Academic year 2025/2026

Course Syllabus:

CHEMICAL ENGINEERING FUNDAMENTALS

FACULTAD DE CIENCIAS QUÍMICAS

1. IDENTIFICATION

Degree	Bachelor's Degree in Chemical Engineering			Course Code	801537
Course Title	Chemical Engineering Fundamentals			ECTS	9
Subject Area	Chemical Production Engineering				
Módulo	Chemical Technology				
Type	Compulsory	Year	First Year	Semester	Full-Year
Responsible Department	Chemical Engineering and Materials				

Lecturers in Charge

Activity	Lecturer	Email	Office
Coordinator	JOSÉ MANUEL TOLEDO GABRIEL	jmtoledo@ucm.es	QA-B61

Grupo A

Activity	Lecturer	Email	Office
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Tª/S/Tut.	JUAN CARLOS DOMINGUEZ TORIBIO	jucdomin@ucm.es	QB 533
Tª/S/Tut.	VICTORIA DE LOS ANGELES RIGUAL HERNANDEZ	vicrigua@ucm.es	QB 536

Grupo B

Activity	Lecturer	Email	Office
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Tª/S/Tut.	JESÚS ESTEBAN SERRANO	jeesteba@ucm.es	QP-114

2. OBJECTIVES

General Objective

To introduce Chemical Engineering, considering its connection with the chemical industry and other related industries, to introduce the fundamental tools upon which it is based, and to describe the physical and chemical operations that constitute chemical processes.

Specific Objectives

- To understand the scope of action of Chemical Engineering and its various components.
- To understand the characteristics of the chemical industry and other related sectors.
- To master the necessary tools for the study of Chemical Engineering.
- To know how to formulate and solve mass balances.
- To know how to formulate and solve energy balances.
- To understand the basic principles of equilibrium and kinetic laws.

- To understand the basic unit operations related to fluid flow, heat transfer, and mass transfer.
- To master the tools used in the study of industrial chemical reactions.
- To understand homogeneous and heterogeneous chemical reactors.
- To know how to formulate and solve design models for ideal reactors.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Prior knowledge

It is advisable to have a background knowledge of mathematics, physics, and chemistry at a high school/baccalaureate level.

Recommendations

It is recommended that students possess a basic proficiency in English to enable them to use English-language literature, conduct information searches, and communicate both in writing and orally in this language. It is also advisable for students to be familiar with computing tools and software for solving complex problems.

4. COURSE CONTENTS

Brief description of contents

The Chemical Industry and Chemical Engineering. Macroscopic conservation equations. Introduction to transport phenomena. Unit operations: fluid transport, heat transfer, mass transfer. Chemical reaction engineering. Chemical kinetics. Ideal reactors.

Program

BLOCK I: GENERAL CONCEPTS

Topic 1

Introduction to Chemical Engineering. Chemical Engineering and the chemical industry. Structure of Chemical Engineering education. Knowledge acquired by a Chemical Engineer. Career opportunities for Chemical Engineers.

Topic 2

Basic Concepts in Chemical Engineering. Ideal gas law (applications). Stoichiometry (concept of mole, limiting reactant, conversion, yield, selectivity, stream composition). Heat (specific heat, heat of reaction, latent heat, sensible heat). Study of the main variables in a chemical process and their unit conversions. Unit systems. Dimensional analysis.

Topic 3

Conservation Equations. Macroscopic mass balances. Component balances in steady state. Elemental balances. Mass balances in unsteady state.

Topic 4

Energy Conservation Equation. Energy balances without chemical reaction. Enthalpy calculations. Energy balances with chemical reaction.

BLOCK II: FUNDAMENTALS OF UNIT OPERATIONS

Topic 5

Molecular and Turbulent Transport. Newton's, Fourier's, and Fick's laws. Transport coefficients.

Topic 6

Fluid Flow. Flow through conduits. Separation operations based on fluid flow.

Topic 7

Heat Transfer and Mass Transfer. Heat transfer: mechanisms; conduction; convection; heat exchangers. Mass transfer: separation operations based on mass transfer.

BLOCK III: CHEMICAL REACTION ENGINEERING

Topic 8

Stoichiometric Study: Matrix B. Matrix v. Extent of reaction. Thermodynamic study: maximum extent of reaction.

Topic 9

Applied Chemical Kinetics. Reaction rate. Production rate. Factors influencing reaction rates. Catalysis: classification. Heterogeneous catalysis. Kinetic models: classification. Derivation of kinetic equations. Calculation methods: Differential and Integral. Kinetic model discrimination and validation methods.

Topic 10

Chemical Reactors. Classification. Ideal homogeneous batch and continuous reactors. Continuous stirred-tank reactor (CSTR). Plug flow reactor (PFR). Reactor networks. Design principles.

BLOCK IV: FUNDAMENTALS OF INDUSTRIAL PROCESSES

Topic 11

Industrial Processes. Ammonia Production.

