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) The adiabatic work done on an ideal gas
(a) is dependent on C_p alone
(b) is depdenent on C_v alone
(c) is dependent on sum of C_p and C_v
(d) is dependent on the ratio of C_p and C_v.

(ii) For a spontaneous process in an isolated system (S is the entropy)
(a) $dS = 0$
(b) $dS > 0$
(c) $dS < 0$
(d) can't be predicted.

(iii) The value of universal gas constant is
(a) 8.314 kJ/mol K
(b) 0.082 L-atm/kmol K
(c) 1.98 cal/mol K
(d) all of these.

(iv) Which of the following have the minimum value of COP for a given refrigeration effect?
(a) Reverse Carnot cycle
(b) Ordinary vapour compression cycle
(c) Absorption refrigeration cycle
(d) Air refrigeration cycle.

(v) Which of the following is an undesirable property for a good refrigerant?
(a) High thermal conductivity
(b) Low freezing point
(c) High latent heat of vaporization
(d) High viscosity.

(vi) Mollier diagram is a plot of
(a) temperature vs. pressure
(b) temperature vs. enthalpy
(c) enthalpy vs. entropy
(d) temperature vs. entropy.

(vii) Which of the following energy properties does not change during the change in phase of pure substance?
(a) Internal energy
(b) Enthalpy
(c) Helmholtz free energy
(d) Gibbs free energy.

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

(ix) Entropy change in a reversible adiabatic process
(a) minimum (b) zero (c) maximum (d) infinity.

(x) The heat gained in a constant pressure process due to increase in temperature can be determined from
(a) Change in enthalpy of the system (b) Change in internal energy
(c) Change in pressure (d) None of above.

Group - B

2. (a) Why heat capacity at constant pressure is higher than heat capacity at constant volume? For a constant volume reversible process show that the heat transferred is equal to the internal energy change of the system. [(CO2)Remember/LOCQ]

(b) Heat is transferred to 10 kg of air which is initially at 100 kPa and 300 K until its temperature reaches 600 K. Determine the change in internal energy, the change in enthalpy, the heat supplied and the work done in the following process:
(i) Constant volume process
(ii) Constant pressure process.
Assume air to be an ideal gas with molecular weight 29. Given, heat capacity ratio is 1.4.
[(CO1)Evaluate/HOCQ]
4 + 8 = 12

3. (a) What is throttling? Show that an adiabatic throttling is an isenthalpic irreversible process. [(CO1,4)(Understand/LOCQ)]

(b) Water at 95°C is pumped from a storage tank at the rate of 25 m^3/h. A pump with 2 hp motor is used for the purpose. The water passes through a heat exchanger, where it gives up heat at the rate of 700 kW and is delivered to a second storage tank at an elevation of 20 m above the first tank. What is the temperature of the water delivered to the second storage tank? Specific heat of water is 4.2 kJ/kg K.
[(CO1)(Evaluate/HOCQ)]
(2 + 4) + 6 = 12

Group – C

4. (a) What is acentric factor of pure substance? What is the empirical basis of defining it?
[(CO2)(Remember/LOCQ)]

(b) The Dieterici equation of state is given by $P(v-b)\exp\left(\frac{a}{RTv}\right) = RT$, where, *a* and *b* are the characteristic of the gas. Develop necessary relation to determine the parameter *a* and *b* in terms of critical pressure P_C and critical temperature T_C.
[(CO2)(Analyze/IOCQ)]
(2 + 2) + 8 = 12

5. (a) Freon-12 for charging domestic refrigerator is usually sold in small cylinder of volume 3 l. Determine the mass of Freon -12 (CCl_2F_2) contained in one such cylinder at 10 MPa and 450 K using compressibility factor chart. Given, P_C = 40 bar and T_C = 385 K. [(CO2)(Apply/LOCQ)]

(b) A mass of 0.5 kg gaseous ammonia is contained in a 30 L closed rigid cylinder in a constant temperature bath at 65ºC. Calculate the pressure of the cylinder using Van der Waals equation of state. Data given: P_C = 111.3 atm, T_C = 405.6 K.

[(CO2)(Understand/LOCQ)]

6 + 6 = 12

Group - D

6. (a) Derive an expression of entropy change when two ideal gases at same temperature and pressure mix with each other without any chemical reaction.

[(CO4) (Remember/LOCQ)]

(b) Hydrocarbon oil is to be cooled from 425 K to 340 K at a rate of 5000 kg/h. If a reversible Carnot engine is to be operated receiving the heat from the oil and rejecting heat to the surroundings at 295 K, how much power can be obtained from it? Given, specific heat of oil is 2.5 kJ/kg K. [(CO4) (Evaluate/HOCQ)]

6 + 6 = 12

7. (a) Two identical blocks of mass m are available at temperature T_1 and T_2 ($T_1 > T_2$). They can be used as source and sink to operate a heat engine. Show that the maximum amount of work that can be obtained from the heat engine is $W = mc\left(\sqrt{T_1} - \sqrt{T_2}\right)^2$ where, c is specific heat of the blocks. [(CO5)(Evaluate/HOCQ)]

(b) Calculate the entropy change if 2 kg super-cooled liquid water at -10°C and 1 bar is converted into ice at -10°C and 1 bar with the given following data. The specific heat at constant pressure for water and ice are 4.2 kJ/kg K and 2.1 kJ/kg K, respectively and latent heat of fusion of water at 0°C is 333.43 kJ/kg. [(CO4)(Apply/LOCQ)]

6 + 6 = 12

Group - E

8. (a) Draw a flow diagram of vapour compression refrigeration cycle and discuss the process with a T-s diagram. Also develop an expression of coefficient of performance (COP) of the cycle. [(CO3,5)(Remember/LOCQ)]

(b) The compression ratio of an air standard ideal Otto cycle is 10. The pressure and temperature of air (γ = 1.4) at the beginning of compression stroke are 1 bar and 300 K, respectively. The amount of energy added to the air as a result of combustion is 1600 kJ/kg of air. Determine the pressure and temperature of the air at the end of each process of the cycle. [(CO3)(Analyze/IOCQ)]

6 + 6 = 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. [(CO3)(Analyze/HOCQ)]

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	45.83	14.58	39.58

Course Outcome (CO):

After completion of the course students will be able to:

1. Apply mass and energy balances to closed and open systems.
2. Evaluate the properties of non-ideal gases and quantify the deviation from ideal behavior of a real gas at any given state.
3. Solve problems involving liquefaction, refrigeration and different power cycles.
4. Evaluate entropy changes in a wide range of processes and determine the reversibility or irreversibility of a process from such calculations.
5. Calculate thermodynamic efficiency of a process.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question