ANEXO I

Escuela Técnica Superior de Ingeniería

GENERAL SPECIFICATIONS

COURSE 25/26

Subject Data

Name:
Análisis y Diseño Avanzado de Operaciones de Transferencia de Materia en la Industria Química y del Refino
English name:
Advanced Analysis and Design of Mass Transfer Separation Operations in the Chemical and Refining Industries

Code:	**Type:**
1180103	Compulsory

Hours:			
	Total	**In class**	**Out class**
Time distribution	150	60	90

ECTS:				
Standard group	**Small groups**			
	Classroom	**Lab**	**Practices**	**Computer classroom**
2.5	2.0	0	0	1.5

Departments:	**Knowledge areas:**
Chemical Engineering, Physical Chemistry and Materials Science	Chemical Engineering
Year:	**Semester**
1°	2°

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TEACHING STAFF

Name:	E-mail:	Telephone
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Others Data (Tutoring, schedule...)

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UNIA: Ángel Salvador González Delgado (CEPSA)

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SPECIFIC INFORMATION OF THE COURSE

1. Contents description:

1.1 In English:

Separation of multicomponent mixtures; advanced methods for separation of complex mixtures; advanced operations of adsorption, extraction, chromatography and ion exchange, humidification and cooling towers; membranes separations and hybrid operations; multicomponent rectification through computer aided simulation.

1.2 In Spanish:

Separación de mezclas multicomponentes. Métodos avanzados de separación de mezclas complejas; operaciones avanzadas de adsorción, cromatografía e intercambio iónico, humidificación y torres de enfriamiento; separaciones mediante membranas y operaciones híbridas; simulación de rectificación multicomponente.

2. Background:

2.1 Situation within the Degree:

The descriptors of this course focus primarily on the study of advanced heat and mass transfer operations. Thus, this course complements the courses "Basic Chemical Engineering Operations I and II," taught in the Bachelor's Degree in Industrial Chemical Engineering. Therefore, the knowledge and skills acquired in these courses, as well as those related to material and energy balances, heat transfer, and phase equilibrium, must be applied.

2.2 Recommendations

To successfully assimilate the subject, students must have prior knowledge of material and energy balances and heat transfer mechanisms, know how to estimate equilibrium data using thermodynamic correlations and handle various phase diagrams, as well as a solid understanding of numerical and matrix calculus.

3. Objectives (as result of teaching, or skills or abilities and knowledge):

- Identify key components and learn calculation algorithms to address multicomponent rectification in the chemical and refining industries.
- Understand advanced distillation techniques for the separation of complex (azeotropic) mixtures in the chemical industry.
- Apply specialized software to solve the above cases and determine concentration, temperature, and flow profiles.
- Understand the fundamentals of advanced separation operations involving surface phenomena or ion exchange.
- Acquire knowledge of the principles and design of humidification and cooling tower operations, a process that involves the simultaneous transfer of heat and matter.
- Understand the fundamentals and design of separation operations based on the transfer of a solute through a membrane, techniques considered complementary or competitive with the above.

4. Skills to be acquired

4.1 Specific Skills:

CEPP2: Design products, processes, systems, and services for the chemical industry, as well as the organization of existing ones, using as a technological basis the various areas of chemical engineering, including transport processes and phenomena, separation operations, and engineering of chemical, nuclear, electrochemical, and biochemical reactions.
CEPP3: Conceptualize engineering models, apply innovative problem-solving methods, and appropriate computer applications for the design, simulation, optimization, and control of processes and systems.
CEPP4: Have the ability to solve problems that are unfamiliar, incompletely defined, or have competing specifications, considering possible solution methods, including the most innovative ones, selecting the most appropriate and being able to correct the implementation, evaluating different design solutions.
CEPP1: Apply knowledge of mathematics, physics, chemistry, biology, and other natural sciences, obtained through study, experience, and practice, with critical reasoning to establish economically viable solutions to theoretical problems.