5. COMPETENCES

General Competences

CG1-TQ1	Use concepts for the autonomous learning of new methods and theories
CG4	Solve problems in the field of chemical engineering with initiative, decision-making ability and critical reasoning.

Specific Competences

CE19-IP1	Perform macroscopic mass and energy balances.
CE20-IP1	Identify the fields of application of Chemical Engineering and its relationship with the Chemical Industry, raw materials, energy sources, and environmental impacts.
CE20-IP2	State the principles of conservation laws, equilibrium laws, and transport phenomena.
CE20-IP3	Describe representative operations and processes of the Chemical Industry.
CE20-IP4	Recognize the fundamentals of unit operations and chemical reaction engineering.
CE20-IP5	Perform simple calculations regarding unit operations, chemical kinetics, and ideal reactor design.

Transversal Competences

CT1	Demonstrate capacity for analysis and synthesis.
CT2	Demonstrate capacity for problem-solving.

6. WORKLOAD AND DISTRIBUTION BY ACTIVITY

Activity	In-Class (hours)	Autonomous Work (hours)	ECTS Credits
Lectures	52	98	6
Seminars	23	34,5	2,3
Scheduled Tutorials	3	4,5	0,3
Preparation for assignments and exams	10		0,4
Total	88	137	9

7. METHODOLOGY

The instructional time of the course is divided into lectures, seminars, and tutorials.

Lectures will be conducted in a single large group consisting of all students enrolled in the course section. Lectures will predominantly consist of masterclasses where the theoretical concepts required to solve the practical examples encountered throughout the course will be presented. Part of the recommended literature and supporting materials uploaded to the UCM Virtual Campus will be in English.

Seminars will also take place in a single group. These classes will focus on solving previously assigned problems as well as addressing complementary, highly practical topics. Seminars will be assessed through at least one written test, consisting of the individual resolution of one or more problems.

Tutorials will be carried out in two sub-groups, each comprising half of the enrolled students. In these sessions, student progress on personalized assignments will be supervised, providing guidance and resolving doubts. The first tutorial will be conducted entirely in English, utilizing English literature. In the third tutorial, the required engineering calculations will be executed using scientific software (Excel). Attendance at tutorial sessions is mandatory.

The UCM Virtual Campus will be utilized to share class materials for lectures and seminars, and as the main communication channel between the teacher and students.

8. BIBLIOGRAPHY

Core Textbooks

- Reklaitis, G.V.: “*Balances de materia y energía*”, Interamericana, México, 1986.
- Calleja, G. (Ed.), “*Introducción a la Ingeniería Química*”, Síntesis, Madrid, 1999.
- Levenspiel, O. “*Chemical Reaction Engineering*”. 3ª edición. John Wiley & Sons. Nueva York 1999. ISBN: 0-471-25424-X.

Supplementary Reading

- Miranda, R.: “*Ingeniería de Procesos. Diseño e integración de procesos químicos*”. Dextra Editorial, Madrid, 2020.
- Felder, R.M.; Rousseau, R.W.: “*Principios elementales de los procesos químicos*”, 3ª ed., Limusa Wiley, México, 2003.
- McCabe, W.L.; Smith, J.C.; Harriot, P.: “*Operaciones básicas de la Ingeniería Química*”, 4ª ed., McGraw Hill, Madrid, 1991.
- Fogler, H.S.: “*Elementos de Ingeniería de las Reacciones Químicas*”, Pearson Educación, Mexico. 2001.
- Santamaría y otros: “*Ingeniería de Reactores*”, Ed. Síntesis, Madrid, 1999.
- Izquierdo, José Felipe: “*Cinética de las Reacciones Químicas*”, Edicions Universitat Barcelona, 2004.
- Izquierdo, José Felipe; Tejero, Javier; Fité, Carles; Cunill, Fidel; Iborra, Montserrat: “*Problemas resueltos de Cinética de las Reacciones Químicas*”. Edicions Universitat Barcelona, 2004

9. EVALUATION

The evaluation of student performance and acquired competences will be carried out through a comprehensive global assessment. This system accounts for written examinations as well as the student's individual coursework performance throughout the year.

To be eligible for the global evaluation, the student must have participated in at least 70% of the in-class face-to-face activities (lectures, seminars, and tutorials).

If a student does not pass the course during the ordinary examination period, they may sit the exam during the extraordinary session. In this case, the exam will still account for 70%

of the overall grade, and the grades obtained from the remaining continuous assessment activities during the academic course will be maintained.

The final grade is computed as a weighted average of all evaluable activities. However, to pass the course, it is mandatory to achieve the minimum required score in each of them. If this requirement is not met, the maximum final grade recorded will be 4.5 out of 10. This criterion applies to both the ordinary and extraordinary examination sessions.

❖ WRITTEN EXAMINATIONS: 70%

Examinations are identical for all enrolled students. Two written partial exams, primarily practical in nature, will be conducted—one at the end of each semester—as well as a final exam during both the ordinary and extraordinary periods. Students who pass both partial exams are exempt from sitting the final exam. The score obtained in the partial exams, or the final exam if applicable, constitutes 70% of the global grade.

