295561 - 295EQ131 - Process Integration

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 713 - EO - Department of Chemical Engineering
Academic year: 2019
Degree: MASTER'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2019). (Teaching unit Optional)
ECTS credits: 6
Teaching languages: Catalan, Spanish, English

Teaching staff
Coordinator: ANTONIO ESPUÑA CAMARASA
Others: Antonio Espuña Camarasa

Opening hours
Timetable: To be defined each semester, according to the students availability.

Prior skills
Those related to the subjects previously planned in these studies, both at the Master and the Degree levels, with special emphasis on the topics indicated as "requirements".

Requirements
The starting points of the subject are:
* Transport Phenomena (and/or associated topics: mass transfer, heat transfer, etc.)
* Process Systems Engineering
* Basic Operations
* Separation Operations
* Process control
* Chemical Reaction Engineering
* Simulation and Optimization of Chemical Processes

They are also fundamental:
* Thermodynamics of equilibrium
* Fluid mechanics
* Informatics/Numerical Methods

Degree competences to which the subject contributes

Generical:
CGMUEQ-01. 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 the matter undergoes changes in its composition, state or energy content, characteristic of the chemical industry and other related sectors among which are the pharmaceutical, biotechnological, materials, energy, food or environmental
CGMUEQ-02. To conceive, project, 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 environment conservation
CGMUEQ-05. Know how to establish mathematical models and develop them through appropriate information technology, as a scientific and technological base for the design of new products, processes, systems and services,
and for the optimization of others already developed
CGMUEQ-08. Lead and define multidisciplinary teams capable of solving technical changes and management needs in national and international contexts

Transversal:

05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

Teaching methodology

The teaching load of the subject is 6.0 ECTS credits, which are distributed in different activities:

• Blackboard / computer sessions (about 15 teaching hours + 15 hours of personal work), in which the basic concepts of the subject are exposed and a limited number of examples are addressed. Special emphasis is placed on the conceptual similarities between the different specific analyzed systems (whose number is also necessarily limited), and on the equivalences in terms of how to approach them, so that the student is able to assess the convenience or not to use a certain approximation or method of calculation to any of the studied systems, or to any other system not studied in this course.

• Problem solving sessions: during the development of the course, several problems will be proposed to be solved both in the teaching room (about 45 hours) and outside (70 hours of personal work). The main process integration and intensification concepts, in terms of modeling, calculation and optimization, will be applied to some specific processes. The resulting proposals built by the students will be corrected to allow a continuous self-assessment, and will also be taken into account in the qualification of the competences related to autonomous learning. Working on these problems is, in any case, a good way to invest part of the 6 hours per week of personal work that, on average, is expected to be dedicated to the subject.

Personal work: Globally, a personal dedication of 1.5 hours of personal work is foreseen for each hour of class (without considering, logically, the time dedicated to "remember" concepts of other subjects, nor the eventual inefficiencies resulting from poor management of the "teamwork").

Note: For the resolution of the problems, the collaboration between students is promoted (approach of the problem, search of information, etc.). An effort must be made so that "teamwork" does not end up being considered as a "joint work", which is not usually efficient or effective (e.g., several people around a single computer).

Learning objectives of the subject

Among the techniques and procedures applicable to the analysis and optimization of Chemical Processes, the "Process Integration" refers to the use of techniques and procedures for calculation and decision making specifically aimed at exploiting interactions between the different tasks which make up a process (and their associated operations), to make use of the available resources in the best possible way.

Overall objective:

It is intended that, at the end of the course, the student understands and correctly apply techniques of Process Integration to the improvement of the effectiveness and / or efficiency of a process (as opposed to the sequential optimization of the different units separately).

To do this, the subject is directly related to the scientific and technical principles of Thermodynamics, Kinetics and Transport Phenomena, rethinking them in the different Basic Operations and integrating the resulting models, in order to
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objectively evaluate the overall performance of a process and to address improvements in its design and operation.

Specific objectives:

It is intended that at the end of the subject the student:
* Has broadened its understanding of the physical, chemical and thermodynamic principles on which the chemical processes are based and the operations and / or previous and / or subsequent transformations that facilitate them, in order to be able to objectively assess the global efficiency and effectiveness of any process, as well as its potential for improvement, beyond the specific study of the units that compose it.
* Know and correctly apply the techniques specifically developed in the framework of "Process Integration", with special emphasis on "Pinch Analysis" and its different applications in the field of energy, water and other elements commonly used in chemical processes.
* Learn how to complement and / or correctly combine the methods of Process Integration with the "standard" methods of simulation and process optimization, and understand the advantages and disadvantages of their use in each case.
* Know how to adapt the required calculations to the different levels of response speed and precision that may be required.
* Be able to use computer calculation tools to perform these calculations.

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<th>Study load</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong> 150h</td>
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<tr>
<td>Hours large group: 28h 18.67%</td>
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<tr>
<td>Hours medium group: 0h 0.00%</td>
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<td>Hours small group: 14h 9.33%</td>
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<tr>
<td>Guided activities: 6h 4.00%</td>
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<td>Self study: 102h 68.00%</td>
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### Introduction - Simulation and optimization - Calculation tools

**Learning time:** 30h  
- Theory classes: 0h  
- Practical classes: 12h  
- Guided activities: 18h

**Description:**  
Introduction to Process Integration.  
Review of the basic concepts of process simulation and optimization. Basic Simulation and optimization tools.

