

GUJARAT TECHNOLOGICAL UNIVERSITY**BE - SEMESTER-III • EXAMINATION – WINTER • 2014****Subject Code: 2131404****Date: 30-12-2014****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) What are ideal gases? Explain why do real gases deviate from ideal behavior? How did Van der Waal explain such deviation? Carbon dioxide gas is available in a closed tank at 327 °C. Its specific volume is 0.42 m³/kg. Calculate **07**

(i) The pressure exerted by the gas in bar using ideal gas equation.

(ii) The pressure exerted by the gas in bar using Van der Waal gas equation.

[Take $R=8.314\text{J/mol K}$, $a = 146.6 \times 10^{-3} \text{ Pa} \left(\frac{\text{m}^3}{\text{mole}} \right)^2$, $b= 0.04 \times 10^{-3} \text{ m}^3/\text{mol}$]

(b) Answer the following: **04**

(i) What is compressibility factor of gases?

(ii) Prove that $C_p - C_v = \bar{R}$ for ideal gases and $C_p - C_v = 0$ for liquids.

(iii) Differentiate between extensive and intensive properties with example.

(iv) What do you understand by reversible process?

(c) Ten kilogram of N₂ gas at 77 °C and 1 bar is heated reversibly and isobarically until its volume increases by 80%. Calculate **03**

(i) The expanded work in kJ

(ii) Change in internal energy and enthalpy in kJ.

[Take $C_p = 36 \text{ J/mol K}$, $R = 8.314 \text{ J/mol K}$]

Q.2 (a) State Zeroth law of thermodynamics and explain its thermodynamic significance for measurement of temperature. Convert 7 °C in Fahrenheit, Kelvin and Rankine scale. The platinum resistance element of a RTD thermometer has a resistance of 5 Ω at 0 °C and 6 Ω at 100 °C. Calculate the temperature coefficient of resistance (α) in per °C. What would be the temperature in Kelvin when the thermometer indicates a resistance of 10 Ω? **07**

- (b) What is the first law of thermodynamics? Explain it in perspective for a closed system operating in a cycle. An ideal gas is allowed to expand isothermally in a reversible manner. Prove that the work done per mole of gas (w in J/mole) is given **07**

by $w = RT \ln \frac{V_2}{V_1}$, where T is absolute temperature and V is volume in m^3 . Five

kilo moles of N_2 gas at 400 K is expands isothermally from initial volume of 1 m^3 to a final volume of 10 m^3 . Calculate the net work done in kJ. If the accompanying change in internal energy is 100 kJ/kmol, calculate heat transfer in kJ.

[Take $R = 8.314 \text{ J/mol K}$].

OR

- (b) Explain first law of thermodynamics for a closed system undergoing a non-cyclic state change process. Differentiate between adiabatic and isentropic process. Show that for an ideal gas undergoing a reversible adiabatic process **07**

$$W = \frac{m\bar{R}}{\gamma - 1} (T_1 - T_2), \text{ where } \gamma \text{ is the ratio of specific heats of gases.}$$

An ideal gas at 25 bar and 227°C expands isentropically to -23°C so as to yield a volume expansion ratio of 6:1. Calculate

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

(ii) Its final pressure.

[Take $R = 8.314 \text{ J/mol K}$, $C_p = 1.005 \text{ kJ/kg K}$, $C_v = 0.72 \text{ kJ/kg K}$]

- Q.3** (a) Define control volume, steady and non-steady flow processes. Write down SFEE for a fluid stream entering and exiting a control volume in terms of energy and work transfer per unit mass. Steam is steadily flowing through a turbine with inlet and outlet conditions given as: **07**

INLET: $h_1 = 3250 \text{ kJ/kg}$
 $v_1 = 0.074 \text{ m}^3/\text{kg}$
 $P_1 = 52 \text{ bar}$
 $T_1 = 700\text{K } ^\circ\text{C}$
 $d_1 = 0.35\text{m}$

OUTLET: $h_2 = 3230 \text{ kJ/kg}$
 $v_2 = 0.083 \text{ m}^3/\text{kg}$,
 $P_2 = 43 \text{ bar}$,
 $T_2 = 660\text{K } ^\circ\text{C}$
 $d_2 = 0.35\text{m}$

The heat loss due to poor insulation is 12 kJ/kg . Calculate the steam inlet and outlet velocities in m/s and its flow rate in kg/s. Assume inlet and outlet elevations are same and so are their cross-sectional areas.

