ENSIC

École Nationale Supérieure des Industries Chimiques

Courses in English

2022-2023

A DETAILED PRESENTATION OF THE COURSES TAUGHT IN ENGLISH AT ENSIC

From 2022-2023 onwards, it will be **possible for *non-French speakers* to study 1 SEMESTER or 1 YEAR in English at ENSIC** (during the final year of ENSIC):

- **Exchange for 1 SEMESTER**
  - Either **1 semester of Courses in English** (September to January or February, Semester 9 at ENSIC) from one of the two specializations taught at ENSIC:
    - Process Engineering for Energy and Environment
    - Innovative Products: from Chemistry to Processes
  - Or **1 semester of Internship (or Research project) in English lasting 4 to 6 months in a Research Laboratory or in Industry**, during the 1st semester (between September and January approximately) or the 2nd semester (between February and June approximately). It is worth pointing out that in France, internships (if longer than 2 months) are paid: Research internships in public laboratories are paid at around 500 euros/month. Internships carried out in industry are paid at around 1000 euros/month.

- **Exchange for 1 YEAR**
  - **During the 1st semester** (September to January/February, Semester 9 at ENSIC)**,** students will follow **Courses in English**, from one of the two specializations taught at ENSIC:
    - Process Engineering for Energy and Environment
    - Innovative Products: from Chemistry to Processes
  - **During the 2nd semester** (January/March to June/July, Semester 10 at ENSIC), students will carry out an **Internship (or a Research Project) in English lasting 4 to 6 months in a Research Laboratory or in Industry.** It is worth pointing out that in France, internships (if longer than 2 months) are paid: Research internships in public laboratories are paid at around 500 euros/month. Internships carried out in industry are paid at around 1000 euros/month.

For students wishing to study French, a **free accelerated French language summer school** is provided by ENSIC in August, before the academic year begins. This summer school is highly recommended for students whose level of French language is lower than B2, or who have not practiced French within the last 2 years. Furthermore, French language classes are available all year long.

The different courses taught during the 1st Semester (September to February, Semester 9 at ENSIC) are presented below. A summary table indicates the different courses, their different components, the language in which they are taught, and the number of hours allocated to lectures (CM), tutorials (TD), laboratory work (TP), tutored projects (P), industrial conferences (C), examinations (Ex) and the number of ECTS credits assigned to the teaching units. The content of the different courses is given in detail. For each course, the objectives, the teaching methods, the prerequisites, the bibliographical references, as well as the types of assessment, are specified.

Most courses are taught in English:

- **22 courses are taught in English**.
- **3 courses are taught in French but are accessible to non-French speakers**: all pedagogical documents are available in English and the project work is tutored in English. Furthermore, the professors will be available to help the non-French speaking students.

- **1 course only, consisting of industrial conferences given in French (except for 1 conference given in English)**.

1st SEMESTER (September to February): COURSE UNITS

COURSES COMMON TO ALL SPECIALIZATIONS

Course units and their components	LANGUAGE	Taught hours	Lectures	Tutorials	Laboratory work	Project	Conference	Exam	ECTS credits
Management and Economics V	**Accessible to non-French speakers**	40	20	20					**2**
Foreign Language V									**3**
English	**English**	48		48					1.5
French	**English**			48					1.5
Research and Development Project	**English**					300			**10**

ELECTIVES V COMMON TO ALL SPECIALIZATIONS

Electives V	LANGUAGE	Taught hours	Lectures	Tutorials	Laboratory work	Project	Conference	Exam	ECTS credits
Polymer-based Processes and Products	**English**	19	8	8		3			**3**
Materials and Nanomaterials for Catalysis	**English**	19	8	8		3			**3**
Kinetics of Fuel Combustion	**English**	19	8	8		3			**3**
Numerical Solution of Transport Equations	**English**	19	7	7		3		2	**3**
Electrochemical Engineering applied to Energy and Environmental Protection	**English**	19	7	7		3		2	**3**

ACADEMIC SPECIALIZATION: Process Engineering for Energy and Environment

Course units and their components	LANGUAGE	Taught hours	Lectures	Tutorials	Laboratory work	Project	Conference	Exam	ECTS credits
Process Engineering and Energy		**60**	**14**	**10**			**33**	**3**	**4**
Industrial Conferences	**French**						33		2
Combustion	**English**		6	6				1.5	1
Exergy Analysis	**Accessible to non-French speakers**		8	4				1.5	1
Dynamic Optimization and Advanced Control		**46**	**30**	**10**		**6**			**4**
Dynamic Optimization	**English**		20				3		2
Advanced Control	**English**		10	10			3		2
Process Intensification and Innovation		**33**	**12**	**9**		**9**		**3**	**4**
Process Intensification	**English**		6	4.5			1.5		1
Membrane Processes	**English**		6	4.5			1.5		1
Innovation Project	**English**					9			2

