Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–III EXAMINATION – WINTER 2015

Subject Code:131404 **Date:29/12/2015**

Subject Name: Food Engineering Thermodynamics

Time: 2:30pm to 5:00pm **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)** What are ideal gases? Explain the causes for deviation of gases from ideal behaviour. What correction factors were introduced by Van *der* Waal to this effect? An insulated rigid vessel of volume 2V is divided into 2-equal compartments by a removable partition. Both compartments contain the same ideal gas. The temperature and pressure on one side of the partition is (P_1, T_1) and on the other side it is (P_2, T_2). The partition is removed gradually so that the gases mix slowly to attain an equilibrium state. Show that the final temperature and pressure (P, T) will be given by $P = \frac{P_1 + P_2}{2}$ and $T = \frac{T_1 T_2 (P_1 + P_2)}{P_1 T_2 + P_2 T_1}$. **07**

(b) Explain the following in perspective : **07**

(i) Law of corresponding states
(ii) Reversible process
(iii) Gauge pressure

An insulated rigid tank of 5 m^3 volume contains 25 kg of nitrogen gas at 4 bar pressure. A paddle wheel is rotated inside the tank so that its pressure increases to 8 bar. Calculate the following:

(i) Net heat transfer (ii) Change in internal energy
(iii) Work done (iv) Entropy change.

Express your answers in S.I. System of units with proper sign convention.
[Take C_p = 1.04 kJ/kgK, R = 8.314 J/mol K]

Q.2 **(a)** Stare Zeroth law of thermodynamics and explain how it serves as a basis for temperature measurement. A platinum resistance thermometer has a resistance of 3 Ω at 0 ^oC and 4 Ω at100 ^oC. Calculate the temperature coefficient of resistance (α) in per ^oC. What would be the temperature in Kelvin when the thermometer indicates a resistance of 9 Ω? **07**

(b) Explain first law of thermodynamics for a closed system operating in a cycle. Write corresponding non-flow energy equation (NFEE) for such a process. An ideal gas is undergoing a reversible adiabatic process (1↔2). Prove that the work done by the system during this process is at the expense of its internal energy change and is given by $W = \frac{m\bar{R}}{\gamma - 1}(T_1 - T_2)$. Symbols have their usual meanings. **07**

OR

(b) State the first law of thermodynamics. An ideal gas is undergoing a reversible adiabatic process (1↔2). Prove that $PV^{\gamma} =$ Constant. Five kilogram of an ideal gas at 227 ºC and 30 bar pressure expands isentropically through a volume ratio of 6:1. Calculate the work done during the process in kJ. **07**
[Take C_p = 1.025 kJ/kgK, C_v = 0.714 kJ/kgK]

Q.3 **(a)** Define steady flow process giving appropriate examples. Write down SFEE for a fluid stream entering and leaving a control volume in terms of work and energy transfer per unit mass. Steam is flowing through a horizontal nozzle in steady state. The inlet and outlet conditions given are: **07**
INLET: h_1 = 3000 kJ/kg, V_1 = 100 m/s, A_1 = 0.1 m^2, v_1 = 0.19 m^3/kg
OUTLET: h_2 = 2760 kJ/kg, v_2 = 0.5 m^3/kg.
Calculate (i) Exit velocity in m/s
(ii) Mass flow rate of steam in kg/s
(iii) Exit area of the nozzle in m^2

(b) What are thermal reservoirs? Explain the operation of a heat engine with the help of a neat diagram. Write down energy balance equations. A heat engine operating between two constant temperature reservoirs at 450 K and 300 K is producing a net steady work output of 5 kW. If the thermal efficiency of the engine is 90% of the maximum possible efficiency; calculate the heat input to the engine and the associated heat rejection in kW. **07**

