Name: Enrolment No:	UPES UNIVERSITY WITH A PURPOSE

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
Special Examination, January 2021

Course: Engineering Thermodynamics	**Semester : III**
Program: B. Tech. (APE-Gas)	**Time : 3 hr**
Course Code: MECH 2001	**Max. Marks : 100**

Instructions: Assume any missing data. The notations used here have the usual meanings. Draw the diagrams, wherever necessary.

SECTION - A (6 × 5 = 30 marks)
(Answer all the questions)

S. No.		Marks	CO
1.	A rigid vessel, containing three moles of nitrogen gas at 30 ^{0}C is heated to 250 ^{0}C. Assume that the average heat capacity of nitrogen to be C_p = 29.1 J/mol-K and C_v = 20.8J/mol-K. The heat required, neglecting the heat capacity of the vessel, is (a) 13728 J (b) 19206 J (c) 4576 J (d) 12712 J	**5**	**CO1**
2.	Keeping the pressure constant, to double the volume of a given mass of an ideal gas at 27 ^{0}C, the temperature should be raised to (a) 270 ^{0}C (b) 327 ^{0}C (c) 300 ^{0}C (d) 540 ^{0}C	**5**	**CO2**
3.	The compressibility factor for steam at 523.15 K and 1800 kPa using the truncated virial equation, with the value of B from generalized Pitzer correlations, is ………….. Virial coefficients B^0 and B^1 are: $B^0 = 0.083 - \frac{0.422}{T_r^{1.6}}$ and $B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$ For steam: T_c = 647.1 K, P_c = 220.55 bar and ω = 0.345. (a) 1 (b) 0.975 (c) 0.938 (d) 0.905	**5**	**CO3**

4.	The degree of freedom for a two phase vapor-liquid system comprised of chloroform, 1,4-dioxane and ethanol (a) 1 (b) 2 (c) 3 (d) 4	**5**	**CO4**
5.	The vapor pressures of benzene and toluene are 3 atm and 4/3 atm, respectively. A liquid feed of 0.4 mol benzene and 0.6 mol toluene is vaporized. Assuming that the products are in equilibrium, the vapor phase mole fraction of benzene is (a) 0.2 (b) 0.4 (c) 0.6 (d) 0.8	**5**	**CO4**
6.	A Carnot refrigeration cycle absorbs heat at 3 ^{0}C and rejects heat at 27 ^{0}C. Calculate the coefficient of performance. (a) 0.125 (b) 1.125 (c) 11.5 (d) 12.5	**5**	**CO5**

SECTION - B (5 × 10 = 50 marks)
(Answer all the questions)

S. No.		**Marks**	**CO**
1.	One mole of gas in a closed system undergoes a four step thermodynamics cycle. Use the data given in the following table to determine the numerical values for the missing quantities:	**10**	**CO1**

Step	**ΔU^t (J)**	**Q (J)**	**W (J)**
1-2	-200	**?**	-6000
2-3	**?**	-3800	**?**
3-4	**?**	-800	300
4-1	4700	**?**	**?**
12341	**?**	**?**	-1400

2.	Determine the expressions for G^R and H^R implied by the three-term virial equation in volume.	**10**	**CO3**
3.	The molar volume (cm^3/mol) of a binary liquid mixture at T and P is given by $$V = 120\, x_1 + 70\, x_2 + (15\, x_1 + 8\, x_2)\, x_1\, x_2$$ Find expressions for partial molar volumes of species 1 and 2. Show that these expressions satisfy Gibbs/Duhem equation.	**10**	**CO3**
4.	A Carnot refrigerator has tetrafluoroethane as the working fluid. For T_C =261.15 K and T_H = 311.15 K, determine (a) the heat addition per kg of fluid (b) the heat rejection per kg of fluid (c) the mechanical power per kg of fluid for each of the four steps (d) the coefficient of performance ω for the cycle Thermodynamic properties of Saturated tetrafluoroethane are given in Table 1.	**10**	**CO4**
5.	A vapor mixture of 20 mol% methane, 30 mol% ethane and 50 mol% propane are available at 30 ^{0}C. Making use of the K factors, determine the pressure at which the condensation begins if the mixture is isothermally compressed. Also, estimate the composition of the first drop of liquid that forms.	**10**	**CO5**
SECTION – C (1 × 20 = 20 marks) **(Answer all the questions)**			
1.(a)	An inventor has devised a complicated non-flow process in which 1 mol of air is the working fluid. The net effects of the process are claimed to be: - A change in state of air from 523.15 K and 3 bar to 353.15 K and 1 bar - A production of 1800 J of work - The transfer of an undisclosed amount of heat to a heat reservoir at 303.15 K Determine whether the claimed performance of the process is consistent with the second law. Assume that air is an ideal gas for which $C_p = (7/2)R$.	**10**	**CO2**
(b)	An ideal gas, $C_p = (7/2)R$, is heated in a steady-flow heat exchanger from 343.15 K to 463.15 K by another stream of the same ideal gas which enters at 593.15 K. The flow rates of the two streams are the same and heat losses from the exchanger are negligible.	**10**	

	(i) Calculate the molar entropy change of the two gas streams for counter current flow in the exchanger? (ii) Calculate the total entropy change?		

