Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 70820

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2021.

Third Semester

Mechanical Engineering

ME 6301 — ENGINEERING THERMODYNAMICS

(Common to Automobile Engineering, Mechanical and Automation Engineering)

(Regulations 2013)

(Also common to PTME 6301 – Engineering Thermodynamics for B.E. (Part Time) – Second Semester – Mechanical Engineering (Regulations 2014))

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State and explain the Zeroth law and its application.

2. Apply steady flow energy equation for a nozzle and state the assumptions made.

3. A heat engine with a thermal efficiency of 45 percent rejects 500 kJ/kg of heat. How much heat does it receive?

4. When a system is adiabatic, what can be said about the entropy change of the substance in the system?

5. What is meant by 'dryness fraction of steam'?

6. Draw the standard Rankine cycle on P-v and T-s coordinates.

7. Express Clausius inequality for various processes.

8. Define Second law efficiency.

9. State Dalton's law of partial pressure. On what assumptions this law is based?

10. What is adiabatic mixing and write the equation for that?

PART B — ($5 \times 13 = 65$ marks)

11. (a) A piston-cylinder assembly contains air (ideal gas with $\gamma = 1.4$) at 200 kPa and occupies a volume of 0.01 m^3. The piston is attached to one end of a spring and the other end of the spring is fixed to a wall. The force exerted by the spring on the piston is proportional to the decrease in the length of the spring from its natural length. The ambient atmospheric pressure is 100 kPa. Now, the air in the cylinder is heated till the volume is doubled and at this instant it is found that the pressure of the air in the cylinder is 500 kPa. Calculate the work done by the gas. (13)

Or

(b) An insulated rigid tank having 5 kg of air at 3 atm and 30°C is connected to an air supply line at 8 atm and 50°C through a valve, The valve is now slowly opened to allow the air from the supply line to flow into the tank until the tank pressure reaches 8 atm, and then the valve is closed. Determine the final temperature of the air in the tank. Also, find the amount of air added to the tank. (13)

12. (a) A heat pump working on the Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C. The heat pump is driven by a reversible heat engine which takes in heat from reservoir at 840ºC and rejects heat to a reservoir at 60°C. The reversible heat engine also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from 5°C reservoir, determine (13)

(i) the rate of heat supply from the 840°C source, and

(ii) the rate of heat rejection to the 60°C sink

Or

(b) Air flows through an adiabatic compressor at 2 kg/s. The inlet conditions are 1 bar and 310 K and the exit conditions are 7 bar and 560 K. Compute the net rate of energy transfer and the irreversibility. Take $T_0 = 298$ K. (13)

13. (a) A steam boiler initially contains $5\,m^3$ of steam and $5\,m^3$ of water at 1 Mpa. Steam is taken out at constant pressure until $4\,m^3$ of water is left. What is the heat transferred during the process? (13)

Or

(b) A steam power plant operates on an ideal regenerative Rankine cycle. Steam enters the turbine at 6 MPa and 450°C and is condensed in the condenser at 20 kPa. Steam is extracted from the turbine at 0.4 MPa to heat the feedwater in an open feedwater heater. Water leaves the feedwater heater as a saturated liquid. Show the cycle on a T-s diagram, and determine (i) the network output per kilogram of steam flowing through the boiler and (ii) the thermal efficiency of the cycle. (13)

14. (a) Derive any three of the Maxwell relations. (13)

Or

(b) Determine the pressure of nitrogen gas at T = 175 K and $v = 0.00375\ m^3/kg$ on the basis of

(i) The ideal-gas equation of state (8)

(ii) The van der Waals equation of state

The van der Waals constants for nitrogen are $\alpha = 0.175\ m^6.kPa/kg^2$, $b = 0.00138\ m^3/kg$. (5)

15. (a) A rigid tank of 5 m^3 contains gas mixture comprising 3 kg of O_2, 4 kg of N_2 and 5 kg of CO_2 at 290 K. calculate the molar specific volume, initial pressure of the gas. If it is heated to 350 K, calculate the heat transfer and change in enthalpy. Also verify the Gibbs theorem for entropy. (13)

Or

(b) A room 7 m × 4 m × 4 m is occupied by an air-water vapour mixture at 38°C. The atmospheric pressure is 1 bar and the relative humidity is 70%. Determine the humidity ratio, dew point, mass of dry air and mass of water vapour. If the mixture of air-water vapour is further cooled at constant pressure until the temperature is 10°C. Find the amount of water vapour condensed. (13)

PART C — (1 × 15 = 15 marks)

16. (a) A quantity of air undergoes a thermodynamic cycle consisting of three processes. Process 1 – 2 : Constant volume heating from P_1 = 0.1 MPa, T_1 = 15°C, V_1 = 0.02 m^3 to P_2 = 0.42 MPa. Process 2-3 : Constant pressure cooling. Process 3-1 : Isothermal heating to the initial state. Employing the ideal gas model with C_p = 1 kJ/kgK, evaluate the change of entropy for each process. Sketch the cycle on p-v and T-s coordinates.

Or

(b) Air at 80 kpa, 27°C and 220 m/s enters a diffuser at a rate of 2.5 kg/s and leaves at 42°C. The exit area of the diffuser is 400 cm^2. The air is estimated to lose heat at a rate of 18 kJ/s during this process. Determine :

(i) the exit velocity and

(ii) the exit pressure of the air.