ACADEMIC SPECIALIZATION: Innovative Products: form Chemistry to Process

Course units and their components	LANGUAGE	Taught hours	Lectures	Tutorials	Laboratory work	Project	Conference	Exam	ECTS credits
Specialty Products		**60**	**45**	**6**			**3**	**6**	**4**
Copolymers: from Processes to Applications	**English**		10.5	4.5				1.5	1
Plastics Formulation	**English**		9				3	1.5	1
Polymers in Solutions, at Interfaces and in Emulsions	**English**		25.5	1.5				3	2
Product Properties and Quality		**62.5**	**38**	**18**				**5.5**	**4**
Process for Health Products	**English**		8	6				1	1
Experimental Design	**English**		6	6					1
Physical Properties of Polymers	**English**		19.5	1.5				4.5	1.5
Crystallization	**English**		4.5	4.5					0.5
Case Study - Innovative Product Design Project		**33**	**18**	**3**		**9**		**3**	**4**
Innovative Product Design Project	**English**		9			9		3	3
Manufacturing Processes of Inorganic Solids	**Accessible to non-French speakers**		9	3					1

Core curriculum			
Course title: Management and economics V			Mandatory
Taught hours 40	Student workload 70	ECTS credits 2	Semester 9

Aims:

To carry out a simulation on company management to teach students how to make quick and effective strategic and operational choices in reaction to market changes, competition and other ongoing economic factors.

Learning outcomes:

At the end of the course, the student engineer should:

- Know how to run a fictional company competing with other companies in a simplified economic market (computer simulation).

Description and teaching methods:

I. **Market estimations: potential and effects of economic changes**
II. **Production and sales management**
III. **Financial risks and investments**
IV. **Personnel management**
V. **Marketing strategy**

Evaluation methods:

Evaluation of management results obtained by a group during the simulation: project and oral presentation of results obtained.

Useful information:

Prerequisites: Company Management: Accounting, Finance, Marketing, Human Resource Management
Language: French, Accessible to non-French speaking students

Bibliographical references:
Needed: None
Advised: None

Core curriculum			
Course title: Foreign Language V			Mandatory
Taught hours 48	Student workload 84	ECTS credits 3	Semester 9

Aims:

- To develop and consolidate linguistic and communicative skills B2/C1/C2 level. Minimum Toeic score of 785/990(See CEFR scales);
- To develop professional language and communication skills needed when working in industry and research laboratories abroad;
- Develop 21st C skills: learning skills, literacy skills and life skills.

Learning outcomes:

At the end of the course, the student engineer should be able to

- Interact with a degree of fluency and spontaneity in a social, academic and professional context;
- Carry out an effective face to face job interview;
- Chair and take part in meetings;
- Understand how cultural differences impact on human interaction in both the workplace and social contexts and reflect on their own culture and its impact on intercultural interactions;
- Understand the need for defining more clearly problems encountered in the chemical industry and use creative solving problem tools;
- Working in teams using 21st C skills and soft skills.

Course content Description and teaching methods:

Students have to follow 2 modules (12 hours each) and a 21-hour intensive session.
Plus one class on "Creativity for Chemical Engineers" (3h): a look at problem definition and use of creative solving problem tools.

MODULE 1: Meetings: compulsory module

- Study of types and purposes of meetings;
- Develop communication skills - how to chair a meeting effectively, analyze and give feedback to other participants in a meeting situation;
- Expressions for meetings: chairing, taking part – express ideas and opinions with precision, present and respond to arguments convincingly, take on role of chair/secretary (taking notes);
- How to write the minutes and agenda;
- Case studies and role play simulations.

MODULE 2: Students are given a choice of different courses, e.g.: TOEIC preparation /project work, Science and Science Fictions, Self-awareness and team building skills.

3 and ½ day Intensive Session: to develop professional and linguistic skills

- Working in small groups on a team project presented at the end of the session;
- Self assessment of linguistic and professional skills used in the project;
- A face to face job interview simulation, filmed and viewed for self assessment : analyzing body language, voice, quality of English, ability to give clear and full answers.

