Name: Enrolment No:	UPES

UPES

End Semester Examination, May 2025

Programme Name: B. Tech Chemical Engineering **Semester : IV**

Course Name : Chemical Reaction Engineering **Time : 03 hrs.**

Course Code : CHCE 2035 **Max. Marks: 100**

Nos. of page(s) : 2

Instructions: (a) Attempt all questions.
(b) Assume the value of any missing data.

This is an open-book, open-notes, and open Laptop (without internet) examination. Students may use MS Excel to solve Questions 2 and 3

<table>
<tr><th>S. No.</th><th></th><th>Marks</th><th>CO</th></tr>
<tr><td>Q 1</td><td>Hexamethylenetetramine (C) is to be produced in a well-stirred semi-batch reactor by adding an aqueous ammonia solution (B) at a constant rate of 10 L/min to an initial charge of formalin solution (A). The chemical reaction is:
$4NH_3$ (B) + 6HCHO (A) = $N_4(CH_2)_6$ (C)+$6H_2O$

The reaction is instantaneous and irreversible. The total volume of the reaction mass is 2000 L. The inlet concentration of ammonia is 15 gmol/L, and the initial concentration of formalin solution is also 15 gmol/L.

(a) Which is the limiting reactant and why? What is the time required for the complete conversion of formaldehyde? (10 M)
(b) If the initial concentration of formaldehyde were increased to 30 gmol/l, how would this affect the time required for its complete conversion? (5 M)
(c) Suppose the aqueous ammonia feed concentration is reduced from 15 gmol/L to 10 gmol/L while keeping the feed rate constant at 10 L/min. How would this change affect the total time required for complete conversion of 30,000 gmol of formaldehyde, and what implications might it have on reactor volume constraints? (5 M)

[Hint: Align your thinking with the stoichiometry of the reaction and solve the problem]</td><td>20 M</td><td>CO1</td></tr>
<tr><td>Q 2</td><td>The following data represent the tracer experiment in CSTR. The tracer concentration has been measured at the reactor outlet. The reactor volume is 2 $m^{3,}$ and the volumetric flow at the outlet is 7.2 m^3/h.

<table><tr><th>Time (min)</th><th>Concentration (mol/L-min)</th></tr><tr><td>0</td><td>0.0*C_{A0}</td></tr><tr><td>2.5</td><td>42.0*C_{A0}</td></tr><tr><td>5</td><td>84.9*C_{A0}</td></tr><tr><td>7.5</td><td>113*C_{A0}</td></tr><tr><td>10</td><td>141.5*C_{A0}</td></tr><tr><td>12.5</td><td>151*C_{A0}</td></tr><tr><td>15</td><td>141.5*C_{A0}</td></tr></table></td><td>45 M</td><td>CO2,4</td></tr>
</table>

17.5	127*C_{A0}
20	113.3*C_{A0}
22.5	85*C_{A0}
25	56.6*C_{A0}
27.5	42*C_{A0}
30	28.3*C_{A0}
32.5	9*C_{A0}
35	5*C_{A0}
37.5	3*C_{A0}
40	C_{A0}

C_{A0} = Last 3 digits of your SAP $\times 10^{-2}$ mol/L

(a) Use Excel to plot the Residence Time Distribution (RTD) function E(t), the cumulative distribution function F(t), and 1 – F(t) versus time and explain the significance of each of the curves. [10 M] [CO2]

(b) Determine the fraction of material that spent between 5 and 25 minutes in the reactor. [5 M] [CO2]

(c) Calculate the mean residence time of the CSTR and determine the fraction of material that spent less than the mean residence time in the reactor. [5 M] [CO2]

(d) Compute the variance and skewness of the RTD. Based on your analysis, comment on any possible non-ideality in the reactor behaviour. [5 M] [CO2]

(e) Assume a first-order, irreversible, isothermal, liquid-phase reaction occurring in a completely segregated flow system with a reaction rate constant of 0.05 min^{-1}. Calculate the mean conversion. [10 M] [CO3]

(f) For the first-order reaction as in part (e), obtain the conversion in a single CSTR and also obtain the conversion using the Tanks-in-Series model. [10 M] [CO3]

Q 3 — **35** — **CO1,2,4**

An adiabatic, irreversible reaction A→B was carried out, and the following rate versus conversion data was recorded. The molar flow rate of A is 290 mol/min.

X_A	0	0.2	0.4	0.45	0.5	0.6	0.8	0.9
$-r_A$ (mol/lit.min)	0	0.23	0.46	0.50	0.54	0.69	0.92	1.035

(a) Construct a Levenspiel plot and determine the required volume of a PFR and a CSTR to achieve a conversion of X_A=0.4. [5 M] [CO1]

	(b) Based on the plot, identify the range of conversions over which the volumes of the PFR and CSTR are approximately equal (within a ±10% difference). [5 M] [CO2] (c) What conversion can be achieved if a CSTR with the volume from part (a) is followed by a PFR with the volume from part (a)? [10 M] [CO4] (d) What conversion can be achieved if a PFR with the volume from part (a) is followed by a CSTR with the volume from part (a)? [10 M] [CO4] (e) Which reactor sequencing (CSTR → PFR or PFR → CSTR) provides better conversion, and why? [5 M] [CO4]		