



École Nationale Supérieure des Industries
Chimiques

“Chemical Engineering M.Eng degree”

Syllabus

2020-2021

ENSIC

Chemical Engineering M.Eng Degree Syllabus 2020 – 2021

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GENERAL INFORMATION

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HISTORY

ENSIC was one hundred and thirty years old in 2017. Founded in 1887 with an agreement between the City of Nancy and the Ministry of Education, the “*Institut Chimique de Nancy*” was inaugurated by President Sadi Carnot in 1892. Half a century later, an audacious reform, the so-called Travers reform, established a new recruitment process consisting of a competitive exam for students following specific classes in Mathematics. The School was renamed “*Ecole Supérieure des Industries Chimiques*”. This recruitment process still exists. At the beginning of 1948, a decree created the National Engineering Schools and our School became “*Ecole Nationale Supérieure des Industries Chimique*” (*Chemical Engineering School*). Graduates are trained to be Process Engineers and to respond to industrial and societal expectations.

While the original syllabus offered by ENSIC was accredited before 1936, a new one was launched in 1997. It is also accredited by the French Commission for engineering degrees and is called “*Ingénieur spécialité Génie Chimique*” or “*FITI*” (*Chemical Engineering with Industrial Experience*). It focuses on Chemical Engineering and is strongly linked to the industrial sector since around half of the syllabus consists in working in a company.

ENSIC is now part of the “*Université de Lorraine*” (University of Lorraine) since 2012 and ENSIC students can enrol for a Masters degree in their final year of training.

DEGREES

The School is authorised to deliver two M.Eng degrees:

- A Chemical Engineering M.Eng degree (*Ingénieur des Industries Chimiques*)
- A Chemical Engineering with Industrial Experience M.Eng degree (*Ingénieur Spécialité Génie Chimique*)

Every year, the School welcomes about 140 new students separated into these two academic courses.

I. AIMS

Challenged by profound industrial changes and by new expectations of society today, ENSIC's ambition is to train engineers with a double skill in Chemical and Physical Chemistry phenomena, in Chemical Engineering and in Process Engineering.

- Providing courses resulting in solid scientific and technical skills using innovative tools and concepts in Process Engineering, Product Engineering and Bioprocess Engineering.
- Taking into account an engineer's role as a citizen and ethic responsibilities to meet human, managerial and societal expectations.

ENSIC's aims are to provide courses which offer:

- ❖ A Syllabus based on an effective "*semestrialisation*": a core curriculum of three half-years (semesters) which covers the basis of essential general knowledge of Chemical Engineering, followed by three specialisation courses in "Advanced Process Engineering", "Product Engineering", and "Bioprocess Engineering". These courses are programmed in the last two half-years of the academic course syllabus.
The first specialisation course covers the development of methodological aspects of Process Engineering. A particular interest is also paid to sustainable processes and processes developed in the field of energy.
The second specialisation course covers conception, formulation and Product Engineering.
Finally, the third specialisation course covers the application of Process Engineering in sizing and optimisation of industrial installations in Pharmacy, Fine Chemistry or in specialities such as Biocatalysts, Fermentation and Chemistry in Life Sciences.
- ❖ A pedagogical approach based on tutorial classes, practical work and projects in which the student becomes an actor of their own training; the academic staff is not only the "transmitter of knowledge" but also the "manager of the acquisition of knowledge". This pedagogy uses all available educational tools.
- ❖ Human, managerial, legal, economic and social sciences classes, necessary for the profession and the responsibilities of the 21st Century engineer.
- ❖ Professional experience and opportunities on a national and international scale to enable students to reflect on their personal career project from the very start of their training.
- ❖ A mode of evaluation in compliance with the "*Bologna Process*", European harmonisation framework, which takes into account the student workload for each module, and capitalises the credits corresponding to the validation of a module.

ENSIC's courses have always been based on the progress and evolution of its Research laboratories which ensure teaching in the state-of-the-art domains; the emergence of specialisation courses such as "Product Engineering" and "Bioprocess Engineering" are the most recent illustrations of this symbiosis and play a federative role in the elaboration of a joint pedagogy, in the same way as the methodological innovations in Process Engineering. 300 researchers, academic staff and PhD students contribute to the organization of the School and insure the supervision of the Research and Development project of the students in the final year.

The School, aware of the importance of partnerships within Industry, regularly calls upon professional speakers who propose courses, conferences and seminars. They give lectures in the core curriculum, specialised courses and take part in the teaching of Humanities and in the Industrial

Process Design project. These partners also play an important role as tutors in the work placements in their companies.

- An operator training period, 1 month minimum, at the end of the first year.
- A six-month work placement as an engineer (minimum 4 months required) at the end of the third year.
- The possibility of doing a work placement as engineer-assistant (3 months maximum) at the end of the second year.

Due to a growing evolution in European education and training, ENSIC also aims to provide students with international experience and has a number of partner universities and international companies. A period of at least three months abroad is compulsory to familiarise future engineers with a professional international environment and to equip them to deal with future careers in other countries. Half of the students carry out a part of this syllabus abroad on work placements, in academic institutions, and/or on a research projects with one of the 40 partner universities of the School.

II. ENTRY REQUIREMENTS

How to enter ENSIC?

Entry requirements for the first year of “*Ingénieurs des Industries Chimiques (I²C)*” (Chemical Engineering Syllabus) are either based on a national competitive exam “*Concours Communs polytechniques*” or an entrance examination and an interview which is also a requirement in the second year. This selection process is called “*admissions parallèles*” and is suitable for students who already have a higher education degree.

NB: The French “classes préparatoires” are an intensive two-year post-baccalauréat course designed to prepare the best students for entry into the “Grandes Écoles”. The “Grandes Écoles” in France are extremely selective higher education establishments which admit students on the basis of the competitive exams. Engineering Schools such as ENSIC belong to “Grandes Écoles”.

Entry requirements for the 1st year of the Engineering course:

By competitive exam

- “*Concours Communs Polytechnique*” : 65 places

« *Admissions parallèles*” (by entrance examination and interview) for students coming from:

- “*DUT de Génie Chimique* » or « *Mesures Physiques* » or « *Licence de Chimie-Physique* » (Two-year technical degree in Chemical Engineering or Physical Measurements or Bachelor degree in Physical Chemistry): 10 places
- « *Cycle Préparatoire Polytechnique* » (An establishment in the University of Lorraine which offers « *Classes préparatoires* »): 6 places
- « *Cycle Préparatoire Intégré* » - *Chimie de Lille ou de Rennes, FGL* (Engineering Schools in Chemistry in Lille or Rennes which offer « *Classes préparatoires* »): 10 places

Entry requirements for the 2nd year of the Engineering course:

“*Admissions parallèles*” (by entrance examination and interview) for students coming from:

- 1st or 2nd year of a Master’s degree (Chemistry, Physical Chemistry, Science of Matter, Product Engineering).
- Foreign students from “N + i” network: 10 places.
- Students completing the 5th year of pharmaceutical studies (Specialisation in Industry): 15 places.

“Admissions parallèles” (by entrance examination and interview) with continuing education

This entry requirement is for DUT-graduated employees justifying a 3-year working activity. The entrance examination and interview must be preceded by foundation courses provided by the University of Lorraine in the continuing education programme.

For “admissions parallèles”, the selection of the candidates is made by a panel of academic staff.

Entry requirements for foreign students

Every year, the School welcomes foreign students in the I²C syllabus who have either spent all or part of their schooling in France, or spent their schooling in a foreign country and are laureate of “Concours Communs Polytechniques”. Their admission to ENSIC depends either on national competitive exams for entrance to National Superior Engineering Schools or by “admissions parallèles” (entrance examination and interview).