- (b) State and explain Clausius statement of second law of thermodynamics. Explain the operation of a heat engine with the help of a neat diagram. Write down basic energy balance equations. What do you mean by PMM1 And PMM2? **07**

OR

- Q.3** (a) Define steady and non-steady flow processes. 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. Show that for steady flow of a gas through a nozzle, the exit velocity is given by $V = \sqrt{h_2 - h_1}$, where h_1 and h_2 are inlet and outlet specific enthalpies respectively in J/kg. Assume no heat loss, no external work interaction and constant elevation of inlet and outlet ports. **07**

- (b) With the help of a neat sketch explain Kelvin-Planck statement of second law of thermodynamics. A heat engine is operating between source and sink maintained at 427°C and 17°C respectively. The heat input to the engine from source is 200 kW and the associated heat rejection to the sink is 120 kW. Calculate the thermal efficiency of the engine and compare it with the maximum possible theoretical efficiency. **07**
- Q.4 (a)** An ideal gas is undergoing a reversible process $1 \rightarrow 2$. **05**
 Show that $(\Delta S)_{1 \rightarrow 2} = C_v \ln \left[\frac{P_2 V_2^{\gamma}}{P_1 V_1^{\gamma}} \right]$.
 The symbols have their usual thermodynamic meanings.
- (b) If P, v, T, g and s are state coordinates and exact differentials, prove the following: **05**
 (i) $dg = v dP - s dT$
 (ii) $\left(\frac{\partial s}{\partial P} \right)_T = - \left(\frac{\partial v}{\partial T} \right)_P$
- (c) What do you understand by thermodynamic degrees of freedom? State Gibb's phase rule. Calculate the degrees of freedom of a pure substance at its critical point. What is the significance of this point? **04**
- OR**
- Q.4 (a)** Prove the Clausius inequality $\oint \frac{dQ}{T} \leq 0$. What would you interpret if $\oint \frac{dQ}{T} > 0$ and $\oint \frac{dQ}{T} = 0$? **05**
- (b) Prove the following: **05**
 (i) $\left(\frac{\partial s}{\partial v} \right)_T = \left(\frac{\partial P}{\partial T} \right)_v$
 (ii) $\left(\frac{\partial P}{\partial V} \right)_T \left(\frac{\partial V}{\partial T} \right)_P \left(\frac{\partial T}{\partial P} \right)_V = -1$
- (c) Illustrate Gibb's phase rule with an example. Calculate the degrees of freedom of water at 25°C and 1 atmosphere pressure. State the types of equilibrium for a thermodynamic system and state conditions for its stability. **04**
- Q.5 (a)** Define the following: **07**
 (i) Dry bulb temperature.
 (ii) Relative humidity.
 (iii) Wet bulb temperature.
- On a certain summer day, the weather report of Anand city was recorded as:
 Ambient Temperature = 40°C , RH = 80%.
 Barometric pressure = 760 mm Hg
 Using Psychrometric Chart, calculate the Dew Point Temperature, Wet Bulb temperature, Absolute humidity and specific enthalpy of the atmospheric air.

- (b) Draw neat labeled P-V and T-s diagrams of water showing its various states. Show that the specific volume of wet steam is given by $v = v_g + (1-x) v_{fg}$. **07**

Using Steam Tables determine the following for saturated steam at 50 °C:

- (i) Saturation pressure in bar
- (ii) Entropy in kJ/kg K
- (iii) Latent heat of vaporization in kJ/kg
- (iv) Specific volume in m³/kg

OR

- Q.5 (a)** Prove that absolute humidity (ω) of moist air is given by $\omega = 0.622 \left(\frac{P_w}{P - P_w} \right)$. **07**

Explain the following w.r.t. moist air:

- (i) Wet Bulb Temperature
- (ii) Relative humidity

Using Psychrometric chart, determine WBT, DPT and specific enthalpy of moist air at 30 °C DBT, 60% RH and 760 mm Hg atmospheric pressure.

- (b) Draw a neat phase diagram of water on P-V coordinates showing all its states. Define the following terms: **07**

- (i) Critical point
- (ii) Dryness fraction
- (iii) Triple point
- (iv) Saturated vapours
- (v) Boiling point
- (vi) Wet steam

Using Steam Tables, calculate the specific volume and specific enthalpy of wet steam at 160 °C having a quality of 75%.
