MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

Chemical and Processing Engineering Department

CHEMICAL ENGINEERING THERMODYNAMICS 1

CODE: HCHE 125

SESSIONAL EXAMINATIONS
APRIL 2021

DURATION: 3 HOURS

EXAMINER: K. NYENYAYI (MR)

INSTRUCTIONS

1. Answer ***any four questions*.**
2. Each question carries 25 marks.
3. Total marks 100

ADDITIONAL MATERIALS

Calculators.

This question paper consists of 5 printed pages

QUESTION ONE

a) Define the following terms as used in thermodynamics and provide an example for each:

i. System boundary

ii. Closed system

iii. Adiabatic process

iv. Isothermal process

v. State property

vi. Intensive property

[9]

b) Starting with the definition of the first law of thermodynamics, show that for a reversible, adiabatic process involving an ideal gas

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

NOTE: For an ideal gas: $C_p - C_v = R$, $\frac{C_p}{C_v} = \gamma$

[16]

QUESTION TWO

a) Define *entropy change*, *zeroth* and *second law of thermodynamics*

[6]

b) Explain using equations the significance of *Gibbs free energy (ΔG)*.

[6]

c) Calculate the change in enthalpy and the change in entropy when 1 mole of SiC is heated from 25°C to 1000°C. The constant pressure molar heat capacity of

SiC varies with temperature as;

$$C_p = 50.79 + 1.97 \text{ x } 10^{-3}T - 4.92 \text{ x } 10^{6}T^{-2} + 8.20 \text{ x } 108T^{-3} \text{ J/mol.K}$$

[13]

QUESTION THREE

a) Air is compressed from an initial condition of 1 bar and 298K (25°C) to a final state of 5bar and 298K (25°C) by two different mechanically reversible process in a closed system.

1. Cooling at constant pressure followed by heating at constant volume.
2. Heating at constant volume followed by cooling at constant pressure. Assuming air to be an ideal gas with the constant heat capacities;

$$C_v = \frac{5}{2}R \quad and \quad C_p = \frac{7}{2}R$$

i. Calculate the work required, heat transferred, and the changes in internal energy and enthalpy of the air for each process. (R=8.314 $Jmol^{-1}K^{-1}$). Assume at 298,15 K and 1 bar, the molar volume of air is 0.02479 m^3/mol.

[16]

b) Calculate change in internal energy (ΔU) and change in enthalpy (ΔH) for 1kg of water when it is vaporized at the constant temperature of 100 ^oC and the constant pressure of 101,33 KPa. The specific volumes of liquid and water vapour at these conditions are 0.00104 and 1,673 m^3/kg. For this change, heat in the amount of 2256,9 KJ is added to the water.

[9]

QUESTION FOUR

a) Illustrate by means of thermodynamics diagrams or otherwise the definition of terms *reversible* and *irreversible* processes.

[9]

b) For one mole or a unit mass of fluid undergoing a mechanically reversible process in a closed system, show that the first law, becomes:

$$dS = C_p^{ig}\frac{dT}{T} - \frac{RdP}{P} \qquad or \qquad \frac{dS}{R} = \frac{C_p^{ig}}{R}\frac{dT}{T} - dlnP$$

[16]

QUESTION FIVE

a) Provide a mathematical statement of the second law of thermodynamics.

[9]

b) A 40 kg steel casting (C_p = 0.5 $kJkg^{-1}K^{-1}$) at a temperature of 723.15 K (450^oC) is quenched in 150 kg of oil (C_p = 2.5 $kJkg^{-1}K^{-1}$) at 298.15 K (25^oC). If there are no heat losses, what is the change in entropy of

i. the casting

ii. the oil

iii. both considered together.

[14]

Process	Constant Volume	Constant Pressure	Constant Temperature	Polytropic	Reversible Adiabatic or Isentropic
Law	$\frac{P}{T} = \text{const}$	$\frac{V}{T} = \text{const}$	PV = const	$PV^n = \text{const}$	$PV^Y = \text{const}$
P, V, T. Relation	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$P_1V_1 = P_2V_2$	$P_1V_1^n = P_2V_2^n$ $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n$ $= \left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}}$	$P_1V_1^y = P_2V_2^y$ $\frac{P_1}{P_2} = \left[\frac{V_2}{V_1}\right]^y$ $= \left[\frac{T_1}{T_2}\right]^{\frac{y}{y-1}}$
Change in Internal Energy ΔU	$mC_v(T_2-T_1)$	$mC_v(T_2-T_1)$	0	$mC_v(T_2-T_1)$	$mC_v(T_2-T_1)$
Work Transfer W=∫ pdv	0	$P(V_2-V_1)$ Or $mR(T_2-T_1)$	$PV \ln\frac{V_2}{V_1}$ Or $mRT \ln\frac{V_2}{V_1}$	$\frac{P_1V_1-P_2V_2}{(n-1)}$ $\frac{mR(T_1-T_2}{(n-1)}$	$\frac{P_1V_1-P_2V_2}{(\gamma-1)}$ $\frac{mR(T_1-T_2}{(\gamma-1)}$ $mC_v(T_1-T_2)$
Heat Transfer Q	$mC_v(T_1-T_2)$	$mC_p(T_1-T_2$	$PV \ln\frac{V_2}{V_1}$ Or $mRT \ln\frac{V_2}{V_1}$	$W + (U_2-U_1)$	0
Change in Entropy ΔS=S₂ –S₁	$mC_v\ln\frac{T_2}{T_1}$ or $mC_v\ln\frac{P_2}{P_1}$	$mC_p\ln\frac{T_2}{T_1}$ or $mC_p\ln\frac{V_2}{V_1}$	$mR\ln\frac{V_2}{V_1}$ or $mR\ln\frac{P_1}{P_2}$	$m\left[R\ln\frac{V_2}{V1} + C_v\ln\frac{T_2}{T_1}\right]$ $m\left[R\ln\frac{P_1}{P_2} + C_p\ln\frac{T_2}{T_1}\right]$ $m\left[C_p\ln\frac{V_2}{V_1} + C_v\ln\frac{P_2}{P_1}\right]$	0

Table 1: List of Perfect Gas Relations