III. OVERVIEW OF THE COURSES

The Chemical Engineering Syllabus is organized so that students can develop their knowledge of themselves and potential, as well as their personal career projects. The aim of the educational programme (see Paragraph IV) is to enable students to become responsible and to answer several essential questions:

- What is my real personality?
- What are my personal skills and capacities?
- What jobs can I apply for?
- How do I get the job I want?

The students, individually or in a group, work on a Personal Project in Semester 8 which allows them to apply project management methods. It also allows them to develop an activity outside the academic framework according to their personal aspirations, and to be able to test their own limits and self-awareness. They can use their capacities of innovation to enhance and differentiate their curriculum vitae.

The Academic course (see synoptic of studies below) begins with a core curriculum for the three first semesters, 5, 6 and 7. The core curriculum courses cover the basis necessary for every I²C engineer in Chemistry and Physical Chemistry as well as in Chemical Engineering and Process Engineering. They are divided into units which are spread over the different semesters.

Courses are made up of lectures, conferences provided by professionals, tutorials and practical work. These courses are evaluated by written examinations, practical work, reports and presentations. Furthermore, the students have to carry out several projects in groups. These projects provide a means to apply the learnt outcomes of the various units and are supervised and evaluated specifically:

- Computer Science Project (Semester 5)
- Reaction Engineering Project (Semester 6)
- Industrial Process Design Project (Semester 8)

The compulsory unit courses are completed by electives that either go more in-depth into some subjects or have a scientific and technical specialisation.

A one-month operator training period must be carried out at the end of the 1st year. The evaluation and the validation of this training period are integrated into Semester 8.

The students also choose a specialisation course and present their arguments to the Head of Studies regarding their motivation and their career project. These specialisation courses begin in Semester 8 and 9.

In Semester 8, students can choose between the different specialisation courses available:

At ENSIC:

- Process Engineering for Energy and Environment.
- Innovative Products : from Chemistry to Process.
- Bioprocess Engineering.

In the Collegium of Engineering Schools of "*Université de Lorraine*":

- inter-school training "Sciences and Technologies for the Environment", with ENSGSI « Ecole Nationale Supérieure en Génie des Systèmes et l'Innovation (National School of Industrial Engineering) and ENSAIA (Ecole Nationale Supérieure de l'Agronomie et des Industries Alimentaires (Engineering School in Agriculture and Food Sciences)

These specialisation courses continue in Semester 9 and 10.

At the end of Semester 8, a three-month period is left free (June, July, August) in order to allow students to spend time abroad or to do another work placement (non-obligatory but under work placement assignment).

In Semesters 9, students can choose between:

- a year at ENSIC in the specialisation course chosen in semester 8
- a year at ENSIC in PROCEDIS
- a year in a university abroad (it can also be limited to one semester)
- a year in a French Engineering School belonging to Fédération Gay-Lussac (FGL)
- a year in a University of Lorraine inter-school cursus (Sciences et Technologies de l'Environnement)
- a year in the Institut National des Sciences et Techniques du Nucléaire
- a year in apprenticeship at the IFP School (École nationale supérieure du pétrole et des moteurs)

A 6-month work placement as an engineer in a company (minimum 4 months) must be carried out in the final year, in Semester 10. Finally, a 2-month period has to be devoted to a Research and Development project and can be carried out either in a research laboratory in France or abroad, or in a company. These two activities (Industrial Placement and Research and Development) are supervised and evaluated.

Depending on their personal career projects, students can interrupt their studies at ENSIC to do a "gap year" between Semester 8 and Semester 9. The aim of this year is to allow the student to acquire skills related to those provided at ENSIC and which contribute to their career project. When constructing this project students can benefit from the school's infrastructure and industrial and international partners. Once the project has been defined, it is submitted to the Head of Studies. The authorisation to carry out this gap year is granted by the degree awarding panel.

SYLLABUS OVERVIEW

S10	Industrial Placement (4-6 months)								
S9	Academic Specialisation Innovation Project	<i>Research and Development</i>	UL inter-school cursus (Sciences et Technologies de l'Environnement)	IFP School (apprenticeship)	Academic specialisation in a FGL School	Academic stay abroad in a partner university	Institut National des Sciences et Techniques du Nucléaire	PROCEDIS (15-months with Industrial Experience)	
	Stay or Work Placement Abroad 3 months: from June to September								
S8	Academic Specialisation	<i>Industrial Process Design Project</i>	UL inter-school cursus : Environment or Bioinformatics						
S7	Core curriculum								
	Operator Training period 1 month: July or August								
S6	Core curriculum	<i>Reaction Engineering Project</i>							
S5		<i>Computer Sciences Project</i>							

IV. DEVELOPING THE CAREER OF THE STUDENT

Different courses in the compulsory units of the syllabus help the students with personal development and preparing them for their future careers.

The first two years allow students to define their personality more clearly and to discover their real skills and capacities. ENSIC student engineers are presented with all the different career prospects open to them. They are given the necessary tools to help them with finding their first job, depending on their aspirations.

At the end of Semester 7, each student does a personalised assessment in order to check whether they are making progress in defining their future career. This is to allow them to choose a specialist course in Semester 8 and to construct the contents of their third year (Semester 9 and 10).

Description of the aims of the development programme

Defining personality, developing skills and capacities

In Semester 5, the aim of the Management course is to enable students to become aware of their own personality: their strengths, weaknesses and way of functioning in relation to others. This course also highlights the behavioural differences between individuals using the Myers Briggs Test Indicator (MBTI) and provides the main tools to manage them. The learnt outcomes of this course are applied in Semester 8, during their **Personal Project**. This project allows the students to test their own limits and to manage a personal project in a totally new and different domain to the usual academic framework of subjects.

The job prospects open to ENSIC engineers

The diversity of industrial domains and professions are studied and presented:

- What is the role of an engineer and reflection on ethical notions: organization of conferences within the framework of the personal project,
- Presentation of the Industrial world and company typologies,
- Presentation of different engineering professions.

Numerous events are organized. These include:

- visits to industrial sites,
- companies presenting at ENSIC, especially during the "Meet ENSIC" day organized in Semesters 5, 7 and 9 where students and companies meet and exchange with each other,
- "Journée Métiers et Carrières" (Career's Day) with the ENSIC alumni organized in Semesters 6 and 8,
- meetings with industrialists in companies or at ENSIC via conferences,
- participation in forums in France and abroad such as "Forum Horizon Chimie" (students and companies meet and exchange with each other in Paris).

These events help students with their choice of different career possibilities: small or large companies, a preferential business sector, production or research posts, etc.

Finding a first job

ENSIC provides an intensive preparation for interviews: workshop in the writing of curriculum vitae and cover letters, and job interview simulations. Two simultaneous days are organized for the interview simulations with professionals from industry.

