GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)
Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-6th
Course Title: Chemical Reaction Engineering
(Course Code: 4360501)

Diploma programme in which this course is offered	Semester in which offered
Diploma in Chemical Engineering	6th

1. RATIONALE

To design Chemical reactor, engineer must have knowledge about many areas of chemical engineering like thermodynamics, chemical kinetics, fluid mechanics, heat transfer, mass transfer, and economics. Chemical reaction engineering integrates the aspects which are required for the appropriate design of chemical reactor. For design and operation of the commercial reactors performing different kind of chemical reactions, essential concepts of chemical reaction engineering are required. This course make diploma engineer to perform task of selecting, sizing and determining the optimal operating conditions for the reactor.

2. COMPETENCY

With the aim to develop the required skills in the students so that they are able to acquire the following competency, the course content should be taught, and the curriculum should be implemented.

- To operate & maintain different kind of chemical reactor to produce chemicals with good quality and minimum cost.

3. COURSE OUTCOMES (COs)

The teaching of theory and the implementation of practical exercises should be designed in a way that enables students to attain the necessary learning outcomes across cognitive, psychomotor, and affective domains, ultimately demonstrating the specified results.

1) Describe fundamental aspects of various chemical reactions.
2) Determine rate, rate constant, activation energy and order of reaction.
3) Analyze kinetic data to find out rate equation for batch reactor.
4) Control different reactors efficiently using fundamental knowledge of their functioning.
5) Estimate volume, space time and space velocity for Ideal reactors.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	70	30*	25	25	150

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

Legends: L - Lecture; **T** - Tutorial/Teacher Guided Student Activity; **P** - Practical; **C** - Credit; **ESE** - End Semester Examination; **CA** – Continuous Assessment

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. Some of the PrOs marked '*' (in approx. Hrs column) are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1.	To determine the activation energy of the reaction between Sodium thio sulphate and HCl using Arrhenius Equation.	II	02
2.	To determine order of the reaction between Sodium thio sulphate and HCl.	II	02
3.	To determine the kinetics of a reaction between Ethyl Acetate and Sodium Hydroxide under condition of excess Ethyl Acetate at room temperature.	III	02
4	To determine the kinetics of a reaction between Ethyl Acetate and Sodium Hydroxide by integral method of analysis at room temperature.	III	02
5	To determine the activation energy of the reaction between Ethyl Acetate and Sodium Hydroxide.	II	02
6	To determine the kinetics of a reaction between Ethyl Acetate and Sodium Hydroxide under by differential method of analysis at room temperature.	III	02
7.	To determine the kinetics of a reaction between n- Butyl Acetate and Sodium Hydroxide by differential method of Analysis at room temperature.	III	02
8.	To determine the kinetics of a reaction between n- Butyl Acetate and Sodium Hydroxide by integral method of Analysis at room temperature.	III	02
9.	To determine the activation energy of the reaction between n- Butyl Acetate and Sodium Hydroxide using Arrhenius Equation.	III	02

10.	Kinetic Study of Batch Reactor.		
11.	Kinetic Study of Continuous Stirred Tank Reactor.	II,IV, V	02
12.	Kinetic Study of Plug Flow Reactor.	II,IV, V	02
13.	Kinetic Study of Semi Batch Reactor.	II,IV, V	02
14.	Kinetic Study of Solid – Liquid Non Catalytic Reactor.	II,IV, V	02
			28 Hrs.

Note:

i) More Practical Exercises can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.

ii) The following are some sample 'Process' and '#Product' related skills (more may be added/deleted depending on the course) that occur in the above listed Practical Exercises of this course required which are embedded in the COs and ultimately the competency

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Handling of apparatus for precise measurements	10
2	Record observations correctly	20
3	Practice and adapt good and safe measuring techniques	10
4	Calculations, Interpretation of results and their conclusion.	20
5	Prepare report of practical in prescribed format	10
6	Solve assignment questions.	20
7	Viva-voce	10
Total		**100**

6. MAJOR EQUIPMENTS/ INSTRUMENTS REQUIRED

These major equipment/instruments and Software required to develop PrOs are given below with broad specifications to facilitate procurement of them by the administrators/management of the institutes. This will ensure the conduction of practice in all institutions across the state in a proper way so that the desired skills are developed in students.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Continuous Stirred Tank Reactor Assembly, MOC: SS 304, Cap.: 2-3 Ltrs , With Stirrer MOC :SS 304 (With Suitable motor)	10
2	Reactor with Glass Tube (Standard Company), (12 mm Dia * 1 M Length), with Rota Meter and Tank, With Air Compressor	11
3	Semi Batch Reactor, 2-3 Ltrs Cap, MOC SS 304, With Stirrer , MOC SS 304	12

7. AFFECTIVE DOMAIN OUTCOMES

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow ethical practices
c) Observe safety measures
d) Good house keeping
e) Time management
f) Practice environmentally friendly methods and processes.

