Q. P. Code: 09854

Time: 3 Hours **Total Marks: 80**

N.B.:
(i) Question No.1. is compulsory.
(ii) Attempt any three questions out of remaining five questions.
(iii) Assume suitable data and justify the same.
(iv) Figures to the right indicate full marks.

1. (a) How are the efficiency of a heat engine and the COP of a heat pump defined? 05
   (b) Explain the physical significance of the triple point and the critical point. 05
   (c) Define fugacity and fugacity coefficient. Show that the fugacity and pressure are identical for an ideal gas. 05
   (d) What are the Maxwell's equations and what are their significance? 05

2. (a) Derive the mathematical expression of First Law of Thermodynamics that can be used for solving steady-state fluid flow problems. 10

   (b) A rigid insulated tank consists of two compartments separated by a partition. One compartment, of volume 2 m^3, contains air at 5 bar and 300 K, the other compartment, of volume 5 m^3, is evacuated. The partition is removed and the air expands to fill the entire tank. Considering air to be thermodynamic system, determine the work done, the heat transfer, the change in internal energy, the temperature and pressure at the end of process. 10

3. (a) The Berthlot equation of state is given by: 10

$$[P + a / (T V^2)] [V - b] = RT$$

where a and b are constants characteristic of the gas. Develop relations to determine the constants a and b in terms of critical temperature and pressure.

   (b) Estimate the molar volume of methanol vapor at 500 K and 10 bar using Berthlot equation of state. 10
   Data: T_c =512.6 K and P_c = 81 bar

4. (a) A lump of steel of mass 10 kg at 900 K is dropped in 100 kg of oil at 300 K. The specific heats of steel and oil are 0.5 kJ/kg/K and 3.5 kJ/kg/K, respectively. Calculate entropy change of steel, the oil and the universe. 10

   (b) A reversible heat engine operates with three reservoirs at 300K, 400K and 1200K. It absorbs 1200kJ energy as heat from the reservoir at 1200K and delivers 400kJ work. Determine the heat interaction with other two reservoirs. 10

5. (a) Derive an expression for Joule Thomson coefficient for a Van der Waals gas. Find the relationship between inversion temperature and inversion pressure for van der Waals gas. 10

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(b) Derive the relations to estimate the residual enthalpy and residual entropy for a fluid using the Redlich Kwong Soave equation of state. 10

Redlich Kwong Soave equation of state is given by:

$$P = \frac{RT}{(V-b)} - \frac{a\alpha}{V(V+b)}$$

Where:

$$a = 0.42748\frac{R^2T_c^2}{P_c} \quad \text{and} \quad b = 0.08664\frac{RT_c}{P_c}$$

$$\alpha = [\,1 + S\,(\,1 - \sqrt{T_r}\,)\,]^2$$

$$S = 0.48508 + 1.55171\,w - 0.15613\,w^2$$

6. Write short notes on any four of the following: 20

(a) Application of First Law of Thermodynamics to reactive processes
(b) Compressibility factor chart
(c) Exergy
(d) Helmholtz energy
(e) Mollier diagram

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