Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Chemical Reaction Engineering**

Course Code : **22512**

1. RATIONALE

Chemical reaction engineering is that engineering activity concerned with the exploitation of chemical reactions on a commercial scale. Its goal is the successful design and operation of chemical reactors, and more than any other activity it sets chemical engineering apart as a distinct branch of the engineering profession. The knowledge of the subject helps in selecting the optimum reactor design for any process by taking into consideration the kinetics of the reaction, heat and mass transfer effects and economics of the process.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain chemical reactor operations to obtain quality products.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a. Maintain the kinetic parameters of various reactions.
b. Use the batch reactor data to determine the order of reactions.
c. Use the relevant parameters for the design of reactors.
d. Select suitable reactor for various applications.
e. Use proper catalyst for various chemical reactions.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	2	-	6	3	70	28	30*	00	100	40	--	--	--	--	--	--

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L***-*Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

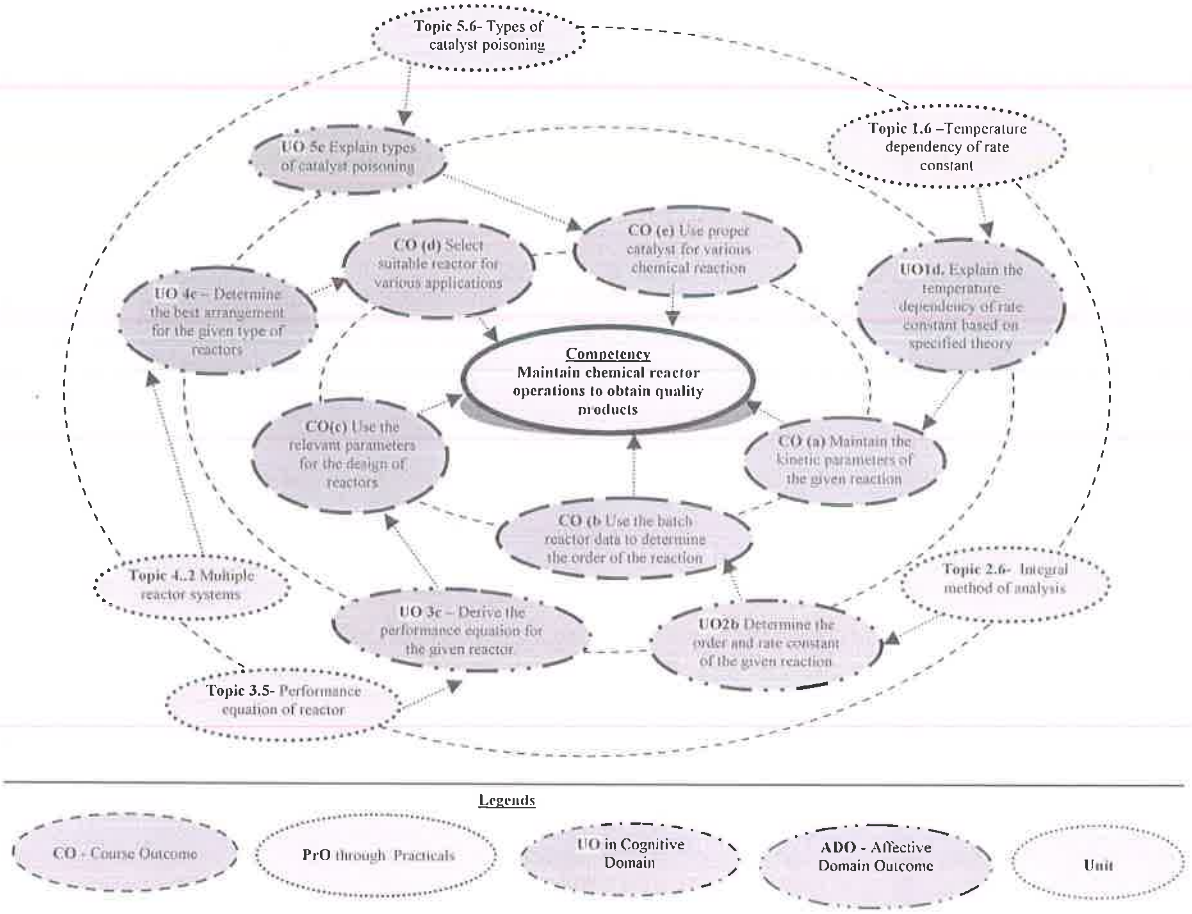

Figure 1 - Course Map

6. SUGGESTED TUTORIALS

The tutorials in this section which are subcomponents of the COs are to be developed and assessed in the student for the attainment of the competency.