The ADOs are best developed through laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Basics of Chemical Reactions	1a. Differentiate between various types of reactions such as chemical reactions Catalytic vs. Non-catalytic and the like 1b. Describe Biochemical Reaction 1c. Describe the factors affecting rate of reaction	1.1 Scope and importance of chemical reaction engineering 1.2 Classification of chemical reactions, a. Homogeneous vs. Heterogeneous, b. Catalytic vs. Non-catalytic c. Reversible vs. Irreversible d. By Molecularity e. Exothermic vs. Endothermic f. By order of reaction 1.3 Introduction to Biochemical reaction 1.4 Reaction rate on various basis and variables affecting the rate of reaction
Unit– II Kinetics of	2a. Derive the rate law 2b. Calculate rate constant	2.1 Rate equation/ Rate law 2.2 Concentration dependent term of rate Equation, Rate constant, Elementary and

Homogeneous Reactions	2c. Estimate Molecularity and order of reaction 2d. Explain temperature dependency from Arrhenius law 2e. Describe the significance of activation energy 2f.Calculate activation energy	non-elementary reactions 2.3 Molecularity and order of reaction 2.4 Temperature dependent term of rate Equation, Temperature dependency from Arrhenius law 2.5 Activation energy
Unit– III **Interpretation of batch reactor data**	3a. Describe the methods for analysis of kinetic data 3b. Explain the relationships for constant volume batch reaction system 3c. Derive integrated rate equation	3.1 Methods for analysis of kinetic data Differential vs. Integral method Half-life method 3.2 Relationship for constant volume batch reaction system 3.3 Total pressure of the system and the partial pressure of reacting material Concentration and Conversion 3.4 Integrated rate equation for different order of irreversible reactions: Uni-molecular first order, Bi-molecular, Second order, Tri-molecular third order, nth order, Zero order
Unit– IV **Ideal reactors**	4a. Describe ideal reactors 4b. Describe the construction, benefits, limitations and applications of different types of reactors such as batch reactors and others. 4c. Describe the construction, benefits, limitations and applications of different types of multiphase reactors such as slurry reactor and others	4.1 Features of ideal reactors 4.2 Different types of reactors: Batch reactor, Semi batch reactor, Flow reactors, MFR/CSTR, PFR (Tubular), Fixed bed reactors, Fluidized bed reactors 4.3 Multi phase reactors: G-L-S reactor, Slurry reactor, Bubble column reactor, Spray reactor, Trickle bed reactor
Unit– V **Design of single Ideal reactor**	5a. Explain the performance equation of different types of reactors such as Ideal batch reactor and other 5b. Explain space time and space velocity 5c. Differentiate holding time and Space time 5d. Calculate time/volume of reactor.	5.1 Performance equation of : Single Ideal reactor for Single reaction Constant density system, Ideal batch reactor, Steady state mixed flow reactor, Steady state plug flow reactor 5.2 Flow reactors: Space time, Space velocity, Holding time Vs. Space time

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	Basics of Chemical Reactions	6	3	4	3	10
II	Kinetics of Homogeneous Reactions	8	4	6	4	14
III	Interpretation of batch reactor data	8	4	6	4	14
IV	Ideal reactors	10	6	6	4	16
V	Design of single Ideal reactor	10	4	5	7	16
Total		**42**	**21**	**27**	**22**	**70**

Legends: R = Remember, **U** = Understand, **A**= Apply and above Level (Bloom's revised taxonomy)
Note: *This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly 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 perform following activities in group and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews.
Following is the list of proposed student activities like:
1. Assignments
2. Technical Quiz/MCQ Test
3. Presentation on some course topic
4. I-net based assignments
5. Undertake micro-Project in team/individually

