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

Question Paper Code : 70147

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2022.

Third Semester

Mechanical Engineering

ME 3391 — ENGINEERING THERMODYNAMICS

(Common to Mechanical Engineering (Sandwich))

(Regulations 2021)

Time : Three hours Maximum : 100 marks

Use of steam table permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. What is equation of state? Write equation of state for ideal gas.

2. Compare path functions and point functions.

3. Define Kelvin-Planck statement of second law of thermodynamics.

4. Prove $COP_{HP} = COP_R + 1$.

5. What is available energy?

6. Define the second law efficiency for a work producing device.

7. Define dryness fraction.

8. A saturated steam has entropy of 6.76 kJ/kg K. What are its pressure, temperature and specific volume?

9. What is the importance of Joule-Thomson coefficient?

10. Consider a gas mixture that consists of 3kg of O_2, 5 kg of N_2 and 12 kg of CH_4. Determine the mass fraction of each component.

PART B — (5 × 13 = 65 marks)

11. (a) (i) A mass of 15 kg of air in a piston-cylinder device is heated from 25 to 95°C by passing current through a resistance heater inside the cylinder. The pressure inside the cylinder is held constant at 300 kPa during the process, and a heat loss of 60 kJ occurs. Determine the electric energy supplied, in kWh. (8)

(ii) In the compression stroke of an internal combustion engine the heat rejected to the cooling water is 35 kJ/kg and the work input is 100 kJ/kg. Find the change in specific internal energy of the working fluid. (5)

Or

(b) (i) An adiabatic air compressor compresses 10 L/s of air at 120 kPa and 20°C to 1000 kPa and 300°C. Determine

(1) The work required by the compressor, in kJ/kg, and

(2) The power required to drive the air compressor, in kW. (8)

(ii) Simplify the steady flow energy equation applied to a adiabatic nozzle with negligible potential energy. (5)

12. (a) A reversible heat engine operates between two thermal reservoirs at temperature 1000 K and 300 K. The engine drives a reversible refrigerator which operates between reservoirs at temperatures 250 K and 300 K. The heat transfer to the heat engine is 2000 kJ and the net work output of combined engine-refrigerator plant is 360 kJ. Evaluate the heat transfer to the refrigerant, (COP) of the refrigerator and heat transfer to the 300 K reservoir.

Or

(b) A power cycle operating between two thermal reservoirs receives energy Q_H by heat transfer from a hot reservoir at T_H = 2000 K and rejects energy Q_C by heat transfer to a cold reservoir at T_C = 400 K. For each of the following cases determine whether the cycle operates reversibly. operates irreversibly, or is impossible.

(i) Q_H = 1000 kJ, η = 60%

(ii) Q_H = 1000 kJ, W_{cycle} = 850 kJ

(iii) Q_H = 1000 kJ, Q_C = 200 kJ.

13. (a) A 50-kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45 kJ/kg K for the iron, determine

(i) The entropy change of the iron block,

(ii) The entropy change of the lake water, and

(iii) The entropy generated during this process.

Or

(b) A heat engine receives heat from a source at 1200 K at a rate of 500 kJ/s and rejects the waste heat to a medium at 300 K. The power output of the heat engine is 180 kW. Determine the reversible power, the irreversibility rate for this process and second law efficiency.

14. (a) An insulated piston-cylinder device initially contains 1.8 kg of saturated liquid water at 120°C. Now an electric resistor placed in the cylinder is turned on for 10 min until the volume quadruples. Determine

(i) the volume of the cylinder,

(ii) the final temperature, and

(iii) the electrical power rating of the resistor.

Or

(b) Steam initially at 1.5 MPa, 573 K expands reversibly and adiabatically in a steam turbine to 313 K. Determine the ideal work output of the turbine per kg of steam.

15. (a) A rigid tank contains 2 kmol of N_2 and 6 kmol of CO_2 gases at 300 K and 15 MPa. Estimate the volume of the tank on the basis of

(i) The ideal-gas equation of state,

(ii) Compressibility factors Amagat's law.

Or

(b) Two grams of a saturated liquid are converted to a saturated vapor by being heated in a weighted piston-cylinder device arranged to maintain the pressure at 200 kPa. During the phase conversion, the volume of the system increases by 1000 cm^3, 5 kJ of heat are required; and the temperature of the substance stays constant at 80°C. Estimate the boiling temperature of this substance when its pressure is 180 kPa.

PART C — (1 × 15 = 15 marks)

16. (a) A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During a cycle, the sum of all heat transfer is (–170 kJ). The system completes 100 cycle per minute. Complete the following tables showing the method for each item, and compute the net rate if work output in kW.

Process	Q (kJ/min)	W (kJ/min)	Δ E (kJ/min)
a-b	0	2,170	–
b-c	21,000	0	–
c-d	–2,100	–	–36,600
d-a	–	–	–

Or

(b) A piston cylinder device initially contains 1.5 kg of liquid water at 150 kPa and 20°C. The water is now heated at constant pressure by the addition of 4000 kJ of heat. Determine the entropy change of water during this process.