Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

BE SEM-III Examination May 2012

Subject Code: 131404

Subject Name: Food Engineering Thermodynamics

Date: 10/05/2012 **Time: 02.30 pm – 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. **Use of Standard Steam Tables and Psychrometric Chart is permitted.**

Q.1 **(a)** State and explain the assumptions for ideal behaviour of gases and reasons why gases deviate from ideal behaviour. Write Van *der* Waals equation for real gases and mention S.I. units of various terms in the equation. Calculate the volume of CO_2 gas in liters at 21°C and 1 atmosphere pressure which would be produced by complete vaporization of 0.5 kg of dry ice (solid CO_2). Assume ideal gas behaviour and take R = 8.314 J/mol K. **07**

(b) Steam at 5 bar and 400°C enters a control volume through a pipe of 10 cm diameter at a velocity of 5 m/s and leaves the control volume at 4 bar and 375 °C through a pipe of 5 cm diameter. The steam flow through the pipe in a steady state. Determine **07**

(i) the flow rate of steam in kg/s and (ii) the exit velocity in m/s.

Data given: Specific Volume at 4 bar and 300 °C = 0.6549 m^3/kg
Specific Volume at 4 bar and 400 °C = 0.7725 m^3/kg
Specific Volume at 5 bar and 400 °C = 0.6172 m^3/kg

Q.2 **(a)** Explain the term enthalpy and express it in terms of state functions U, P and V. The heat capacity of a certain system at constant pressure is expressed as follows: $C_p = \left[2 + \frac{42}{t+100}\right]$ J/K, where t is temperature in °C. **07**

The system is heated at constant pressure till its volume increases from 2 liter to 3 liters & its temperature increases from 10 °C to 100 °C. Calculate

(i) The amount of heat exchange in J
(ii) The work done in J
(iii) The change in internal energy in J

(b) Draw a neat labeled T-s diagram of water as a pure substance indicating critical point, saturations lines, triple point line, superheated and sub-cooled zones. How much heat in kJ is required to convert 5 kg water at 25 °C to steam at 1 bar and 125 °C.? [Steam Tables can be used] **07**

OR

	(b)	Explain the following terms for a pure substance: (i) Mollier diagram (ii) Triple point (iii) Saturation state (iv) Dryness fraction Ten kilogram of wet steam (x = 0.7) is available in a rigid tank at 200 ^{o}C. Using steam tables calculate its specific volume (v) in m^3/kg, specific enthalpy (h) in kJ/kg, specific entropy (s) in kJ/kg K.	**07**
Q.3	**(a)**	One mole of an ideal gas with γ = 1.4 initially at 27^{o}C and 1 bar is compressed reversibly and adiabatically to 6 bar and then it is cooled at constant pressure to the original temperature. The gas is then restored to the initial state through an isothermal process. Calculate the net work and heat interaction.	**07**
	(b)	Specify the most widely used sign convention for work and heat interaction. Suppose an ideal gas which is initially at P_1, v_1, and T undergoes isothermal expansion till it reaches the final state P_2, v_2, and T. Estimate the work and heat interactions. For an ideal gas $u = u(T)$ only.	**07**
		OR	
Q.3	**(a)**	What is a polytropic process and how does it reduce to other known processes? Show these processes on P versus v diagram.	**07**
	(b)	Name a few measurements or quantities which can be used as thermometric properties. Air (ideal gas with γ = 1.4) at 4 bar and 350 K enters a reversible and adiabatic nozzle with negligible velocity and leaves at 1 bar. Calculate the velocity and temperature of the air leaving the nozzle. The molar mass of air is 29 x 10^{-3} kg/mol.	**07**
Q.4	**(a)**	Explain the terms – thermal reservoir, source and sink. What is meant by a heat engine and what are its characteristics? With help of a schematic diagram, mention the index of performance of a heat engine.	**07**
	(b)	Prove that violation of Clausius statement leads to violation of Kelvin – Planck statement of the second law of thermodynamics.	**07**
		OR	
Q.4	**(a)**	State the Carnot theorems which are the consequences of second law of thermodynamics. It is proposed to design a cold storage for maintaining certain vegetables under frozen conditions at –20^{o}C. The ambient temperature in summer is 37^{o}C and the estimated energy transfer as the heat into the cold stotage through the doors, walls and roof is 3 kJ/s. Determine the minimum power required to operate a refrigeration plant for maintaining the cold storage.	**07**
	(b)	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 $dS \geq dQ/T$.	**07**

Q.5 **(a)** Prove that mass of moist air per kg dry air is given by (1+ ω), where ω is the specific humidity of moist air in kg/kg d.a. For a certain location the following data are available for the atmospheric air: **07**

Temperature = 35 °C
Barometric Pressure = 760 mm Hg
Relative humidity = 70%

Using Psychrometric Chart determine

(i) Absolute humidity in kg/kg d.a
(ii) Dew point temperature in °C
(iii) Wet bulb temperature in °C
(iv) Dry bulb temperature in °C
(v) Mass of moist air in kg/kg d.a
(vi) Specific volume in m^3/kg d.a.

(b) Write an expression for Joule-Kelvin coefficient (μJ, T) as a function of temperature, pressure and specific enthalpy of a gas undergoing a throttling process. If for real gases $\mu_{J,T} = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - v\right]$, prove that $\mu_{J,T} = 0$ for ideal gases & the temperature remains constant during the process. **07**

OR

Q.5 **(a)** Explain 'Dew point temperature' and Relative humidity' in relation to moist air. The following data are available for a moist air sample: **07**

Partial vapour pressure of water vapour in air = 15 mm Hg (0.02 bar)
Saturation pressure of moisture in air (p_s) = 20 mm Hg
Atmospheric pressure = 730 mm Hg
Dry bulb temperature = 20 °C

Calculate (i) Dew point temperature in °C
(ii) % Relative humidity
(iii) Specific humidity in kg/kg d.a
(iv) Specific enthalpy in kJ/kg d.a

(b) What is Gibb's Phase rule? Using this rule find out the thermodynamic degrees of freedom for the following systems in equilibrium: **07**

(i) A single-phase mixture of ammonia and water.
(ii) Water at critical point.
(iii) A two-phase mixture of benzene and toluene.
(iv) Ice at – 20 °C
(v) Three phase mixture of water.
(vi) Two-phase mixture of ethanol, methanol and water.

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