4.2 General, Basic or Transversal Skills:

CB10: Students will have the learning skills to continue their studies in a manner that will be largely self-directed or autonomous.
CB6: Possess and understand knowledge that provides a basis or opportunity for originality in the development and/or application of ideas, often in a research context.
CB7: Students should be able to apply acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
CB8: Students should be able to integrate knowledge and address the complexity of making judgments based on information that, while incomplete or limited, includes reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.
CG1: Ability to apply the scientific method and the principles of engineering and economics to formulate and solve complex problems in processes, equipment, facilities, and services, in which matter undergoes changes in its composition, state, or energy content, characteristic of the chemical industry and other related sectors, including pharmaceuticals, biotechnology, materials, energy, food, and the environment.
CG2: Conceive, design, calculate, and design processes, equipment, industrial facilities, and services in the field of chemical engineering and related industrial sectors, in terms of quality, safety, economy, rational and efficient use of natural resources, and environmental conservation.
CG7: Possess the independent learning skills to maintain and improve chemical engineering competencies that enable the continued development of the profession.
CG5: Know how to establish mathematical models and develop them using appropriate computing, as a scientific and technological basis for the design of new products, processes, systems, and services, and for the optimization of others already developed.
CT1: Adequately manage acquired information, expressing advanced knowledge and demonstrating, in a context of scientific and technological or highly specialized research, a detailed and well-founded understanding of the theoretical and practical aspects and working methodology in the field of study.
CT5: Make advanced use of information and communication technologies, developing, to the required level, Computer and Information Skills (CI2).
CT3: Develop an attitude and aptitude for the permanent pursuit of excellence in academic work and future professional practice.

5. Training Activities and Teaching Methods

5.1 Training Activities:

- Theoretical contents lectures.
- Solving problem seminars.
- Computer aided case studies workshops.
- Teacher-guided assignments.

5.2 Teaching Methods::

- Master class.
- Computer aided case studies, in small groups.
- Problem solving.
- Individual or Group Tutoring. Direct interaction between teachers and students.
- Assessments and exams.

5.3 Development and Justification:

1. Master class: Presentation of the theoretical content of the subject. During this presentation, the teacher can constantly interact with the students by asking questions, providing examples and proposing solutions, soliciting opinions, etc., encouraging active participation and the development of the teaching-learning process.
2. Problem solving: Presentation and completion of exercises, standard problems, and practical cases related to the theoretical content. Various problems will be presented and, in some cases, students will submit the problems. The exercises will be solved using MS Excel functions and macros. Mathcad Prime may also be used occasionally.
3. Individual or Group Tutoring: They include individual student monitoring through activities proposed by the lecturer. Cooperative learning can be also encouraged.
4. Assessments and exams: Knowledge assessment will be done through practical numerical exercises and multiple-choice theoretical and practical tests.
These first four methodologies represent 4.5 ECTS credits (0.5 of which are taught by a specialist technician from CEPSA).
5. Computer aided case studies: The tasks presented will help develop, at a practical level, the knowledge acquired in theory. Exercises and practical scenarios will be completed in the computer lab using the **Aspen Plus** simulator. Teaching this type of content will be supported with self-created **video tutorials**. The possibility of joint teaching activities with foreign universities (**COIL**) is also being considered. This latter methodology represents 1.5 ECTS credits.

6. Detailed Contents

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BLOCK I: Gas-liquid operations

CHAPTER 1. RECTIFICATION OF MULTICOMPONENT MIXTURES

1. Introduction. Key Components
2. Profiles in Multicomponent Rectification
3. Approximate Calculation Methods: Fenske-Underwood-Gilliland Method
4. Step-by-Step Calculation Methods: Lewis-Matheson Method
5. Matrix Methods. Introduction to Aspen Plus

CHAPTER 2. ADVANCED METHODS OF RECTIFICATION OF COMPLEX MIXTURES

1. Introduction. Residue Curves
2. Rectification of Binary Azeotropic Mixtures
   2.1. Azeotrope Shift by Pressure Changes (Pressure Swing)
   2.2. Mixtures with Heteroazeotropes
3. Rectification with the Addition of a Third Component
   3.1. Azeotropic
   3.2. Extractive

CHAPTER 3. HUMIDIFICATION AND COOLING TOWERS

1. Introduction. Definitions
2. Psychrometric diagram of the air-water vapor mixture
3. Wet bulb and adiabatic saturation temperatures
4. Cooling tower design

