MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: CHEMICAL ENGINEERING THERMODYNAMICS I/PRINCIPLES OF ENGINEERING THERMODYNAMICS

CODE: CHEP 121/ENGT 125

SESSIONAL EXAMINATIONS
NOVEMBER 2022

DURATION: 3 HOURS

EXAMINER: 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

Explain the meaning of the following terms:

i. *Closed system,*

ii. *Isolated system,*

iii. *State function,*

iv. *Internal energy.* [4]

a. What is the implication of the first law of thermodynamics? [1]

b. 3 kg of water are vaporized at the 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 $m^3 \cdot kg^{-1}$ and 1.673 $m^3 \cdot kg^{-1}$, respectively. For this change, heat in the amount of 6770.7 kJ is added to the water. Determine

i. internal energy change (ΔU),

ii. enthalpy change (ΔH) for the system. [5]

c. 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. What is meant by an
   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. $n = 1.5$ [6]
   ii. $n = 0$. [3]

a. 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]

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

c. 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 $CO_2(s)$ or 1 mol of $CO_2(g)$
   ii. 3 mol of $O_2(g)$ or 2 mol of $O_3(g)$
   iii. seawater at 2°C or at 23°C [6]

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

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

QUESTION 3

a. Differentiate between saturated and superheated 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 the Clausius' statement of the second law of thermodynamics and explain how it supports the refrigeration cycle. [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 **°C**.

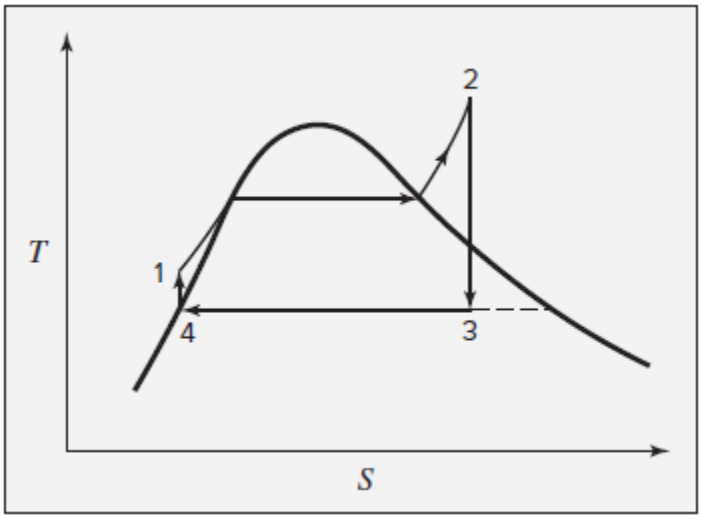

Fig. 1: Rankine Cycle on a TS diagram

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 °C when the air surrounding the refrigerator is at 22 °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