

PART B — (5 × 16 = 80 marks)

11. (a) A three process cycle operating with nitrogen as the working substance has constant temperature compression at 34°C with initial pressure 100 kPa. Then the gas undergoes a constant volume heating and then polytropic expansion with 1.35 as index of compression. The isothermal compression requires -67kJ/kg of work. Determine

- (i) P, v and T around the cycle
- (ii) Heat in and out
- (iii) Net work.

For nitrogen gas, $C_v = 0.7431 \text{ kJ/kg-K}$. (16)

Or

- (b) (i) Derive the steady flow energy equation, stating the assumptions made. (6)
- (ii) Prove that energy is a property of a system. (5)
- (iii) Enumerate and explain the limitations of first law of thermodynamics. (5)

12. (a) (i) Prove that increase in entropy in a polytropic process is

$$\Delta s = mc_v \frac{\gamma - n}{n} \ln \left(\frac{p_1}{p_2} \right). \quad (6)$$

- (ii) An irreversible heat engine with 66% efficiency of the maximum possible, is operating between 1000 K and 300 K. If it delivers 3 kW of work, determine the heat extracted from the high temperature reservoir and heat rejected to low temperature reservoir. (10)

Or

- (b) (i) Helium enters an actual turbine at 300 kPa, 300°C and expands to 100 kPa, 150°C. Heat transfer to atmosphere at 101.325 kPa, 25°C amounts to 7 kJ/kg. Calculate the entering stream availability, leaving stream availability and the maximum work. For helium, $C_p = 5.2 \text{ kJ/kg}$ and molecular weight = 4.003 kg/kg-mol. (10)
- (ii) List out and explain various causes of irreversibility. (6)

13. (a) (i) Steam at 30 bar and 350°C is expanded in a non flow isothermal process to a pressure of 1 bar. The temperature and pressure of the surroundings are 25°C and 100 kPa respectively. Determine the maximum work that can be obtained from this process per kg of steam. Also find the maximum useful work. (10)

- (ii) With the aid of T-v diagram explain various phases of conversion of ice at -20°C to steam at 125°C. (6)

Or

(b) (i) With the help of a schematic diagram, explain the regenerative Rankine cycle and derive the expression for its efficiency. Also represent the process in p - v and T - s diagram. (8)

(ii) Steam at 50 bar, 400°C expands in a Rankine cycle to 0.34 bar. For a mass flow rate of 150 kg/sec of steam, determine

(1) Power developed

(2) Thermal efficiency

(3) Specific steam consumption. (8)

14. (a) (i) Derive Clausius-Clapeyrons equation. What assumptions are made in this equation? (10)

(ii) Consider an ideal gas at 303 K and 0.86 m³/kg. As a result of some disturbance the state of the gas changes to 304 K and 0.87 m³/kg. Estimate the change in pressure of the gas as the result of this disturbance. (6)

Or

(b) (i) From the basic principles, prove the following

$$c_p - c_v = -T \left(\frac{\partial v}{\partial T} \right)_p^2 \left(\frac{\partial p}{\partial v} \right)_T \quad (8)$$

(ii) Verify the validity of Maxwell's relation, $\left(\frac{\partial s}{\partial p} \right)_T = - \left(\frac{\partial v}{\partial T} \right)_p$ for steam at 300°C and 500 kPa. (8)

15. (a) (i) Derive the sensible heat factor for cooling and dehumidification process. Also explain the process. (6)

(ii) One kg of air at 40°C dry bulb temperature and 50% relative humidity is mixed with 2kg of air at 20°C dry bulb temperature and 20°C dew point temperature. Calculate the temperature and specific humidity of the mixture. (10)

Or

(b) (i) Prove that specific humidity of air is $\omega = 0.622 \frac{p_v}{p_b - p_v}$. (6)

(ii) With the aid of model psychometric chart explain the following processes.

(1) Adiabatic mixing

(2) Evaporative cooling. (10)