15. (a) A vessel is divided into three compartments (a), (b) and (c) by two partitions. Part (a) contains oxygen and has a volume of 0.1 m^3, (b) has a volume of 0.2 m^3 and contains nitrogen, while (c) is 0.05 m^3 and holds CO_2 . All three parts are at a pressure of 2 bar and a temperature of 13°C. When the partitions are removed the gases mix, determine the change of entropy of each constituent, the final pressure in the vessel and the partial pressure of each gas. The vessel may be taken as being completely isolated from its surroundings.

Or

(b) Prove that $C_P - C_V = -T(\partial V / \partial T)^2 p * (\partial P / \partial V)_T$.

PART C — (1 × 15 = 15 marks)

16. (a) Explain Joule Kelvin effect and derive Clausius Clapeyron equation.

Or

(b) In a counterflow heat exchanger, oil (Cp = 2.1 kJ/kgK) is cooled from 440 to 320 K, while water (Cp = 4.2 kJ/kg K) is heated from 290 K to temperature T. The respective mass flow rates of oil and water are 800 and 3200 kg/h. Neglecting pressure drop, KE and PE effects and heat loss, determine

(i) The temperature T

(ii) The rate of exergy destruction

(iii) The second law efficiency, Take T_0 = 17°C and P_0 = 1 atm.

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Question Paper Code : 21294

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2023.

Third/Fourth Semester

Manufacturing Engineering

ME 3391 – ENGINEERING THERMODYNAMICS

(Common to : Mechanical Engineering/Mechanical Engineering (Sandwich) and Agricultural Engineering)

(Regulations 2021)

Time : Three hours Maximum : 100 marks

(Use of Steam table, Mollier chart and Psychrometric chart is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State zeroth and the first law of thermodynamics.

2. Write down the steady flow energy equation for the turbine and nozzle.

3. Prove COP of the heat pump is greater than the COP of the refrigerator.

4. Calculate the entropy change of the universe as a result of placing a copper block 600 g mass with Cp of 150 J/K at 100°C in a lake at 8°C.

5. Define first law and second law efficiency.

6. State Gouy-Stodola equation and its inference.

7. Define the term dryness fraction and wetness fraction.

8. Find the properties of dry steam at 10 bar from the steam table.

9. State principle of corresponding states.

10. Draw the inversion curve and mark the maximum inversion temperature on the T-P diagram.

PART B — (5 × 13 = 65 marks)

11. (a) 100 liters of an ideal gas at 300 K and 1 bar is compressed adiabatically to 10 bar. It is then cooled at constant volume and further, expanded isothermally so as to reach the condition from where it started. Draw the PV diagram and calculate: (i) pressure at the end of constant volume cooling, (ii) change in internal energy during the constant volume process, and (iii) net work done, and heat transferred during the cycle. Assume, Cp = 14.3 kJ/kg K, and Cv = 10.2 kJ/kg K.

Or

(b) In a cooling tower, air enters at a height of 1 m above ground level and leaves at a height of 6 m. The inlet and outlet velocities are 20 m/s and 30 m/s, respectively. Water enters at a height of 8 m and leaves at a height of 0.8 m. The velocity of water at entry and exit are 3 m/s and 1 m/s, respectively. Water temperatures are 77°C and 47°C at the entry and exit, respectively. Air temperatures are 30°C and 70°C at the entry and exit respectively. The cooling tower is well insulated and a fan of 2.5 kW drives the air through the cooler. Find the amount of air per second required for 1 kg/s of water flow. The value of Cp of air and water are 1.005 and 4.187 kJ/kg K, respectively.

12. (a) Two Carnot heat engines A and B are connected in series between two thermal reservoirs at T_1 = 1000 K and T_2 = 100 K, respectively. Engine A receives 1700 KJ of heat from the high temperature reservoir and rejects heat to the Carnot engine B. Engine B takes in heat rejected by engine A and rejects heat to the low temperature reservoir. If engines A and B have equal thermal efficiencies, determine (i) the heat rejected by engine B, (ii) The temperature at which heat is rejected by engine A, and (iii) The work done during the process by engines A and B, respectively. If engines A and B, deliver equal work, determine (iv) The amount of heat taken in by engine B, and (v) the efficiencies of engines A and B.

Or

(b) An aluminium block (Cp = 400 J/kg K) with a mass of 5 kg is initially at 40°C in room air at 20°C. It is cooled reversibly by transferring heat to a completely reversible cyclic heat engine until the block reaches 20°C. The 20°C room air serves as a constant temperature sink for the engine. Compute (i) the change in entropy for the block, (ii) the change in entropy for the room air, (iii) the work done by the engine.

If the aluminium block is allowed to cool by natural convection to room air, compute (1) the change in entropy for the block, (2) the change in entropy for the room air (3) the net change in entropy for the universe.

13. (a) Steam at 10 bar, 250°C flowing with negligible velocity at the rate of 3 kg/min mixes adiabatically with steam at 10 bar, 0.75 quality flowing (with negligible velocity) at the rate of 5 kg/min. The combined stream of steam is throttled to 5 bar and then expanded isentropically in a nozzle to 2 bar. Determine

(i) The state of steam after mixing

(ii) The state of steam after throttling

(iii) The increase in entropy due to throttling

(iv) The velocity of steam at the exit from the nozzle

(v) The exit area of the nozzle. Neglect the K.E. of steam at the inlet to the nozzle.

Or

(b) Boiler steam at 8 bar, 250°C, reaches the engine control valve through a pipeline at 7 bar, 200°C. It is throttled to 5 bar before expanding in the engine to 0.1 bar, 0.9 dry. Determine per kg of steam.

(i) The heat loss in the pipeline

(ii) The temperature drop in passing through the throttle valve

(iii) The work output of the engine

(iv) The entropy change due to throttling

(v) The entropy change in passing through the engine.

14. (a) A pressure vessel has a volume of 1 m^3 and contains air at 1.4 MPa, 175°C. The air is cooled to 25°C by heat transfer to the surroundings at 25°C. Calculate the availability in the initial and final states and the irreversibility of this process. Take P_0 = 100 kPa.

Or

(b) An economizer, a gas-to-water finned tube heat exchanger, receives 67.5 kg/s of gas, Cp = 1.0046 kJ/kg K, and 51.1 kg/s of water, Cp = 4.186 kJ/kg K. The water rises in temperature from 402 to 469 K, where the gas falls in temperature from 682 K to 470 K. There are no changes of kinetic energy and P_0 = 1.03 bar and T_0 = 289 K. Determine:

(i) Rate of change of availability of the water

(ii) The rate of change of availability of the gas

(iii) The rate of entropy generation.