Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

B.E. Sem-III Remedial Examination May 2011

Subject code: 131404 Subject Name: Food Engineering Thermodynamics

Date: 28-05-2011 **Time: 10.30 am – 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. **Use of Steam Tables and Psychrometric Chart is permitted**

Q.1 **(a)** Define and differentiate between ideal gas and real gas. Write ideal and Van *der* Waals real gas equation, specifying what do the various terms in the equation stand for and mention their S.I. units. Oxygen gas is stored in a 1000 litre tank at a temperature of 27 ^{o}C and 5 bar gauge pressure. Calculate the mass of oxygen in kg assuming that it behaves ideally. [Take R = 8.314 J/mol K and Atmospheric pressure = 1 bar] **07**

(b) What is a steady flow process? In a steady flow apparatus, 200 kJ of work is done by each kg of fluid. The specific volume of the fluid, pressure and velocity at the inlet are 0.35 m^3/kg, 600 kPa and 15 m/s. The inlet is 6 m above the floor and the discharge pipe is at the floor level. The discharge conditions are 0.6 m^3/kg, 100 kPa and 250 m/s. The total heat loss between the inlet and discharge is 12 kJ/kg of fluid. In flowing through this apparatus, does the specific internal energy increase or decrease, and by how much? **07**

Q.2 **(a)** Define specific heat at constant pressure (C_p), specific heat at constant volume (C_v) and prove that for an ideal gas, $C_p - C_v = \bar{R}$ and for solids and liquids, Cp – C_v = 0. A gas is compressed ideally from initial volume of 0.4 m^3 to a final volume of 0.2 m^3 at a constant pressure of 1 bar. During this process 50 kJ heat was removed from the system. Calculate the work done and the accompanying change in internal energy in kJ specifying proper sign convention. **07**

(b) Prove that the specific volume of a 2-phase mixture (L +V) of water is given by $v = v_f + x\, v_{fg}$, where x is the dryness fraction of the mixture. Ten kg of wet steam at 120 ^{o}C containing 75% steam and 25% water in liquid state is allowed to completely condense to water at 94 ^{o}C during a certain process. Calculate the amount of heat released in the process in kJ. **07**

OR

(b) Draw a neat labeled P-v diagram of a pure substance (Water) clearly showing its different states and explain the terms: boiling point, saturation temperature and pressure, critical point, triple point. Using Steam Tables, determine the latent heat of vaporization (h_{fg}) at (i) Triple point (ii) 100 ^{o}C (iii) 225 ^{o}C (iv) 300 ^{o}C (v) Critical point. Do you see any pattern in the successive values of h_{fg}? Comment. **07**

Q.3 **(a)** With the help of schematic diagram, explain briefly the operation of a heat engine, a refrigerator and a heat pump clearly mentioning their indices of performance. Show that $(COP)_{HP} = 1 + (COP)_R$. **07**

(b) At the start of compression in a diesel engine air is at a pressure of 200 kPa and 25 ^{0}C. The air is compressed till the final volume is 1/16th of the original volume. The compression process is expected to follow the polytropic process $PV^{1.25}$ = constant. Determine **07**

(i) The pressure and temperature of the gas at the end of compression
(ii) The work done on the gas
(iii) The energy transfer as heat per mole of air

OR

Q.3 **(a)** State the first law of thermodynamics for a cyclic process. Enumerate the consequences and practical limitations of first law of thermodynamics. **07**

(b) What are the characteristics of a heat engine? It is proposed to construct a refrigeration plant for a cold storage to be maintained at - 4 ^{0}C. The ambient temperature is 35 ^{0}C. If 5 x 10^6 kJ/h of energy has to be continuously removed from the cold storage, estimate the minimum power required to run the refrigerator. **07**

Q.4 **(a)** What do you mean by a carnot engine? Draw the schematic diagram of a carnot engine operating between source temperature T_1 and sink temperature T_2 and derive the expression for its efficiency. Also draw the P- V and T- S diagram for this carnot cycle. **07**

(b) What do you mean by a Perpetual Motion Machine of First Kind (PMM1)? State the Kelvin –Planck statement of the second law of thermodynamics. Briefly explain the violation of Kelvin –Planck statement implies violation of Clausius statement through illustrative diagram. **07**

OR

Q.4 **(a)** State the zeroth law of thermodynamics. Briefly explains the reference points on which the celcius scale is based. Show diagrammatically the sign convention for heat and work interactions. **07**

(b) Briefly explain the statement of Clausius Inequality and concept of entropy. **07**

Q.5 **(a)** For an infinitesimally reversible thermodynamic process, prove the following Maxwell's equations: **04**

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

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

(b) Define thermodynamic degrees of freedom. Explain Gibb's phase rule for multi-component and multi-phase systems. A mixture of Benzene and & Toluene is in equilibrium with its own vapours. How many independent properties are required to fix the state of the system? Mention the different set of intensive properties which can be used to describe the state of the system. **05**

(c) Explain the terms 'Wet Bulb Temperature' 'Dew Point Temperature' and 'Relative Humidity'. The atmospheric air at a hill station is at a pressure of 750 mm Hg, 27 ^{o}C DBT & 18 ^{o}C WBT. Calculate specific humidity in kg w.v./kg d.a., % relative humidity and dew point temperature at this location. **05**

OR

Q.5 **(a)** Prove the following for a pure substance undergoing an infinitesimally reversible process: **04**

(i) dU = TdS – PdV (ii) dH = TdS + VdP

(iii) dA = - (PdV + sdT) (iv) dG = VdP − sdT

(b) Prove that specific humidity and mass of moist air per kg of dry air are given by: **05**

$\omega = 0.622\left(\frac{p_\omega}{p - p_\omega}\right)$ and m = (1+ ω) kg respectively. On a particular summer day the weather report for a certain city states the following: Atmospheric pressure = 1.01325 bar, Air temperature = 38 ^oC & Relative humidity = 60%. Using Psychrometric chart find out the following: Dry Bulb Temperature (DBT), Wet Bulb Temperature (WBT), Absolute humidity in kg/kg d.a., Dew point temperature, Specific volume in m^3/kg d.a. & Specific enthalpy in kJ/kg d.a.. Indicate your findings on the Psychometric chart and attach it with your answer script.

(c) Starting from the Gibb's equation "dg = vdP –sdT" prove that, for a vapour-liquid system in equilibrium, **05**

$\left(\frac{dP}{dT}\right) = \left(\frac{h_{fg}}{T \times v_{fg}}\right)$. Estimate the approximate pressure at which water would boil at 157 ^oC if it is known that it boils at 100 ^oC at 1.01325 bar.

[Take R = 8.314 J/ mol K, and Mol. Wt. of water = 18; h_{fg} at 100 ^0C = 2257 kJ/kg]

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