Table: 1 Thermodynamic properties of Saturated Tetrafluoroethane

Temperature (K)	Saturation pressure MPa	Liquid density kg/m^3	Specific volume of vapor m^3/kg	Enthalpy (kJ/kg)		Entropy (kJ/kg-K)	
	P	ρ^l	V^v	H^l	H^v	S^l	S^v
261.15	0.18516	1331.8	0.10749	184.16	391.55	0.9410	1.7351
309.15	0.91172	1163.2	0.02241	250.41	417.78	1.1715	1.7129
313.15	1.0165	1146.5	0.01999	256.35	419.58	1.1903	1.7115

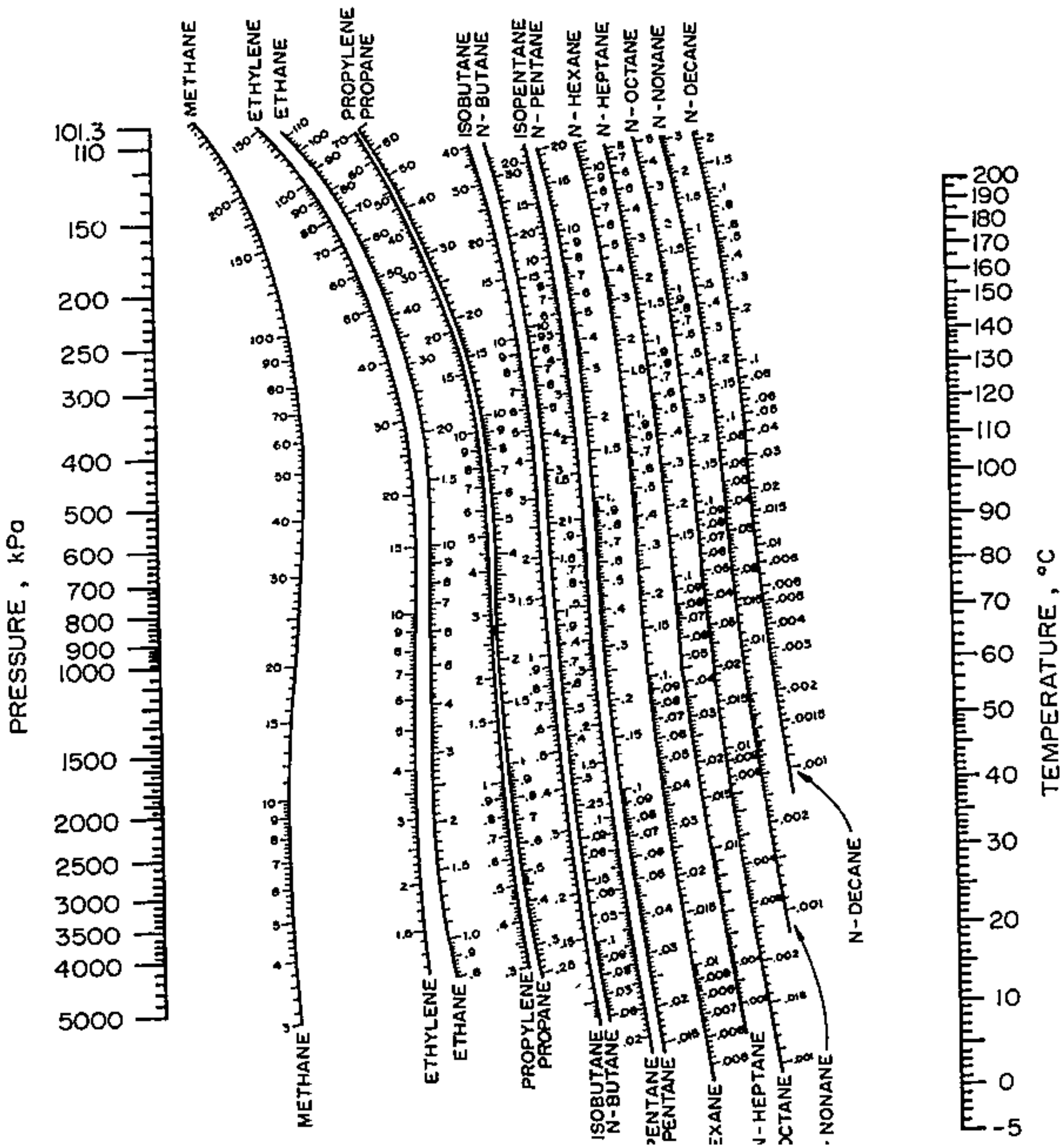

Figure 1. DePriester Chart at high temperature