Evaluation methods:

CERTIFICATION: Pass or fail

1) Meetings and written report
2) Option and written report
3) Session participation and presentation
4) Job interview

RESITS: personal work or PowerPoint presentation or written report or job interview

USEFUL INFORMATION:

PREREQUISITES: B2+
LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:
Needed: None
Advised: None

CORE CURRICULUM			
COURSE TITLE: RESEARCH AND DEVELOPMENT PROJECT			MANDATORY
TAUGHT HOURS -	STUDENT WORKLOAD 300	ECTS CREDITS 10	SEMESTER 9

AIMS:

Students will carry out an individual research and development work placement either in a company or a university laboratory. The subject chosen should be scientific or technological. The work placement will last 2 months at the end of S9 and can take place in France or abroad.
The aim is to introduce student engineers to a research and development approach when carrying out a research project.

LEARNING OUTCOMES:

At the end of the R&D project, the student engineer should be able to:

- Write a detailed and exhaustive bibliography based around a given research subject;
- Integrate into a university or industrial research and development team;
- Write a report of work carried out;
- Provide well-informed scientific opinions on their chosen research subject;
- Show imagination and creativity with a proactive approach and ability to work autonomously on the assigned research subject.

DESCRIPTION AND TEACHING METHODS:

Each year in semester S9 the school publishes a list of R&D projects proposed by the site's research laboratories and tutorial laboratories. The student engineers following courses in Process Engineering, Product Process Engineering and Biotechnological Process Engineering are invited to choose a project. The student engineers may also suggest projects with companies to the Head of Studies (engineering placements…).
The list of subjects assigned is published by the Head of Studies.

EVALUATION METHODS:

The students must write a report on their work and results obtained and also give an oral presentation to a panel composed of the tutor supervising this course and the school's academic staff.

- The research project is evaluated according to:
- The work carried out;
- The ability to integrate the required knowledge;
- The quality of the two written reports;
- The student's success in working on their project.

USEFUL INFORMATION:

PREREQUISITES:

- To have defined a professional project;
- Report writing skills;
- Master all the concepts taught at the School.

LANGUAGE: French or English if the student is non-French speaking.

BIBLIOGRAPHICAL REFERENCES:
Needed: None
Advised: None

Core curriculum			
Course title: Polymer-based processes and products			Elective
Taught hours 19	Student workload 58	ECTS credits 3	Semester 9

Aims:

- To present the design methodology for the design of polymer-based speciality products and polymer production processes for specific properties;
- To provide students with a knowledge of the links between macromolecular structures, the morphology of materials, operating conditions for production processes and application properties;
- To present the specific features of the main application fields of formulated plastic materials.

Learning outcomes:

At the end of the course, the student engineer should be able to:
- Write technical production specifications;
- Use software to design experiment plans;
- Use production process design software;
- Make the right links between certain usage properties, conditions for formulation and how the production process works.

Description and teaching methods:

The course is made up of general and more specific lessons along with project groups working on case studies. The course summary is as follows:
- Technical production specifications, multi-criteria experiment and optimization plans: 4 hours;
- Polymer formulation processes, the example of extrusion, presentation of an extrusion simulation software program: 2 hours;
- Case examples (reinforced elastomers, polyurethanes for medical applications, master batches and compounds etc.): 8 hours;
- Supervision of project group work: 3 hours;
- Oral presentations of project work: 2 hours.

Evaluation methods:

A multiple choice questions test (30 minutes) at the end of a lesson. The date of this test is given on the first day of the course. Secondly an oral presentation of the case study work of the project group.

Useful information:

<u>Prerequisites:</u> None
<u>Language:</u> English

<u>Bibliographical references:</u>
<u>Needed:</u> None
<u>Advised</u>: None

Core curriculum			
Course title: Materials and Nanomaterials for catalysis			Elective
Taught hours 19	Student workload 58	ECTS credits 3	Semester 9

Aims:

The tremendous growth in the industrial usage of organometallic chemistry between 1950 and nowadays has resulted in marked improvements in the production of commodity chemicals. During the last years, the development of new (nano)materials has led also to significant improvements in catalysis, these materials allow the enhancement of the efficiency of numerous chemical processes from fine synthesis to pollutant degradation (liquids or gas).
Technical challenges encountered in scaling up the reactions from small quantities to production amounts will also be described.

Learning outcomes:

At the end of the course, the student engineer should be able to:
- Associate the materials/organometallic complexes with their syntheses and characterizations;
- Develop organometallic complexes and nanoparticles used in homogeneous and heterogeneous catalysis;
- Study mechanisms of organometallic catalysis;
- Develop materials for photocatalysis.