V. CORE CURRICULUM COURSE UNITS (Semesters 5 to 7)

Semester 5 course units	ECTS credits	Lectures / Tutorials	Practical work	Project supervision	Taught hours total
Organic Chemistry I	5	60	28		88
Process and Reaction Engineering I	6	72	32		104
Thermodynamics and Energetics	4	60			60
Transport Phenomena I	3	48			48
Computer Sciences and Applied Mathematics	6	88		6	94
Management and Economics I	3	40			40
Foreign Languages I	3	40			40
TOTAL	30	408	60	6	474
Semester 6 course units	ECTS credits	Lectures / Tutorials	Practical work	Project supervision	Taught hours total
Inorganic Chemistry	5	52	28		80
Analytical Chemistry and Technology	5	48	32		80
Process and Reaction Engineering II	4	60			60
Reaction Engineering and Computer Engineering	4	24		6	30
Transport Phenomena II	5	51,5	32	4,5	88
Management and Economics II	3	34	6		40
Foreign Languages II	3	40			40
Industrialists' Conferences	1	12			12
TOTAL	30	321,5	98	10,5	430
Semester 7 course units	ECTS credits	Lectures / Tutorials	Practical work	Project supervision	Taught hours total
Polymer Chemistry	3	24	28		52
Industrial Processes and Sustainable Development	7	79	24		103
Transport Phenomena III	3	32	24		56
Thermal separation processes	5	54	24	2	80
Process Systems Engineering	5	68			68
Management and Economics III	2	24			24
Foreign Languages III	3	40			40
Electives	1	12			12
Industrialists' Conferences	1	12			12
TOTAL	30	345	100	2	448
SEMESTER 5 TO 7: CORE CURRICULUM TOTAL	90	1074	258	18,5	1351

Vocabulary Elements

Lecture: *cours magistral (CM)*; Tutorial: *travaux dirigés (TD)*; practical work: *travaux pratiques (TP)*

Student Workload

1 hour of lecture or tutorial corresponds to 1h 45 mins of individual work

1 hour of practical classes corresponds to 1h 30 mins of individual work

1 hour of project tutoring corresponds to 10 hours of individual work

The student individual workload amount is about 2400 hours for the whole core curriculum.

VI. SPECIALISATION COURSE UNITS (Semesters 8 to 10)

Some course units are common to all students while the others are part of a specialisation course.

Semester 8 course units	ECTS credits	Lectures/Tutorials	Practical work	Project supervision	Taught hours total
<i>Management and Economics IV</i>	2	32	8		40
<i>Foreign Languages IV</i>	2	44			44
<i>Industrial Design Project</i>	6	12		18	30
<i>Operator training period</i>	4				
<i>Personal Project</i>	3	20		6	26
<i>Electives</i>	1	16		2	18
Academic Specialisation : Process Engineering for Energy and Environment					
Advanced Separation Processes and Multiphase Reactors	4	60			60
<i>Sustainable Processes</i>	4	28,5		7,5	36
<i>Process Design and Simulation</i>	4	60			60
Academic Specialisation : Innovative Products - from Chemistry to Process					
<i>Micro-and Nanostructured Products</i>	4	60			60
<i>Introduction to Product Engineering</i>	4	28,5		7,5	36
<i>From Molecules to Products</i>	4	36	24		60
Academic Specialisation : Bioprocess Engineering					
<i>Introduction to Biological Sciences</i>	4	60			60
<i>Biocatalysts and Bioreactors</i>	4	30		6	36
<i>Bioseparations</i>	4	40	20		60
TOTAL	30				314
Semester 9 course units	ECTS credits	Lectures/Tutorials	Practical work	Project supervision	Taught hours total
<i>Management and Economics V</i>	2	40			40
<i>Foreign Languages V</i>	3	48			48
Option	3	16		3	19
Research and Development Project	10				
Academic Specialisation : Process Engineering for Energy and Environment					
<i>Process Engineering and Energy</i>	4	60			60
<i>Dynamic Optimisation and Advanced Control</i>	4	40		6	46
<i>Process Intensification and Innovation</i>	4	24		9	33
Academic Specialisation : Innovative Products - from Chemistry to Process					
<i>Specialty Products</i>	4	60			60
<i>Product Properties and Qualities</i>	4	61,5			61,5
<i>Case Study – Innovative Product Design Project</i>	4	24		9	33
Academic Specialisation : Bioprocess Engineering					
<i>Bioprocess</i>	4	60			60
<i>Industrial Biotechnological Processes</i>	4	50			50
<i>Tools and Methods</i>	4	24		9	33
TOTAL	30				Ca. 250
Semester 10 course units	ECTS				
<i>Industrial Placement</i>	30				

CLASSES : SEMESTERS 5 to 10	Around 1920 h
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VII. APPRENTICESHIP STUDIES IN PROCESSES, PRODUCTS OR BIOTECHNOLOGIES - *PROCEDIS*

This programme is for engineering students who wish to switch between academic courses and working in a company during their final year of training including various fields, such as Chemistry, Pharmacy, Cosmetology, or the Agri-Food sector. It also meets existing needs and contributes to integrating new sustainable development requirements by emphasising the interactivity between the workplace and educational institutions.

The maximum duration of this option is 15 months (when starting the placement in early July) and it is carried out in semesters S9 and S10. Students alternate between training in companies and following academic courses. However this period of studies is variable and depends on the placement starting date.

The programme aims at :

- Providing a theoretical basis to be able to work on the design of a product, regarding the physical chemistry of Colloids and interfaces plan, as well as engineering processes applied to complex environments.
- Developing knowledge of the different states of matter in engineering products (massive or dispersed, solid or fluid systems, dispersed systems, polymers and gels), as well as the understanding of characterisation methods and the phenomena that can occur during the production or use of the product.
- Managing the main biotechnological processes that exist in pharmaceutical, chemical and energetic industries.
- Knowing how to integrate the specificities of biocatalysts (couplings, constraints).
- Knowing how to use the specific tools of bio process engineering to understand and conduct the production processes.
- Providing the theoretical and practical concepts necessary for the design or simulation as well as the choice of the discontinuous equipment as part of a production batch.
- Providing the knowledge and the tools to set up and manage a single or multi-product batch workshop.

The students must attend one of the courses offered in semester 8 ("Process Engineering for Energy and Environment", "Innovative Products: from Chemistry to Process" or "Bioprocess Engineering") and validate chapters 1 and 2. The course at ENSIC represents a total of 540 hours over semesters 9 and 10. The balance is maintained between scientific disciplines and work organization disciplines in terms of managerial, technological and economical aspects:

- About 264 hours of interactive pedagogy with a focus on discovery learning.
- About 276 hours focused on practical and technical training
- The final project entails the study of implementing a new product. Students will study workshop facilities (designing and sizing the equipment), determine the constraints and the necessary investment, define the cost price and carry out market research.

Semesters 9 and 10 course units	ECTS credits	Lectures/ Tutorials	Practical work	Project supervision	Taught hours total
Management and Economics V	2	40			40
Foreign Languages V	3	48			48
Personal Project	9				
Specialty study (2 UE)	8	93			93
Discontinuous Process engineering	4	66			66
Design and conduct of multi-products facilities	4	6		11	17
Industrial Placement	30				
TOTAL	60	253		11	264

DETAILED PRESENTATION OF THE COURSE UNITS

The course is presented in chronological order of the semesters.

For each semester, a summary table indicates the teaching units and their division into constituent elements, also the names of staff responsible for the units of the constituent elements and the distribution of hours in lectures (CM), tutorials (TD), practical work (TP), project coaching (P), industrial conference (C), and examination (Ex) and the number of ECTS credits assigned to the teaching units .

The syllabus course units describe the pedagogical content of the courses in each semester. In addition to the general and specific aims of the courses, the content and teaching methods are given in detail. The type of assessment is indicated and details of the modalities of assessment are given in a separate document. Information about the prerequisites and bibliographical references are also provided. The overview of the syllabus course units are found on the following pages below.

