Seat No.: ________ Enrolment No.___________

# GUJARAT TECHNOLOGICAL UNIVERSITY

**BE - SEMESTER–III (New) EXAMINATION – WINTER 2018**

**Subject Code:2131404 Date:05/12/2018**

**Subject Name:Food Engineering Thermodynamics**

**Time:10:30 AM TO 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. **Standard Steam Tables and normal range Psychrometric Chart can be used.**

**Q.1 (a)** Define ideal gases and state how do they differ from real gases? A sealed container of 500 litres volume contains methane gas at a temperature of –13 °C and 5 bar pressure. Calculate the mass of the gas in kg using ideal gas equation. [[Take R = 8.314 J/mol K and M = 16] **03**

**(b)** Write down Van *der* Waal's equation of state for real gases. What do the constants 'a' and 'b' in the equation stand for? Hundred moles of $CO_2$ gas is stored in a 5 liter closed container at – 23 °C. Calculate the pressure of the gas in kPa using Van *der* Waal's gas equation.
Take a = 0.363 Pa $(m^3/mole)^2$, b = 4.3 x $10^{-5}$ $m^3$/mole, R = 8.314 J/mole K **04**

**(c)** Match the entities of Column-I with most appropriate entity from a set of possible entities available in Column-II. Reconstruct a matched table. **07**

| Column-I | Column-II |
|---|---|
| Vacuum of 650 torr equals | (i) Real gases (ii) 86.66 kPa |
| $C_p - C_v$ is | (iii) > 0 for ideal gases |
| Van der Waal's gas equation | (iv) NkT (v) 14 g (vi) 25 °C |
| Specific gas constant for $O_2$ gas is | (vii) 28 g (viii) $\bar{R}$ T |
| PV is equal to | (ix) < 0 for real gases |
| Mass of 1 mole $N_2$ gas at NTP is | (x) Freeze drying |
| 77°F is equal to | (xi) 14.67kPa (xii) 259.8 J/kg K |
| Sublimation | (xiii) 259.8 J/mol K |

**Q.2 (a)** A gas at 6 bar and 187 °C kept in a container of 250 liter volume is cooled isobarically to 37 °C. Calculate the following in kJ: **03**
(a) Heat transferred.
(b) Work done and its direction.
(c) Change in internal energy.
[Take Cp = 40 J/mol K, R = 8.314 J/mol k]

**(b)** State Zero$^{th}$ law of thermodynamics. A wire made from an unknown alloy having a temperature of 21 °C carries a current of 0.5 Ampere at a given potential difference. At 49.5 °C, the current carried by the wire is 0.36 Ampere for the same potential difference. Calculate the temperature coefficient (α) of the alloy. **04**

**(c)** State First Law of thermodynamics. What are its practical limitations? Prove that $PV^\gamma$ = Constant for an ideal gas undergoing a reversible adiabatic process. The temperature of 10 kg of a gas held in a rigid cylinder was increased from 10 °C to 50 °C by adding 35 kJ of heat. Calculate the work **07**

done and the change in internal energy of the system. [Take $C_v = 741$ J/kg K]

**OR**

(c) Define control volume. Write down the generalized SFEE for a fluid stream entering and leaving a thermodynamic system in terms of work and energy transfer per unit time. Steam flows through a turbine in steady state with the following inlet and outlet conditions: **07**

Inlet conditions

$h_1 = 3250$ kJ/kg, $v_1 = 0.074$ m$^3$/kg
$P_1 = 54$ bar, $t_1 = 410$ °C, $d_1 = 0.24$m

Outlet conditions

$h_2 = 3234$ kJ/kg, $v_2 = 0.084$ m$^3$/kg
$P_2 = 42$ bar, $t_2 = 390$ °C, $d_2 = 0.24$m

The heat loss due to poor insulating material is 10 kJ/kg. Calculate the steam inlet and outlet velocities in m/s and its flow rate in kg/s. Assume turbine inlet and outlet points to be at the same height.

