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Question Paper Code : 11653

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2026.

Third Semester

Mechanical Engineering

ME3391 — ENGINEERING THERMODYNAMICS

(Common to: Mechanical Engineering (Sandwich))

(Regulations 2021)

Time : Three hours

Maximum : 100 marks

(Use of Steam Table, Mollier Chart, Psychrometric Chart are permitted)

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Name three temperature scales and write the relationship between any two.
2. Define thermodynamic system and give examples of open, closed, and isolated systems.
3. Write the relationship between the COP of the heat pump and the COP of the refrigerator.
4. What is the qualitative difference between heat and work?
5. Why is the work done by a closed system remain maximum in a reversible process while interacting with the surrounding?
6. A turbine gets a supply of 5 kg/s of steam at 7 bar and 250°C, discharges it at 1 bar. Calculate the availability.
7. Draw the p-T diagram for a pure substance.
8. Define the dryness fraction of steam.
9. What is the compressibility factor of van der Waals gas at the critical point?
10. What is the Joule-Thomson coefficient? Why is it zero for an ideal gas?

PART B — ($5 \times 13 = 65$ marks)

11. (a) A fluid is confined in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume ($p = a + bV$). The internal energy of the fluid is given by the following equation: $U = 34 + 3.15 pV$.

Where U is in kJ, p in kPa, and V in cubic metres. If the fluid changes from an initial state of 170 kPa, 0.03 m^3 to a final state of 400 kPa, 0.06 m^3 , with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer.

Or

- (b) In a gas turbine the gas enters at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg and leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. The loss of heat from the gases to the surroundings is 25 kJ/kg. Assume for gas $R = 0.285 \text{ kJ/kg.K}$ and $C_p = 1.004 \text{ kJ/kg.K}$ and the inlet conditions to be at 100 kPa and 27°C . Determine the power output of the turbine and the diameter of the inlet pipe.

12. (a) (i) State the Kelvin-Planck and Clausius statements of the second law of thermodynamics. Prove that violation of one statement leads to violation of the other, establishing their equivalence. (9)
- (ii) Show that the COP of a heat pump is greater than the COP of a refrigerator by unity. (4)

Or

- (b) 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 . A heat engine is driven by a source at 840°C and rejects heat to a reservoir at 60°C . The reversible heat engine, in addition to driving the heat pump, also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from the 5°C reservoir, determine

- (i) the rate of heat supply from the 840°C source and (7)
- (ii) the rate of heat rejection to the 60°C sink. (6)
13. (a) In a steam boiler, hot gases from a fire transfers heat to water which vaporizes at constant temperature. In a certain case, the gases are cooled from 1100°C to 550°C while the water evaporates at 220°C . The specific heat of gases is 1.005 kJ/kg.K , and the latent heat of water at 220°C is 1858.5 kJ/kg . All the heat transferred from the gases goes to the water. How much does the total entropy of the combined system of gas and water increase as a result of the irreversible heat transfer? Obtain the result on the basis of 1 kg of water evaporated. If the temperature of the surroundings is 30°C , find the increase in unavailable energy due to irreversible heat transfer.

Or

- (b) 5 m³ of air at 2 bar and 27°C is compressed up to 6 bar pressure following $pV^{1.3} = \text{constant}$. It is subsequently expanded adiabatically to 2 bar. Considering the two processes to be reversible, determine the network, net heat transfer and change in entropy. Also plot the processes on T-s and p-V diagrams.
14. (a) A closed vessel of 0.2 m³ contains steam at 1 MPa and a temperature of 250°C. If the vessel is cooled so that pressure falls to 350 kPa. Determine the final temperature, heat transfer and change of entropy during the process.

Or

- (b) (i) Steam at 0.8 MPa, 250°C and flowing at the rate of 1 kg/s passes into a pipe carrying wet steam at 0.8 MPa, 0.95 dry. After adiabatic mixing the flow rate is 2.3 kg/s. Determine the properties of the steam after mixing. (8)
- (ii) Briefly explain the process of superheated steam formation with the help of a T-s diagram. (5)
15. (a) Derive Maxwell's thermodynamic relations and explain their importance in thermodynamics.

Or

- (b) Describe the use of reduced properties, the principle of corresponding states and the compressibility chart.

PART C — (1 × 15 = 15 marks)

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

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.

