B.E. CHEMICAL ENGINEERING SECOND YEAR FIRST SEMESTER EXAM 2019
ENGINEERING THERMODYNAMICS

Time: 3 Hours | Full Marks: 100

Attempt any *five* questions
Steam and other tables may be used
Assume any data, if required

1. (a) Discuss about thermal equilibrium and explain how the concept of empirical temperature is obtained from it. (5+6=11)

   (b) A substance is at 2 Mpa, 17°C in a rigid tank. Using only the critical properties, can the phase of the mass be determined if the substance is nitrogen, water or propane? (9)

2. (a) Prove that stored energy is a property of a system. (10)

   (b) 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 transfers is -170 kJ. The system completes 100 cycles per minute. Complete the following table showing the method for each item, and compute the net rate of work output in kW.

Process	*Q{kJ/min)*	*W(kJ/min)*	*ΔE(kJ/min)*
a-b	0	2170	
b-c	21000	0	
c-d	-2100		-36600
d-a			

(10)

3. (a) Show that for a reversible heat engine $\frac{|Q_2|}{|Q_1|} = \frac{T_2}{T_1}$, where the terms have their usual meanings. (10)

   (b) A heat pump is to heat a house in the winter and then reversed to cool the house in the summer. The interior temperature of the house is to be maintained at 20°C. Heat transferred through the walls and roof is estimated to be 2400 kJ per hour per degree Celsius temperature difference between the inside and outside.
   (i) If the outside temperature in the winter is 0°C, what is the minimum power required to drive the heat pump?
   (ii) If the power input is the same as that in part a., what is the maximum outside temperature for which the inside can be maintained at 20°C? (10)

4. (a) Derive the energy balance equation for a control volume executing a steady state steady flow process. (10)

(b) A steam turbine receives water at 15 MPa, 600 °C at a rate of 100 kg/s. In the middle section 20 kg/s is withdrawn at 2 MPa, 350°C, and the rest exit the turbine at 75 kPa, and 95% quality. Assuming no heat transfer and no changes in kinetic energy, find the total turbine work. (10)

5. (a) Discuss i) Useful work, ii) Dead state and iii) Flow exergy (3+3+4=10)

   (b) A 500 kg iron block is initially at 200°C and is allowed to cool to 27°C by transferring heat to the surrounding air at 27°C. Determine the reversible work and the irreversibility for this process. Consider average specific heat of the iron block to be 0.45 kJ/(kg.K). (10)

6. (a) Derive the four Maxwell relationships for a pure substance. (10)

   (b) At the beginning of compression in an air standard Otto cycle, t = 50°C, P_1 = 100 kPa and V_1 = 0.2 m^3. If the compression ratio is 6 and the maximum cycle temperature is 1400°C, calculate i) the heat added, ii) the heat rejected, iii) the net work done, and iv) the efficiency. (10)

7. A steam power plant operating on the Rankine cycle has steam at 3.5 MPa, 400°C leaving the boiler. The turbine exhausts to the condenser operating at 10 kPa. Find the specific work and the heat transfer in each of the ideal components and the cycle efficiency. Draw the schematic diagram of the plant. Plot the cycle on h-s plane and label properly. (20)

8. Write short notes on any *four* of the following: (5x4=20)

   (a) Kelvin-Planck and Clausius statements of the second law of thermodynamics
   (b) Carnot cycle
   (c) Diesel cycle
   (d) Clausius-Clapeyron equation
   (e) Entropy generation and Irreversibility