PART C — (1 × 15 = 15 marks)

16. (a) The compressors of a production facility maintain the compressed-air lines at a (gauge) pressure of 700 kPa at sea level where the atmospheric pressure is 101 kPa. The average temperature of air is 20° C at the compressor inlet and 24° C in the compressed-air lines. The facility operates 4200 hours a year, and the average price of electricity is Rs.50/kWh. Taking the compressor efficiency to be 0.8, the motor efficiency to be 0.92, and the discharge coefficient to be 0.65, determine the energy and money saved per year by sealing a leak equivalent to a 3 mm diameter hole on the compressed-air line.

Or

(b) The interior lighting of refrigerators is provided by incandescent lamps whose switches are actuated by the opening of the refrigerator door. Consider a refrigerator whose 40-W lightbulb remains on continuously as a result of a malfunction of the switch. If the refrigerator has a coefficient of performance of 1.3 and the cost of electricity is Rs. 8/- per kWh, determine the increase in the energy consumption of the refrigerator and it's cost per year if the switch is not fixed.

———————

10/6/23 - AN

Reg. No. : [ ]

Question Paper Code : 50871

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2023.

Third/Fourth Semester

Mechanical Engineering

ME 8391 – ENGINEERING THERMODYNAMICS

(Common to : Automobile Engineering/Industrial Engineering/ Mechanical and Automation Engineering/Plastic Technology)

(Regulations 2017)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is meant by quasi equilibrium process?

2. How are heat, Internal energy and thermal energy related to each other?

3. Why are Engineers interested in reversible process even though if can never be achieved?

4. Relate the COP of a Heat Pump and Refrigerator.

5. What do you understand by the degree of superheat and the degree of subcooling?

6. State Phase rule of pure substances.

7. Show that Joule Thomson Coefficient is zero for an ideal gas.

8. Why do the specific heats of an ideal gas depend only on the atomic structure of the gas?

9. Which is closely related to human comfort, the humidity ratio or the relative humidity? Give reason.

10. Why does a car with an air conditioner running often have water dipping out?

PART B — (5 × 13 = 65 marks)

11. (a) (i) Air flows steadily through a compressor. It is compressed reversibly from 0.1 MPa and 30° C to 0.9 MPa. Determine the specific work of compression. (9)

(1) If the process is isothermal;

(2) If the process follows the reversible adiabatic law $pV^k = C$, where k = 1.4 for air.

(3) What is the nonflow work in each case?

(ii) What are the conditions for steady flow process? (4)

Or

(b) (i) In a steam power station, steam flows steadily through a 0.2 m diameter pipeline from the boiler to the turbine. At the boiler end, the steam conditions are found to be: p = 4 MPa, t = 400° C, h = 3213.6 kJ/kg, and v = 0.073 m^3/kg. At the turbine end, the conditions are found to be: p = 3.5 MPa, t = 392° C, h = 3202.6 kJ/kg, and v = 0.084 m^3/ kg. There is a heat loss of 8.5 kJ/kg from the pipeline. Calculate the steam flow rate. (9)

(ii) Show that the enthalpy of a fluid before throttling is equal to that after throttling? (4)

12. (a) (i) A cyclic heat engine operates between a source temperature of 800° C and a sink temperature of 30° C. What is the least rate of heat rejection per kW net output of the engine? (8)

(ii) A domestic food freezer maintains a temperature of –15° C. The ambient air temperature is 30° C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s what is the least power necessary to pump this heat out continuously? (5)

Or

(b) One kg of water at 300 K is heated to 500 K by bringing it in contact with a heat reservoir at 500 K.

(i) Determine the entropy change of the universe.

(ii) If instead the water is first heated to 400 K by bringing it in contact with an intermediate heat reservoir at 400 K, and then to 500 K as before, what will be the entropy change of the universe in this case?

(iii) State how water could be heated from 300 K to 500 K almost without any change in the entropy of the universe.

13. (a) Consider a steam power plant operating on the ideal regenerative Rankine cycle with one open feedwater heater. Steam enters the turbine at 15 MPa and 600° C and is condensed in the condenser at a pressure of 10 kPa. Some steam leaves the turbine at a pressure of 1.2 MPa and enters the open feedwater heater. Determine the fraction of steam extracted from the turbine and the thermal efficiency of the cycle. (13)

Or

(b) 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 condition of steam after mixing. The mixture is now expanded in a frictionless nozzle isentropically to a pressure of 0.4 MPa. Determine the velocity of the steam leaving the nozzle. Neglect the velocity of steam in the pipeline. (13)

14. (a) (i) Derive a relation for the internal energy change as a gas that obeys the van der Waals equation of state. Assume that in the range of interest cv varies according to the relation $C_v = C_1 + C_2 T$, where C_1 and C_2 are constants. (6)

(ii) Show that the internal energy of (1) an ideal gas and (2) an incompressible substance is a function of temperature only, u = u (T). (7)

Or

(b) (i) Derive the Clausius - Clapeyron's equation. What assumptions are made in this equation? (9)

(ii) Using the Clapeyron equation, estimate the value of the enthalpy of vaporization of refrigerant - 134a at 20° C, and compare it with the tabulated value. (4)

15. (a) Atmospheric air at 1.0132 bar has 20° C DBT and 65% RH. Find the humidity ratio, wet bulb temperature, dew point temperature, degree of saturation, enthalpy of the mixture and density of air and density of vapour in the mixture.

Or

(b) Consider a gas mixture that consists of 3 kg of O_2, 5 kg of N_2, and 12 kg of CH_4. Determine (i) the mass fraction of each component, (ii) the mole fraction of each component, and (iii) the average molar mass and gas constant of the mixture.