MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: CHEMICAL ENGINEERING THERMODYNAMICS

CODE: CHEP 121

SESSIONAL EXAMINATIONS
APRIL 2023

DURATION: 3 HOURS

EXAMINER: MRS C. MUHEZWA

INSTRUCTIONS

1. *Answer **All** questions.*
2. *Start a new question on a fresh page*
3. *Total marks 100*

Additional material(s): *Calculator, Steam Tables,*

QUESTION 1

a. Explain the meaning of the following terms:

   i. *System,*

   ii. *Closed system,*

   iii. *Extensive property,*

   iv. *Internal energy.* [4]

b. State the first law of thermodynamics? [1]

c. 1.5 kg of water was vaporized at a constant temperature of 100 °C and constant pressure of 101.33 kPa. The specific volumes of liquid water and water vapor at these conditions are 0.00104 and 1.475 $m^3 \cdot kg^{-1}$, respectively. For this change, heat in the amount of 4750.7 kJ is added to the water. Determine

   i. Internal Energy Change (ΔU),

   ii. Enthalpy Change (ΔH) For The System. [5]

d. One mole of N_2 gas is contained at 273 K and a pressure of 1atm. The addition of 3000 J of heat to the gas at constant pressure causes 832 J of work to be done during the expansion. Determine

   i. The final state of the gas [6]

   ii. The values of internal energy change (δu) and enthalpy change (δh) for the change of state [5]

   iii. The values of c_v and c_p for nitrogen (n_2). [4]

   Assume that nitrogen behave as an ideal gas and that the above change of state is conducted reversibly

QUESTION 2

a. Explain the following terms:
   i. *Adiabatic change?*
   ii. *Isobaric change?* [2]

b. A gas in a piston–cylinder assembly undergoes an expansion process for which the relationship between pressure and volume is given by the equation $PV^n = constant$. The initial pressure is 3 bar, the initial volume is 0.1 m^3, and the final volume is 0.2 m^3. Determine the work for the process, in kJ, if
   i. $n = 1.0$ [6]
   ii. $n = 0$. [3]

c. Draw separate *PV* graphs to represent the two processes in (b) above and show on them, the work done by the gas in each case [4]

d. Explain the meaning of the term *entropy.* [1]

e. Choose the member with the higher entropy in each of the following pairs, and justify your choice assuming constant temperature for (i) and (ii)
   i. 1 mol of KBr(*s*) or 1 mol of KBr(*aq*)
   ii. 3 mol of $O_2(g)$ or 2 mol of $O_3(g)$
   iii. ice at -2°C or at -10°C [6]

f. Explain the significance of the Gibb's free energy. [2]

g. What is the effect of increasing entropy on the Gibbs free energy? [1]

QUESTION 3

a. Differentiate between dry and wet saturated steam. [2]

b. Describe the steps that make up the cycle of any Carnot engine [4]

c. A closed system containing steam undergoes a reversible constant pressure process during which 400 kJ/kg of heat transfer takes place. Initially the

steam has a dryness fraction, x, of 1.0 and a temperature of 365.7 ^{0}C. Using the steam tables, and using linear interpolation where necessary, determine:

i. The specific enthalpy, specific internal energy and specific volume at the beginning of the process. [4]

ii. The specific enthalpy, temperature and specific internal energy of the steam at the end of the process. [10]

iii. The specific work transfer. [3]

d. Heat in the amount of 7.5 kJ is added to a closed system while its internal energy decreases by 12 kJ. How much energy is transferred as work? [2]

QUESTION 4

a. State Second law of thermodynamics [2]

b. Outline two ways in which the Rankine cycle differs from the Carnot (power) cycle. [2]

c. Power is generated in a cyclic process in which steam generated in a boiler is expanded in an adiabatic turbine to produce work. The processes that occur as the working fluid flows around the cycle are represented by lines on the *TS* diagram in **Fig. 1**.

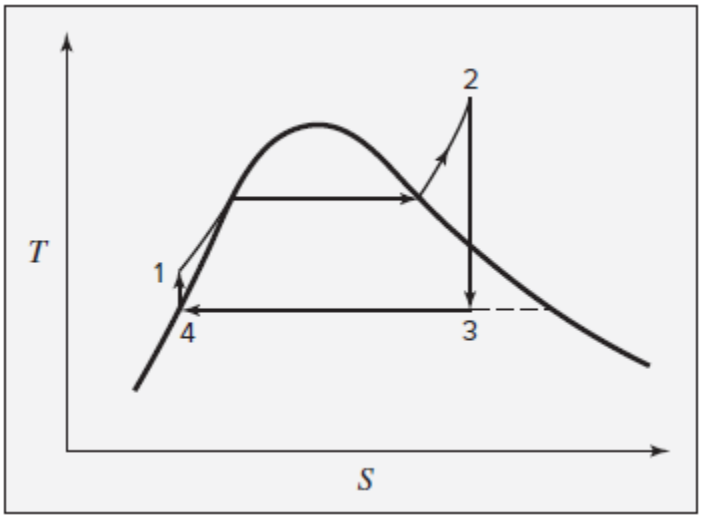

Fig. 1: Rankine Cycle on a TS diagram

i. Describe what happens between point 1 and 2. [3]

ii. Draw a similar TS diagram and represent an ordinary Carnot cycle. [2]

d. A refrigerator works by steadily circulating a refrigerant at low temperature through passages in the walls of the freezer compartment. The rate of heat transfer from the freezer compartment to a refrigerant is 8000 kJ/h and the power input required to operate the refrigerator is 3200 kJ/h.

i. Determine the coefficient of performance of the refrigerator. [3]

ii. The refrigerator now maintains the freezer compartment at -5 ^{0}C when the air surrounding the refrigerator is at 22 ^{0}C through a reversible refrigeration cycle operating between the two heat reservoirs. Determine the new coefficient of performance of the refrigerator. [4]

e. Give one examples of large-scale commercial process requiring refrigeration. [1]

f. Outline the factors to be considered when choosing a refrigerant. [4]

g. Gibbs Phase rule states that a heterogeneous system in equilibrium is not affected by gravity or by electrical and magnetic forces, but by the *number of degrees of freedom*.

i. Explain what is meant by *number of degrees of freedom* [2]

ii. A Water system consists of solid, liquid and vapor. Determine the number of degrees of freedom for the system [2]

END OF EXAMINATION