Ref No. Ex/Che/ES/B/Mech/T/212/2023

B.E. Chemical Engineering Second Year First Semester 2023
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 energy of a system is a thermodynamic property.	2+2+4
b)	A 0.12-m3 rigid tank contains saturated refrigerant-134a at 800 kPa. Initially, 25 percent of the volume is occupied by liquid and the rest by vapor. A valve at the bottom of the tank is now opened, and liquid is withdrawn from the tank. Heat is transferred to the refrigerant such that the pressure inside the tank remains constant. The valve is closed when no liquid is left in the tank and vapor starts to come out. Determine the initial mass, final mass, initial internal energy, final internal energy and total heat transfer for this process.	2+2+2+2+4
2.a)	State Kelvin-Planck and Clausius statements of Second Law of Thermodynamics.	4
b)	Show that the two statements are equivalent.	6
c)	State Clausius inequality.	2
d)	Show that entropy of a system is a thermodynamic property.	8
3.a)	State zeroth law of thermodynamics. How is temperature defined with a suitable thermometric property? Define ideal gas temperature.	2+2+2
b)	Determine the specific volume of superheated watervapor at 10 MPa and 400°C, using the ideal-gas equation,the generalized compressibility chart, and the steamtables. Also determine the error involved in the first two cases. If now the pressure of the water vapour becomes 5 MPa, while the temperature remains the same, what is the change in internal energy assuming it to be an ideal gas? What is the change in internal energy using the steam table?	3+3+2+2+2+2
4.a)	Define COP. What is the expression of maximum COP of a refrigerator working between two isothermal reservoirs? Show the relationship of COP of a Heat Pumpwiththe COP of arefrigerator.	2+2+4
b)	A household refrigerator with a COP of 1.2 removes heat from the refrigerated space at a rate of 60 kJ/min. The refrigerated space is at 5^0C and the kitchen air is at 25^0 C. Determine the electric power consumed by the refrigerator, the rate of heat transfer to the kitchen air and the minimum	

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power required for same rate of heat removal from the refrigerated space. 4+4+4

5.a) Show the critical point, triple point, sublimation curve and vaporization curve on pressure temperature (p-T) plane for a substance that contracts upon melting with a sketch. Explain the characteristics of the vaporization and fusion curve. 8

b) A spherical balloon contains 10kg of air at 100 kPa, 300 K. If the pressure inside the balloon is proportional to square of its diameter, calculate the work done, final temperature, change in internal energy and change in entropy, if the volume of the balloon doubles due to heating. 4+3+2+3

6.a) Show that pressure versus volume exhibits a linear relationship for a piston cylinder system containing a fluidwhen the piston is loaded with a spring with constant stiffness. 6

b) A 0.5-m^3 rigid tank contains refrigerant-134a initially at 160 kPa and 40 percent quality. Heat is now transferred to the refrigerant until the pressure reaches 700 kPa. Determine the mass of the refrigerant in the tank, work done, the amount of heat transferred and entropy change of the system. Also, show the process on a *P-v* diagram with respect to saturation lines. 2+4+4+2+2

7.a) Draw the block diagram and TS plot of a vapour compression refrigeration cycle. 8

b) Steam enters an adiabatic turbine at 8 MPa and 500°C at a rate of 3 kg/s and leaves at 20 kPa. If the power output of the turbine is 2.5 MW, determine the temperature, enthalpy and entropy at the turbine exit. What is the entropy generation in the process? Neglect kinetic energy changes. 4+2+4+2

8.a) Evaluate temperature changefor an infinitesimal change in entropy of an ideal gas for an isobaric and isochoric process? Show a constant volume and constant pressure process, starting from a fixed state on TS plane. 4+4

b) Water in a piston/cylinder is at 101 kPa, 25◦C and mass 0.5 kg. The piston rests on some stops, and thepressure inside should be 1000 kPa to lift the piston from the stops. We now heat the water from a 200◦C reservoir, Calculate the temperature, change in internal energy, heat added, change in entropy and entropy generation when the piston is just lifted from the stops. Heating from the same reservoir is continued till thevolume becomes five times the initial value. Find the total work done, change in internal energy, heat transfer and the entropy generation. 12

9.a) What do you mean by exergy and irreversibility? Write down the expressions of exergy for a closed system, for a flow process and heat transfer. 3+5

b) A well-insulated valve is used to throttle steam from 8 MPa and 500°C to 6

MPa. Determine the final temperature of the steam. Also calculate the change in internal energy, change in enthalpy, change in entropy, work done, heat transfer and entropy generation for unit mass of steam. 2+2+2+2+2+2+2

10. Write short notes on any four (5x4) 5×4=20

a) Carnot cycle
b) Quasi-static process
c) Heat Engine and PMM-2
d) SSSF process in a nozzle
e) Second law efficiency
f) Analogy of work and heat transfer