Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER– III (NEW) EXAMINATION – SUMMER 2015

Subject Code: 2131404 **Date:04/06/2015**

Subject Name: Food Engineering Thermodynamics

Time:02.30pm-05.00pm **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** Define ideal and real gases. State key assumptions made by scientists to model ideal behaviour of gases. Why do real gases deviate from ideal behaviour? What correction factors were introduced by Van *der* Waal to describe real gases? A sealed container contains air at 87 ^oC and 1 bar. The container was evacuated using a vacuum pump so that the vacuum inside the can is recorded as 17324 Pa. Calculate the final temperature & absolute pressure inside the can. **07**

(b) State Zeroth law of thermodynamics and illustrate the concept of temperature measurement. List various types of thermometers and their principles of operation. Explain the functioning of any one of them. The platinum resistance element of a RTD thermometer has a resistance of 12 Ω at 0 ^oC and 15 Ω at 100 ^oC. Calculate the temperature coefficient of resistance (α) in / ^oC. **07**

Q.2 **(a)** State how first law of thermodynamics can be applied for closed systems operating in a cyclic and non-cyclic process. Write mathematical expressions in support of your answer. Prove that "$TV^{\gamma-1}$ = constant" for an ideal gas undergoing a reversible process. **07**

(b) Show that $C_p - C_v = \overline{R}$ for ideal gases and $C_p - C_v = 0$ for solids and liquids. The specific heat of 50 kg of a gas held in a container at constant pressure is empirically established as a function of temperature as given below: **07**

$$C_p = \left(\frac{1.05}{t+100} + 0.048 \right) \text{ J/kg K, where t is in } ^oC.$$

The container top has a movable lid which can move freely up and down. The container and its contents are heated at 1 bar uniformly until the volume increases from 2.5 liters to 3.5 liters and correspondingly the temperature increases from 5^oC to 127 ^oC. Calculate the following in SI units:

(a) The heat transfer during the process.
(b) Work done and its direction.
(c) Change in internal energy of the system.

OR

(b) Answer the following questions: **07**

(i) What is SI unit of specific gas constant?
(ii) Explain law of corresponding states.
(iii) Define enthalpy and specific heat and mention their SI units.
(iv) What do you understand by isothermal process?
(v) What is compressibility factor of gases?
(vi) Write SI units of Van der Waals constants 'a' and 'b'
(vi) What are intensive properties? Give examples.

Q.3 **(a)** Draw a properly labeled 'P-v diagram' of pure water showing various state points and zones of thermodynamic interest. Prove that for a 2-phase mixture of liquid and vapour of a pure substance, the specific volume of the mixture (v) is given by $v = v_f + xv_{fg}$, where the symbols have their usual meanings. Determine the following using Steam Tables for saturated steam at 8 bar pressure: **07**

(i) Saturation temperature in Kelvin
(ii) Specific Entropy in kJ/kg K
(iii) Latent heat of vaporization in kJ/kg
(iv) Enthalpy of saturated vapours in kJkg.

(b) Define steady and non-steady flow processes. Write down SFEE for a fluid flow process in terms of energy and work interactions. A steam turbine developing 400 kW receives a flow of 20 ton/h of steam at 100 m/s. The exit velocity of steam is 320 m/s. The inlet pipe is 5 m above the exhaust pipe. Using Steady Flow Energy Equation (S.F.E.E) calculate the change in enthalpy. **07**

OR

Q.3 **(a)** Show various state points of water on a "temperature-entropy diagram". Explain sub-cooling, superheating, critical point & triple point of water. Using Steam Tables, calculate the heat in kJ that will be is required to convert 5 kg water at 25°C to saturated steam at 1 bar and 125 ^{o}C? **07**

(b) What are functions of turbine and throttling device? Air having specific volume of 0.85 m^3/kg flows steadily at a rate of 0.5 kg/s through an air compressor entering at 5 m/s & 1 bar and leaving at 6 m/s & 8 bar having a specific volume of 0.16 m3/kg. The enthalpy of air leaving the compressor is 90 kJ/kg more than that of the air entering. The cooling water circulating in a jacket surrounding the cylinder absorbs heat from the air at the rate of 60 W. Calculate the power required to drive the compressor and the inlet and outlet cross-sectional areas of air flow ports. **07**

Q.4 **(a)** State second law of thermodynamics and explain the equivalence of Kelvin – Planck and Clausius statements with neat diagram. What do you mean by PMM1 And PMM2? **07**

(b) Define thermal reservoirs. Can a heat engine operate with only a high-temperature heat reservoir? Draw a block diagram of a heat engine indicating work-energy flow directions and write energy balance equations. How will you express its Carnot and actual thermal efficiency? A heat engine operating on Carnot cycle produces 100 kW of power while operating between temperature limits of 800°C and l50^{o}C. Determine the engine efficiency and the amount of heat input to the engine. **07**

OR

Q.4 **(a)** Prove that $\oint(\frac{dQ}{T}) < 0$; for any cyclic irreversible process. What is entropy? Explain its significance. Apply the Clausius inequality for a system which undergoes an irreversible cyclic change and show that the entropy change of the system is given by $(ds) \geq \frac{dQ}{T}$. **07**

(b) Prove that $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$ **07**

Explain the following with examples:

(i) Types of equilibria and conditions of stability.

(ii) Gibb's Phase rule

(iii) Joule Kelvin effect.

Q.5 **(a)** State practical applications of the following vis-a-vis food processing: **07**

(i) Hot and humid air

(ii) Cool dehumidified air

(iii) Hot dehumidified air

Atmospheric air for Anand city on a certain April day records the following:
Temperature = 40 ^oC
Barometric Pressure = 760 mm Hg
WBT = 27 ^oC

Using Psychrometric Chart determine:

(i) DPT in ^oC

(ii) %Relative humidity

(iii) DBT in ^oC

(iv) Specific humidity in kg/kg d.a

(b) Prove the following for a pure substance undergoing an infinitesimally reversible process: **07**

(i) dU = TdS – PdV

(ii) dH = TdS + VdP

(iii) dA = - (PdV + sdT)

(iv) dG = VdP – sdT

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

OR

Q.5 **(a)** Prove that for any gas undergoing a throttling process, **04**

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

(b) What is Gibb's phase rule? Calculate the degrees of freedom of water at 25 ^0C and 1 atmosphere pressure and at its triple point. State the types of equilibrium for a thermodynamic system and conditions for its stability. **03**

(c) Indicate the following processes on psychrometric chart for moist air: **07**

(i) Sensible cooling
(ii) Dehumidification and heating
(iii) Cooling and dehumidification
(iv) Heating and humidification

Atmospheric air on a certain day records the following:
Temperature = 38 ^{o}C
Barometric Pressure = 760 mm Hg
Relative humidity = 90%.
Using Psychrometric Chart determine:

(i) DPT in ^{o}C
(ii) WBT in ^{o}C
(iii) Absolute humidity in kg/kg d.a

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