Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

B.E. Sem-III Regular / Remedial Examination December 2010

Subject code: 131404

Subject Name: Food Engineering Thermodynamics

Date: 16 /12 /2010 **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 Standard Steam Tables and Psychrometric Chart is permitted.**

Q.1 **(a)** Compare the behaviour of ideal and real gases and explain why and how real gases deviate from ideal behaviour? State the law of corresponding states for gases. **07**

A sealed container of 300 litres volume contains nitrogen gas at a temperature of –73 ^oC and 20 bar pressure. Calculate the mass of nitrogen gas in kg using

(i) Ideal gas equation

(ii) Real gas equation of state incorporating compressibility factor.

[Take R = 8.314 J/mol K, z = 0.68]

(b) Differentiate between a nozzle and a diffuser. At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end, the enthalpy is 2762 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it. **07**

(i) Find the velocity at exit from the nozzle.

(ii) If the inlet area is 0.1 m^2 and the specific volume at inlet is 0.187m^3/kg, find the mass flow rate.

If the specific volume at the nozzle exit is 0.498 m^3/kg, find the exit area of the nozzle.

Q.2 **(a)** Define enthalpy and specific heats C_p and C_v. Establish that $C_p - C_v = \overline{R}$ for ideal gases. The temperature of 4 kg of a gas held in a rigid cylinder was increased from 20 ^oC to 30 ^oC by adding 25 kJ of heat externally. Calculate the work done and the effected change in internal energy of the system. Specify the direction and nature of the change. **07**

[Take C_v = 745 J/kg K]

(b) Show different states of a pure substance (Water) on a neatly drawn P-v diagram and explain the following terms in perspective: **07**

(i) Critical temperature (ii) Triple point

(iii) Wet vapours (iv) Superheated vapours.

Using Steam Tables determine the following:

(i) State of water at 120 ^oC and 2.25 bar.

(ii) Saturation pressure of water at 180 ^oC.

(iii) h_g at 125 ^oC and 1 bar.

(iv) s_g at 140 ^oC.

(v) Saturation temperature at 1 MPa.

(vi) h_{fg} at critical temperature.

OR

	(b)	Define dryness fraction of steam. For a 2-phase mixture (Liquid + Vapour) of water, prove that the specific volume can be represented as $v = v_f + x\, v_{fg}$, where x is the dryness fraction of steam. What is the state of water when x = 1 and x = 0? A rigid vessel contains wet steam (x = 0.971) at a pressure of 2 bar. Calculate the following for wet steam using Steam Tables: (i) Saturation temperature (ii) Specific volume in m^3/kg (iii) Enthalpy in kJ/kg (iv) Internal energy in kJ/kg	**07**
Q.3	**(a)**	A fluid is confined in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume (p = a + bV). The internal energy of the fluid is given by the following equation $U = 50 + 3.15\, pV$ Where, U is in kJ, p in kPa and V in cubic meter. If the fluid changes from an initial state of 170 kPa, 0.03 m^3 to a final state of 400 kPa, 0.06 m^3, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer.	**07**
	(b)	With the help of schematic diagram, explain the operation of a heat engine, a refrigerator and a heat pump clearly mentioning their indices of performance. Show that the COP of a heat pump is one more than the COP of a refrigerator.	**07**
		OR	
Q.3	**(a)**	State the first law and Clausius's statement of second law of thermodynamics. Enumerate the consequences and practical limitations of first law of thermodynamics.	**07**
	(b)	It is desired to compress isothermally one kmol of ammonia from the initial state of 25 m^3/kmol and 27 ^{0}C to final state of 5m^3/kmol and 27 ^{0}C. It is known that ammonia obeys the relations $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ and $du = C_v.dT + \frac{a}{V^2}.dV$ Where, a = 423.3 kPa $(m^3/kmol)^2$ b = 0.0373 m^3/kmol R = 8.314 kJ/kmol.K C_v = 27.2376 kJ/kmol.K Calculate the heat and work interaction associated with the compression process.	**07**
Q.4	**(a)**	What do you mean by a heat engine? A cyclic heat engine operates between a source temperature of 600 ^{0}C and a sink temperature of 30 ^{0}C. What is the least rate of heat rejection per kW net output of the heat engine?	**07**
	(b)	State the Kelvin –Planck statement of the second law of thermodynamics. Briefly explain a Perpetual Motion Machine of Second Kind (PMM2) with schematic diagram.	**07**
		OR	
Q.4	**(a)**	Briefly explain the statement of Clausius Inequality and the criterion of the reversibility of a cycle. Justify the statement "The second law of thermodynamics- a directional law of nature"	**07**
	(b)	State the zeroth law of thermodynamics. Explain briefly the triple point of water showing its different state. At what temperature and pressure triple point of water exists?	**07**
Q.5	**(a)**	Define the following for moist air: (i) Dry bulb temperature (ii) Wet bulb temperature (iii) Dew point temperature (iv) Relative humidity (v) Degree of saturation (vi)Adiabatic saturation temperature.	**05**

The weather report for a certain place states that atmospheric air is at 27 ^oC DBT, 18 ^oC WBT and a pressure of 750 mm Hg. Calculate specific humidity in kg w.v./kg d.a., specific enthalpy in kJ/kg d.a., % relative humidity and dew point temperature at this location.

(b) What do you understand by thermodynamic degrees of freedom? State Gibb's phase rule to determine degrees of freedom. Calculate degrees of freedom for the following thermodynamic systems: **05**

(i) Water at 27 ^oC and 1 bar
(ii) Water at critical point
(iii) Water in superheated state
(iv) Water at triple point
(v) A 2-phase equilibrium mixture NH_3 and H_2O

(c) For a pure substance undergoing an infinitesimal reversible process prove the following thermodynamic property relationships: **04**

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

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

OR

Q.5 (a) Prove that absolute humidity (ω) of moist air per kg of dry air are given by: **05**

$$\omega = 0.622\left(\frac{p_\omega}{p - p_\omega}\right)$$

The weather report of a city on a particular summer day states the following:

Atmospheric pressure = 1.01325 bar,
Air temperature = 40 ^oC &
Relative humidity = 60%.

Using Psychrometric Chart find out the following: (i) Dry Bulb Temperature (DBT), (ii) Wet Bulb Temperature (WBT), (iii) Absolute humidity in kg/kg d.a., (iv) Mass of moist air in kg/kg d.a., (v) Dew point temperature, (vi) Specific volume in m^3/kg d.a. & (vii) Specific enthalpy in kJ/kg d.a. Mark the findings on the Psychometric chart and attach it with your answer sheet.

(b) Explain Joule–Kelvin coefficient specifying its importance. **05**

For a 2-phase Liquid-Vapour system in thermal equilibrium, prove that: $\ln\left(\frac{P_2}{P_1}\right) = \frac{h_{fg}}{\overline{R}}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$.

Using the above equation calculate the pressure in bar at which water would boil at 157 ^oC if at 1 atmosphere it boils at 100 ^oC.

[Take R = 8.314 J/ mol K, h_{fg} (at 100 ^oC) = 2257 kJ/kg]

(c) Prove that for an ideal gas the point function state variables P,V,T are interrelated as follows: **04**

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

(ii) $\left(\frac{\partial V}{\partial T}\right)_P = \frac{1}{\left(\partial T/\partial V\right)_P}$

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