Description and teaching methods:

This course is composed of lectures and related small projects.

Four topics will be explored:
- Materials/Complexes and associated characterizations;
- Organometallic complexes and nanoparticles used in homogeneous and heterogeneous catalysis;
- Industrial applications of organometallic catalysis and future perspectives;
- Materials for photocatalysis.

Evaluation methods:

Project and oral presentation.
Resits: written exam.

Useful information:

Prerequisites: Basic knowledge of catalysis
Language: English

Bibliographical references:
Needed: None
Advised: None

Core curriculum			
Course title: Kinetics of fuel combustion			Elective
Taught hours 19	Student workload 58	ECTS credits 3	Semester 9

Aims:

The aim of this course is to provide an introduction to experimental techniques for the kinetic study of combustion reactions and detailed kinetic modelling of these reactions.

Learning outcomes:

At the end of the course, the student engineer should be able to:

- Master the nature of the elementary processes involved in combustion reactions and thus: Understand specific phenomena observed in these reactions (cool flame, negative temperature coefficient, auto-ignition);
- Construct a combustion mechanism for simple species (n-alkanes);
- Carry out a kinetic analysis of a model to identify the main consumption pathways for reactive and the most sensitive reactions.
- Use the various experimental techniques to carry out kinetic studies and thus be able to choose the most effective technique for a given problem (measuring auto-ignition times, flame speed, profiles of species, etc.).

Description and teaching methods:

The fundamental subjects will be presented in lectures while exercises on real problems will be used to illustrate the main principles covered in lectures. The last exercise will consist of constructing a detailed kinetic mechanism for a small-scale alkane using systematic construction rules.

Evaluation methods:

Individual assessment: using multiple choice question tests and exercises

Useful information:

Prerequisites: Basic knowledge of Kinetics
Language: English

Bibliographical references:
Needed: None
Advised:

[1] SCACCHI, G., BOUCHY, M., FOUCAUT, J.F. and ZAHRAA, O., *Cinétique et Catalyse*, Lavoisier-Tec & Doc.

Core curriculum			
Course title: Biorefinery			Elective
Taught hours 19	Student workload 58	ECTS credits 3	Semester 9

Aims:

- To present the different bio-refinery concepts;
- To understand the difference between biomasses and the issues related to their forest or agricultural production;
- To analyze the reactions, reactors and process involved in these bio-refineries.

Learning outcomes:

At the end of the course, the student engineer should:

- Know the different bio-refinery concepts;
- Be able to determine the process with a given source of biomass;
- Understand the phenomena involved in the 3 types of reactors (chemical, thermo-chemical and biological reactors);
- Be able to achieve preliminary computations for reactor sizing.

Description and teaching methods:

The teaching will be composed of lectures and projects.

Evaluation methods:

Written examination (1h)
One oral presentation of the project

Useful information:

Prerequisites: None
Language: English

Bibliographical references:
Needed: None
Advised: None

CORE CURRICULUM			
COURSE TITLE: NUMERICAL SOLUTION OF TRANSPORT EQUATIONS			MANDATORY
TAUGHT HOURS 19	STUDENT WORKLOAD 58	ECTS CREDITS 3	S9

AIMS:

The aim is to provide a short introduction to computational fluid dynamics. This course focuses on a theoretical background for CFD software technical training, and also enables the student to implement a quick solution for simple cases.

LEARNING OUTCOMES:

At the end of the course, the student should:

- Understand methods and main algorithms for the solution of coupled fluid flow and transfers;
- Be able to implement a solution for simple problems;
- Be able to understand the influence of method settings on the solution, and check its validity;
- Know how to post-process the calculation results.

DESCRIPTION AND TEACHING METHODS:

Fundamentals will be taught as lectures. A main example will be treated as a project. Tutorials (on computers) will be dedicated either to the project or to give examples of some lecture topics.

EVALUATION METHODS:

Project report and individual oral presentations

USEFUL INFORMATION:

PREREQUISITES: Fluid Mechanics (Navier-Stokes Equations, Momentum Balance), Heat And Mass Transfer, Numerical Methods, Mathematics (Linear Algebra), Computer Programming

LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:

Needed:

Advised:

[1] VERSTEEG, H.K. and MALALASEKERA, W., 1995, *An introduction to computational fluid dynamics*, Longman Scientific & Technica.