S. No.	Tutorials	Unit No.	Approx. Hrs. Required
1.	Solve the problem based on Arrhenius law analytically	I	02
2.	Solve the problem based on Arrhenius law graphically	I	02
3.	Estimate the rate constant from the given data for first order and second order reaction.	II	02
4.	Estimate the time required to achieve a desired conversion from the given data for constant volume first order and second order reaction.	II	02
5.	Predict the order and rate constant of the reaction from the given concentration-time data	II	02
6.	Predict the order and rate constant of the reaction from the given conversion-time data,	II	02

S. No.	Tutorials	Unit No.	Approx. Hrs. Required
7.	Calculate ϵ_A for the given reactions	II	02
8.	Determine the order and rate constant of the reaction, based on half life method	II	02
9.	Given rate of reaction and concentration data, predict the order of the reaction	II	02
10.	Find out rate constant from the given data for variable volume system for the given problem.	II	02
11.	Determine the time required to achieve the desired outlet concentration in a batch reactor graphically.	III	02
12.	Estimate the volume of PFR required to achieve the desired conversion graphically for the given fractional conversion-rate of reaction data.	II!	02
13.	Estimate the volume of PFR required to achieve the desired outlet concentration graphically for the given concentration-rate of reaction data.	III	02
14.	Estimate the volume of MFR required to achieve the desired outlet concentration graphically for the given concentration-rate of reaction data.	III	02
15.	Compare the volume of MFR and PFR required to achieve a desired conversion from the given data.	IV	02
16.	Estimate the fraction of feed to be supplied to each branch for the given series-parallel arrangement of PFRs	IV	02
	Total		**32**

Note

A suggestive list of tutorials are given in the above table. More such tutorials can be added to attain the COs and competency. All the above listed tutorials need to be performed compulsorily, so that the student reaches the 'Applying Level' of Blooms's 'Cognitive Domain Taxonomy' as generally required by the industry.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

Not applicable

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Kinetics of homogeneous reactions	1a. Determine the reaction rate based on the specified parameter. 1b. List the variables affecting the rate of the given reaction. 1c. Describe the unit of rate constant for the given order of reaction.	1.1 Scope of Chemical reaction Engineering 1.2 Variables affecting the rate of reaction. 1.3 Reaction rate , Rate of reaction in various forms, rate equation, rate constant , units of rate constant, Concentration dependent term of rate equation 1.4 Types of Reactions: a. Homogeneous and Heterogeneous reaction b. Single and multiple reaction.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	1d. Explain the temperature dependency of rate constant based on the specified theory. 1e. Calculate the frequency factor and activation energy for the reaction using given data analytically and graphically.	c. Elementary and non-elementary reaction, d. Molecularity and Order of reaction, e. Chain and non chain reaction, f. Types of intermediates formed in non-elementary reactions. 1.5 Activation energy and its significance 1.6 Temperature dependent term of rate equation Temperature dependency of rate constant from- a. Arrhenius law b. Transition state theory c. Collision theory d. Comparison of different theories
Unit II-Interpretation of batch reactor data	2a. Derive the integrated rate expression for the given order reactions 2b. Determine the order and rate constant of the reaction from the given data. 2c. Give the value of slope of the graph plotted between concentration term and time for the given reaction. 2d. Estimate the time required to obtain the fractional conversion from the given data.	2.1 Constant volume batch reactor-Reaction rate 2.2 Analysis of total pressure data obtained in a constant volume system 2.3 Concept of fractional Conversion x_A 2.4 Methods for analyzing kinetic data General procedure for Integral method of analysis of data, general procedure for differential method of analysis of data, Method of isolation, method of initial rate, method of least square, method of excess 2.6 Integral method of analysis – Integrated rate expression for irreversible unimolecular first order reaction, irreversible bimolecular second order reaction of the type A + B → Product and 2 A →Product, nth order reaction, zero order reaction, autocatalytic reactions 2.7 Parallel and series reaction, Application of half life method for- Zero order, First order, Second order and nth order irreversible reactions. 2.8 Variable volume batch reactor, Concept of ϵ_A, Integral method of analysis based on variable volume system for zero order reaction, first order reaction and second order reaction.
Unit-III Introduction to reactor design	3a. Give the material balance equation for the specified reactor 3b. List the applications of any given reactor 3c. Derive the performance equation for the given reactor. 3d. Calculate the reactor volume for a specified conversion using the given data	3.1 Factors to be considered while designing a reactor, material balance equation for a reactor 3.2 Types of reactors- Batch reactor, Semi batch reactor, Continuous stirred tank reactor, Plug flow reactor . application of different reactors 3.3 Relation between C_A and X_A for constant density and changing density systems at constant temperature and pressure for batch system. 3.4 Performance equation for ideal batch reactor (constant and variable volume system) 3.5 Concept of space time and space velocity

