Name:

Enrolment No:

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UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 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 (5 ×4 = 20 marks)

(Answer all the questions)

<table>
<tr><th>S. No.</th><th></th><th>Marks</th><th>CO</th></tr>
<tr><td>1.</td><td>Steam at 14 bar and 315 ^oC (state 1) enters a turbine through a 75 mm diameter with a velocity of 3 m/s. The exhaust from the turbine is carried through a 250 mm diameter pipe and is at 0.35 bar and 93 ^oC (state 2). What is the power output of the turbine. Property values are:
$H_1 = 3074.5$ kJ/kg $V_1 = 0.1909$ m^3/kg
$H_2 = 2871.6$ kJ/kg $V_2 = 4.878$ m^3/kg</td><td>4</td><td>CO2</td></tr>
<tr><td>2.</td><td>Heat in the amount of 150 kJ is transferred directly from a hot reservoir at $T_H = 550$ K to two cooler reservoirs at $T_1 = 350$ K and $T_2 = 250$ K. The surrounding temperature is $T_\sigma = 300$ K. If the heat transferred to the reservoir at T_1 is half that transferred to the reservoir at T_2, Calculate the lost work.</td><td>4</td><td>CO2</td></tr>
<tr><td>3.</td><td>1 kmol of ethylene is contained in a 0.6 m^3 steel vessel immersed in a constant temperature bath at 200 ^0C. Determine the pressure developed by the gas using the van der Waals equation of state. For ethylene: $T_c = 283.1$ K, $P_c = 51.17$ bar and parameters assigned for equations of state are:
<table>
<tr><th>Equation of state</th><th>$\alpha(T_r)$</th><th>σ</th><th>ε</th><th>Ω</th><th>Ψ</th><th>Z_c</th></tr>
<tr><td>Van der Waals (vdW)</td><td>1</td><td>0</td><td>0</td><td>1/8</td><td>27/64</td><td>3/8</td></tr>
</table></td><td>4</td><td>CO3</td></tr>
</table>

4.	Components A and B form ideal solution. At 350 K, a liquid mixture containing 40 % (mole) A is in equilibrium with a vapor containing 70 % (mole) A. If the vapor pressure of A at 350 K is 70 kPa. What is the vapor pressure of B?	**4**	**CO4**
5.	Discuss Linde liquefaction process with the help of a neat sketch.	**4**	**CO5**

SECTION - B (4 × 10 = 50 marks)

(Answer all the questions)

S. No.		**Marks**	**CO**
1.	An ideal gas is initially at a pressure of 0.1 MPa and a total volume of 2 m^3. It is compressed to 1 MPa by a reversible adiabatic process and then cooled at constant pressure to a final volume of 0.2 m^3. Calculate the work done in kJ on the gas for the entire process. The heat capacity at constant pressure, $C_p = 2.5\ R$.	**10**	**CO1**
2.	A Carnot engine is coupled to Carnot refrigerator so that all of the work produced by the engine is used by the refrigerator in the extraction of heat from a heat reservoir at 273.15 K at the rate of 35 kW. The source of energy for the Carnot engine is a heat reservoir at 523.15 K. If both the devices discard heat to the surroundings at 298.15 K, how much heat does the engine absorb from its heat source reservoir?	**10**	**CO2**
3.	At 298.15 K and atmospheric pressure, the volume change of mixing of binary liquid mixtures of species 1 and 2 is given by the equation: $$\Delta V = x_1 x_2 (45 x_1 + 25 x_2)$$ where ΔV is in cm^3/mol. At these conditions, $V_1 = 110$ and $V_2 = 90\ cm^3$/mol. Determine the partial molar volumes $\bar{V}_1$ and $\bar{V}_2$ in a mixture containing 40 mol % of the species 1 at the given conditions.	**10**	**CO3**
4.	The stream from a gas well is a mixture containing 50% methane, 10 % ethane, 20% propane and 20 % n-butane. The composition is expressed in mole percent. This stream is fed into a partial condenser maintained at a pressure of 17.24 bar, where its temperature is brought to 27 ^{0}C. Determine (a) the molar fraction of the gas that condenses (b) the composition of the liquid and vapor phase leaving the condenser. The K-values for system of light hydrocarbons are given in Fig. 1.	**10**	**CO4**

SECTION – C (2 × 20 = 40 marks)

(Answer all the questions)

1.

Find the values of Compressibility factor Z, residual enthalpy H^R and residual entropy S^R for propane at 375 K and ***(xx)*** bar as given by Redlich/Kwong equation, where ***(xx)*** are the last two digits of your ***SAP ID*** . For propane: T_c = 369.8 K, P_c = 42.48 bar and ω = 0.152.