Core curriculum			
Course title: Electrochemical engineering applied to energy and environmental protection			Elective
Taught hours 19	Student workload 58	ECTS credits 3	Semester 9

Aims:

- Acquire basic knowledge in theoretical electrochemistry and electrochemical engineering
- Have a synthetic view of the application of electrochemical engineering in the fields of energy and environmental protection

Learning outcomes:

At the end of the courses the student should:

- Be familiar with electrochemical processes
- Know how to evaluate the kinetics of charge transfer and mass transport by determining the constants of charge transfer and mass transport, respectively.
- Know how to establish mass balances in ideal electrolysers.
- Be able to size:
  1. A fuel cell or a water electrolyzer
  2. An electrochemical cell for anodic oxidation applied to water treatment.

Description and teaching methods:

Electrochemical engineering is enjoying great interest both in the conversion and storage of energy and in emerging applications in the field of environmental protection. The course consists of a common theoretical base:

i. Reminder of thermodynamics for electrochemical systems, cell potentials and voltages, energy, Nernst relation, equilibrium constant and redox potential, spontaneity of reactions, notion of electrodes (anode and cathode), Joule effect, notions of electrochemical reactors and generators,
ii. Quantity of electricity, Faraday's law and faradic or capacitive currents,
iii. Notion of catalyst and electrochemical kinetics, Butler-Volmer relation and Tafel slopes, mass transport and charge transfer, distribution of electric current

General electrochemistry lectures are followed by a presentation of the two targeted applications:

- - Energy: sizing of batteries and electrolysers and overall energy balances,
- - Environmental protection: mass balance in ideal electrolysers, application of electrolysis to water treatment (electrode materials, oxidants formed, reaction parameters and control), application of anodic oxidation to disinfection and treatment of wastewater (methodology, kinetic models, sizing, equipment used, costs, health and safety aspects).

This training, in the form of tutorials integrated into the course, is delivered by two CNRS researchers who develop these topics within the Reactions and Chemical Engineering Laboratory (LRGP).

Evaluation methods:

2h final examination (100%)

Useful information:

Prerequisites: Knowledge in chemical engineering
Language: English
Bibliographical references:
Needed: Course material delivered to students; scientific database
Advised:

Academic Specialisation: Process Engineering for Energy and Environment			
Course title: Process Engineering and Energy			Mandatory
Taught hours 60	Student workload 105	ECTS credits 4	Semester 9

Aims:

The lessons aim to:

- Raise students' awareness of the technological and societal challenges linked to energy production, through lectures given by industrial speakers and visits to energy production sites.
- Understand the main chemical phenomena involved in combustion for industrial applications (boilers, engines, gas turbines, etc.)
- Understand how to perform the exergy analysis of a process in order to reduce energy degradation

Learning outcomes:

At the end of this module, students should:

- Understand the global context of energy production and demand
- Know the main processes dedicated to the transformation of energy
- Know how to analyze combustion parameters and know how to calculate the main associated chemical parameters
- Know how to construct combustion diagrams and apply them to practical cases
- Be able to assess the exergy of pure fluids or mixtures from appropriate data
- To be able to carry out exergy balances on closed systems (reactive or non-reactive) and open in steady state.

Description and teaching methods:

Combustion: 4 lectures of 1h30, 4 tutorial sessions (1h30); definition and determination of physico-chemical parameters involved in combustion; thermodynamic approach to combustion: combustion diagrams; Wobbe index, combustion efficiency and concept of losses by combustion products, application to combustion in boilers and internal combustion engines, ideal thermodynamic cycles; 1h30 exam.

Exergy analysis: 7h30 of lectures, 4h30 of tutorials; definition of exergy; exergy balances in closed and open systems; calculation of the exergy of multi-constituent systems by gamma-phi and phi-phi approaches; exergy analysis of reactive systems; practical applications to chemical industry processes, 1h30 exam.

Industrial conferences and visits: 11 sessions (3 hrs); themes covered: global energy context, petroleum extraction and oil & gas processes, CO_2 capture and storage, wind and hydroelectric energy, solar energy, biomass and energy, nuclear energy and nuclear waste management, anaerobic digestion processes; Assessment: final MCQ, writing of summaries and attendance.

