

**B.E. Chemical Engineering Second Year First Semester Examination 2024  
Engineering Thermodynamics**

Full Marks: 100

Time : 3 hours

**Tables and charts for thermodynamic properties are allowed**

**Answer any five questions**

- 1.a) State the first law of thermodynamics of a closed system undergoing i) a cycle and ii) a non-cyclic process. Show that for an isobaric process heat transfer is equal to change in enthalpy. 2+2+4
- b) A 1.8-m<sup>3</sup> rigid tank contains steam at 220°C. One-third of the volume is in the liquid phase and the rest is in the vapor form. Determine the pressure of the steam, the quality of the saturated mixture, the density, the enthalpy, internal energy and the entropy of the mixture. 12
- 2.a) Define the efficiency of a heat engine. 2
- b) Show that working between two fixed reservoirs, no heat engine can have a higher efficiency than a reversible heat engine. 6
- c) State Clausius inequality. 2
- d) Show that for any process  $dS \geq \frac{\delta Q}{T}$  10
- 3.a) Define i) thermodynamic equilibrium and ii) properties. 8
- b) Consider air enclosed in a piston-cylinder assembly. The initial volume inside the cylinder is 0.1 m<sup>3</sup>. At this state, the pressure inside is 100 kPa and temperature 300 K. A spring just touches the piston but exerts no force on it. The gas is now heated until the volume is doubled. The final pressure is 300 kPa. During the process, the spring force is proportional to the piston displacement. Calculate the work done by the gas, change in internal energy, enthalpy and total heat transfer during the process. Also determine the change in entropy. 3+2+2+2+
- 4.a) Define COP. What is the expression of maximum COP of a heat pump working between two isothermal reservoirs? Show the relationship of COP of a heat pump with the COP of a refrigerator 2+2+4
- b) The structure of a house is such that it loses heat at a rate of 5400 kJ/h per °C difference between the indoors and outdoors. A heat pump that requires a power input of 6 kW is used to maintain this house at 21°C. i) Determine the lowest outdoor temperature for which the heat pump can meet the heating requirements of this house. ii) Also determine the rate of heat leakage between the indoor and outdoor. 8+4
- 5.a) Show the critical point, saturated liquid line, saturated vapour line, isotherm from the superheated vapour zone to the compressed liquid zone and critical isotherm on p-v plane for a pure substance with a sketch. 8
- b) A piston-cylinder device contains steam initially at 1 MPa, 450°C, and 2.5 m<sup>3</sup>. Steam is allowed to cool at constant pressure until it touches the saturated vapour line. Show the process on a T-v diagram with respect to

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- saturation lines and determine (i) the mass of the steam, (ii) the final temperature, and (iii) the amount of heat transfer. Also determine the change in enthalpy and entropy during the process. 2+2+2+2+2+2
- 6.a) Derive the expression of work done and heat transfer for an ideal gas for a polytropic process ( $pv^n = c$ ). 10
- b) Two tanks (Tank A and Tank B) are separated by a partition. Initially Tank A contains 2-kg steam at 1 MPa and 300°C while Tank B contains 3-kg saturated liquid-vapour mixture at 150°C with a vapor mass fraction of 50 percent. Now the partition is removed and the two sides are allowed to mix until the mechanical and thermal equilibrium are established. If the pressure at the final state is 300 kPa, determine (i) the temperature and quality of the steam (if mixture) at the final state and (ii) the amount of heat lost from the tanks. Also determine the work done and entropy change in the process. 2+2+2+2+2
- 7.a) Draw the block diagram and TS plot of a Rankine cycle. 8
- b) Steam enters a turbine at 8 MPa and 500°C at a rate of 3 kg/s and leaves at 20 kPa. Considering the process to be ideal (reversible adiabatic), determine the power output, temperature, enthalpy and entropy at the turbine exit. What is the entropy generation in the process? Neglect kinetic energy changes. 4+2+2+2+2
- 8.a) Derive the expression of change in entropy for an ideal gas. Hence derive the entropy change for an ideal gas for an isothermal process and an isochoric process 6+4
- b) A 1.5-m<sup>3</sup> insulated rigid tank contains 2.7 kg of air at 100 kPa. Now paddle-wheel work is done on the system until the pressure in the tank rises to 150 kPa. Determine the work done and entropy change of air during this process. Assume constant specific heats. 10
- 9.a) Define exergy of a system. Derive the expression of exergy of either a system or a control volume. 3+7
- b) Two blocks of equal mass and specific heat are initially at temperature  $T_1$  and  $T_2$  respectively ( $T_1 > T_2$ ). If a reversible heat engine is installed between two, determine the final temperature, work done and total entropy generation. 4+4+2
- 10 Write short notes on any four 5×4=20
- a) Vapour compression refrigeration cycle
- b) Reversible process
- c) Macroscopic and microscopic approach
- d) SSSF process in a turbine
- e) Isentropic efficiency
- f) Flow work