Ex/PG/MEC/PC/T/111C/2025

M. MECH ENGG. EXAMINATION 2025
First year, 1ST Semester

ADVANCED THERMODYNAMICS

Assume any data, if not furnished, consistent with the problem. Use of relevant tables and charts are permitted.
All parts of a question must be answered together. If answers of different parts are scatterd, marks shall be deducted.

Answer Q No. 1 and any four (4) from the rest.

1. a) Show the law of cyclic differentiations holds true for ideal gas.
   b) A refrigerator has a COP of 4. If the cycle is reversed as heat engine what is the maximum value of efficiency?
   c) Four distinguishable particles are to be divided into two orbits. Find out the possible macrostates and number of microstates corresponding to each macrostate.
   d) Plot the Carnot cycle in h-s and T-V plane. Explain why such a cycle is not used in real life.
   e) Explain the concept of chemical potential.

2+2+8+4+4

2. a) Discuss the exergetic efficiency and isentropic efficiency of a steam turbine.
   b) A piston-cylinder arrangement contains 1 kg of saturated water at 30^0 C. The piston has cross-sectional area of 0.065 m^2, a mass of 40 Kg and is resting on two stops. The volume at this point is 0.1 m^3. Atmospheric pressure is 94 kPa and the local gravitational acceleration is 9.75 m/s^2. Heat is now transferred to the system until the cylinder is filled up with saturated vapor. What is the temperature and dryness fraction of the water when the piston rises from the stop? Calculate the work done by the water during the overall process.

8+12

3. a) Starting from van-dar Wale's equation of state, derive the following relationship for reduced properties:

$$\left(p_r + \frac{3}{v_r^2}\right)\left(v_r - \frac{1}{3}\right) = \frac{8}{3}T_r$$

   b) Calculate the stoichiometric airfuel ratio for the combustion of a fuel of following composition bymass : C 90%, H 3%, O 2.5%, N 1%, S 0.5% ash 3%.

10+10

4. a) Establish the four Maxwell's relationships. Subsequently prove that
   $dh = c_p dT + [\, v - T(\partial v/\partial T)_p]dp$
   b) Derive an expression for Joule Thomson Coefficient from the above equation.

(8+8)+4

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5. (a) Discuss the statistical interpretation of work and heat starting from large number of molecules in a cubical box of volume V.
   b) Derive the number of microstates for one of the three distributions Maxwell Statistics, Fermi Dirac statistics or Bose statistics (any one).

12+8

6. (a) Discuss first order and second order phase transition.
   (b) The vapor pressure of the solid and liquid of a material is given by
   ln p = 0.04- 6/T and ln p = 0.03- 4/T
   Find out the values of pressure and temperature at the triple point. Also find out the three latent heats of phase transformation

8+12

7. (a) In a reaction two chemical species A and B react to form species C and D. Show the criterion for chemical equilibrium is

$$\nu_C g_c + \nu_D g_D - \nu_A g_A - \nu_B g_B = 0$$

   (b) Develop an expression for equilibrium constant K_P for the above reaction

8+12

8. a) Three distinguishable particles have total energy 3ε. The particles are distributed over four energy levels of 0, ε, 2ε and 3ε. Calculate the number of macrostates and corresponding microstates.
   b) In a gas turbine, the gas at 27^0 C enters with a velocity of 50 m/s and enthalpy of 900 kJ/kg and leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. The mass flow rate and heat loss from the turbine are 5 kg/s and 125 KW, respectively. Determine the power output of the turbine and the diameter of inlet pipe. Assume c_p= 1.004 kJ/kgK and R = 0.285 kJ/kgK
   c) State Gibb's phase rule. Find out the degrees of freedom for wet steam and water at triple point using the rule

6+10+(2+2)