Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III • EXAMINATION – SUMMER • 2014

Subject Code: 131404 **Date: 28-05-2014**

Subject Name: Food Engineering Thermodynamics

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.**

Q.1 **(a)** Define real gases and explain clearly why and when they deviate from ideal behaviour. A vessel of 4.5 m^3 volume contains oxygen at 27 ^{0}C and 1 bar pressure. The vessel is evacuated isothermally to a vacuum of 730 mm Hg. Calculate the mass of oxygen pumped out in kg. The vessel is then cooled to 7^0C. Calculate the vacuum inside the vessel in mm Hg after cooling. **07**
[Take R = 8.314 J/mol K]

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

(i) If absolute pressure is 8000 Pa, calculate vacuum in mm Hg.
(ii) Prove that $C_p - C_v = \bar{R}$ for ideal gases.
(iii) State the law of corresponding states.
(iv) A gas is heated at constant volume so that its temperature doubles. Indicate the process on a T-s diagram.
(v) Calculate the specific enthalpy change when water (C_p= 4.186 kJ/kg K) at 20 ^{0}C is heated to 80 ^{0}C at constant pressure.
(vi) An insulated rigid cylinder containing CO_2 gas falls from a height of 5m so that 1.32 MJ energy is added to the system as work. Calculate the change in internal energy in MJ.
(vii) What is compressibility factor of gases?

Q.2 **(a)** State Zeroth law of thermodynamics and explain how it facilitates measurement of temperature. The thermodynamic property "p" of a system is related to temperature 't' on a thermometric scale as follows: **07**

$t = C_1 \ln p + C_2$, where, C_1 and C_2 are constants and t is in ^{0}C.

The values of 'p' at ice point and steam points are 3 and 8 respectively. Calculate the temperature corresponding to p = 4 on the thermometer.

(b) State first law of thermodynamics for a closed system undergoing a state change process. An ideal gas is allowed to expand isothermally in a reversible manner. **07**

Establish that the work done per mole of gas is given by $W = nRT \ln \frac{V_2}{V_1}$.

One kmol of NH_3 gas at 300 K is compressed isothermally from initial volume of 3 m^3 to a final volume of 1 m^3. If the accompanying change in internal energy is 150 kJ/kmol, calculate the net work done and heat transfer in kJ. [Take R = 8.314 J/mol K]

OR

(b) Write a generalized mathematical expression for first law of thermodynamics. Show that for an ideal gas undergoing a reversible adiabatic process **07**

$T\,(V)^{\gamma - 1}$ = Constant, where $\gamma = \dfrac{C_p}{C_v}$.

An ideal gas at 30 bar & 227 ^{0}C expands isentropically to 6–times its original volume. Calculate

(i) Its final temperature and pressure.

(ii) The work done during the process in kJ/kg.

[Take C_p = 1.02 kJ/kg K, C_v = 0.72 kJ/kg K]

Q.3 **(a)** Differentiate between steady and non-steady flow processes with atleast one example. Write down SFEE for a fluid stream entering and exiting a turbine. For a steady flow of steam through a turbine the following data are available: **07**

Inlet	Outlet
P_1 = 60 bar t_1 = 510 ^{0}C h_1 = 3500 kJ/kg v_1= 0.07 m^3/kg	P_1 = 48 bar t_1 = 480 ^{0}C h_1 = 3480 kJ/kg v_1= 0.08 m^3/kg

A heat loss of 10 kJ/kg occurs through the turbine due to inadequate insulation. Calculate the inlet and outlet velocities of steam in m/s. Assume inlet and outlet cross-sectional areas and elevations are same.

(b) Define unavailable energy and state Clausius statement of second law of thermodynamics. A heat engine is operating between two thermal reservoirs maintained t 227 ^{0}C and 27 ^{0}C. The heat input to the engine is 18kW and the associated heat rejection is 12 kW. Calculate the thermal efficiency of the engine and compare it with the maximum possible theoretical efficiency. **07**

OR

Q.3 **(a)** Write down generalized SFEE for a fluid stream entering and leaving a control volume of a device in terms of its K.E., P.E., enthalpy, heat and work interactions. Using this SFEE show that for steady flow of an ideal gas through a nozzle the exit velocity can be given by $V = \sqrt{2C_p\left(T_2 - T_1\right)}$, where C_p is the specific heat of gas at constant pressure in kJ/kg K, T_1 and T_2 are inlet and outlet temperatures respectively in K. Assume adiabatic conditions, no external work interaction and same elevation of inlet and outlet ports. **07**

(b) Demonstrate the equivalence of Kelvin-Plank and Clausius statement of second law of thermodynamics. A reversible heat engine is attached between two thermal reservoirs maintained at 480 K and 300 K. The reservoir maintained at higher temperature transfers heat to the engine by steady state conduction @ 2 kW. Calculate the work output generated by the engine and the % heat rejected w.r.t. to the input. **07**

Q.4 **(a)** Prove that for a thermodynamically feasible cyclic process $\oint \dfrac{dQ}{T} \leq 0$. **05**

(b) If P,V,T G and S are point functions, prove the following: **05**

(i) dG = VdP – SdT

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

(c) Explain Gibb's phase rule with an example. Calculate the degrees of freedom of water at its triple point. State the thermodynamic conditions for stable equilibrium of a system. **04**

OR

Q.4 **(a)** An ideal gas is undergoing a reversible process 1 → 2. **05**

Show that $(\Delta s)_{1\to 2} = C_v \ln \left[\frac{\left(\frac{T_2}{T_1}\right)^{\gamma}}{\left(\frac{P_2}{P_1}\right)^{\gamma-1}}\right]$.

Treat the symbols to have their usual meanings.

(b) If P,V,T H and S are point functions, prove the following: **05**

(i) dH = TdS + VdP

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

(c) Calculate the thermodynamic degrees of freedom of a component mixture of water and ammonia which exist in liquid state together. State thermodynamic conditions for a system in a state of meta-stable equilibrium. **04**

Q.5 **(a)** Define the following terms: **07**

(i) Dryness fraction of steam (ii) Critical point of water
(iii) Sublimation (iv) Saturated steam

Using steam tables, calculate the specific enthalpy, saturation temperature, specific volume of steam at 15 bar and 0.8 dryness fraction.

(b) Explain the following w.r.t. moist air: **07**

(i) Relative humidity (ii) Dew point temperature
(iii) Sensible heating (iv) Adiabatic saturation temperature

Moist air at a certain location is at 30 ^{0}C, 80% RH, 1 atmosphere pressure. Determine its WBT, DPT and specific enthalpy using Psychrometric chart.

OR

Q.5 **(a)** Draw a neat P-V phase diagram of water indicating all state points and define the following terms: **07**

(i) Saturation temperature (ii) Critical point
(iii) Triple point (iv) Normal boiling point

Using steam tables, calculate the specific enthalpy and entropy of saturated steam at 7 bar.

(b) Explain the following w.r.t. moist air: **07**

(i) Wet Bulb Temperature (ii) Relative humidity
(iii) Specific humidity (iv) Sensible cooling

Using Psychrometric chart, determine % RH, DPT and specific enthalpy of moist air at 35 ^{0}C DBT, 1 atmosphere, and 25 ^{0}C WBT.

****