Name:

Enrolment No:

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, Dec 2021

Course: Thermodynamics -I | **Semester: III**
Program: B. Tech (CE+RP) | **Time: 3 hrs**
Course Code: CHCE 2012 | **Max. Marks: 100**

Instructions: (1) Answer **ALL** questions
(2) Assume the appropriate value of missing data, if any.
(3) The thermodynamic terms have their usual meanings as described in the class

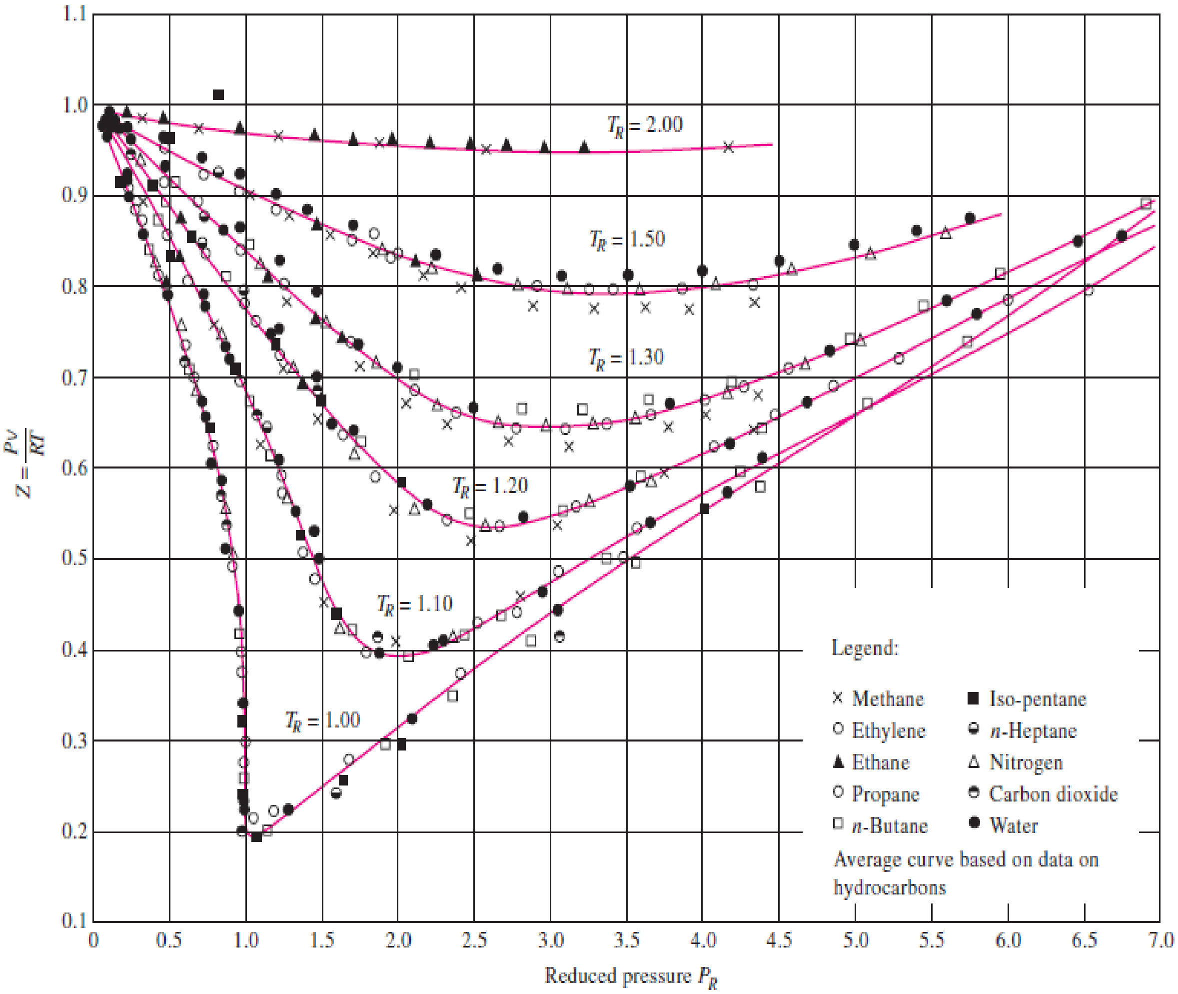
S. No.		Marks	CO
	SECTION A (20 M)		
Q1	What criteria a system should satisfy for it to be in a state of thermodynamic equilibrium?	**4**	**CO1**
Q2	Find the degree of freedom for a pure substance existing as (a) saturated liquid (b) saturated vapor?	**4**	**CO2**
Q3	Compare and contrast the properties of a control mass and a control volume system.	**4**	**CO2**
Q4	Discuss the significance of volume expansivity and isothermal compressibility.	**4**	**CO2**
Q5	Explain the term thermal reservoir, source and sink.	**4**	**CO1**
	SECTION B (50 M)		
Q6	Derive an iterative scheme for the calculation of of vapour volume and liquid volume using the Redlich- Kwong equation of state.	**10**	**CO3**
Q7	A hot hydrocarbon oil (C_P = 2.512 kJ/kg K) is cooled from 422 K to 339 K in a heat exchanger at the rate of 2500 kg/h. Cooling water at the rate of 5000 kg/h enters the exchanger at 294 K. Assume that there is no heat loss in the exchanger. (a) What is the change in entropy of the oil? (b) What is the total change in entropy? (c) How much work could be obtained if the cooling of the oil were carried out by a reversible Carnot engine rejecting heat to a sink at 294 K?	**10**	**CO3**

