$

$v_1 = 0.02846\ m^3/kg$ **(from Table A-13) (because the fluid is a superheated vapor)**

$\longrightarrow m = 1 / 0.02846 = \boxed{35.137\ kg}$

Part (b)

$T_2 = 20$ºC

$v_2 = v_1 = 0.02846\ m^3/kg$ **(because the tank is rigid and the system is closed)**

At 20ºC, $v_f = 0.0008157\ m^3/kg$ **and** $v_g = 0.0358\ m^3/kg$ **(from Table A-11)**

$\longrightarrow v_f < v < v_g \longrightarrow$ **the phase is** $\boxed{\text{saturated liquid vapor mixture}}$

Part (c)

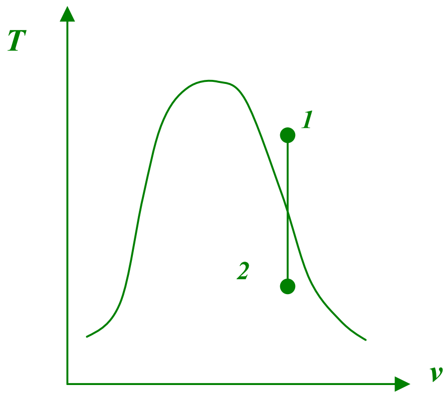
$u_1 = 261.62$ **(from Table A-13)**

$u_2 = u_f + x\ u_{fg}$

To find *x*: $x = (v - v_f) / (v_g - v_f) = (0.02846 - 0.0008157)/(0.0358 - 0.0008157) = 0.79$

$\longrightarrow u_2 = 76.8 + 0.79 \times (237.91 - 76.8) = 204.11$ kJ/kg $\longrightarrow \Delta u = u_2 - u_1 = 204.11 - 261.62 = \boxed{-57.5\ kJ/kg}$

Part (d)



Problem 4

A stationary piston-cylinder device contains 2 kg of air at 27ºC and 100 kPa. The air is now compressed to a pressure of 500 kPa according to the relation $PV^{1.4}$ = constant. Determine the following:

a. the initial volume of air.
b. the final volume of air.
c. the work input during the process.
d. the change in total internal energy of the system (ΔU) (Hint: use Table A-17)
e. the amount of heat transfer (Q) during the process.

Given: m = 2 kg, T_1 = 27ºC = 300 K, P_1 = 100 kPa, P_2 = 500 kPa, $PV^{1.4}$ = constant.

Part (a)

$$P_1V_1 = mRT_1 \longrightarrow V_1 = mRT_1/P_1 = 2\times0.287\times300 / 100 = \boxed{1.722\ \text{m}^3}$$

Part (b)

$$PV^{1.4} = \text{constant} \longrightarrow P_1V_1^{1.4} = P_2V_2^{1.4} \longrightarrow V_2 = \boxed{0.545\ \text{m}^3}$$

Part (c)

For a polytropic process:

$$W_b = (P_2V_2 - P_1V_1) / (1 - n) = (500\times0.545 - 100\times1.722) / (1 - 1.4) = \boxed{-251.3\ \text{kJ}}$$

Part (d)

$$\Delta U = U_2 - U_1 = m(u_2 - u_1)$$

u_1 = 214.07 kJ/kg (from Table A-17 at T_1 = 300 K)

To find u_2, we need to calculate T_2.

$$P_2V_2 = mRT_2 \longrightarrow T_2 = P_2V_2 / mR = 500\times0.545 / 2\times0.287 = 475\ \text{K}.$$

By interpolation:

u_2 = 341 kJ/kg (from Table A-17 at T_2 = 475 K)

$$\longrightarrow \Delta U = 2\times(341 - 214.07) = \boxed{253.86\ \text{kJ}}$$

Part (e)

Apply energy balance for the system:

$$Q_{net,in} - W_{net,out} = \Delta U \longrightarrow Q_{net,in} - (-251.3) = 253.86 \longrightarrow Q_{net,in} = \boxed{2.56\ \text{kJ}}$$