

Seat No.: \_\_\_\_\_

Enrolment No. \_\_\_\_\_

## GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER-III (New) EXAMINATION – WINTER 2018

**Subject Code:2131404**

**Date:05/12/2018**

**Subject Name:Food Engineering Thermodynamics**

**Time:10:30 AM TO 01:00 PM**

**Total Marks: 70**

**Instructions:**

1. Attempt all questions.
2. Make suitable assumptions wherever necessary.
3. Figures to the right indicate full marks.
4. Standard Steam Tables and normal range Psychrometric Chart can be used.

- Q.1**
- (a) Define ideal gases and state how do they differ from real gases? A sealed container of 500 litres volume contains methane gas at a temperature of  $-13^{\circ}\text{C}$  and 5 bar pressure. Calculate the mass of the gas in kg using ideal gas equation. [Take  $R = 8.314 \text{ J/mol K}$  and  $M = 16$ ] **03**
- (b) Write down Van der Waal's equation of state for real gases. What do the constants 'a' and 'b' in the equation stand for? Hundred moles of  $\text{CO}_2$  gas is stored in a 5 liter closed container at  $-23^{\circ}\text{C}$ . Calculate the pressure of the gas in kPa using Van der Waal's gas equation. Take  $a = 0.363 \text{ Pa (m}^3/\text{mole)}^2$ ,  $b = 4.3 \times 10^{-5} \text{ m}^3/\text{mole}$ ,  $R = 8.314 \text{ J/mole K}$  **04**
- (c) Match the entities of Column-I with most appropriate entity from a set of possible entities available in Column-II. Reconstruct a matched table. **07**

Column-I	Column-II
Vacuum of 650 torr equals	(i) Real gases (ii) 86.66 kPa
$C_p - C_v$ is	(iii) $> 0$ for ideal gases
Van der Waal's gas equation	(iv) $NKT$ (v) 14 g (vi) $25^{\circ}\text{C}$
Specific gas constant for $\text{O}_2$ gas is	(vii) 28 g (viii) $\bar{R} T$
PV is equal to	(ix) $< 0$ for real gases
Mass of 1 mole $\text{N}_2$ gas at NTP is	(x) Freeze drying
$77^{\circ}\text{F}$ is equal to	(xi) 14.67kPa (xii) 259.8 J/kg K
Sublimation	(xiii) 259.8 J/mol K

- Q.2**
- (a) A gas at 6 bar and  $187^{\circ}\text{C}$  kept in a container of 250 liter volume is cooled isobarically to  $37^{\circ}\text{C}$ . Calculate the following in kJ: **03**
- (a) Heat transferred.
  - (b) Work done and its direction.
  - (c) Change in internal energy.
- [Take  $C_p = 40 \text{ J/mol K}$ ,  $R = 8.314 \text{ J/mol k}$ ]
- (b) State Zero<sup>th</sup> law of thermodynamics. A wire made from an unknown alloy having a temperature of  $21^{\circ}\text{C}$  carries a current of 0.5 Ampere at a given potential difference. At  $49.5^{\circ}\text{C}$ , the current carried by the wire is 0.36 Ampere for the same potential difference. Calculate the temperature coefficient ( $\alpha$ ) of the alloy. **04**
- (c) State First Law of thermodynamics. What are its practical limitations? Prove that  $PV^\gamma = \text{Constant}$  for an ideal gas undergoing a reversible adiabatic process. The temperature of 10 kg of a gas held in a rigid cylinder was increased from  $10^{\circ}\text{C}$  to  $50^{\circ}\text{C}$  by adding 35 kJ of heat. Calculate the work **07**

done and the change in internal energy of the system. [Take  $C_v = 741 \text{ J/kg K}$ ]

OR

- (c) Define control volume. Write down the generalized SFEE for a fluid stream entering and leaving a thermodynamic system in terms of work and energy transfer per unit time. Steam flows through a turbine in steady state with the following inlet and outlet conditions: 07

Inlet conditions

$$h_1 = 3250 \text{ kJ/kg}, \quad v_1 = 0.074 \text{ m}^3/\text{kg}$$

$$P_1 = 54 \text{ bar}, \quad t_1 = 410 \text{ }^\circ\text{C}, \quad d_1 = 0.24\text{m}$$

Outlet conditions

$$h_2 = 3234 \text{ kJ/kg}, \quad v_2 = 0.084 \text{ m}^3/\text{kg}$$

$$P_2 = 42 \text{ bar}, \quad t_2 = 390 \text{ }^\circ\text{C}, \quad d_2 = 0.24\text{m}$$

The heat loss due to poor insulating material is  $10 \text{ kJ/kg}$ . Calculate the steam inlet and outlet velocities in  $\text{m/s}$  and its flow rate in  $\text{kg/s}$ . Assume turbine inlet and outlet points to be at the same height.

