B.E. FOOD TECHNOLOGY AND BIO-CHEMICAL ENGINEERING SECOND YEAR
SECOND SEMESTER - 2022

THERMAL ENGINEERING

Time: Three hours | Full Marks: 100

Answer any ***five*** questions.
All parts of the same question must be answered at the same place.
Assume any relevant data if unfurnished.

Q.1

(a) Define 'heat' and 'work'. Discuss the similarities between them. **[8]**

(c) A gas expands polytropically in a frictionless piston-cylinder arrangement following the relation PV^n = constant. Find an expression for the work done by the gas during the process. **[6]**

(b) A gas, initially at 2 MPa, 300 ^0C, is contained in a frictionless piston-cylinder arrangement with an initial volume of 0.1 m^3. The gas expands in a quasi-static process according to the relation PV = constant, until the final pressure falls to 200 kPa. Determine the final volume of the gas and the work done during the process. **[6]**

Q.2

(a) Define 'quasi-static process' and explain how you can attain such a process. **[6]**

(b) Explain the terms 'point function' and 'path function'. **[4]**

(c) Write the first law of thermodynamics for a system undergoing a thermodynamic cycle. Hence, derive the first law for a system undergoing a change of state. Also, show that energy is a property of the system. **[10]**

Q.3

(a) Discuss what type of thermodynamic process (isobaric, isothermal etc.) is taking place in each of the following cases. Also draw the corresponding thermodynamic process for each case. Finally, find expressions to estimate the work transfer and heat transfer during each of the following processes in terms of appropriate process parameters and properties of the system: **[20]**

(i) A soup is being cooked in a pressure cooker with lid closed and the pressure relief valve remains closed during the process.

(ii) A gas is being heated in a frictionless piston cylinder arrangement, with a fixed weight on top of the piston.

[Turn over

Q.4

(a) Draw the following processes for steam, showing the subcooled zone, saturation zone, and the superheated zone. The initial state is wet steam and the final state is in the superheated zone. For each case, draw two such isolines, showing the relative magnitudes: **[12]**

(i) Isobaric process on *T-v* diagram,

(ii) Constant volume process on *T-s* diagram,

(iii) Isothermal process on *P-v* diagram.

(b) With reference to the *h-s* diagram for steam, draw two isobaric lines, starting from the wet saturation state to the superheated state. Mathematically justify the shapes of the isobars. **[8]**

Q.5

(a) An insulated vessel is built in the form of a circular cylinder of diameter 0.3 m and height 1.5 m, contains superheated steam at 100 kPa and 130 ^0C. The steam is colled until the steam attains the dry saturated state. Calculate the mass of the steam present in the vessel and heat required to be extracted during the process. **[10]**

(c) A mass of 0.5 kg of superheated steam, contained in a piston cylinder arrangement, initially at 130 ^0C, 100 kPa, is cooled isobarically to saturated water. Determine the amount of heat removed and the work transferred during this process. **[10]**

Q.6

(a) Explain how the dryness fraction of relatively dry steam is measured. **[10]**

(b)The following observations are obtained from a combined separating and throttling calorimeter:

Pressure in the steam main = 0.8 MPa
Pressure after throttling = 0.1 MPa
Temperature after throttling = 110 ^0C
Mass collected in the separator in 10 minutes = 0.3 kg
Mass collected in the condenser in 10 minutes = 2.5 kg

Determine the dryness fraction of the steam in the main pipeline. **[10]**

Q.7

(a) Draw the schematic diagram of a simple steam power plant and draw the Rankine cycle on T-s diagram. **[10]**

(b) Find the energy transfer rates across different components of the above plant in terms of specific enthalpy and mass flow rate of steam. Hence find the thermal efficiency of the Rankine cycle. **[10]**

Table 1: Properties of saturated steam

T_{sat} (^0C)	P_{sat} (kPa)	v_f (m^3/kg)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kgK)	S_g (kJ/kgK)
90	70.13	0.0010361	2.3610	376.91	2660.0	1.1905	7.4789
99.62	100	0.0010432	1.6945	417.46	2675.4	1.3026	7.3595
170.44	800	0.0011149	0.2441	721.13	2769.1	2.0462	6.6628

Table 2: Properties of superheated steam (P=100 kPa)

T_{sup} (^0C)	v (m^3/kg)	h (kJ/kg)	u (kJ/kg)
100	1.69	2676	2507.0
150	1.94	2776	2583.0