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		3.6 Performance equation for Steady state (MFR) Mixed Flow Reactor (constant and variable volume system) 3.7 Performance equation for steady state (PFR) Plug Flow Reactor (constant and variable volume system), Holding time and space time for flow reactors
Unit –IV Design for single reactions	4a. Compare the specified types of reactors according to the given parameters. 4b. Compare the volume of MFR and PFR required for obtaining the given conversion of reactants. 4c. Determine the optimized arrangement for the given types of reactors for obtaining a specified conversion. 4d. Estimate the fraction of feed to be admitted to each branch when PFR's for the given parameters.	4.1 Size comparison of single reactors- Batch reactor v/s PFR, MFR v/s PFR 4.2 Multiple reactor systems- a. Plug Flow Reactors in Series and/or in Parallel, b. PFR's in parallel-series combination, c. Equal size MFR in series, d. MFR's of different size in series- i. Finding the conversion for a given system, ii. Determining the best system for a given conversion 4.3 Different types of reactors in series- Best Arrangement for set of Ideal Reactors
Unit-V Catalysis	5a. Describe the specified property required for any ideal catalyst. 5b. Explain the role of the given ingredient for the specified catalyst 5c. Explain the catalyst poisoning of the given type(s).	5.1 Nature of catalytic reactions, Important properties of catalyst- Specificity, activity, porous structure. 5.2 Promoters, accelerators and inhibitors. 5.3 Mechanism of solid catalyzed gas phase reactions. 5.4 Different methods of catalyst preparation- Precipitation, Gel formation, Simple mixing, Impregnation, Types of Catalyst poisoning –. Diffusion, Deposited, Stability, Selectivity, Sintering, Chemisorbed 5.5 Methods of Catalyst regeneration; Fluidized bed reactor; Packed bed reactor- concept of hot spot formation in packed bed reactor, application of the above reactors.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Kinetics of homogeneous reactions	10	02	04	04	10

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
II	Interpretation of batch reactor data	20	02	04	14	20
III	Introduction to reactor design	14	02	04	10	16
IV	Design for single reactions	16	02	04	10	16
V	Catalysis	04	02	02	04	08
	Total	**64**	**10**	**18**	**42**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note: *This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare report on the reactors used in specific chemical processes.
b) Give seminar on relevant topic.
c) Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) **Prepare model**: Prepare a model of any given type of reactor .
b) **Prepare a report**: Prepare the report on the catalysts used in various processes(Minimum 5) and state its properties, poisoning, life and regeneration
c) **Prepare chart**: Prepare a chart of different promoters, inhibitors and accelerators used along with the catalyst in chemical reaction.
d) Any other micro-projects suggested by subject faculty on similar line.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Chemical Reaction Engineering	Octave Levenspiel	Wiley India, New Delhi, 2015 ISBN-978-81-265-1000-9
2	Elements of Chemical Reaction Engineering	H. Scott Fogler	Pearson New Delhi, 2015 ISBN 978-81-317-1430-0
3	Chemical Engineering Kinetics	J.M.Smith	Mc-Graw Hill New Delhi, 2015 ISBN 0-07-066574-5
4	Elements of Chemical Reaction Engineering	Srivastav R.P.S.	Khanna Pulblishers, New Delhi, 2015 ISBN 81-7409-083-5

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) www.quora.com
b) https://authors.library.caltech.edu
c) https://terpconnect.umd.edu
d) https://chem.libertexts.org>core>chem
e) www.thoughtco.com/types-of-chemical-reactions-604038
f) www.the-seventh-dimension.com>testlev
g) www.che.iitb.ac.in
h) www.acadenia.edu/12091631/Interretation_of_Batch_Reaction_Data
i) www.scibd.com/mobile/doc/33996988/3-Batch-reactor
j) www.che.utah.edu>~ring>Lecture_Ppts
k) https://archieve.org/details/AnintroductionToChemicalEngineeringKineticsReactorDesign
l) www.chemguide.co.uk/physical/catalysis/intoduction.html
m) www.britannica.com/science/catalysis