INTRODUCTION TO THERMODYNAMICS
(CHEN 2104)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Which of the following is not an intensive property?
(a) Volume (b) Density
(c) Temperature (d) Pressure.

(ii) First law of thermodynamics is also called law of conservation of
(a) momentum (b) mass
(c) energy (d) mass & energy.

(iii) Under which of the following condition of temperature (T) and pressure (P) cubic equation of state yield three real solutions?
(a) $T>T_c$ and $P>P_c$ (b) $T>T_c$ and $P<P_c$
(c) $T<T_c$ and $P>P_c$ (d) $T<T_c$ and $P<P_c$
where, T_c and P_c are critical temperature and pressure respectively.

(iv) Irreversibility is associated with a process is due to
(a) mechanical and fluid friction
(b) unrestricted expansion
(c) transfer of species due to concentration difference
(d) all of these.

(v) The point at which both liquid and gas phases are indistinguishable
(a) critical point (b) triple point
(c) boiling point (d) inversion point.

(vi) Free expansion is a good example of
(a) static process (b) equilibrium process
(c) non-equilibrium process (d) isothermal process.

(vii) In working refrigerator, value of COP is always
(a) 0 (b) 1
(c) less than 1 (d) greater than 1.

(viii) Degree of freedom at triple point is
(a) 0 (b) 1
(c) 2 (d) 3.

(ix) In a polytropic process (PV^n = constant), n = 1; it means
(a) an adiabatic process (b) a reversible process
(c) an isothermal process (d) none of these.

(x) A liquid at a pressure less than its vapour pressure at the existing temperature is called
(a) supersaturated liquid (b) saturated liquid
(c) subcooled liquid (d) none of these.

Fill in the blanks with the correct word

(xi) Entropy is defined in _____ law of thermodynamics

(xii) Throttling (Joule-Thomson effect) process is a constant _____ process.

(xiii) All spontaneous processes are _____.

(xiv) Pressure is a _____ thermodynamic property.

(xv) Number of degrees of freedom for a three phase system in equilibrium comprising of three non-reacting chemical species is _____.

Group - B

2. (a) One mole of an ideal gas with γ = 1.4 initially at 300 K and 1 bar is compressed reversibly and adiabatically to 6 bar and then it is cooled at constant pressure to the original temperature. The gas is then restored to their initial state by an isothermal process. Calculate the net work and heat interaction.
[(CO1)(Evaluate/HOCQ)]

(b) A fluid at a pressure of 3 bar, with specific volume of 0.18 m^3/kg, contained in a cylinder behind a piston expand reversibly to a pressure of 0.6 bar a according to a law $Pv^2 = C$ where C is a constant and v is specific volume. Calculate the work done by the fluid on the piston. *[(CO1)(Apply/LOCQ)]*

7+ 5 = 12

3. (a) A closed system at constant volume experiences a temperature rise of 25°C when a certain process occur. The heat transfer in the process is 30 kJ. The specific heat at constant volume for the pure substance comprising of the system is 1.2 kJ/kg K and the system contains 2.5 kg of this substance. Determine the work done and change in internal energy. *[(CO1)(Evaluate/HOCQ)]*

(b) A turbine, operating under steady flow conditions, receives steam at the rate of 4500 kg/h. The steam enters the turbine at a velocity of 45 m/s, an elevation of 5.5 m and a specific enthalpy of 2800 kJ/kg. It leaves the turbine at velocity of 90 m/s, an elevation of 1.5 m and a specific enthalpy of 2300 kJ/kg. Heat losses from the turbine to the surrounding amounts to 16000 kJ/h. Determine the power output of the turbine. *[(CO1) (Evaluate/HOCQ)]*

6 + 6 = 12

Group – C

4. (a) Specify the conditions which must be satisfied by every equation of state. *[(CO2)(Remember/LOCQ)]*

   (b) Estimate the Van-der Waals constant for ethane (C_2H_6) if critical temperature and pressure of ethane are 32°C and 49 bar. *[(CO2)(Remember/LOCQ)]*

   (c) Derive the relation for estimating the coefficient of thermal expansion and the coefficient of isothermal compressibility for ideal gas. *[(CO2)(Apply/IOCQ)]*

4 + 4 + 4 = 12

5. (a) Define the following related to pure substace property: Crtical point, Triple point, acentric factor. *[(CO2)(Remember/LOCQ)]*

   (b) Calculate the molar volume of methanol at 500 K and 15 bar pressure using Redlich-Kwong equation of state. Given that critical temperature and pressure of methanol are 513 K and 81 bar. *[(CO1)(Evaluate/HOCQ)]*

6 + 6 = 12

Group – D

6. (a) Using Clausius inequality show that the change in entropy of a process is related to the heat interaction as $\Delta S \geq \int \frac{dQ}{T}$ where the greater than sign refers to an irreversible process and equal to sign refers to a reversible process. *[(CO4)(Understand/LOCQ)]*

   (b) One mole of an ideal gas is compressed isothermally at 400 K from 100 kPa to 1000 kPa. The work required for this irreversible process is 20% more than that for a reversible compression. The heat liberated during the process of compression is absorbed by a thermal reservoir at 300 K. Calculate: (i) the entropy change of the gas, (ii) the entropy change of the reservoir and (iii) total entropy change. *[(CO4) (Analyze/HOCQ)]*

3 + 9 = 12

7. (a) What is the significance of Joule-Thompson coefficient? Sketch the isenthalpic curve for a gas and show the inversion curve. *[(CO4)(Remember/LOCQ)]*

   (b) Hydrocarbon oil is to be cooled from 450 K to 330 K at a rate of 5000 kg/h in a heat exchanger. Cooling water at a rate of 10000 kg/h at 290K is available. The mean specific heat of oil and water are 2.5kJ/kg K and 4.2 kJ/kg K respectively. Determine the rate of entropy change of the continuous process. If a reversible carnot engine is to be operated receiving the heat from the oil and rejecting the heat to the surrounding at 290K, how much work would be available? *[(CO4)(Evaluate/HOCQ)]*

5 + 7 = 12

Group – E

8. (a) Derive an expression to estimate the thermal efficiency of ideal air-standard diesel cycle. *[(CO5)(understand/LOCQ)]*

(b) The compression ratio in an air-standard otto cycle is 8. The temperature and pressure at the beginning of the compression stroke are 290 K and 100 kPa. Heat transferred per cycle is 450 kJ/kg of air. The specific heat of air are C_p = 1.005 kj/kg K and C_v = 0.718 kJ/kg K. Determine the pressure and temperature of air at the end of each process. Also determine the thermal efficiency of the cycle. *[(CO3,5)(Evaluate/HOCQ)]*

5 + 7 = 12

9. (a) Discuss with a flow diagram of the linde process for gas liquefaction and determine an expression of single pass fractional liquefaction of gas for the process. *[(CO3)(Understand/LOCQ)]*

(b) The work output from a Carnot engine operating between two thermal reservoirs at 500 K and 300 K respectively, is utilised by a Carnot refrigeration machine for absorbing heat at the rate of 4 kW from a cold room at 270 K and discharging heat to the surrounding at 300 K. Determine the quantity of heat absorbed by the engine at 500 K. If COP of the refrigerator and efficiency of the engine are two-third of the ideal values, what is the quantity of heat absorbed by the engine at 500 K? *[(CO5)(Apply/IOCQ)]*

7 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	40.62	9.38	50

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 behaviour 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.*