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SEMESTER 5: COURSE UNITS

Academic supervisor: Axelle ARRAULT

SEMESTER OVERVIEW

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Organic Chemistry I	Axelle ARRAULT	88¹	34,5¹	22,5¹	28¹			3¹	5
<i>Organic Chemistry: Basics</i>	Axelle ARRAULT		25,5	19,5				3	
<i>Organic Chemistry: Advanced</i>	Guillaume PICKAERT		27	18				3	
<i>Organic chemistry support</i>	Axelle ARRAULT		9	3					
<i>Organic Chemistry Practical work</i>	Guillaume PICKAERT				28				
Reactive systems and industrial processes, PART I	René FOURNET	104	21	46,5	32			4,5	6
<i>Adsorption and Heterogeneous Catalysis</i>	Laurent MARCHAL-HEUSSLER		2	20,5				1,5	
<i>Homogeneous Chemical Kinetics</i>	René FOURNET		9,5	13				1,5	
<i>Chemical Reaction Engineering</i>	Eric SCHAER		9,5	13				1,5	
<i>Process and Reaction Engineering I Practical work</i>	Yves Simon				32				
Thermodynamics and Energetics	Jean-Noël JAUBERT		31,5	24,5				4	5
<i>Thermodynamics and Energetic</i>			27,5	17,5				3	
<i>Process engineering assessment</i>			4	7					
Transport Phenomena I	Huai-Zhi LI	48	20	25				3	3
Computer Sciences and Applied Mathematics	Jean Marc COMMENGE	94	31	51,25		6		5,75	6
<i>Computer Sciences for Chemical Engineers</i>	Romain PRIVAT		3	19,25				2,75	
<i>Numerical Methods</i>	Jean Marc COMMENGE		10,5	10,5				2	
<i>Statistics</i>	Jean Marc COMMENGE		5,5	9,5				1	
<i>Computer Sciences Project</i>	Romain PRIVAT					6			
<i>Mathematic support</i>	François LESAGE		12	12					
Management and Economics I	Vera IVANAJ	40	22	14				4	3
<i>People Management and Organizations</i>	Vera IVANAJ		14	14				4	
<i>Health and Safety at Work</i>	Laurent PERRIN		8						
Foreign Languages I	Jude BOWDEN	40		40					3
<i>English</i>	Jude BOWDEN			20					
<i>Modern Languages</i>	Jude BOWDEN			20					
TOTAL		474							30

¹ Course load for the « Baby » group

CORE CURRICULUM			
COURSE TITLE: ORGANIC CHEMISTRY – LEVEL 1			MANDATORY
TAUGHT HOURS 88	STUDENT WORKLOAD 147	ECTS CREDITS 5	SEMESTER 5

AIMS:

The aims of this course are to:

- learn the basic principles (properties and reactivity) of organic compounds:
- learn organic reactions and apply them to multistep syntheses.
- apply basic principles of organic chemistry to predict plausible mechanisms for organic reactions.
- bring tools allowing a better understanding of the mechanisms studied

LEARNING OUTCOMES:

By the end of this level 1 the student should be able to do the following.

- design multi-step synthesis for compounds of moderate complexity and predict or explain the formation of co-products.
- predict the reaction mechanism of a chemical reaction as well as its result.
- know and analyze the parameters influencing the result of a reaction
- know how to use the appropriate tools to analyze and deduce the result of a reaction
- analyze and interpret infrared and nuclear magnetic resonance spectra to propose the structure of organic molecule
- perform experimental procedures for synthesis, purification, and characterisation of some organic compounds

DESCRIPTION AND TEACHING METHODS:

The teaching will be composed of lectures, tutorials and practical courses.

Lectures will concern:

- preparation and the reactivity of the various classes of organic compounds
- study of solvents and their influence on the progress of a chemical reaction
- introduction to the tools allowing the understanding of reaction mechanisms. (Hammond postulate, HSAB theory, kinetic and thermodynamic control, etc.)
- identification of the usual organic functional groups by basic spectroscopic techniques (RMN, IR).

Tutorials are designed to illustrate some parts of lectures with help of exercises about synthesis and characterization of organic molecules.

Practical courses will allow students to apprehend the necessary scientific reasoning to synthesize an organic molecule. They will have to achieve a multi-step synthesis of a target molecule. Under supervision of a teacher, students will synthesize, purify and characterize the intermediates of each step.

EVALUATION METHODS:

Evaluation of students will be made as follow:

One mid-and (Ei : 1h) and one end-semester (Ef :) written examination + One practical course report (TP)

→Note = (Ei + 2xEf + TP)/4

Resit: Ef : 2h

USEFUL INFORMATION:

PREREQUISITES: Organic chemistry initiation – option – 12h

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

CORE CURRICULUM			
COURSE TITLE: ORGANIC CHEMISTRY – LEVEL 2			MANDATORY
TAUGHT HOURS 88	STUDENT WORKLOAD 147	ECTS CREDITS 5	SEMESTER 5

AIMS:

This module aims to :

- Give an overview of organic chemistry reactivity
- Sensitize students to fundamental principles, to explain the main organic chemistry reaction

LEARNING OUTCOMES:

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

- Name the main reactive classes in organic chemistry
- Explain the reactivity between the organic molecules (identification of reaction sites, determination of reaction preferences, etc ...)
- Apprehend organic chemistry as a whole, where logic and reflection take precedence over learning
- Design strategies for synthesizing a target molecule

DESCRIPTION AND TEACHING METHODS

The teaching will be given in the form of lectures, tutorials and practical work.

The lecture of organic chemistry will be structured in four parts: Addition reactions, substitution reactions, elimination reactions, IR and NMR spectroscopy

The aim of the tutorials will be to illustrate some points of the lecture with exercises on the synthesis and characterization of organic molecules.

The practical work will enable students to understand the scientific process needed to synthesize an organic molecule. They will indeed carry out the multi-step synthesis of a target molecule. Under the guidance of a teacher, students will have to synthesize, purify and characterize all the intermediaries of each stage.

EVALUATION METHODS:

An intermediate examination (Ei: 1h) + final exam (Ef: 2h) + report of TP (written in English) in Note = $(E_i + 2 \times E_f + \text{Practical Work}) / 4$

USEFUL INFORMATION:

PREREQUISITES: 'Organic chemistry level 1" modules or equivalence

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised:

1. Advanced Organic Chemistry, 4^{ème} édition, Jerry March, Wiley Interscience
2. Mécanismes Réactionnels en Chimie Organique, Reinhard Brückner, DeBoeck Université.
3. Chimie Organique, K. Peter C. Vollhardt, DeBoeck Université

CORE CURRICULUM			
COURSE TITLE: REACTIVE SYSTEMS AND INDUSTRIAL PROCESSES, PART I			MANDATORY
TAUGHT HOURS 104	STUDENT WORKLOAD 174	ECTS CREDITS 6	SEMESTER 5

AIMS:

The module “reactive systems and industrial processes” consists in:

- Analyzing industrial processes in terms of mass and energy balances;
- Studying the kinetic of homogeneous reactions;
- Implementing these types of reactions in ideal reactors (batch, CSTR, plug flow);
- Gaining basic knowledge in heterogeneous catalysis;
- Elucidating the mechanisms involved in surface interactions between solid, liquid and gas phases.

LEARNING OUTCOMES:

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

- Formulate mass and energy balances;
- Choose and calculate the ideal dimensions of an appropriate reactor for a given chemical reaction;
- Identify the operating mode of a reactor (with/without chemical reactions, flow type, transitory or permanent regime, ...);
- Optimise conversions, yields or selectivities (branching ratio);
- Identify the stability conditions for exothermic reactors;
- Measure the rate of a reaction in a perfect reactor and to determine the empirical rate equations;
- Develop detailed mechanisms for simple homogeneous reactions;
- Use the main kinetic theories in order to calculate the rate coefficients of elementary reactions;
- Identify the presence of interfacial phenomena in chemical reactions;
- Implement and interpret gas-solid and liquid-solid sorption isotherms;
- Characterise the macro-structure and the physico-chemical properties of a catalyst;
- Use basic heterogeneous catalytic mechanism to calculate reaction rates;
- Identify and take into account the different limitation steps of a heterogeneous catalytic reaction.