Equation of state	$\alpha(T_r)$	σ	ε	Ω	Ψ	Z_c
Redlich/Kwong (RK)	$T_r^{-1/2}$	1	0	0.08664	0.42748	1/3

20

CO3

OR

The expressions for activity coefficient of species 1 and 2 in a binary liquid mixture at a given T and P are:

$$\ln\gamma_1 = x_2^2\,(0.273 + 0.096\,x_1)$$

$$\ln\gamma_2 = x_1^2\,(0.273 - 0.096\,x_1)$$

(i) Determine the implied expression for G^E/RT.

(ii) Verify Gibbs/Duhem equation.

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2.

A vapor compression refrigeration cycle with tetrafluoroethane as refrigerant operates with an evaporation temperature of -12 ^{0}C and a condensation temperature of 27 ^{0}C. Determine the coefficient of performance for

(a) Assuming isentropic compression of vapor

(b) Assuming a compressor efficiency of 75%.

Thermodynamic properties of saturated tetrafluoroethane and PH-diagram of tetrafluoroethane are given in Table 1 and Figure 2, respectively.

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CO5

Table: 1 Thermodynamic properties of Saturated Tetrafluoroethane

Temperature (^{0}C)	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
-12	0.18516	1331.8	0.10749	184.16	391.55	0.9410	1.7351
24	0.64566	1210.1	0.03189	233.05	411.93	1.1149	1.7169
28	0.72676	1194.9	0.02829	238.77	413.95	1.1338	1.7155