OR

Q.3 **(a)** Define flow work. Write down SFEE for a fluid stream entering and leaving a diffuser in terms of work and energy transfer per unit time. Steam is steadily flowing through a turbine with inlet and outlet conditions given as: **07**
INLET: h_1 = 3215 kJ/kg, v_1 = 0.075 m^3/kg, P_1 = 50 bar, t_1 = 400 ºC, d_1 = 0.25m
OUTLET: h_2 = 3200 kJ/kg, v_2 = 0.085 m^3/kg, P_2 = 40 bar, t_2 = 390 ºC, d_2 = 0.25m
The heat loss due to poor insulation is 9 kJ/kg. Assuming turbine inlet and outlet points to be at the same elevation, calculate the steam inlet and outlet velocities in m/s and its flow rate in kg/s.

(b) State and explain Kelvin-Plank statement of second law of thermodynamics. What do you mean by PMM1 And PMM2? Draw neat P-V and T-s diagram of a Carnot cycle showing various state points/processes and explain the practical significance of such a cycle. **07**

Q.4 **(a)** Explain Clausius inequality. Show that for any thermodynamic process (1→2), **07**
$(\Delta s)_{1-2} \geq \int_1^2 (\frac{dQ}{T})$, where Δs is the entropy change during the process in kJ/K and dQ is the heat interaction at absolute temperature T.

Q.4 **(b)** Explain Joule-Kelvin effect with the help of a T-P diagram. Prove that for any gas undergoing a throttling process, $\mu_{j,T} = \frac{1}{C_P}\left[T\left(\frac{\partial v}{\partial T}\right)_P - v\right]$ **04**

Q.4 **(c)** Define thermodynamic degrees of freedom and state Gibb's phase rule. Calculate the degrees of freedom of water at its triple point. **03**

OR

Q.4 **(a)** Prove that $\oint(\frac{dQ}{T}) < 0$; for any cyclic irreversible process. **07**

An ideal gas is undergoing a reversible process (1↔2). Show that the specific entropy change for this process is given by $(\Delta s)_{1-2} = C_v \ln\left(\frac{P_2V_2^{\gamma}}{P_1V_1^{\lambda}}\right)$.

Q.4 **(b)** Prove the following: **04**

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

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

Q.4 **(c)** Illustrate Gibb's phase rule with an example. State the types of equilibrium for a thermodynamic system and conditions for its stability. **03**

Q.5 **(a)** Draw a neat phase diagram of water on P-V coordinates showing all its states. Define the terms 'critical point' and 'superheated vapours'. **07**
Using Steam Tables, calculate the specific volume and specific enthalpy of steam at 200 ^{o}C having a quality of 70%.

(b) Define the following terms: (i) Dew Point Temperature (ii) Absolute humidity. **07**

Prove that absolute humidity (ω) of moist air is given by $\omega = 0.622\left(\frac{P_w}{P - P_w}\right)$.

On a certain day, the weather report of Anand city was recorded as:
Atmospheric pressure = 760 mm Hg, Ambient Temperature = 27 ^{o}C, RH = 60%.
Using Psychrometric Chart, calculate the Dew Point Temperature, Wet Bulb temperature, Specific enthalpy and Absolute humidity of the atmospheric air.

OR

Q.5 **(a)** Draw a neat T-s phase diagram of water indicating all its phases and states. Define the terms (i) Normal boiling point (ii) Steam quality. **07**
A rigid vessel of 0.86 m^3 volume contains 1 kg of wet steam at 2 bar pressure. Calculate its specific volume and dryness fraction. Using Steam Tables determine its temperature, enthalpy and entropy.

(b) Explain the following terms: **07**
(i) Relative humidity (ii) Wet Bulb Temperature
(iii) Sensible cooling (iv)Dehumidification
On a certain day, the weather report of Anand city was recorded as:
Atmospheric pressure = 740 mm Hg, Ambient Temperature = 20 ^{o}C, DPT = 15 ^{o}C.
Calculate the % RH, DBT, Absolute humidity and Specific enthalpy of the moist air.

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