DESCRIPTION AND TEACHING METHODS:

- I. **Homogeneous Chemical Kinetics**
 - [1] Definition and measure of the rate for any reactor and applying this to perfect reactors
 - [2] Rate a reaction (order of reaction, constants rate, energy activation)
 - [3] Kinetic theories and kinetic rules
 - [4] Detailed reactional mechanisms in gas-phase and liquid-phase

- II. **Chemical Reaction Engineering**
 - A. Mass balance in ideal reactors
 - B. Conversion optimization
 - C. Yield and selectivity optimization
 - D. Energy balance and stability of exothermic reactors

- III. **Heterogeneous Catalysis**
 - E. Definition and Structural Characteristics of Catalysts
 - F. Steps of catalytic reaction
 - G. Rate formulations of the heterogeneous catalytic reactions
 - H. Modelling of catalytic reactions

Description of teaching methods:

The courses are completed by tutorial sessions organized by $\frac{1}{4}$ class for the CRE. For the kinetic part, the tutorials are organized as problem-based learning sessions to explore certain parts of the course in greater depth. In this latter case, the sessions are organized by $\frac{1}{2}$ class. The heterogeneous catalytic course is divided into 10% lectures, 50% active learning sessions (tutorials, class divided into 4 groups) and 40% practical work. Practical labs are proposed in this module, their duration is 4 hours and they deal with the following points:

- Gas phase kinetics;
- Photolysis of the pyridine;
- Enzymatic catalysis;
- Liquid phase kinetics : solvent effect;
- Ionic reaction in liquid phase: salt effect;
- Adiabatic batch reactor;
- BET;
- Photocatalysis;
- Hydrogenolysis of n-butane;
- Hydrogenation of butane.

EVALUATION METHODS:

I. Course content:

The purpose of the evaluation is to verify the extent of knowledge and the skills acquired by the student in the field of chemical reaction engineering (CRE), chemical kinetics and catalysis, that are applied to industrial processes. A written examination of 1h30 is taken at the end of each teaching module (kinetics, CRE, catalysis). The second session of examinations is carried out under the same conditions.

II. Practical work: The examination is based on several written reports (in French or English). The main purpose is to determine whether a student is able to realise practical work related to chemical kinetics or chemical reaction engineering by using knowledge acquired during the courses. It also aims at evaluating their ability to write up a scientific report and to bring to light the major results obtained.

III. Calculation of students marks

The final mark obtained by a student is calculated by including all the marks obtained in the different subjects and the following weighting system is applicable:

- Chemical Kinetics, Chemical Reaction Engineering and Catalysis examinations: $\frac{3}{4}$ of the final mark, with the same weighting for three subjects.
- Practical labs: $\frac{1}{4}$ of the final mark.

USEFUL INFORMATION:

PREREQUISITES: Teaching of physical chemistry, mathematics, level: BAC+2

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Strongly advised:

- [1] BOUCHY, M., FOUCAUT, J.F., FOURNET R., SCACCHI, G. and ZAHRAA O., 2011, *Cinétique et Catalyse*, Tec et Doc, Lavoisier.

Advised :

- [1] ADAMSON A.W., *Physical chemistry of surfaces*, John Wiley and Sons
[2] VILLERMAUX J., 1993, *Génie de la Réaction Chimique*, Tec et Doc, Lavoisier

CORE CURRICULUM			
COURSE TITLE: THERMODYNAMICS AND ENERGETICS			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 5
60	125	4	

AIMS:

The constituent element Balances in Chemical Engineering is an introductory lecture which aims at:

- Presenting the basic principles of chemical engineering
- Presenting the general principles of process schematic representations
- Proposing a methodology to carry out mass and energy balances

The course unit Thermodynamics and Energetics more broadly aims at:

- Explaining in detail and clarifying the first and the second law of thermodynamics and to highlight the usefulness of properties such as internal energy, enthalpy, entropy, Gibbs energy or Helmholtz energy;
- Learning how to estimate the properties of a pure compound (vapour pressure, boiling temperature, vaporisation quantities, heat capacities, enthalpy, entropy) by using an equation of state, a chart, a correlation or the law of corresponding states;
- Explaining how a power cycle or a refrigeration cycle works;
- Describing the subsonic and supersonic flows.

LEARNING OUTCOMES:

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

- Understand basic notions of chemical engineering (continuous/discontinuous processes, reaction/separation/recycling)
- Understand and analyse a process from the diagram knowledge
- Write and solve mass and energy balances in stationary/transient regime, for non-reactive/reactive systems
- Use the energy and entropy rate balances for a control volume;
- Estimate the properties of a pure compound, in the solid state, in the liquid state, in the vapour state or in the two-phase region;
- Perform calculations with the equations of state widely used in chemical industries as well as with the corresponding states charts;
- Understand the characteristics of the various devices that appear in the thermodynamic cycles (valve, turbine, compressor, heat exchanger, pump);
- Calculate the property change of a fluid flowing through a nozzle or in a pipe.

DESCRIPTION AND TEACHING METHODS:

I. Constituent Element : Balances in Chemical Engineering

1. Processes classification
2. Elaboration of industrial processes schematic representations
3. Mass balances on single unit systems
4. Mass balances on several units systems
5. Mass balances in reactive systems
6. Energy balances
 - a. Non reactive systems
 - b. Reactive systems
7. Mass balances in transient conditions

This constituent element involves 4h lecture and 7 h tutorials. During tutorials, students work within groups of 4 or 5 while teachers help and guide them. A detailed correction is provided to students at the end of each session.

II. Constituent Element : Thermodynamics and Energetics

- I. **Defining systems (closed systems, control volumes, selecting the system boundary)**
- II. **Energy and the first law of thermodynamics (closed system, control volume, steady state)**
- III. **Entropy and the second law of thermodynamics (closed system, control volume, steady state)**
- IV. **Evaluating properties: general considerations**
State functions
Characteristic functions
Chemical potential
- V. **The perfect gas**
- VI. **The phase rule**
- VII. **Pure-component in vapour liquid equilibrium**
- VIII. **Introducing power generation**
Simple power cycles and simple refrigeration cycles
- IX. **The equations of state**
Use of an equation of state to estimate the properties of a pure compound
Use of an equation of state to determine vapour-liquid equilibrium conditions
- X. **The corresponding states law**
- XI. **Chemical reactions**
- XII. **Subsonic and supersonic flows**

EVALUATION METHODS:

I. Constituent Element : Balances in Chemical Engineering

Written examination at the end of the course (1h)

II. Constituent Element : Thermodynamics and Energetics

Written examination at the end of the course (1h 30 minutes or 2 hours)

2 intermediate written examinations of 30 to 45 minutes each

USEFUL INFORMATION:

PREREQUISITES: Mathematical tools: differential calculus, integral calculus, functions of several variables.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed:

Advised:

- [1] GHASEM, HENDA, *Bilans matière et énergétique pour l'ingénierie chimique, Principes et applications pratiques*, Ed. De Boeck, 2012
- [2] POLING, B.E., PRAUSNITZ, J.M. and O'CONNELL, J.P., *The Properties of Gases and Liquids*, The McGraw-Hill Chemical Engineering Series;
- [3] SMITH, M., VAN NESS, H.C., and ABBOTT, M., *Introduction to Chemical Engineering Thermodynamics*, The McGraw-Hill Chemical Engineering Series;
- [4] SONNTAG, R.E., VAN WYLEN, G.J. and DESROCHERS, P., *Thermodynamique appliquée*, Edition: Erpi.

