Course guide
295561 - 295EQ131 - Process Integration

Last modified: 09/08/2024

Unit in charge: Barcelona East School of Engineering
Teaching unit: 713 - EQ - Department of Chemical Engineering.

Degree: MASTER'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2019). (Optional subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: ANTONIO ESPUÑA CAMARASA

Others: Primer quadrimestre:
ANTONIO ESPUÑA CAMARASA - Grup: T1

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
* Unit Operations
* Separation Operations
* Process control
* Chemical Reaction Engineering
* Simulation and Optimization of Chemical Processes

Other fundamental topics include:

* 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 ECTS credits, which are distributed in 2 basic activities:

• Blackboard / computer sessions (about 15 hours), in which the basic concepts of the topic are exposed and a limited number of examples are addressed. Special emphasis is placed on the conceptual similarities among the different 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 calculation method to any of the studied systems, or to any other system not addressed in detail in this course.

• Problem solving sessions ("problem based learning"): during the development of the course, several problems will be proposed to be solved both in the classroom (about 30 hours) and outside (110 hours of personal work, including autonomous learning/training). The main process integration and intensification concepts, and the related modeling, calculation and optimization procedures, will be applied to these specific cases/processes. The resulting proposals built by the students will be presented and discussed 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 a significant part of the 6-8 hours per week of personal work that, on average, are expected to be invested by the student to this specific course.

Personal work: Globally, a personal dedication of 1.5/2.0 hours of personal work is foreseen for each hour of class (6-8 hours/week) without considering, logically, neither the time required to "remind/recover" concepts discussed in previous courses, nor the eventual inefficiencies resulting from a poor management of the "teamwork".

Note: For the resolution of the problems, the collaboration between students is promoted (approach to the problem, search of information, etc.). An effort must be made so that "teamwork" does not end up being considered as a "joint work" (e.g., several people around a single computer), which usually is neither efficient nor effective.

LEARNING OBJECTIVES OF THE SUBJECT

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

Overall objective:

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

The course topics are directly related to the scientific and technical principles of Thermodynamics, Kinetics and Transport Phenomena, rethinking them in the different Unit Operations and integrating the resulting models, in order to 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 term, the student:

* Will have broadened his/her understanding of the physical, chemical and thermodynamic principles on which the chemical processes are based, as well as 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.

* Will be able to correctly apply the techniques specifically developed in the framework of "Process Integration", with special emphasis on the "Pinch Analysis" and its different applications in the field of energy, water and other "resources" commonly used in chemical processes.

* Will be able 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.

* Will know how to adapt the required calculations to the different levels of response speed and precision that may be required.

* Will be able to use computer calculation tools to perform these calculations.

STUDY LOAD

Type	Hours	Percentage
Self study	108,0	72.00
Hours large group	21,0	14.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

Introduction - 1: Simulation and optimization - Calculation tools

Description:
The "Process Integration need": Review of the basic concepts of process simulation and optimization. Basic Simulation and optimization tools.

Specific objectives:
The main objective of this chapter consist on framing the Process Integration principles in the general field of Process Systems Engineering, and their relationship with other alternative and complementary techniques such as Process Synthesis or Process Optimization

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.

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.

Full-or-part-time: 7h
Theory classes: 1h
Laboratory classes: 2h
Guided activities: 2h
Self study : 2h

Inroduction -2: Synthesis and optimization of reaction, separation and control networks

Description:
In this topic, the systematic decision-making procedures 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.)

Specific objectives:
Review of the process networks synthesis concepts. Strategies for the optimization of structures.

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

Full-or-part-time: 9h
Theory classes: 1h
Laboratory classes: 2h
Guided activities: 4h
Self study : 2h

Introduction - 3: Process Analysis

Description:
Establishment of feasible targets. Use of efficiency / effectiveness ratios (KPIs) to assess the improvement potential over a process.

Specific objectives:
The student must be able to assess the overall efficiency and effectiveness of a process, as well as its characterization in terms of sustainability (economic, environmental and social) within the framework and the limits imposed by the basic principles of thermodynamics, kinetics, etc.

Related activities:
Study of examples (and counterexamples) of good (or wrong) application of optimization techniques.

Full-or-part-time: 7h
Theory classes: 1h
Laboratory classes: 2h
Guided activities: 2h
Self study : 2h

Introduction - 4: MultiObjective Optimization and Uncertainty Management

Description:
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.

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.

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.

Resolution of the multi-objective problem. Resolution of the problem under uncertainty. Overall assessment.