Q8	An insulated tank of volume 2 m^3 is divided into two equal compartments by a thin and rigid partition. One compartment contains an ideal gas at 400 K and 200 kPa, while the other is completely evacuated. Now, the partition is suddenly removed and the gases are allowed to mix. The equilibrium is established by equalizing the pressure and temperature. Estimate the change in entropy of the gas.	**10**	**CO3**
Q9	A small leakage is observed from a rigid cylinder of nitrogen gas kept in the research lab of UPES Dehradun. If m_{cv} and U_{cv} are the mass and specific internal energy of the nitrogen gas present inside the control volume, respectively. *H* is the speciifc enthalpy of the gas leaving the control volume. Assume the valve in the supply line for the discharge of nitrogen gas into the cylinder is completely closed and negligible heat loss to the surrounding. Show that the mass leaving from the control volume can be related to the *H* and and U_{cv} as $\ln m_{cv} = \int \frac{1}{H - U_{cv}} dU_{cv}$	**10**	**CO3**
SECTION C (40 M)			
Q10	The first law of thermodynamics states that energy is always conserved. The second law of thermodynamics gives the direction of flow of energy and states that total entropy of the universe is always increasing. The entropy can also be expressed in terms of the increase in unavailable energy. Thus, according to the first and second law of thermodynamics, the unavailable energy of the universe is always increasing and the energy available for useful work is always decreasing. Thus, there will be a time when energy will not be available for accomplishing the useful work in the universe. Discuss the pros and cons of the above argument	**20**	**CO4**

Q11	The liquefied nitrogen gas (LNG) at 8000 kPa pressure is generally used for research purposes. The gas is bottled by the Eureka gas services, Dehradun, India and supplied to different laboratories. The purchase department of the UPES released the purchase order of a LNG cylinder with 7 kg of nitrogen gas. The operator at the Eureka gas services mistakenly filled the nitrogen cylinder with the ethylene gas at 8000 kPa and -20.76 ^oC. Had the same cylinder filled with the nitrogen gas at the temperature of 8000 kPa and -20.76 ^oC, it contains around 6.8 kg of nitrogen. After filling the nitrogen cylinder with the ethylene gas the operator realized the mistake. What is the approximate weight of the ethylene gas filled in the nitrogen cylinder at 8000 kPa and -20.76 ^oC. Data: The critical properties of nitrogen are Pc = 3394 kPa and Tc = 126.2 K, and the critical properties of ethylene are Pc = 5117 kPa and Tc = 283.1 K. You can use the generalized compressibility factor chart given on the last page of this QP		**CO4**

The generalized compressibility factor chart

Source: Gour-Jen Su, "Modified Law of Corresponding States," Ind. Eng. Chem. (international ed.) 38 (1946), p. 803



$Z = \frac{Pv}{RT}$
Reduced pressure P_R
$T_R = 2.00$
$T_R = 1.50$
$T_R = 1.30$
$T_R = 1.20$
$T_R = 1.10$
$T_R = 1.00$
Legend:
× Methane
○ Ethylene
▲ Ethane
○ Propane
□ n-Butane
■ Iso-pentane
n-Heptane
△ Nitrogen
Carbon dioxide
● Water
Average curve based on data on hydrocarbons