CORE CURRICULUM			
COURSE TITLE: TRANSPORT PHENOMENA I: FLUID MECHANICS APPLIED TO CHEMICAL ENGINEERING AND PROCESSES			MANDATORY
TAUGHT HOURS 48	STUDENT WORKLOAD 84	ECTS CREDITS 3	SEMESTER 5

AIMS:

The course aims at:

- Consolidating the fundamental concepts of Applied Physics associated to suitable mathematical tools;
- Developing the understanding of Fluid Mechanics in Chemical Engineering and processes;
- Acquiring problem solving skills such as the design of physical and numerical experiments for scale-up;
- Providing a solid base on different types of flows.

LEARNING OUTCOMES:

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

- Describe various flows with a suitable mathematical formula;
- Propose a strategy to find a solution for engineering problems;
- Comment on and justify the proposed solution within the framework of process engineers;
- Design an operating system, component or process to meet desired needs.

DESCRIPTION AND TEACHING METHODS:

Description of the lectures:

- I. **Introduction: Fluid statics**
- II. **Flow fields, particle paths and stream lines - Euler and Lagrange approaches**
- III. **Conservation equations of mass, energy and momentum in integral form - Bernoulli equation**
- IV. **Applications of conservation equations**
- V. **Viscosity and friction - Navier-Stokes equations - Concepts of non-Newtonian fluids**
- VI. **Notion of dimensional analysis - Buckingham-Pi theorem - Dimensionless numbers - Similitude and scaling laws**
- VII. **Flows in the laminar regime - Analytic solutions**
- VIII. **Notion of turbulence - Main characteristics - Fluctuations and different scales**
- IX. **Turbulent stresses – Turbulence in pipe flows - Friction at walls and pressure drop**
- X. **Pipes and circuits - Singularities, valves, flow meters and pumps**
- XI. **Boundary layers and wakes**
- XII. **Flows past an obstacle - Drag coefficient**
- III. **Notions of multiphase flows - Introduction to complex flow patterns of dispersed systems**

Organization of the tutorials in parallel with the lectures for 4 groups of students:

- Tutorial 1: Molecular phenomena – Hydrostatics - Internal pressure and gravity
- Tutorial 2: Hydrodynamics of inviscid fluids
- Tutorial 3: Application of Bernoulli equation
- Tutorial 4: Principle of dimensional analysis
- Tutorial 5: Similitude and scale-up
- Tutorial 6: Flows in the laminar regime
- Tutorial 7: Turbulent flows
- Tutorial 8: Flows in circuits
- Tutorial 9: Aging and wear of circuits and pumps
- Tutorial 10: Operations involving pumps and fans
- Tutorial 11: Flows past obstacles and boundary layers

EVALUATION METHODS:

Two written examinations of 1h 30mins each with authorised documents

Resits: either an oral examination for a small number of students or a written examination of 1h30mins

USEFUL INFORMATION:

PREREQUISITES: Basic concepts of Physics and Mathematics

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: Class handouts provided.

Advised:

- [1] GUYON, HULIN J-P. and PETIT, A., 2001, *Hydrodynamique physique*, EDP Sciences;
- [2] BIRD, R.B., STEWART, W.E. and LIGHTFOOT, E.N., 2002, *Transport phenomena*, John Wiley & Sons, Inc.

CORE CURRICULUM			
COURSE TITLE:	COMPUTER SCIENCES AND APPLIED MATHEMATICS		MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 5
94	214	6	

AIMS:

The aim of the course sessions and tutorial classes dedicated to Computer Sciences and Numerical Analysis is to enable students to solve engineering problems using appropriate numerical methods. Detailed goals include:

- Learning the algorithmic bases;
- Familiarisation of students with languages enabling them to code the resolution of numerical problems or data processing;
- Teaching basic programming techniques, particularly the use of the debugger;
- Knowledge of appropriate numerical methods available for the numerical computation of a physical problem. As far as possible, students will work on a project aimed at illustrating the methodology of modelling for chemistry and physics.

The aim of the Modelling Project is first to apply the concepts learned during the Computer Sciences and Numerical Analysis classes, through autonomous practice. Secondly, this project enables students to gain experience in collaborative work and project management. Finally, this project also intends to improve the ability of students to present and promote personal work.

The course sessions and tutorial classes dedicated to statistical methods intend to:

- Explain the main statistical concepts and probability laws related to the work of a process engineer;
- Help students understand the concept of statistical hypothesis testing and the notion of confidence intervals;
- Introduce experimental design, as well as the associated calculation methods and interpretation.

LEARNING OUTCOMES:

After the Computer Sciences course, the student engineer should be able to:

- Design simple algorithms;
- Write a computer code adapted to engineering needs;
- Write a computer code in Fortran language;
- Understand and use existing subroutines.

The specific objectives of the Modelling Project are to:

- Discover project management and collaborative work: planning and time management;
- Propose a personalized and novel development of the proposed project
- Design a medium-length computer program;
- Organise and write a report;
- Summarise and present the work orally;
- Defend and criticise choices in terms of design and implementation of the program.
- Analyze calculation results, to discuss orders of magnitude, model accuracy etc.

For the Numerical Analysis course, the student should be able to:

- Analyse a physical problem and deduce the type of numerical methods required for its resolution;
- Transform a physical problem to get a numerical solution;
- Choose which numerical methods are necessary and available to solve a given physical problem, under a set of constraints, such as their convergence speed, stability and precision.

At the end of the course dedicated to Statistical Methods, the student should:

- Know how to implement statistical hypothesis testing and estimate confidence intervals;
- Be able to implement experimental designs to obtain significant statistical models.

DESCRIPTION AND TEACHING METHODS:

I. Computing

- 3 hours of lectures on the basics of algorithmic and procedural programming;
- 20 hours of tutorial classes dedicated to programming in Fortran 90 on personal computers:
 - o Approximately 5 tutorial classes for language learning;
 - o Approximately 5 tutorial classes for numerical methods program.

II. Numerical analysis

- Interpolation and approximation;
- Numerical Integration;
- Solving equations by iterative methods;
- Matrix Operations;
- Solving algebraic systems;
- Numerical integration of ordinary differential equations;
- Numerical integration of partial differential equations.

III. The Modelling Project is in groups of 2 or 3 students, except in exceptional cases decided by the team of supervisors. The technical objectives of the project are set at the beginning and describe the specifications of the program. A supervisor is assigned to each group. Students are then free to make their own strategic choices along the different parts of the project:

- The first part is dedicated to the design of the program structure. Depending on the project topic, students will be invited to work on modelling issues (model development, parametrization ...)
- The second part consists in programming the structure defined in the first part in the language used during tutorial classes;
- In the third part, students present their project in a written report and then orally; results will be critically analyzed.
- Intermediate progress reports (about two) have to be written during the project and presented at meetings with their supervisor.

IV. Statistical Methods

- Probability laws, normal law, chi 2 law, Student law, Fisher-Snedecor law;
- Hypothesis Testing;
- Estimation and confidence intervals;
- Linear fitting and multivariate regression;
- Design of Experiments, ANOVA.

EVALUATION METHODS:

- 1 intermediate written exam in Computer Sciences (45 minutes)
- Short written exams will take place during the tutorial classes to monitor learning progress
- 1 final written exam in Computer Sciences (2 hours)
- 1 final written exam in Numerical Analysis (2 hours)
- For the Modelling Project: the assessment is carried out firstly by the supervisor during the validation stages and meetings, but also through a written report and a final oral defence. The evaluation focuses on the quality of code design and programming, as well as project management and personal contributions.
- Statistical methods: short exams (15 minutes) are scheduled at the beginning of each tutorial class as from the second tutorial class
- Statistical Methods: Final exam (1 hour).