Evaluation methods:

Mandatory attendance at conferences, final MCQ and writing of abstracts (20%); combustion examination (40%), exergy analysis examination (40%)

Useful information:

Prerequisites: knowledge of chemical engineering, kinetics and thermodynamics

Language: Conferences and visits in French, Combustion course in English, Exergy course accessible to non-French speakers

Academic Specialisation: Process Engineering for Energy and Environment			
Course title: Dynamic Optimization and Advanced Control			Mandatory
Taught hours 46	Student workload 130	ECTS credits 4	Semester 9

Aims:

The aim of the Dynamic Optimization course is to:

- Review the different types of process dynamic models (differential, differential-algebraic and partial differential-algebraic) define and formulate a dynamic optimization problem;
- Present dynamic optimization methods;
- Use PROMS software for case studies.

The aim of the Advanced Process Control is to:

- Discover the methods of parametric identification in order to determine the models of transfer functions;
- Apply a variety of control strategies on various chemical engineering problems;
- Discover the methods of single input single output control by means of transfer functions and multivariable control in state space for multivariable systems.

Learning outcomes:

At the end of the Dynamic Optimization course, the student engineer should be able to:

- Simulate a process described by ordinary differential equations, differential-algebraic equations and partial differential- algebraic equations;
- Formulate a dynamic optimization problem;
- Use gproms software to solve (un)constrained dynamic optimization problems.

At the end of the Advanced Control course, the student should be able to:

- Identify a single input single output system based on a discrete transfer function;
- Choose a process control strategy as a function of the system dynamics, specifications and constraints;
- Design a process control using a transfer function for single input single output systems and a state space control for multivariable systems, using examples chosen in the domain of process engineering.

Description and teaching methods:

I. Dynamic optimization

1. Process dynamic models
    - Models described by ordinary differential equations (ODE)
    - Models described by differential-algebraic equations (DAE)
    - Models described by partial differential-algebraic equations (PDAE)
2. Dynamic simulation
    - Specification of initial conditions
    - Simple and higher order integration formulae (combined BDF and Newton methods, prediction-correction steps)
    - Introduction of index and high index systems of DAE
    - Use gPROMS software for simulation of batch and fedbatch reactors
3. Dynamic optimization
    - Review some static optimization aspects
        - Karush-Kuhn-Tucker (KKT) optimality conditions
    - Successive quadratic programming (SQP)
    - Definition and mathematical formulation of a dynamic optimization problem

- Determination of gradients by means of sensitivity method
- Computation of solution using “Control vector parameterization (CVP)” method
- Use gPROMS software for optimization of batch reactors

4. Project
- Description and modelling of a process (distillation columns, reactors, …)
- Dynamic simulation using gPROMS software
- Definition and mathematical formulation of dynamic optimization problems
- Solution computation using gPROMS software

II. Advanced control
- Use of the Matlab Simulink environment for simulation of dynamic systems and process control synthesis,
- Direct application and synthesis of various continuous-time control strategies: feedback using various methods, internal model, feed-forward, etc.
- Multivariable control
- Project: design a SISO or MIMO control using Simulink.

EVALUATION METHODS:

Optimization project (50%) and Advanced Process Control project (50%)

USEFUL INFORMATION:

PREREQUISITES: Chemical engineering methods – Balance Equations Development – Numerical Analysis and Optimization Methods – Informatics (programming)
LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:
Needed: Course handouts
Advised:
[1] BRYSON, A. E. and HO, Y-C.,1988, *Applied Optimal Control: Optimization, Estimation, and Control*, Revised Edition, Taylor & Francis Inc;
[2] CORRIOU, J-P., 2003, *Commande des Procédés,* 2ème édition, Lavoisier Tec & Doc;
[3] MOKHTAR, S., BAZARAA, H., SHERALI, D. and SHETTY, C.M.; 1993, *Nonlinear Programming: Theory and Algorithms*, 2nd edition, Wiley.

Academic Specialisation: Process Engineering for Energy and Environment			
Course title: Process Intensification and Innovation			Mandatory
Taught hours 33	Student workload 132	ECTS credits 4	Semester 9

Aims:

- To educate students on engineering equipment and technologies for process intensification;
- To train students in a structured approach for process intensification and innovation;
- To provide the basic knowledge needed to calculate membrane separation processes;
- To educate students on the importance of an innovative approach and methodologies.

Learning outcomes:

At the end of the course, the student engineer should be able to:

- Analyse and propose improvements for a given process (determination of limiting phenomena, development of an intensification strategy);
- Select a membrane separation process based on a set of constraints (nature of the mixture to be separated, target performance, operating conditions);
- Size a membrane process for a given application and compare its performance to other technologies (energy efficiency, productivity);
- Understand the importance and the interaction between the three pillars of innovation: creativity (new generation), value (of esteem, use and exchange), and socialization (control the conduct of change).

