Seat No.: ________ Enrolment No.______________

GUJARAT TECHNOLOGICAL UNIVERSITY
BE SEM-III Examination-Dec.-2011

Subject code: 131404 **Date: 17/12/2011**
Subject Name: Food Engineering Thermodynamics
Time: 2.30 pm -5.00 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 'Law of corresponding states' for ideal gases and prove that $PV_{real} = z\ n\ R\ T$, where z is compressibility factor. A tank of 250 liter volume contains CO_2 gas at a pressure of 1.03 bar and 20 ^oC. If 250 gram of additional CO_2 gas is injected into the tank, determine the new pressure in bar assuming that the temperature remains constant and the gas obeys ideal gas law. Take R = 8.314 J/mol K. **07**

(b) Compare and contrast the properties of a control mass and a control volume. **07**
Dry saturated steam at 5 bar enters an adiabatic nozzle at a velocity of 2 m/s and leaves as dry saturated steam at 2 bar. Calculate the exit velocity of the steam.
Data given: Specific enthalpies of inlet and exit steam are 2747.5 kJ/kg and 2706.3 kJ/kg respectively.

Q.2 (a) Explain the following with the help of suitable diagrams wherever applicable: **07**
- (i) Reversible and irreversible process
- (ii) Gauge and absolute pressure
- (iii) Closed and open system
- (iv) State and path
- (v) Isenthalpic and isothermal process
- (vi) Extensive and intensive properties
- (vii) Enthalpy and specific heat

(b) Write mathematical expressions for C_P and C_v in terms of state functions (t,h,p) and (t,u,v) respectively and prove that $C_p - C_v = \overline{R}$ for ideal gases and $C_p - C_v = 0$ for solids/liquids. Five kilogram of CO_2 gas is heated reversibly at constant pressure from an initial state of [T = 300 K, P= 1.2 bar] until its volume triples. Calculate the work done, change in internal energy and enthalpy in kJ. **07**
[Take Cp = 30 J/mol K, R = 8.314 J/mol k]

OR

(b) Draw a labeled P-V diagram of a pure substance showing its various states. **07**
Show that the specific volume of wet steam is given by $v = v_g + (1–x)\ v_{fg}$.
Using Steam Tables determine the following for saturated steam at 1 MPa:
- (i) Saturation temperature in ^oC
- (ii) Latent heat of vaporization (h_{fg}) in kJ/kg

(iii) Specific volume in m^3/kg

Q.3 **(a)** Air (ideal gas with $\gamma = 1.4$) enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K, and a velocity of 6 m/s through an inlet with an area of 0.1 m^2. At the exit, the pressure is 7 bar, the temperature is 450 K, and the velocity is 2 m/s. The compressor is horizontal and heat transfer from the compressor to its surroundings occurs at a rate of 180 kJ/min. Employing the ideal gas model, calculate the power input to the compressor, in kW. **07**
Given that : Specific enthalpies at 290 K and 450 K are 290.16 kJ/kg and 451.8 kJ/kg respectively

(b) What is a Carnot heat pump or Carnot refrigerator? Express the coefficient of performance (COP) a Carnot heat pump and Carnot refrigerator in terms of temperature of the thermal reservoirs between which they operates. Derive a relationship between their COP. **07**

OR

Q.3 **(a)** Prove that violation of Kelvin-Planck statement leads to violation of Clausius statement of the second law of thermodynamics. **07**

(b) State the Clausius inequality and define entropy. **07**
A reversible heat engine delivers 0.65 kW power and rejects energy at the rate of 0.4 kJ/s to a reservoir at 27°C. Determine the efficiency of the engine and the temperature at which energy is absorbed by the engine.

Q.4 **(a)** State the important consequences of the first law of thermodynamics. **07**
One kg of ice at 0°C is completely melted into water at 0°C at 1 bar pressure. Given that the latent heat of fusion is 333.44 kJ/kg and the densities of the water and ice at 0°C are 999.85 kg/m^3 and 916.23 kg/m^3, respectively, calculate the work done and energy transfer as heat.

(b) In a piston – cylinder assembly one mole of air is compressed from the initial state of 300K and 1 bar till its volume is reduced to 1/15 of its original volume. The compression process can be approximated as $Pv^{1.25}$ = constant. Determine the **07**
(i) pressure and temperature of the gas at the end of compression process
(ii) work done on the gas and
(iii) the energy transfer as heat.
The air may be treated as an ideal gas.

OR

Q.4 **(a)** What conclusions can be drawn from the first law of thermodynamics for a system undergoing adiabatic process? Estimate the work done by an ideal gas, if it undergoes a reversible adiabatic expansion from P_1, v_1, T_1 to P_2, v_2, T_2. It is know that the internal energy of an ideal gas is a function of temperature only. That is, for an ideal gas $u = u(T)$ only. **07**

(b) Distinguish between extensive and intensive properties with the help of an example. **07**
It is desired to compress one mole of air (ideal gas with $\gamma = 1.4$) from 1 bar and 27°C to 10 bar and 27°C. For this purpose compare the work to be done for the following processes:
(i) isothermal compression
(ii) constant volume heating followed by a constant pressure compression

Q.5 **(a)** Differentiate between 'Wet bulb temperature' and 'Adiabatic saturation' temperature of moist air. Air at a certain location has a temperature of 35 **07**

^{o}C and the partial vapour pressure of water vapours present in the air is 15 mm Hg. A barometer installed at that location reads 750 mm Hg. Calculate the following:

(i) Dry bulb temperature (ii)Relative humidity
(ii) Absolute humidity (iv)Dew point temperature
(v) Specific enthalpy of moist air

(b) What is the purpose of developing thermodynamic property relationships for pure substances? For a compressible gaseous system prove that: **07**

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

OR

Q.5 **(a)** Draw a profile sketch of psychrometric chart indicating various properties of moist air and show the following processes on the drawn chart: **07**

(i) Sensible cooling (ii)Humidification
(ii) Sensible heating (iv) Cooling and dehumidification
(v) Dehumidification

For an atmospheric air at 40^{o}C DBT and 50% RH. Determine specific humidity in kg/kg d.a., specific enthalpy in kJ/kg d.a. DPT in ^{o}C and WBT in ^{o}C of the air using a standard psychrometric chart.

(b) State Gibb's phase rule with an example. Explain with examples the various equilibrium states of a thermodynamic system. What are the conditions of stability? Prove that for stability of a thermodynamic system, we must have $\left(\frac{T}{C_v}\right) > 0$ **07**

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