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/subtopics.
b) Guide student(s) in undertaking micro-projects/activities.
c) Different types of teaching methods i.e. video demonstration, activity based learning, case study, m-learning need to be employed by teachers to develop the outcomes.
d) Some of the topics/sub-topics which is relatively simpler or descriptive is to be given to the students for self-learning but to be assessed using different assessment methods.

e) Teachers need to ensure to create opportunities and provisions for co-curricular activities.
f) Guide students to address issues on environment and sustainability with reference to using the knowledge of this course
g) OERs, Vlab, and Olabs may be used to teach for the teaching of different concepts.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-project is group-based (group of 3 to 5). However, in the **fifth and sixth semesters**, 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 the integration of PrOs, UOs, and ADOs. Each student will have to maintain dated work diary consist in go find individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16 (fourteen to sixteen) student engagement hours** during the course. The students ought to submit micro-project by the end of the semester (so that they develop industry-oriented COs).

A suggestive list of micro-projects is given here. This should relate highly to the competency of the course and the COs. Similar micro-projects could be added by the concerned course teacher.

Sr. No.	Micro Project
1.	Power Point Presentation on All the Topics of the syllabus.
2.	Prepare a chart on Classification of the Reactions.
3.	Prepare a chart on Arrhenius Law.
4.	Prepare a chart on comparison of Differential & Integral Method.
5.	Prepare a chart or model of Batch Reactor.
6.	Prepare a chart or model of Semi Batch Reactor.
7.	Prepare a chart or model of Continuous Stirred Tank Reactor.
8.	Prepare a chart or model of Plug Flow Reactor.
9.	Prepare a chart or model of Fixed Bed Reactor.
10.	Prepare a chart or model of Fluidized Bed Reactor.
11.	Prepare a chart or model of different multi-phase reactor.
12.	Prepare chart on Performance Equation of different types of Ideal Reactor.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Chemical Reaction Engineering	Octave Levenspiel	Third Edition, John Wiley and Sons
2	Essentials of Chemical Reaction	H. Scott Fogler	Fourth Edition, Prentice Hall

	Engineering		International
3	The Engineering of Chemical Reactions	Lanny D. Schmidt	Second Edition, Oxford University Press

14. SOFTWARE/LEARNING WEBSITES

1. http://nptel.ac.in/courses/103108097/
2. http://www.umich.edu/~elements/toc/frames.html
3. http://ocw.mit.edu/courses/chemical-engineering/10-37-chemical-and-biologicalreaction-engineering-spring-2007/lecture-notes/
4. https://www.youtube.com/watch?v=DpLAsVcofao&list=PLwdnzlV3ogoUC9IWVOPTGqV5eEVNRAfGa
5. https://www.youtube.com/watch?v=uNC9acjbK2c&list=PLwdnzlV3ogoUC9IWVOPTGqV5eEVNRAfGa&index=3
6. https://www.youtube.com/watch?v=w3DcsesIYyo&list=PLidJKPid3sndR_OdT8OU5oC2I6-Qa4pAO&index=2
7. https://www.youtube.com/watch?v=kHmOntjDT1I&list=PLidJKPid3sndR_OdT8OU5oC2I6-Qa4pAO&index=3

15. PO-COMPETENCY-CO MAPPING

Semester							
	POs						
Competency & Course Outcomes	**PO 1 Basic & Discipline specific knowledge**	**PO 2 Problem Analysis**	**PO 3 Design/ development of solutions**	**PO 4 Engineering Tools, Experimentation & Testing**	**PO 5 Engineering practices for society, sustainability & environment**	**PO 6 Project Management**	**PO 7 Life- long learning**
Competency	To operate & maintain different kind of chemical reactor to produce chemicals with good quality and minimum cost.						
CO 1) Describe fundamental aspects of various chemical reactions.	3.0	--	--	2.0	1.0	1.0	2.0
CO 2) Determine rate, rate constant, activation energy and order of reaction.	3.0	1.0	3.0	2.0	1.0	1.0	1.0
CO 3) Analyze kinetic data to find out rate equation for batch reactor.	3.0	2.0	3.0	2.0	1.0	1.0	--
CO 4) Control different reactors efficiently using fundamental knowledge of their functioning.	3.0	1.0	1.0	2.0	2.0	1.0	2.0
CO 5) Estimate volume, space time and space velocity for Ideal reactors.	3.0	2.0	2.0	2.0	--	1.0	--

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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