Description and teaching methods:

Process intensification: 4 class sessions (1h30) - 3 tutorials (1h30); definition of intensification; existing technologies (rotating disk reactor, reactive distillation, etc.); intensification by micro-structuring; generalization of the choice of intensification strategy through the analysis of process limitations (transfer, equilibrium, risk, saturation, etc.) and the identification of technologies to overcome these limitations; case study on industrial methods of synthesis or effluent treatment.

Membrane processes: 4 class sessions (1h30) - 3 tutorials (1h30); concept of selectivity, rejection rate and permeability; membrane materials and modules; transfer in the membrane; concentration polarization; osmotic effects; industrial case studies (concentration of a macromolecular solution, desalination of seawater by reverse osmosis, process intensification of absorption by gas-liquid contactors).

Innovation Project: Work on the various facets of innovation and experimentation of an innovative approach on an example in the domain of the chemical industry (in collaboration with our industrial partners).

Evaluation methods:

Project (60 %), 2 written exams (40 %)

Useful information:

Prerequisites: Basic knowledge of Chemical Engineering and Thermodynamics
Language: English

Bibliographical references:
Needed: Course handouts
Advised:

ACADEMIC SPECIALISATION: INNOVATIVE PRODUCTS – FROM CHEMISTRY TO PROCESS			
COURSE TITLE: SPECIALTY PRODUCTS			MANDATORY
TAUGHT HOURS 60	STUDENT WORKLOAD 105	ECTS CREDITS 4	SEMESTER 9

AIMS:

The aims of this course are:

- To introduce basic concepts about free radical copolymerisation;
- To give examples illustrating main types of copolymers and their specificities;
- To acquire the methodology for designing copolymerisation reactors;
- To discover plastics processing industries and corresponding polymer shaping processes;
- To acquire basic knowledge of polymers in solutions, at interfaces and in emulsion;
- To acquire basic knowledge of how to select and characterise relevant polymer properties;
- To describe the main water-soluble polymers used in formulations.

LEARNING OUTCOMES:

At the end of the course, the student engineer should:

- Have knowledge of the interest of copolymers compared to homopolymer blends;
- Know how to do kinetic calculations prior to selection of the best suited reactor;
- Know how to design a copolymerisation reactor;
- Be able to define the best ways of formulating and shaping polymeric materials;
- Have knowledge of the use of specific properties of polymers in solution, at interfaces or in emulsion to obtain formulated products with targeted end-use properties;
- Understand the links between product properties and structural characteristics especially at interfaces.

DESCRIPTION AND TEACHING METHODS:

The teaching is composed of lectures, exercises and work in project teams.
Three courses:

1. Copolymers: from copolymerisation processes to applications
2. Formulation and shaping of plastics
3. Polymers in solution, at interfaces and in emulsion

EVALUATION METHODS:

Course 1: one final written examination (1h30)
Course 2: one final written examination (1h30)
Course 3: two written examinations (1h30 each)

USEFUL INFORMATION:

PREREQUISITES: Fundamentals of Chemistry and Physical Chemistry of Interfaces, basic knowledge of Chemical Engineering and Polymer Chemistry.
LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:
Needed:
Advised:

[1] ODIAN, G.,1991, *Principles of Polymer Chemistry*, 3rd edition, Chapter 6 "Chain copolymerisation", John Wiley and Sons, pages 452-531;

[2] SEYMOUR, R.B. and CARRAHER, C.E., 2003, *Polymer Chemistry – An introduction*, 6th edition, Marcel Dekker, Chapter 9 "Copolymerisation", pages 332-367.

Academic specialisation: Innovative products – from chemistry to process			
Course title: Product Properties and Quality			Mandatory
Taught hours 60	Student workload 108	ECTS credits 4	Semester 9

Aims:

The aims of this course are to:

- Understand experimental design;
- Discover batch production planning;
- Make the link between macroscopic properties of polymers and their associated structural and morphological characteristics;
- Introduce the different types and mechanisms of polymer degradation and their impact on polymer properties;
- Present industrial strategies for polymer stabilization with the reasoned use of various stabilizing agents;
- Address transport phenomena in polymers and gels;
- Present the crystallization process and how to model it;
- Understand rheology as a tool to characterise complex systems.