**Q.3** (a) Explain different types of thermodynamic equilibria and state conditions of stability. **03**

(b) What is Joule-Kelvin effect? Show that for ideal gases, $\mu_{J,T} = 0$ **04**

(c) Show that for an infinitesimal reversible process **07**

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

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

**Q.3** (a) Define thermodynamic degrees of freedom. What is Gibb's phase rule? Calculate the degrees of freedom of water at its triple point. **03**

(b) Show that for an infinitesimal reversible process, **04**

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

(c) Define entropy and show that for any thermodynamic process $(\Delta s)_{1-2} \geq \int_1^2 (\frac{dQ}{T})$. **07**

An ideal gas is undergoing a reversible process ($1 \leftrightarrow 2$). Show that the specific entropy change for this process is given by

$(\Delta s)_{1-2} = C_v \ln\left(\frac{T_2}{T_1}\right) + \bar{R} \ln\left(\frac{v_2}{v_1}\right).$

**Q.4** (a) Using Clausius-Clayperon equation, determine the approximate pressure at which water would boil at 120 °C. It is given that water boils at 100 °C at 1 atmosphere. [Take R = 8.314 J/mol K, $h_{fg}$ (at 100 °C) = 2257 kJ/kg] **03**

(b) State Carnot theorems. A stem engine is operating between two constant temperature reservoirs at 329 °C and 15 °C and producing a work output of 50 kW. If the thermal efficiency of the engine is 75% of the maximum possible efficiency, calculate the required heat input to the engine and heat rejection rate in kW. **04**

(c) Explain the following in brief: **07**

i. Thermal reservoirs
ii. PMM1 And PMM2
iii. Carnot cycle
iv. Available and unavailable energy
v. Clausius inequality
vi. Entropy principle
vii. Law of corresponding states

**Q.4** **(a)** Explain Carnot cycle showing various state points and processes and explain the significance of this cycle. **03**

**(b)** Draw a schematic diagram showing the operation of heat pump. A heat pump is operating between source and sink maintained at - 5 $^0$C and 25 $^0$C and respectively. The heat absorbed from the source is 5 kW and the heat pumped into the sink is 40% more than what the system absorbs from the source. Calculate the power requirement and COP of the device. What is the ratio of actual COP to the maximum possible COP? **04**

**(c)** Explain Kelvin-Plank (K-P) and Clausius statements of second law of thermodynamics & prove that if K-P statement is violated then Clausius statement will also be violated and vice-versa. **07**

**Q.5** **(a)** Define the following in relation to moist air: **03**

(i) Wet bulb temperature.
(ii) Dry bulb temperature.
(iii)Absolute humidity.

**(b)** Show the following processes on a psychrometric chart: **04**

i. Heating and dehumidification of air
ii. Cooling and dehumidification of air

The barometric pressure of atmospheric air at a certain place is 1bar and its temperature is 30°C. If the partial vapour pressure of water vapours present in the atmosphere is 15 mm Hg, calculate the following:

(i) Absolute humidity
(ii) Relative humidity

**(c)** Draw phase diagram of a pure substance (water) on T-s coordinates and explain the following for water/steam: **07**

(i) Steam quality (ii) Triple point (iii) Superheated steam

A rigid vessel contains saturated steam at a temperature of 200 °C. Determine the following using Steam Tables:

(i) Saturation Pressure (ii) Specific volume in m$^3$/kg
(iii) Enthalpy in kJ/kg (iv) Internal energy in kJ/kg

**Q.5** **(a)** Define the following in relation to moist air: **03**

(i) Relative humidity.
(ii) Wet bulb temperature.
(iii)Degree of saturation

**(b)** Show the following processes on a psychrometric chart: **04**

i. Sensible heating of air
ii. Dehumidification of air

The weather report for a certain place is as follows:

i. DBT = 25 °C
ii. DPT = 18 °C
iii. Barometric pressure = 760 mm Hg.

Using psychrometric chart, determine WBT, specific enthalpy, relative and absolute humidity of air at this place.

**(c)** Draw and explain phase diagram of a pure substance (water) showing various states on P-v coordinates and explain critical point. Using standard Steam Tables determine the following for saturated steam at 10 bar pressure: **07**

i. Saturation temperature in °C
ii. Entropy in kJ/kg K
iii. Enthalpy of saturated steam in kJ/kg
iv. Density in kg/ $m^3$

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