INTRODUCTION TO ENGINEERING THERMODYNAMICS
(CHE2104)

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) $C_p = C_v$ for a fluid
(a) which is compressible
(b) whose volume coefficient of expansion is negliglble
(c) which is homogeneous
(d) under normal temperature and pressure.

(ii) First law of thermodynamics deals with
(a) direction of energy transfer
(b) conversion of different form of energy
(c) reversible process only
(d) irreversible process only.

(iii) Degrees of freedom at triple point will be
(a) 0 (b) 1 (c) 2 (d) 3

(iv) Select an equation of state from the given options that is not a cubic equation of state
(a) van der Waals equation (b) virial equation
(c) Peng-Robinson equation (d) Redlich-Kwong equation.

(v) For an irreversible cyclic process change of entropy of the system
(a) is not possible to be determined (b) is always positive
(c) is always negative (d) zero.

(vi) COP for a reversed Carnot cycle working between temperatures T_1 and T_2 ($T_1 < T_2$) is
(a) $\frac{T_2}{T_1-T_2}$ (b) $\frac{T_1}{T_1-T_2}$ (c) $\frac{T_1-T_2}{T_1}$ (d) $\frac{T_1-T_2}{T_2}$

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

(viii) In an ideal Rankine cycle, boiler is used for
(a) reversible isothermal expansion
(b) reversible adiabatic expansion
(c) reversible isobaric expansion
(d) reversible constant volume heating

(ix) The path followed by a vapour compression refrigeration cycle
(a) expansion valve- condenser- compressor- evaporator
(b) evaporator-compressor-condenser-expansion valve
(c) compressor-evaporator-condenser-expansion valve
(d) evaporator-expansion valve-condenser-compressor.

(x) In Otto cycle, spark plug fires shortly before
(a) compression stroke (b) expansion stroke
(c) intake stroke (d) exhaust stroke.

Fill in the blanks with the correct word

(xi) In throttling process _____ remains constant.

(xii) Degrees of freedom of a pure component system at vapour liquid equilibrium is _____.

(xiii) The maximum possible efficiency of a heat engine working between 300 K and 600 K temperature is ____.

(xiv) As cut-off ratio increases for a diesel cyle, its efficiency _____.

(xv) Linde process of gas liquefaction is _____ efficient than the Claude process of gas liquefaction.

Group - B

2. (a) How do you define extensive and intensive properties? State whether the following properties are intensive or extensive: (i) volume, (ii) density, (iii) pressure, (iv) temperature, (v) heat capacity. *[(CO1)(Understand/LOCQ)]*

(b) Differentiate between reversible and irreversible process. Give example of a quasi-static process which is not reversible. *[(CO1)(Remember/LOCQ)]*

(c) Derive an expression in terms of temperature and pressure to determine the work done by an ideal gas for a reversible isothermal expansion. *[(CO2)(Apply/IOCQ)]*

(2 + 2) + (3 + 1) + 4 = 12

3. (a) What is throttling? Show that an adiabatic throttling is an isenthalpic irreversible process. *[(CO2)(Remember/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. *[(CO2)(Analyse/IOCQ)]*

(2 + 4) + 6 = 12

Group - C

4. (a) Define the following related to pure substace property: Crtical point, Triple point, acentric factor. *[(CO3)(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. *[(CO3)(Apply/IOCQ)]*

6 + 6 = 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 10MPa and 450 K using compressibility factor chart. Given, P_C = 40 bar and T_C = 385 K. *[(CO3)(Evaluate/HOCQ)]*

   (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. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - D

6. (a) Show that for a spontaneous process total entropy of the universe always increases. *[(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)(Evaluate/IOCQ)]*

3 + 9 = 12

7. (a) What are thermodynamic energy properties? Derive the Maxwell's relations from each of the fundamental property relations of thermodynamic energy properties. *[(CO5)(Remember/LOCQ)]*

   (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? *[(CO4)(Evaluate/HOCQ)]*

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

Group - E

8. (a) Draw a flow diagram of Rankine power cycle and discuss the process with a T-s diagram. Also develop an expression of efficiency of the process. *[(CO6)(Remember/LOCQ)]*

(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 energy added as heat, net work done and maximum temperature in the cycle. *[(CO6)(Analyse/IOCQ)]*

6 + 6 = 12

9. (a) Explain the advantages of Claude gas liquefaction process over the Linde gas liquefaction process. Drawing a qualitative temperature-entropy diagram, discuss how fractional liquefaction per pass can be determined for Claude gas liquefaction process. *[(CO6)(Understand/IOCQ)]*

(b) A vapour compression cycle using ammonia as refrigerant is employed in an industry. Cooling water at 288 K enters the condenser at a rate of 0.25 kg/s and leaves at 300 K. Ammonia at 294 K condenses at a rate of 0.5 kg/min. Enthalpy of liquid ammonia at 294K is 281.5 kJ/kg. The compressor efficiency is 90%. Saturated ammonia vapour at 258 K and enthalpy of 1426 kJ/kg enters the compressor. Find out the power required by the compressor and also the refrigeration capacity in tons. *[(CO6)(Evaluate/HOCQ)]*

7 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	36.46	39.58	23.96