USEFUL INFORMATION:

PREREQUISITES:

- For Numerical Analysis: mathematical knowledge of aspects such as the integration of functions, linear algebra, integration of differential equations, partial differential equations
- For the Modelling Project: Computer Sciences classes and Numerical Analysis
- For Statistical Methods: matrix operations. Use of a programmable calculator

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Required:

- [1] CORRIOU, J-P, Numerical methods and optimization, Ed TEC&DOC, Paris Lavoisier;

- [2] A programmable calculator to use in Numerical Analysis and Statistical Methods;
- [3] Lecture notes for Computer Sciences, Numerical Analysis and Statistical Methods.

CORE CURRICULUM			
COURSE TITLE: MANAGEMENT AND ECONOMICS I			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 5
40	70	3	

AIMS:

The course aims to:

- Identify the Human, Social, Economic, Legal and Health & Safety challenges in a company;
- Integrate risk management and organizational analysis in the daily practices and projects of a company;
- Explain the differences in the behaviour of individuals, based on the theory of psychological types of Carl Jung, with the “Myers-Briggs Type Indicator” (MBTI) test;
- Recognize the main dimensions and tools of interpersonal and group communication (verbal and nonverbal);
- Write an effective CV and covering letter;
- Describe and analyze the main dimensions of an organization and the work environment.
- Increase students’ knowledge and understanding of culture and communication needed to work effectively in multicultural and global contexts.

LEARNING OUTCOMES:

At the end of the course, students should be able to:

- Carry out an assessment of industrial risks and implement prevention and protection strategies;
- Understand the variables of their personal and professional development in order to manage their strengths and weaknesses;
- Work with others and in a team with people having different behavioural preferences;
- Speak in public, to conduct a face-to-face interview and manage a meeting, according to people and professional situations encountered;
- Conceive and adapt a job application for an internship or a first employment;
- Carry out a strategic analysis of an organization and elaborate a strategy.
- 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.

DESCRIPTION AND TEACHING METHODS:

Management of people and organizations

- Self-knowledge
- Attitudes and personality; self-image; the value system
- Interpersonal communication: The dimensions of verbal and nonverbal communication; the basic techniques of oral communication
- The main job positions and the main sectors for chemical industries
- The organization and its dimensions: organizational structure, strategy, management system, stakeholders, culture, technology, internal environment, external environment, performance

Hygiene, Health and Safety at Work

This part is based on the “BES & ST” standards (Basics Essential for Health and Safety at Work) developed by the National Council for Teaching Health and Safety (CNES & ST) including representatives of the Directorate General of Higher Education (GHGD) and the National Health Insurance Fund for Employees (CNAM-TS)

- Introduction to “Health and Safety” at work
- The human, social, economic and legal aspects of S & ST
- The mechanisms and the origins of a work accident
- Preparation for the industrial internship and future jobs: Discovering the “world of business” by participating in an employment fair organized by the management department and Industrial Relations

department. Students discover the world of business through panels and meetings with many industrialists.

Cultural Sensitisation

Study differences in perception of time, body language, space and use of language in different cultures and John Mole's work on organization and leadership in companies in different countries.

Discussion in small groups.

EVALUATION METHODS:

Case study analysis, written and oral examinations

USEFUL INFORMATION:

PREREQUISITES: None

TEACHING LANGUAGE: French and English

REFERENCES:

- [1] "INIST" and "ANACT" documentations and Notes;
- [2] Handbooks and bibliography for all courses;
- [3] Case studies and videos illustrating management practices and risk analysis methodology.

CORE CURRICULUM			
COURSE TITLE: FOREIGN LANGUAGES I			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 5
40	70	3	

LANGUAGE 1: ENGLISH

AIMS:

- To enable students to become more responsible for their own learning;
- To consolidate and acquire linguistic and communicative skills in English. B1/B2/C1/C2 levels (See CEFR scales);
- To develop professional language 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:

- Analyse and evaluate their language level (B1/B2/C1/C2) and their general and professional skills in English;
- Manage their own learning objectives;
- Interact with average (B1/B2) or good (C1) command and fluency in pairs and in a group;
- Write their own CV, cover letter and e-mails;
- Write a lab report, describe the main steps of a laboratory experiment;
- Write short reports.

DESCRIPTION AND TEACHING METHODS:

- Work in pairs on a defined personal project;
- Use of personal computer and various resources – written documents, videos, DVDs, CDs, internet sites;
- Workshops : work in groups on CV's, letters, e-mails, lab/scientific reports;
- Study different formats for CVs (chronological, functional, targeted), functional language to write formal and informal letters, e-mails. Write their own CV;
- Study Chemical Engineering vocabulary specific to the ENSIC;
- Presentation of lab/scientific reports and functional language to describe an experiment;
- Write a personal project report.

EVALUATION METHODS:

CERTIFICATION: Pass or Fail

- 1) Written report on personal project and academic staff observation
- 2) Curriculum Vitae

RESITS: Personal work or Curriculum Vitae

USEFUL INFORMATION:

PREREQUISITES: B1 for English

LANGUAGES: English

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

LANGUAGE 2: GERMAN, SPANISH, FRENCH
NO DESCRIPTORS AVAILABLE FOR:
SPANISH AND GERMAN - SECOND LANGUAGE: BEGINNERS

AIMS:

- To consolidate and acquire linguistic and communicative skills in Spanish, German and French A2/B1/B2 level (See CEFR scales);
- To develop academic and professional language skills to study and work in industry and research laboratories abroad.

LEARNING OUTCOMES:

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

- Understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. Very basic personal and family information, shopping, local geography, employment);
- Communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters.

COURSE CONTENT AND TEACHING METHODS:

- Use of various resources – written documents, videos, DVDs, CDs, internet sites in different domains eg. Social, cultural, economic, scientific, environmental;
- Work either individually, in pairs or groups;
- Different speaking activities.

EVALUATION METHODS:

CERTIFICATION: Pass or Fail - Class tests (per group)

RESITS: Personal work or tests based on class work

USEFUL INFORMATION :

PREREQUISITES: A1 level

LANGUAGE: Spanish // German // French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

SEMESTER 6: COURSE UNITS

Academic supervisor: Axelle ARRAULT

SEMESTER OVERVIEW

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Inorganic Chemistry	Mohammed BOUROUKBA	80	33	16	28			3	5
<i>Inorganic Chemistry</i>	Mohammed BOUROUKBA		33	16				3	
<i>Inorganic Chemistry: Practical Work</i>	Nathalie HUBERT				28				
Analytical Chemistry and Technology	Véronique SADTLER	80	10	33	32			3	5
<i>Principles of Chemical Equilibrium</i>	Fabrice MUTELET		2	12				0,75	
<i>Electrochemistry and Corrosion</i>	Cornélius SCHRAUWEN		4	10				0,75	
<i>Methodology - Spectrophotometry - Chromatography</i>	Véronique SADTLER		4	11				1,5	
<i>Analytical Chemistry: Practical Work</i>	Véronique SADTLER				32				
Process and Reaction Engineering II	Eric SCHAER	60	22	32				6	4
<i>Reaction Engineering for Heterogeneous Systems</i>	Eric SCHAER		8	14				2	
<i>Separation Processes</i>	Eric FAVRE		14	18				4	
Reaction Engineering and Computer Sciences	Guillain MAUVIEL	30		22		6		2	4
<i>Reaction Engineering Project</i>	Guillain MAUVIEL					6			
<i>Computer Sciences II</i>	François LESAGE			22				2	
Transport Phenomena II	Alexandra GIGANTE	88	18,5	30	32	4,5		3	5
<i>Mass and Heat Transfer</i>	Alexandra GIGANTE		17,5	28				3	
<i>Heat Exchanger Design</i>	Eric SCHAER		1	2		4,5			
<i>Transport Phenomena II: Practical Work</i>	Rainier HREIZ				32				
Management and Economics II	Vera IVANAJ	40	24	8	6			2	3
Foreign Languages II	Jude BOWDEN	40		40					3
<i>English</i>	Jude BOWDEN			20					
<i>Modern Languages</i>	Jude BOWDEN			20					
Industrialists' Conferences I	Axelle ARRAULT	12					12		1
TOTAL		430							30

CORE CURRICULUM			
COURSE TITLE: INORGANIC CHEMISTRY			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
80	133	5	

AIMS:

The inorganic course aims at:

- Acquiring the concepts of inorganic physical chemistry;
- Predicting chemical reactivity by the systematic use of physical, chemical and thermo chemical data;
- Understanding the relationship between the chemical and physical properties of solids and their electronic structure.

