THERMODYNAMICS - I
(CHEN 2104)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) An isentropic process is always
(a) reversible isothermal (b) reversible adiabatic
(c) irreversible isothermal (d) irreversible adiabatic

(ii) The temperature at which real gas behaves like an ideal gas at low pressure is called
(a) Boyle temperature (b) critical Temperature
(c) triple point temperature (d) inversion point

(iii) During throttling process
(a) internal energy does not change (b) enthalpy does not change
(c) Helmholtz free energy does not change (d) Gibbs free energy does not change

(iv) The degrees of freedom of a binary azeotropic mixture under vapour liquid equilibrium is
(a) 0 (b) 1 (c) 2 (d) 3

(v) The ratio of isobaric thermal expansion coefficient to isothermal compressibility coefficient for ideal gas is
(a) proportional to molar volume (b) inversely proportion to molar volume
(c) proportional to temperature (d) inversely proportional to temperature

(vi) The mass flow rate in a pipe with cross sectional area A and specific volume, γ is a function of
(a) $A\gamma$ (b) A/γ
(c) $A\gamma^2$ (d) γ

(vii) Measurement of thermodynamic property of temperature is facilitated by ___ law of thermodynamics

(a) zeroth (b) first
(c) second (d) third

(viii) Mollier diagram is a plot of

(a) temperature vs enthalpy (b) temperature vs entropy
(c) temperature vs humidity (d) enthalpy vs entropy

(ix) Which of the following has highest efficiency

(a) steam engine (b) carnot engine
(c) otto engine (d) diesel engine

(x) The pressure of real gases is less than that of ideal gas because of

(a) increase in the number of collisions
(b) finite size of particles
(c) intermolecular attraction
(d) increase in kinetic energy of the molecules

Group – B

2. (a) Derive a general energy balance equation of open system. Give an example of a system where rate of useful work obtained from an open system is equal to the rate of change of total enthalpy of the system.

(b) In a power plant operating in steady state in adiabatic steam turbine receives 1 kg/s of superheated steam at 3MPa and 400 ºC. The steam enters the turbine with a velocity of 10 m/s at an elevation of 10 m above the ground level. The steam leaves the turbine at 0.1 bar with 10% moisture content. The velocity of steam at the exit is 30 m/s and the exit is at an elevation of 4 m above the ground level. Calculate the power output of the turbine.

6 + 6 = 12

3. (a) One kg of an ideal gas (Mol.Wt. 44) contained in a closed system undergoes a reversible isobaric process. During the process 48 kJ of internal energy is decreased. Determine the work done during the process. Given c_p = 840 J/kg-K

(b) A turbine, operating under steady flow conditions, receives 4500 kg of steam per hr. The steam enters the turbine at a velocity of 2800 m/min, an elevation of 5.5 m and a specific enthalpy of 2800 kJ/kg. It leaves the turbine at a velocity of 5600 m/min, an elevation of 1.5 m and a specific enthalpy of 2300 kJ/kg. Heat losses from the turbine to the surroundings amounts to 16000 kJ/h. Determine the power output (in MW) from the turbine.

5 + 7 = 12

Group – C

4. (a) Van-der-waals equation for real gas is given by $\left(P+\frac{a}{v^2}\right)(v-b)=RT$. Determine expressions for '*a*' and '*b*' in terms of P_c and T_c. (Symbols bear usual significance)

   (b) Calculate the molar volume of methanol at 500 K and 15 bar pressure using Redlich-Kwong equation of state. Given the critical temperature and pressure of methanol are 513 K and 81 bar respectively.

5 + 7 = 12

5. (a) Discuss the *P-v* and *P-T* diagram of pure component system. What is cubic equation of state? Describe the characteristics of solution of a cubic equation of state at different temperature and pressure condition of real gas.

   (b) Calculate the molar volume of methane (CH_4) at 210 K and 70 bar pressure using generalized compressibility chart. Given, T_c = 190.7 K and P_c = 46.4 bar

(3 + 1) + 8 = 12

Group – D

6. (a) Show that, for an irreversible non cyclic process $\Delta S > \int \frac{dQ}{T}$ where, ΔS is the entropy change of the system, Q is the heat interaction with the surrounding and T is temperature of system.

   (b) Calculate the entropy change if 2 kg supercooled liquid water at -5°C and 1 bar is converted into ice at -5°C and 1 bar. The specific heat at constant pressure for water and ice are 4.2 kJ/kg K and 2.1 kJ/kg K, respectively and the latent heat of fusion of water at 0°C is 333.43 kJ/kg

6 + 6 = 12

7. (a) What are thermodynamic energy properties? Derive the Maxwell's relations from each of the fundamental property relations of thermodynamic energy properties.

   (b) An hydrocarbon oil (c_p = 2512 J/kg K) is cooled from 422 K to 399 K in a heat exchanger at the rate of 2500 kg/h. Cooling water at the rate of 5000 kg/h enters the exchanger at 294 K. Assume there is no heat loss in the heat exchanger.
   (i) What is the rate of change of entropy (in W/K) of the system?
   (ii) How much maximum power could be obtained if the cooling of hydrocarbon oil is carried out by a heat engine rejecting heat to a sink at 294 K?

(2 + 4) + (3 + 3) = 12

Group – E

8. (a) Discuss the Rankine cycle related steam power cycle with a suitable T-s diagram. What modification in existing practical Rankine cycle can be made in order to increase the efficiency of the power cycle?

(b) An air-standard ideal diesel cycle operates with a compression ratio of 14 and a cut-off ratio of 2. At the beginning of compression stroke the air is at 1 bar and 290 K. Assuming air as an ideal gas with γ=1.4, calculate

i) energy added as heat,
ii) net work done,
iii) thermal efficiency and
iv) maximum temperature in the cycle.

(4 + 2) + (2 + 2 + 1 + 1) = 12

9. In a 1-MW steam power plant, superheated steam at 2800 kPa and 598 K enters the turbine and it is expanded to the condenser pressure of 5 kPa. Assuming an isentropic turbine efficiency of 85% and an isentropic pump efficiency of 80% determine the following

i) The ideal Rankine cycle efficiency for the stated conditions
ii) The thermal efficiency of the plant
iii) The rate of steam consumption.

4 + 4 + 4 = 12

Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTM4NDQxNTExMDc2/a/MjE0OTU3MTYwOTYz/details