Learning outcomes:

At the end of the course, the student engineer should be able to:

- Design experiments;
- Optimise batch production;
- Design and dimension a reactor yielding a desired product and relate the process, the structures and the properties of a product;
- Identify the causes of polymer degradation on the basis of first-hand information;
- Define a strategy for its prevention and implement an appropriate combination of stabilizing agents;
- Stabilise a polymer efficiently for its processing or its intended uses;
- Understand transport in polymers and gels;
- Model with population balance, the processes of crystallization, aggregation and breakage;
- Apply the DLVO theory;
- Master rheology as a tool to characterise complex systems.

Description and teaching methods:

Experimental design:

- Introduction: history, terminology, matrix formulation, empirical models
- Methodology: definition of the problem, cause and effect diagram, selection of factors (controlled inputs) and responses (outputs)
- Types of experiments: Designs for Screening, Factorial and Fractional Design, Response Surface Methods (RSM) ...
- Interpretation: Hadamard matrix, Main effect and Interaction effect, Main effect and Interaction plot for results
- Statistics: Model-based, randomized design, coefficient of dispersion
- Practical work with the software Design-Expert®

Polymers: thermophysical properties, degradation and stabilization

Thermophysical properties of polymers

- General aspects of polymer materials: chemical structure, morphology, properties
- Glass transition temperature and melting point: definition, measurement and estimation methods
- Relation between chemical structure and thermomechanical transitions: interpretation from physical considerations, consequences and application to material forming.

Degradation and stabilization of polymers

- The consequences of chemical and physical degradation of polymer properties
- The different types of chemical and physical degradations
- The different mechanisms involved in polymer material degradation
- The industrial strategies for polymer stabilization with the reasoned use of various stabilizing agents (i.e. thermal, photochemical, fungicide, bactericide, and fireproof stabilizing agents)
- Impact of the stabilisers on the environment and on health

Transport in polymers, controlled release
- Concept of permeability and solution-diffusion model
- Experimental methods for the determination of transport coefficients
- Diffusion mechanisms and models in polymers and gels
- Controlled release of active substances (reservoir systems, matrix system): process and modelling of release kinetics
- Canning processes, products and application examples

Crystallization
- Crystallization processes, aggregation and breakage
- Modelling via population balance (DLVO theory)

Rheology
- Description of the main non-Newtonian behaviours (shear-thinning, yield stress, thixotropic)
- Transport of non-Newtonian fluids in pipes
- Agitation of non-Newtonian fluids
- Systemic rheology
- Rheology of formulated systems
- Rheology of polymers

EVALUATION METHODS:

Experimental design: no evaluation

Degradation and stabilization: written examination

Polymers-thermophysical properties, mass transport in polymer-controlled release: project with an oral presentation

Rheology: written examination

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Macromolecular Chemistry and Physical Chemistry, general knowledge of Fluid Mechanics.

LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:

Advised:

[1] ECOLE, J., 1991, *La stabilisation des polymères*, Nathan, Encyclopédie technique pratique;

[2] GIROIS, S., 2004, *Stabilisation des plastiques: aspects généraux*, Les techniques de l'ingénieur, Traité plastiques et composites, Volume AM 3 232;

[3] SCOTT, G., 1999, *Polymers and the environment*, RSC Paperbacks, The Royal Society of Chemistry, Cambridge;

[4] VERDU, J., 2002, *Vieillissement chimique des plastiques : aspects généraux*, Les techniques de l'ingénieur, Traité plastiques et composites, Volume AM 3 151.

Academic specialisation: Innovative products – from chemistry to process			
Course title: Case study-Innovative product design project			Mandatory
Taught hours 33	Student workload 132	ECTS credits 4	Semester 9

Aims:

The aims of this course are to:

- Develop global and creative thinking;
- Acquire basic skills in innovation process and innovation process planning;
- Use already acquired chemical engineering skills in the field of speciality chemical products;
- Acquire and implement basic entrepreneurial skills.

Learning outcomes:

At the end of the course, the student engineer should be able to:

- Mobilise required chemical engineering skills to design a new chemical product from scratch to proof of concept and theoretical proof of feasibility;
- Analyze patents and test the product for intellectual property rights;
- Develop and use project management skills for innovative project designs.

Description and teaching methods:

Learning methods

- Team work;
- Case study;
- Learning by experience;
- Problem-based learning.

Learning content

- All knowledge relevant to design new Speciality Chemical Products.

Evaluation methods:

Proof of concept and theoretical feasibility report
Oral presentation

Useful information:

Prerequisites: Chemical and Chemical Engineering skills at undergraduate level
Language: English

Bibliographical references:
Needed: None
Advised: None