M. MECH ENGG. EXAMINATION 2024
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 cyclic engine operating between two thermal reservoirs has a thermal efficiency of 0.8. What is the COP of the same system if reversed to use as a refrigerator?
   c) Entropy value cannot be directly measured – so how do you think they are calculated – explain.
   d) Express the availability of an open system and closed system at state 1. The surrounding is at state 0.
   e) An inventor claims to have a hat engine that is capable of developing 9 kW while working between the temperature limits of 20^0 C and 40^0 C. It receives 1047 kJ/minute of heat. Discuss the possibility of the claim.
   f) For a system total energy is such that $n_x^2 + n_y^2 + n_z^2 = 66$. Show that number of associated macrostates are 12- analyze by providing calculations in a tabular form..

2+3+2+3+4+6

2. a) Explain the concept of chemical potential.
   b) Water-vapour mixture at 100^0 C is contained in a rigid vessel of 0.5 m^3 capacity. Water is now heated till it reaches the critical state. What was the mass and volume of liquid water initially?
   c) Calculate the stoichiometric air-fuel ratio for the combustion of a fuel of following composition by mass : C 90%, H 3%, O 2.5%, N 1%, S 0.5% ash 3%.

4+8+8

3. a)Starting from van-dar Waal's equation of state, develop the following relationship, where suffix r refers to reduced property states:

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

   b) A piston-cylinder contains 0.5 kg air at 200 kPa and 1000 K. The air is now cooled to 400 K. The cylinder has stops below the piston. The minimum volume enclosed is 0.03 m^3 when the piston comes down to rest on the top. Find the final volume and pressure and comment if the piston hits the stops. Calculate total work and heat transfer. Sketch the processes on p-v plane.

10+10

4. (a) Derive the four Maxwell relationships.
b) Develop the Clapeyron equation connecting saturated pressure and temperature
b) Find out an expression for Joule Thompson coefficient using Maxwell's relations

6+6+8

5. (a) Discuss the statistical interpretation of work and heat starting from large number of molecules in a cubical box of volume V
b) The total energy of a system is 3Ɛ, where 3 distinguishable particles A, B, C are distributed over energy levels O,Ɛ, 2Ɛ and 3Ɛ. Calculate the possible macrostates and microstates

12+8

6. (a) Discuss first order and second order phase transition.
(b) In the vicinity of triple point, the vapor pressure of liquid NH_3 is given by
$\ln p = 15.16 - 3060/T$
For solid ammonia vapor pressure curve is given by : $\ln p = 18.70 - 3750/T$
Find out the values of pressure and temperature at triple point. Also find out the latent heats of sublimation, vaporization and fusion

12+8

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

$$\nu_C \bar{g}_C + \nu_D \bar{g}_D - \nu_A \bar{g}_A - \nu_B \bar{g}_B = 0$$

(b) Steam at 0.6 MPa, 200^0 C enters an insulated nozzle with a velocity of 50 m/s. It leaves at a pressure of 0.15 MPa and a velocity of 600 m/s. Determine the isentropic efficiency of the nozzle and show the process on h-s, T-v and p-v diagrams.

6+14

8. (a) Using Maxwell's relationship show

$$c_p - c_v = Tv\beta^2/k$$

b) Air at 20^0 C and 1.05 bar occupies 0.025 m^3 .The air is heated at constant volume until the pressure is 4.5 bar, and then cooled at constant pressure back to original temperature. Calculate a) the net work heat flow from the air, b) the net entropy change.

12+8

(c) Dry saturated water at 200 kPa is in a constant pressure piston cylinder assembly. At this state, the piston is 0.1 m from the cylinder bottom. How much is the distance and what is the temperature if the water is cooled to occupy half the original volume. Find out the final state of the water.

5+5+10