- To pass the course via partial exams, the student must achieve a mean score greater than or equal to 5.0 across both tests. To compute this average, a minimum score of 4.0 must be achieved in each individual partial exam.
- Partial exams are mid-term tests that release content. If a student fails one partial exam with a score below 4.0 but scores 5.0 or higher on the other, they are only required to sit the failed content during the ordinary final exam.
- Released content is valid only for the ordinary final exam session. If a student fails the ordinary final exam, they must take a comprehensive exam covering all course contents during the extraordinary session.
- When sitting the complete final exam (ordinary or extraordinary), a minimum score of 5.0 points out of 10 is required to access the weighted global continuous assessment. If the student sits only one part during the ordinary final exam, they must score a minimum of 4.0 to average it with the previously passed mid-term content, provided the combined mean score is 5.0 or higher.

Competences CG1-TQ1 y CG4; CT1 y CT2; CE19-IP1 y CE20 (IP1 a IP5) will be evaluated in the written examinations section.

❖ INDIVIDUAL COURSEWORK: 30%

The completion of exercises during the written seminar tests and tutorials is mandatory. Additionally, a set of model problems will be assigned for each part of the course; these must be completed by students prior to their discussion and resolution during seminar sessions. Collectively, these tasks contribute 30% to the overall global assessment. This continuous coursework grade is valid for both ordinary and extraordinary sessions. Parts of these activities will be evaluated in English. In the third tutorial, each student group must submit their scientific computing files (Excel spreadsheet).

Competences CG1-TQ1 y CG4; CT1 y CT2; CE19-IP1 y CE20 (IP1 a IP5) will be evaluated in this individual coursework section.

The grades for the activities scheduled for the course assessment (midterm exams, seminars, tutorials, and problem set submissions) will be communicated to students with sufficient advance notice before the final exam, allowing them to adequately plan their study for this or other courses.

In particular, midterm exam grades will be announced within a maximum of 20 days, except for the second midterm, where the turnaround time may be shorter to accommodate the final exam scheduling.

In any case, a minimum period of seven days will be maintained between the publication of grades and the date of the course's final exam.

ACTIVITY PLANNING AND TIMELINE (CHRONOGRAM)

TOPIC	ACTIVITY	HOURS	GROUPS	START	END
1. Introduction to Chemical Engineering	Lectures	2	1	Week 1	Week 1
2. Basic concepts in Chemical Engineering.	Lectures	6	1	Week 1	Week 5
	Seminars	3	1		
3. Conservation Equations. Mass Balances.	Lectures	12	1	Week 6	Week 14
	Seminars	6	1		
4. Energy consetvation equation. Energy balances with and without chemical reaction.	Lectures	8	1	Week 15	Week 19
	Seminars	3	1		
5. Molecular and Turbulent Transport molecular y turbulento. Transport properties	Lectures	2	1	Week 20	Week 20
6. Fluid Flow. Heat Transfer. Mass Transfer. Separation operations	Lectures	2	1	Week 20	Week 21
	Seminars	2	1		
7. Heat and Mass Transfer. Separation Operations.	Lectures	2	1	Week 21	Week 2
	Seminars	2	1		
8. Stoichiometry and Thermodynamics.	Lectures	3	1	Week 22	Week 24
	Seminars	2	1		
9. Applied Chemical Kinetics.	Lectures	7	1	Week 24	Week 27
	Seminars	3	1		
10. Chemical reactors. Classification. Ideal homogeneous batch and continuous reactors. Reactor networks. Design principles.	Lectures	6	1	Week 27	Week 29
	Seminars	2	1		
11. Industrial processes. Ammonia production	Lectures	2	1	Week 29	
Temas 1- 11	Tutorial*	3	2	Weeks 11, 15 y 27	

* The scheduled tutorials are subject to potential modifications based on the joint planning of the course.

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SUMMARY OF ACTIVITIES

TEACHING ACTIVIDAD	ASSOCIATED COMPETENCES	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY	ASSESSMENT PROCEDURE	P	NP	TOTAL	C
Lectures	CG1 CE19, CE20	Presentation of theoretical concepts.	Active attention and participation during the course of the class.		52	98	150	
Seminars	CG1, CG4 CE19, CE20 CT1, CT2	Posing and solving exercises and problems. Conducting at least one written test.	Completing exercises.	Grading of written responses (approach and result) for solving practical exercises and numerical problems.	23	34,5	57,5	30%
Scheduled tutorials	CG1, CG4 CE19, CE20 CT1, CT2	Proposing numerical exercises in tutorials. Direction and supervision of student activities.	Discussion and resolution of proposed questions and problems. Formulating questions and doubts.	Grading of responses and evaluation of active participation and work completed.	3	4,5	7,5	
Exams	CG1, CG4 CE19, CE20 CT1, CT2	Design, proctoring, and grading of the exam.	Preparation and taking of the exam.	Exam	10			70%

P: In-person activities

NP: Non-contact activities (Independent study)

C: Grading/Weight