Full-or-part-time: 7h
Theory classes: 1h
Laboratory classes: 2h
Guided activities: 2h
Self study : 2h

Topic 1: Global view: Process Integration - Energy Integration I

Description:
Initial derivation of the Process Integration techniques: Basic Pinch Analysis applied to Energy Integration

Specific objectives:
To be able of consciously apply the Basic Process Integration techniques and rules to the design and/or improvement of specific situations of energy management.

Related activities:
Application of the Basic Process Integration techniques to the design of Heat exchange networks

Full-or-part-time: 32h
Theory classes: 4h
Laboratory classes: 10h
Guided activities: 10h
Self study : 8h

Topic 2: Global view: Energy Integration - II

Description:
The thermodynamic optimum do not necessarily coincide with the economic/environmental and/or social optimum for many reasons (Topic 1). In this topic, some systematic techniques for the case of energy management will be analyzed, in order to see why, and how to use them in order to improve the initially obtained results.

Specific objectives:
To further analyze and understand when the different Process Integration principles and rules should be applied and why they may sometimes fail, in order to re-dress the initially taken decisions.

Related activities:
The same cases already analyzed in the previous topic will be used to further improve the obtained solutions.

Full-or-part-time: 44h
Theory classes: 4h
Laboratory classes: 13h
Guided activities: 19h
Self study : 8h

Topic 3: Global view: Water Integration

Description:
The same principles already applied to energy management (topics 1 and 2) can be directly applied to water management.

In this topic, the general (conceptual) principles of Process Integration will be re-formulated for this specific case, and their integrated management will allow to face the common energy+water integration

Specific objectives:
To recognize the equivalent application of the Process Integration principles to manage other cases (like water management and/or integrated water and energy management... but also to extend them to other cases)

Related activities:
To apply the Process Integration principles to different water management cases

Full-or-part-time: 44h
Theory classes: 4h
Laboratory classes: 13h
Guided activities: 19h
Self study : 8h

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GRADING SYSTEM

Nfinal = 0.20 max (Npp1; Nef1) + 0.35 max (Npp2; Nef2) + 0.35 max (Npp3; Nef3) + 0.10 * Ncg

Where:
Npp1... Npp3 are the marks of 3 partial exams (weeks 8/10/14 approx.)
Nef1... Nef3 are the final exam marks (the Final exam will be divided in 3 independent parts - each student must decide in which parts of the exam he/she wants to participate, according to his/her marks obtained in the partial exams)
Ncg is the evaluation score of the generic competence to be evaluated (autonomous learning level 3)

RE-EVALUATION: Following the EEBE Evaluation and Permanency Regulations (hhttps://eebe.upc.edu/ca/estudis/normatives-academiques) there will NOT be re-evaluation exam in this (elective) course.

EXAMINATION RULES.

There will be 3 partial exams, following the 3 main topics of the course.

The final exam will be divided into 3 independent parts (Nef1 ... Nef3): the qualification of each part will replace, if it is higher, the qualification of the corresponding partial exam.

In all cases, the tests / exams will consist of several questions based on the examples worked in the classroom, of high theoretical load, designed to evaluate if the student has adequately understood the basic concepts of the course. 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/discussed in the classroom, in similar (but somehow 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 way of communication with other students or third parties.

BIBLIOGRAPHY

Basic:
- Smith, Robin. Chemical process : design and integration. Chichester, UK: John Wiley & Sons, cop. 2005. ISBN 0471486809.
- Seider, Warren D. [et al.]. Product and process design principles : synthesis, analysis, and evaluation. 4th ed. Hoboken, NJ: John Wiley & Sons, [2017]. ISBN 9781119588009.
- Biegler, Lorenz T.; Grossmann, I.E.; Westerberg, A. W. Systematic methods of chemical process design. Upper Saddle River (New Jersey): Prentice Hall, cop. 1997. ISBN 0134924223.
- Douglas, James M. Conceptual design of chemical processes. New York [etc.]: McGraw-Hill, cop. 1988. ISBN 0070177627.
- Edgar, Thomas F. Optimization of chemical processes. 2nd ed. Boston [etc.]: McGraw-Hill, cop. 2001. ISBN 0070393591.
- Peters, Max Stone; Timmerhaus, Klaus D.. Plant design and economics for chemical engineers. 5th ed. New York: McGraw-Hill International Book, cop. 2003. ISBN 9780071240444.

RESOURCES

Other 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.