- Q.3 (a) Explain different types of thermodynamic equilibria and state conditions of stability. 03

- (b) What is Joule-Kelvin effect? Show that for ideal gases,  $\mu_{j,T} = 0$  04

- (c) Show that for an infinitesimal reversible process 07

(i)  $\left(\frac{\partial T}{\partial V}\right)_s = -\left(\frac{\partial P}{\partial S}\right)_v$

(ii)  $\left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial P}\right)_V = -1$

- Q.3 (a) Define thermodynamic degrees of freedom. What is Gibb's phase rule? Calculate the degrees of freedom of water at its triple point. 03

- (b) Show that for an infinitesimal reversible process, 04

$$\left(\frac{\partial T}{\partial P}\right)_s = \left(\frac{\partial V}{\partial S}\right)_P$$

- (c) Define entropy and show that for any thermodynamic process  $(\Delta s)_{1-2} \geq \int_1^2 \left(\frac{dQ}{T}\right)$  07

An ideal gas is undergoing a reversible process ( $1 \leftrightarrow 2$ ). Show that the specific entropy change for this process is given by

$$(\Delta s)_{1-2} = C_v \ln\left(\frac{T_2}{T_1}\right) + \bar{R} \ln\left(\frac{v_2}{v_1}\right)$$

- Q.4 (a) Using Clausius-Clayperon equation, determine the approximate pressure at which water would boil at  $120 \text{ }^\circ\text{C}$ . It is given that water boils at  $100 \text{ }^\circ\text{C}$  at 1 atmosphere. [Take  $R = 8.314 \text{ J/mol K}$ ,  $h_{fg} \text{ (at } 100 \text{ }^\circ\text{C)} = 2257 \text{ kJ/kg}$ ] 03

- (b) State Carnot theorems. A stem engine is operating between two constant temperature reservoirs at  $329 \text{ }^\circ\text{C}$  and  $15 \text{ }^\circ\text{C}$  and producing a work output of  $50 \text{ kW}$ . If the thermal efficiency of the engine is 75% of the maximum possible efficiency, calculate the required heat input to the engine and heat rejection rate in  $\text{kW}$ . 04

- (c) Explain the following in brief: 07
- i. Thermal reservoirs
  - ii. PMM1 And PMM2
  - iii. Carnot cycle
  - iv. Available and unavailable energy
  - v. Clausius inequality
  - vi. Entropy principle
  - vii. Law of corresponding states
- Q.4 (a)** Explain Carnot cycle showing various state points and processes and explain the significance of this cycle. 03
- (b)** Draw a schematic diagram showing the operation of heat pump. A heat pump is operating between source and sink maintained at  $-5^{\circ}\text{C}$  and  $25^{\circ}\text{C}$  and respectively. The heat absorbed from the source is 5 kW and the heat pumped into the sink is 40% more than what the system absorbs from the source. Calculate the power requirement and COP of the device. What is the ratio of actual COP to the maximum possible COP? 04
- (c)** Explain Kelvin-Planck (K-P) and Clausius statements of second law of thermodynamics & prove that if K-P statement is violated then Clausius statement will also be violated and vice-versa. 07
- Q.5 (a)** Define the following in relation to moist air: 03
- (i) Wet bulb temperature.
  - (ii) Dry bulb temperature.
  - (iii) Absolute humidity.
- (b)** Show the following processes on a psychrometric chart: 04
- i. Heating and dehumidification of air
  - ii. Cooling and dehumidification of air
- The barometric pressure of atmospheric air at a certain place is 1 bar and its temperature is  $30^{\circ}\text{C}$ . If the partial vapour pressure of water vapours present in the atmosphere is 15 mm Hg, calculate the following:
- (i) Absolute humidity
  - (ii) Relative humidity
- (c)** Draw phase diagram of a pure substance (water) on T-s coordinates and explain the following for water/steam: 07
- (i) Steam quality
  - (ii) Triple point
  - (iii) Superheated steam
- A rigid vessel contains saturated steam at a temperature of  $200^{\circ}\text{C}$ . Determine the following using Steam Tables:
- (i) Saturation Pressure
  - (ii) Specific volume in  $\text{m}^3/\text{kg}$
  - (iii) Enthalpy in  $\text{kJ}/\text{kg}$
  - (iv) Internal energy in  $\text{kJ}/\text{kg}$
- Q.5 (a)** Define the following in relation to moist air: 03
- (i) Relative humidity.
  - (ii) Wet bulb temperature.
  - (iii) Degree of saturation

(b) Show the following processes on a psychrometric chart:

04

- i. Sensible heating of air
- ii. Dehumidification of air

The weather report for a certain place is as follows:

- i. DBT = 25 °C
- ii. DPT = 18 °C
- iii. Barometric pressure = 760 mm Hg.

Using psychrometric chart, determine WBT, specific enthalpy, relative and absolute humidity of air at this place.

(c) Draw and explain phase diagram of a pure substance (water) showing various states on P-v coordinates and explain critical point. Using standard Steam

07

Tables determine the following for saturated steam at 10 bar pressure:

- i. Saturation temperature in °C
- ii. Entropy in kJ/kg K
- iii. Enthalpy of saturated steam in kJ/kg
- iv. Density in kg/ m<sup>3</sup>

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