BLOCK II: Solid-fluid operations

CHAPTER 4. ADSORPTION, CHROMATOGRAPHY AND ION EXCHANGE

1. Introduction
2. Description of Adsorption Equilibrium
3. Adsorption Operations
   3.1. Single Stage
   3.2. Cross Currents
   3.3. Countercurrent
3.4. Unsteady State (Fixed Bed)
4. Chromatography and ion exchange

BLOCK III: Membrane separation operations

CHAPTER 5. INTRODUCTION TO MEMBRANE SEPARATIONS

1. Introduction
2. Membrane Classification
3. Materials Used in Membrane Manufacturing
4. Membrane Preparation Techniques
5. Membrane Characterization Techniques

CHAPTER 6. MEMBRANE TRANSPORT

1. Introduction
2. Transport in Porous Membranes
   2.1. Viscous Flow
   2.2. Knudsen Flow
3. Transport in Nonporous Membranes
4. Transport in Ionic Membranes
5. Polarization and Fouling

CHAPTER 7. MEMBRANE PROCESSES

1. Flow Models
2. Pressure Difference-Controlled Processes
   2.1. Micro- and Ultrafiltration
   2.2. Reverse Osmosis
3. Concentration Difference-Controlled Processes
   3.1. Gas Permeation
   3.2. Pervaporation
   3.3. Dialysis
4. Electric Potential Difference-Controlled Processes
   4.1. Electrodialysis

7. Bibliography

7.1 Basic Bibliography:

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PROBLEMAS RESUELTOS DE OPERACIONES DE SEPARACIÓN
F.J. Montes. Paraninfo Universidad, Madrid, 2019

7.2 Additional Bibliography:

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P.A. Schweitzer. McGraw-Hill, New York, 1997
CHEMICAL ENGINEERING, VOL. 2, PARTICLE TECNOLOGY AND SEPARATION PROCESSES (5th ED.)
J.F. Richardson, J.H. Harker. Butterworth-Heinemann, Oxford, 2002
PRINCIPLES OF CHEMICAL SEPARATIONS WITH ENVIRONMENTAL APPLICATIONS
R.D. Noble, P.A. Terry. CUP, Cambridge, 2004
OPERACIONES DE SEPARACIÓN EN INGENIERÍA QUÍMICA. MÉTODOS DE CÁLCULO
P.J. Martínez de la Cuesta, E. Rus Martínez. Prentice Hall, Madrid, 2004
DESIGN AND CONTROL OF DISTILLATION SYSTEMS FOR SEPARATING AZEOTROPES
W.L. Luyben, I-Lung Chien. New Jersey, Wiley: AIChE, 2010
ASPEN PLUS V8.0. GETTING STARTED BUILDING AND RUNNING A PROCESS MODEL
Aspen Technology Inc., Burlington, 2012
DISTILLATION DESIGN AND CONTROL USING ASPEN SIMULATION (2nd ED.)
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DISTILLATION: EQUIPMENT AND PROCESSES
A. Gorak, Z. Olujic. Elsevier, Amsterdam, 2014
TUTORIAL DE ASPEN PLUS. INTRODUCCIÓN Y MODELOS SIMPLES DE OPERACIONES UNITARIAS
F. Espínola. Universidad de Jaén, Jaén, 2015
USING ASPEN PLUS IN THERMODYNAMICS INSTRUCTION: A STEP-BY-STEP GUIDES
I. Sandler. New Jersey, Wiley: AIChE, 2015
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8. Systems and Assessment Criteria

8.1 System for Assessment:

- Theory/Problems Exam
- Practical defense
- Practical assignment
- Individual student monitoring

8.2 Assessment Criteria and Marks:

8.2.1 Examinations Convocatory I

1. Theory/Problems Exam (70 %): competences CEPP1, CEPP2, CG2 and CG1 will be assessed through **a final exam** (date officially assigned by ETSI) which will be composed of 3-4 numerical problems on the Theory/Problems lectures. The student will have to solve the exam using a **MS Excel** spreadsheet.
2. Practical assignment (15 %): through an **Aspen Plus assignment,** in couples, which will deal with the computer sessions contents; **Practical defense (10 %):** the students will be also asked to prepare a **video-report** of results, in English language. Competences CEPP3, CT5, CT3, CG5, CG1, CB10 and CB7 will be evaluated.
3. Individual student monitoring (5 %): The students will be asked to complete an **online multiple-choice test** (10-20 questions) on Chapter 2 (Rectification of Complex Mixtures).