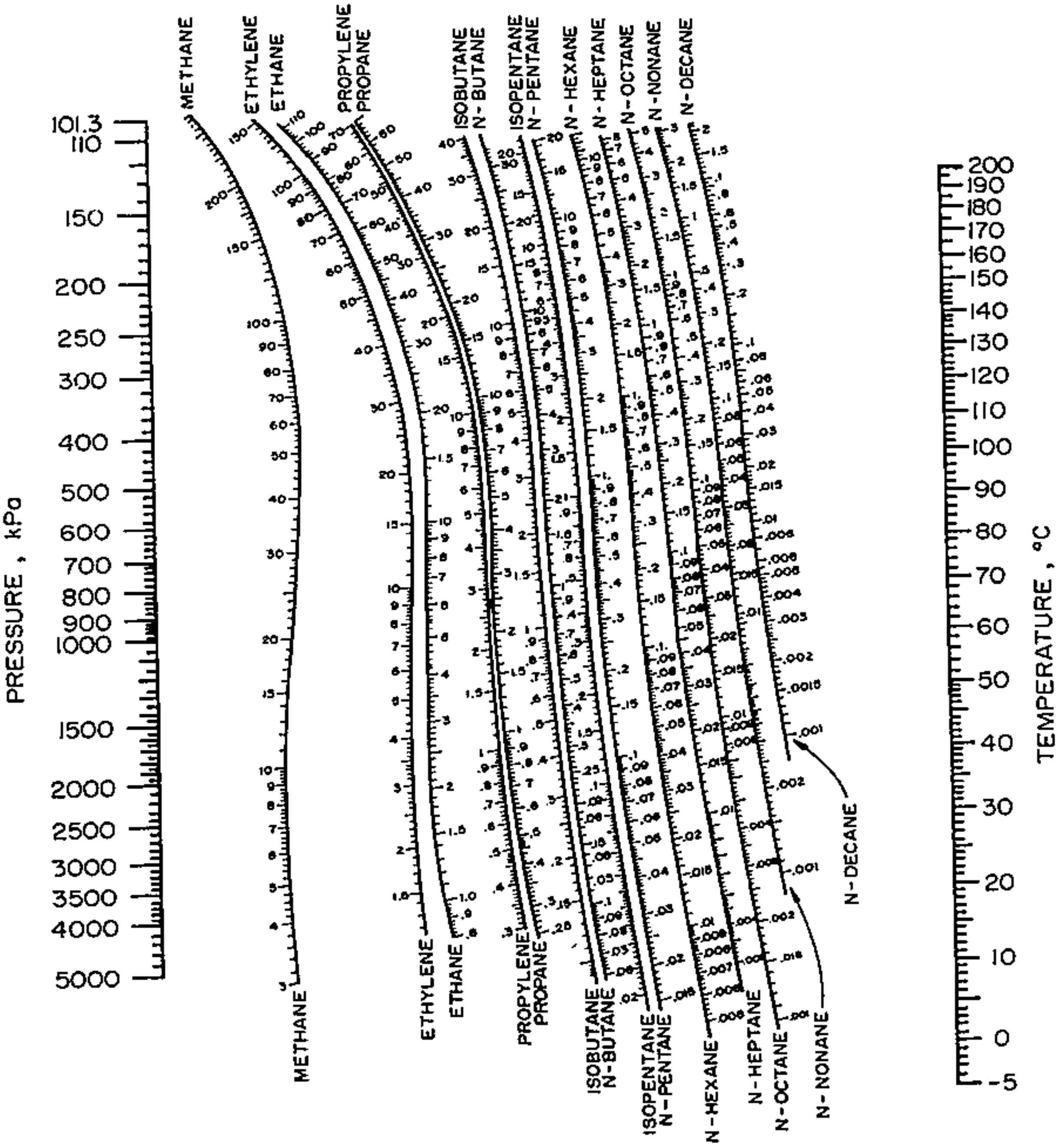

Figure 1: K- values for system of light hydrocarbons

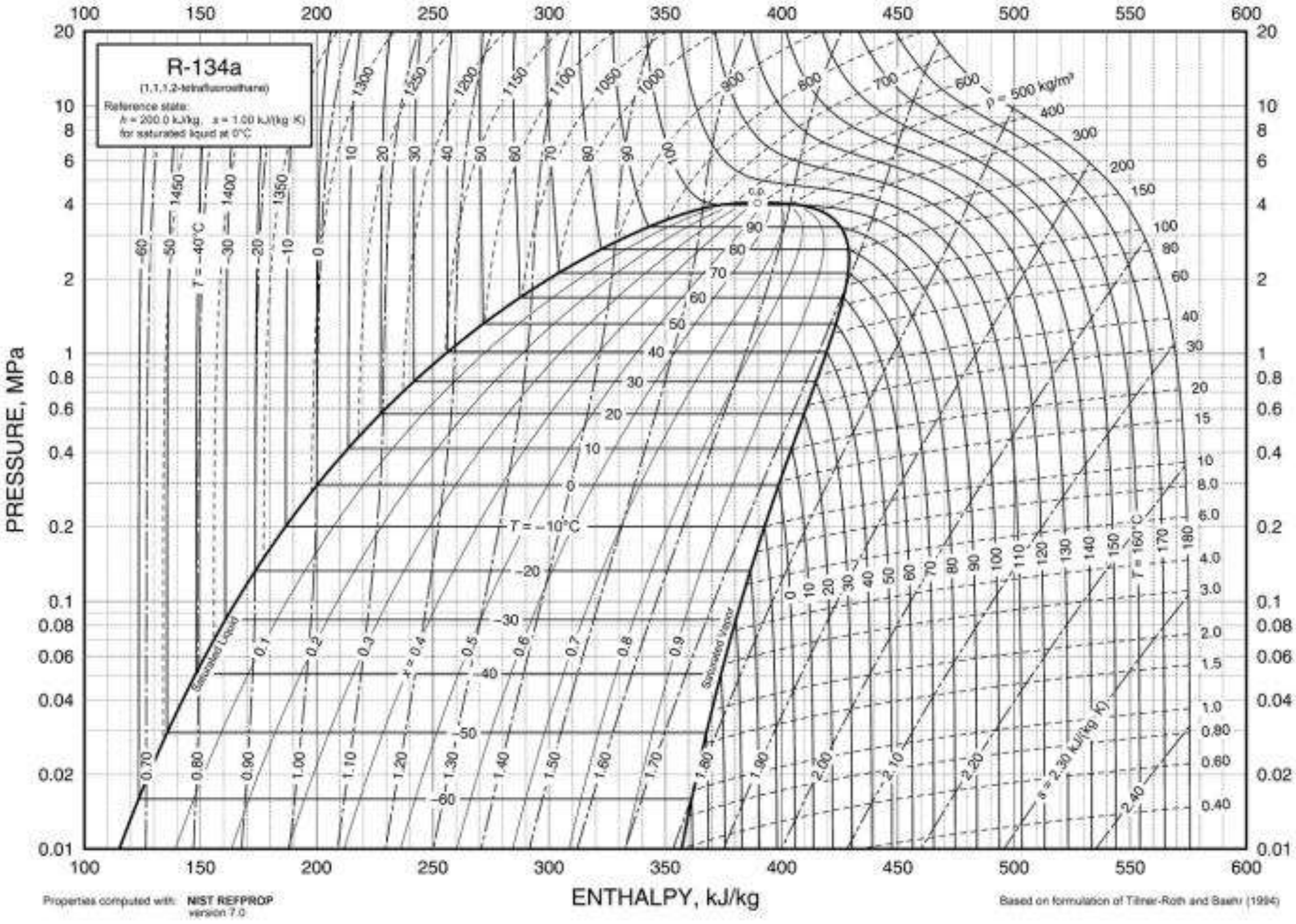

Figure 2: PH diagram of Tetrafluoroethane