Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III (NEW) EXAMINATION – SUMMER 2019

Subject Code: 2131404 Date: 11/06/2019

Subject Name: Food Engineering Thermodynamics

Time: 02:30 PM TO 05:00 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)** Why do gases deviate from ideal behaviour? Ten kilogram of CH_4 is injected into a 110 liter vessel containing oxygen at 2 bar absolute pressure and 13 ^oC. Calculate the partial pressure of methane gas and the total pressure in the container in kPa assuming isothermal process. **03**

(b) Write down Van *der* Waal's equation of state for real gases. Hundred kg of N_2 gas is stored in a 100 liter closed container at – 23 ^oC. Calculate the pressure of the gas in kPa using Van *der* Waal's gas equation. Take a = 0.137 Pa $(m^3/mole)^2$, b = 3.86 x 10^{-5} m^3/mole, R = 8.314 J/mole K **04**

(c) Answer the following: **07**

(i) State law of corresponding states.
(ii) If vacuum is 600 torr, calculate absolute pressure in kPa.
(iii) Write SI unit and dimensions of universal gas constant.
(iv) Calculate the specific gas constant of O_2 gas.
(v) Differentiate between cyclic and reversible process with an example.
(vi) Define ideal gas.
(vii) Show that $C_p - C_v = \bar{R}$ for ideal gases.

Q.2 **(a)** Explain Zeroth law of thermodynamics. List various types of thermometers and briefly explain the working principle constant volume type of thermometer. **03**

(b) Define flow work. Steam is steadily flowing through a turbine with inlet and outlet conditions given as: **04**

INLET CONDITION
h_1 = 3250 kJ/kg, v_1 = 0.07 m^3/kg, P_1 = 60 bar, t_1 = 550 ^oC
OUTLET CONDITION
h_2 = 3230 kJ/kg, v_2 = 0.08 m^3/kg, P_2 = 50 bar, t_2 = 480 ^oC
The heat loss due to poor body insulation is 16 kJ/kg. Calculate the steam inlet and outlet velocities in m/s and steam flow rate in kg/s. Assume that turbine inlet and outlet points are at the same elevation.

(c) Explain first law of thermodynamics. Prove that PV^{γ} = 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 5 ^oC to 25 ^oC by adding 55 kJ of heat. Calculate the work done and the change in internal energy of the system. **07**
[C_v = 742 J/kg K]

OR

(c) Define control volume. Derive SFEE for a stream of fluid entering and leaving a nozzle in terms of work and energy transfer per unit mass and state the assumptions made. **07**

Q.3 **(a)** For a 2-phase Liquid-Vapour system in thermal equilibrium, prove that: **03**

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{h_{fg}}{\overline{R}}\left[\frac{1}{T_1} - \frac{1}{T_2}\right].$$

(b) Explain different types of thermodynamic equilibria and state their conditions of stability. **04**

(c) Explain Joule-Kelvin effect. Prove that for a gas undergoing a throttling process, the Joule-Kelvin coefficient is given by **07**

$$\mu_{j,T} = \frac{1}{C_P}\left[T\left(\frac{\partial v}{\partial T}\right)_P - v\right]$$

Q.3 **(a)** Define entropy. A refrigerator is operating between -5°C and 35 °C at a COP of 60% of the maximum possible COP. If the refrigeration effect is 5TR, calculate the power requirement and the heat it has to reject to the ambient. **03**

(b) What is Gibb's phase rule? **04**

(i) Calculate the maximum number of phases in which a 2- component mixture can exist in equilibrium with each other.

(ii) Calculate the degrees of freedom of water at its triple point.

(c) Show that for any reversible thermodynamic process: **07**

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

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

(ii) $(\Delta s)_{1-2} \geq \int_1^2 \left(\frac{dQ}{T}\right)$.

Q.4 **(a)** Explain the following: (i) Carnot cycle (ii) Thermal reservoirs **03**

(b) Explain Carnot theorems. A heat engine is operating between two constant temperature reservoirs at 650 K and 270 K. The engine produces a net steady work output of 10 HP. If the thermal efficiency of the engine is 60% of the Carnot efficiency, calculate heat input to the engine and heat rejection in kW. **04**

(c) Explain Kelvin-Plank and Clausius statements of second law of thermodynamics. A heat engine produces 100 kW of power when operating between two thermal reservoirs maintained at 700°C and 70°C. The thermal efficiency of the engine is 50% of the maximum possible. Determine **07**

(i) The engine efficiency.

(ii) Rate of heat input to the engine.

(iii) Heat rejected.

Q.4 **(a)** Explain the following in related perspective: **03**

(i) Clausius inequality

(ii) Available and unavailable energy

(b) Explain the following: **04**
(i) Second law of thermodynamics (ii) PMM1 And PMM2

(c) Explain the operation of heat engine, refrigerator and heat pump with the help of schematic diagrams. A refrigerator is operating between source and sink maintained at 0^0C and 40^0C and respectively. The heat extracted from the source is 5 kW and the heat rejected to the sink is 60% more than what the system absorbs. Calculate the power requirement and COP of the device. What is the ratio of actual COP to the maximum possible COP? **07**

Q.5 **(a)** Define relative humidity. Prove that specific humidity of moist air is given by **03**

$$\omega = 0.622\left(\frac{p_w}{p_o - p_w}\right).$$

(b) Air at a certain place having a barometric pressure of 755 torr has a temperature of 25 ^{o}C. If the partial vapour pressure of water vapours present in unsaturated air is 24 mm Hg, calculate the following: **04**

(i) Specific humidity
(ii) Specific enthalpy
(iii) Relative humidity
(iv) Dew point temperature

(c) Explain phase diagram of water on a P-V diagram showing various states. Define and indicate the location of triple point. **07**
Using standard Steam Tables determine the following for saturated steam at 200 ^{o}C:

(i) Saturation pressure in kPa
(ii) Entropy in kJ/kg K
(iii) Enthalpy of saturated steam in kJ/kg
(iv) Specific volume m^3/kg

Q.5 **(a)** Define the following in relation to moist air: **03**

(i) Wet bulb temperature
(ii) Specific humidity
(iii) Dehumidification

(b) The weather report of Anand city on a summer day is recorded as: Atmospheric air temperature = is 42 ^{o}C **04**
WBT of air = 27 ^{0}C
Atmospheric pressure = 760 mm Hg.
Find out absolute humidity, enthalpy, relative humidity and dew point temperature.

(c) Explain the following for water/steam: **07**

(i) Superheated steam (ii) Critical temperature (iii) Sub-cooled water

A rigid vessel contains 100 kg saturated steam (x = 1) at a pressure of 8 bar. Calculate the following for using Steam Tables:
(i) Density in kg/m^3 (ii) Enthalpy in kJ
(iii) Internal energy in kJ (v) Entropy in kJ/K

****