**Related activities:**  
Application of the specific Process Systems Engineering optimization procedures to basic cases (optimization of the design of individual units): Heat recovery systems, separation systems, reaction systems, etc.

**Specific objectives:**  
Framing the Process Integration principles in the general field of Process Engineering, and their relationship with other alternative and complementary techniques such as Process Optimization, Process Synthesis or Process Intensification  
Review / update of the basic concepts of Process Engineering. Introduction to the use of the calculation tools available on campus.

Application of optimization procedures of the Process Engineering to basic cases of optimization of the design of individual units.

### Synthesis and optimization of reaction, separation and control networks

**Learning time:** 46h  
- Theory classes: 0h  
- Laboratory classes: 22h  
- Guided activities: 24h

**Description:**  
In this topic, the systematic procedures for decision making applicable to process synthesis, design and operation will be reviewed, with special emphasis on structural decisions (type, and sequence of the equipment to be installed, connections between them, etc.)

**Related activities:**  
Application of systematic procedures for decision-making analysis on process structures: synthesis of distillation sequences, synthesis of reactor networks, etc.

**Specific objectives:**  
Review of the process networks synthesis concepts. Strategies for the optimization of structures.
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### Analysis of processes

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<th>Learning time:</th>
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<tr>
<td>Theory classes:</td>
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<tr>
<td>Practical classes:</td>
<td>6h</td>
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<td>Guided activities:</td>
<td>4h</td>
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<td>Self study:</td>
<td>4h</td>
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**Description:**
Establishment of feasible targets. Use of efficiency / effectiveness ratios (KPIs) to assess the improvement potential over a process.

**Related activities:**
Study of examples and counterexamples of application of optimization techniques, and analysis of them using the thermodynamic tools that constitute the basis of the specific Process Integration techniques.

**Specific objectives:**
The student must be able to assess the overall efficiency and effectiveness of a process, based on the limits established by the basic principles of thermodynamics, kinetics, etc., and global sustainability objectives (economic, environmental and social).

### Global vision: integration of processes

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<th>Learning time:</th>
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<tr>
<td>Theory classes:</td>
<td>0h</td>
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<tr>
<td>Practical classes:</td>
<td>20h</td>
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<tr>
<td>Guided activities:</td>
<td>15h</td>
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<td>Self study:</td>
<td>15h</td>
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**Description:**
Specific Porcess Integration techniques - Pinch Analysis

**Related activities:**
Application of specific Process Integration techniques to different situations: Heat exchange networks, integration of water use, improvement of energy efficiency, integration of mass transfer systems, etc.

**Specific objectives:**
The student must be able to apply the specific Process Integration techniques to the design or improvement of specific situations.
### MultiObjective Optimization and Uncertainty Management

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<th>Learning time:</th>
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<tr>
<td>Theory classes:</td>
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<td>Laboratory classes:</td>
<td>4h</td>
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<tr>
<td>Guided activities:</td>
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<td>Self study:</td>
<td>6h</td>
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#### Description:
- Please, check the Spanish version.
- Interpretation of the balance between different objectives. Pareto space.

- Specific resolution methods for multiobjective problems
- Quantification and management of uncertainty. Endogenous uncertainty and exogenous uncertainty.
- Decision making under uncertainty. The robustness as an additional objective.

#### Related activities:
- Extension of the Energy Integration Approach already applied to a multi-objective and uncertain scenario.
- Assessment of the previously obtained results and alternative solutions in other scenarios.

#### Specific objectives:
- At the end of this topic, the student must be able to propose the solution of a Process Integration problem in the framework of a multi-objective optimization in an uncertain environment, and quantitatively evaluate different alternate solutions in this framework.

### Qualification system

\[ N_{\text{final}} = 0.45 \max (N_{\text{pp}}; N_{\text{ef1}}) + 0.45 * N_{\text{ef2}} + 0.1 * N_{\text{cg}} \]

Where:
- \( N_{\text{pp}} \) is the partial test grade (week 8 approx.)
- \( N_{\text{ef1}} \) is the final exam mark, corresponding to the first part of the subject
- \( N_{\text{ef2}} \) is the final exam mark, corresponding to the second part of the subject
- \( N_{\text{cg}} \) is the evaluation score of the generic competence to be evaluated (autonomous learning level 3)


The mark obtained in the re-evaluation exam, if higher, will replace the grade of the final exam and that of the partial exam, under the conditions established by the aforementioned EEBE's Evaluation and Permanence Regulations.
Regulations for carrying out activities

There will be a partial test (Npp, orientatively at week 8) and a final exam (Nef, on the date determined by the "academic management"). The final exam will be divided into two parts (Nef1 and Nef2): the qualification of the first part (corresponding to the topics included in the partial test) will replace, if it is higher, the qualification of the partial test. In all cases, the tests/exams will consist of several problems of high theoretical load, designed to evaluate if the student has adequately understood the basic concepts of the subject. It is intended to determine if the student is able to "identify", "understand", "describe", "predict" and "improve" the behavior of a specific system, applying the systematics explained in class in similar but new situations. In all tests students may use any information of their own (books, notes, calculator, own computer, etc.), with the logical exception of those systems that can be used as a means of communication with other students or abroad.

Bibliography

Basic:


Others resources:

In addition to the textbooks indicated as "main references", copies of the slides used in class and other materials (technical articles, manuals, etc.) will be distributed through the intranet.