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B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2025.

Third Semester

Mechanical Engineering

ME 3391 — ENGINEERING THERMODYNAMICS

(Common to: Mechanical Engineering (Sandwich))

(Regulations 2021)

Time : Three hours Maximum : 100 marks

(Steam tables, Mollier chart permitted)

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. State the Zeroth Law of Thermodynamics and its significance.

2. State the First Law of Thermodynamics for a closed system undergoing a cyclic process.

3. Define a heat engine and list its two essential components.

4. Write the Clausius inequality and state its physical meaning.

5. State the difference between high-grade energy and low-grade energy with examples.

6. Define the principle of increase in entropy.

7. Define dryness fraction and state its values for saturated liquid and saturated vapor.

8. Mention the use of Mollier charts in thermodynamic calculations.

9. Write the Van der Waals equation for a real gas and define its terms.

10. Outline about the Maxwells relation with its significance in thermodynamics.

PART B — ($5 \times 13 = 65$ marks)

11. (a) Explain the first law of thermodynamics for a closed system. Discuss its application to a constant volume process.

Or

(b) Explain the concept of displacement work. Illustrate with a P-V diagram for a polytropic process.

12. (a) Compare the performance of a Carnot cycle and a Reversed Carnot cycle. Highlight their key differences.

Or

(b) A reversible heat engine operates between two reservoirs at temperatures 700°C and 50°C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 50°C and – 25°C. The heat transfer to the engine is 2500 kJ and the network output of the combined engine refrigerator plant is 400 kJ.

(i) Determine the heat transfer to the refrigerant and the net heat transfer to the reservoir at 50°C; (6)

(ii) Reconsider (i) given that the efficiency of the heat engine and the C.O.P. of the refrigerator are each 45 per cent of their maximum possible values. (7)

13. (a) (i) Define availability and irreversibility. (5)

(ii) Discuss the factors that lead to irreversibility in thermodynamic processes. List methods to minimize irreversibility. (8)

Or

(b) 8 kg of air at 650 K and 5.5 bar pressure is enclosed in a closed system. If the atmosphere temperature and pressure are 300 K and 1 bar respectively, determine:

(i) The availability if the system goes through the ideal work producing process. (6)

(ii) The availability and effectiveness if the air is cooled at constant pressure to atmospheric temperature without bringing it to complete dead state. (7)

Take $C_v = 0.718$ kJ/kg K ; $C_p = 1.005$ kJ/kg K.

14. (a) Explain the concept of dryness fraction and its determination using a throttling calorimeter.

Or

(b) Steam initially at a pressure of 15 bar and 0.95 dryness expands isentropically to 7.5 bar and is then throttled until it is just dry. Determine per kg of steam:

(i) Change in entropy. (5)

(ii) Change in enthalpy. (4)

(iii) Change in internal energy. (4)

15. (a) (i) Explain the Joule-Thomson effect for a real gas. (6)

(ii) Explain the difference between ideal gases and real gases. (7)

Or

(b) (i) Describe the key assumptions in the Van der Waals equation of state. (6)

(ii) Analyze how these assumptions influence its accuracy compared to the ideal gas law. (7)

PART C — ($1 \times 15 = 15$ marks)

16. (a) A frictionless piston is free to move in a closed cylinder. Initially there is 0.035 m^3 of oxygen at 4.5 bar, 60°C on one side of the piston and 0.07 m^3 of methane at 4.5 bar and –12°C on the other side. The cylinder walls and piston may be regarded as perfect thermal insulators but the oxygen may be heated electrically. Heating takes place so that the volume of oxygen doubles.

Find:

(i) Final state condition. (5)

(ii) Work done by the piston. (5)

(iii) Heat transferred to oxygen. (5)

Treat both gases as perfect and take:

For oxygen Cp = 0.88 kJ/kg K, R = 0.24 kJ/kg K

For methane Cp = 1.92 kJ/kg K, R = 0.496 kJ/kg K.

Or

(b) A vessel contains at 1 bar and 20°C a mixture of 1 mole of CO_2, and 4 moles of air. Calculate for the mixture:

(i) The masses of CO_2, O_2 and N_2, and the total mass. (5)

(ii) The percentage carbon content by mass. (5)

(iii) The apparent molecular weight and the gas constant for the mixture. (5)

The volumetric analysis of air can be taken as 21% oxygen and 79% nitrogen.