Please, do NOTE that:

- **100 % attendance to computer sessions is compulsory**.
- A minimum overall mark of 5 over 10 is required to pass.
- If a minimum mark of 4 over 10 is not attained in part 1, parts 2 and 3 will not be considered. Likewise, parts 2 and 3 will not be considered if their marks are lower than part 1's. In both cases, part 1 will represent 100 %.
- Students are free to opt for maintaining part 2 and/or 3 marks forever (as long as they reach a minimum mark of 5 over 10) or repeating them the following academic course.
- Mobile phones are forbidden in class, computer sessions and exams.

8.2.2 Examinations Convocatory II

1. Theory/Problems Exam (70 %): competences CEPP1, CEPP2, CG2 and CG1 will be assessed through **a final exam** (date officially assigned by ETSI) which will be composed of 3-4 numerical problems on the Theory/Problems lectures. The student will have to solve the exam using a **MS Excel** spreadsheet.
2. Practical assignment (15 %) + Practical defense (10 %): Convocatory I (February) grades will be applied.
3. Individual student monitoring (5 %): Convocatory I (February) grades will be applied.

Please, do NOTE that:

- **100 % attendance to computer sessions is compulsory**.
- A minimum overall mark of 5 over 10 is required to pass.
- If a minimum mark of 4 over 10 is not attained in part 1, parts 2 and 3 will not be considered. Likewise, parts 2 and 3 will not be considered if their marks are lower than part 1's. In both cases, part 1 will represent 100 %.
- Students are free to opt for maintaining part 2 and/or 3 marks forever (as long as they reach a minimum mark of 5 over 10) or repeating them the following academic course.
- Mobile phones are forbidden in class, computer sessions and exams.

8.2.3 Examinations Convocatory III

1. Theory/Problems Exam (70 %): competences CEPP1, CEPP2, CG2 and CG1 will be assessed through **a final exam** (date officially assigned by ETSI) which will be composed of 3-4 numerical problems on the Theory/Problems lectures. The student will have to solve the exam using a **MS Excel** spreadsheet.
2. Practical assignment (15 %) + Practical defense (10 %): Convocatory I (February) grades will be applied.
3. Individual student monitoring (5 %): Convocatory I (February) grades will be applied.

Please, do NOTE that:

- **100 % attendance to computer sessions is compulsory**.
- A minimum overall mark of 5 over 10 is required to pass.
- If a minimum mark of 4 over 10 is not attained in part 1, parts 2 and 3 will not be considered. Likewise, parts 2 and 3 will not be considered if their marks are lower than part 1's. In both cases, part 1 will represent 100 %.
- Students are free to opt for maintaining part 2 and/or 3 marks forever (as long as they reach a minimum mark of 5 over 10) or repeating them the following academic course.

Mobile phones are forbidden in class, computer sessions and exams.

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8.2.4 Extraordinary Convocatory

1. Theory/Problems Exam (70 %): competences CEPP1, CEPP2, CG2 and CG1 will be assessed through **a final exam** (date officially assigned by ETSI) which will be composed of 3-4 numerical problems on the Theory/Problems lectures. The student will have to solve the exam using a **MS Excel** spreadsheet.
2. Practical assignment (15 %) + Practical defense (10 %): Convocatory I (February) grades will be applied.
3. Individual student monitoring (5 %): Convocatory I (February) grades will be applied.

Please, do NOTE that:

- **100 % attendance to computer sessions is compulsory**.
- A minimum overall mark of 5 over 10 is required to pass.
- If a minimum mark of 4 over 10 is not attained in part 1, parts 2 and 3 will not be considered. Likewise, parts 2 and 3 will not be considered if their marks are lower than part 1's. In both cases, part 1 will represent 100 %.
- Students are free to opt for maintaining part 2 and/or 3 marks forever (as long as they reach a minimum mark of 5 over 10) or repeating them the following academic course.

Mobile phones are forbidden in class, computer sessions and exams.

8.3 Single Final Evaluation:

Theory/Problems Exam (100 %): competences CEPP1, CEPP2, CG2 and CG1 will be assessed through **a final exam** (date officially assigned by ETSI) which will be composed of 3-4 numerical problems on the Theory/Problems lectures. The student will have to solve the exam using a **MS Excel** spreadsheet.