LEARNING OUTCOMES:

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

- Establish a link between the structure of matter and the resulting chemical and physical properties;
- Understand, analyze and predict the chemical reactions or transformations involved in different steps of a process;
- Make a judicious choice of materials to be used to manufacture a reactor, a furnace or any part of an installation used in an industrial process.

DESCRIPTION AND TEACHING METHODS:

The teaching of inorganic chemistry is based on lectures (37h) and tutorials (15h), which are applications of the courses, in which students must actively participate. Practical work in inorganic synthesis (28h) is related to industrial processes from inorganic chemical and extractive metallurgy. In addition to development of a procedure, students must integrate treatment of gases, liquids and the resulting solid waste.

EVALUATION METHODS:

The evaluation of the module consists in a written examination of 4 hours in total, which can be divided into two sessions of 2 hours: one in the middle of the semester (April) and the other at the end of the semester (June). The mark for practical work accounts for 25% of the overall mark for the module.

The exam can be taken again during second exam session: 3 hours written exam covering the entire course.

USEFUL INFORMATION:

PREREQUISITES: Concepts of: atoms and molecules, chemical bonding and periodic table concept, periodic trends in physical and chemical properties of elements, Acid/base and redox chemical reaction.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: ANALYTICAL CHEMISTRY AND METHODOLOGY			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
80	132	5	

AIMS:

- To acquire basic knowledge of chemical and physicochemical analysis;
- To understand phenomenological aspects of corrosive attacks;
- To acquire knowledge in all aspects of an analytical process from sampling to the use of results.

LEARNING OUTCOMES:

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

- Have a good understanding of chemical equilibria in an aqueous medium and be able to solve problems taking into account the combination of these equilibria;
- Have practical experience in chemical analysis by titration and instrumental techniques such as chromatography, spectroscopy and electrochemistry;
- Be able to choose the relevant chromatographic methods and conditions ;
- Be able to build current-potential curves and use them to choose the relevant electrochemistry technique to detect the equivalence point of a titration;
- Select materials for a given process taking into account corrosive resistance, identify corrosion mechanism and choose protection of engineering systems against corrosion;
- Apply the concepts of analytical methodology;
- Be able to choose spectroscopic techniques and implement quantification methods taking into account the matrix effect.

DESCRIPTION AND TEACHING METHODS:

I. Chemical equilibrium: 12h

- 1.1 Activity and activity coefficient
- 1.2 Electrodes and electrochemical cells
- 1.3 Chemical equilibrium (precipitation, complexation, acid-base, oxydo-reduction reactions)

II. Chromatography: 5h

- 2.1 Fundamentals of analytical chromatography
- 2.2 Gas chromatography, instrumentation and applications
- 2.3 Liquid chromatography, instrumentation and applications

III. Current-potential curves ($I=f(E)$): 6h

- 3.1 Electrochemistry kinetics
- 3.2 Construction of a network of curves during titration
- 3.3 Applications: choice of electrochemical techniques

IV. Corrosion: 8h

- 4.1 Uniform corrosion
- 4.2 Corrosion cells
- 4.3 Protection of engineering systems against corrosion

V. Analytical methodology: 19h

- 5.1 The various stages of chemical analysis
- 5.2 Spectroscopy
- 5.3 Conference made by an industrial speaker on the role of analytical chemistry in industry

VI. Practical work: 32h

Titration; measurement of activity coefficients; chromatography; corrosion; electrochemistry; spectroscopy

EVALUATION METHODS:

Written examination (3h)

USEFUL INFORMATION:

PREREQUISITES: Basic concepts of chemistry

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] ROSSET, R., *Chromatographie en phase liquide et supercritique*, éditeur : Masson
- [2] SKOOG, WEST and HOLLER, *Chimie Analytique*, éditeur : De Boeck Université
- [3] TRANCHANT, J., *Manuel pratique de chromatographie en phase gazeuse*, éditeur : Masson
- [4] TREMILLON, B., *Electrochimie analytique et réactions en solution*, éditeur : Masson

CORE CURRICULUM			
COURSE TITLE: PROCESS AND REACTION ENGINEERING II			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
60	105	4	

AIMS:

The objectives of this module are to:

- Understand the coupled hydrodynamic and kinetic transport phenomena involved in heterogeneous catalytic reactions;
- Explain the concepts used to describe these phenomena;
- Select and design reactors for the implementation of catalytic and heterogeneous reactions;
- Know the main separation processes used in chemical process industries (cpi);
- Understand the basic concepts and phenomena which are involved in modelling and design purposes;
- Apply design methodology to the most frequently used separation processes.

LEARNING OUTCOMES:

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

- Know, identify and take into account the different limitation processes involved in heterogeneous and catalytic reaction;
- Be able to apply these concepts for the design of heterogeneous and catalytic reactors;
- Have acquired fundamental knowledge of isothermal staged separation processes (absorption, liquid-liquid extraction, adsorption, membranes);
- Be able to explain the different phenomena which can take place in various separation processes;
- Know how to select the most appropriate separation process for a given application and how to design it.

DESCRIPTION AND TEACHING METHODS:

I. Heterogeneous Reaction Engineering

- 1.1. Presentation of the main industrial heterogeneous reactors
- 1.2. Implementation of heterogeneous gas-solid catalytic reactions,
 - 1.2.1. Coupled transport & kinetic reactions,
 - 1.2.2. Notions of external and internal diffusional limitations,
 - 1.2.3. Calculation of internal effectiveness factor,
- 1.3. Implementation of non-catalytic gas-solid reactions, shrinking core model,
- 1.4. Implementation of gas-liquid reactions, Hatta criterium number, calculation of enhancement factor.

II. Separation Engineering

- 2.1. Introduction
 - 2.1.1 Classification of separation processes
 - 2.1.2 Minimal work of separation
- 2.2 Equilibrium staged processes:
 - 2.2.1 Notion of the theoretical stage
 - 2.2.2 Multistaged processes (cross and counter current):
 - a. Graphical and analytical resolution, minimal solvent flowrate
 - b. Plate efficiency and mass transfer
 - c. Continuous separation process (NUT, HUT)
 - d. General design methodology
- I.3. Gas-liquid absorption and stripping:
 - 2.3.1 Industrial applications
 - 2.3.2 Technological aspects
 - 2.3.3 Absorption with solvent regeneration

III. Liquid-liquid extraction:

- 3.1. Industrial applications
- 3.2. Theoretical extraction stage (graphical resolution)
- 3.3. Counter-current extraction unit: design methodology (operating line, number of theoretical stages, minimal solvent flow rate)
- 3.4. Supercritical fluid extraction

IV. Adsorption & chromatography:

- 4.1. Adsorbents and applications
- 4.2. Resolution factor definition
- 4.3. General differential balance equation and breakthrough curves
- 4.4. Adsorption under plug flow conditions: Rosen analytical method

V. Membrane separations processes:

- 5.1. Classification of membrane separations
- 5.2. Ideal separation factor
- 5.3. Gas permeation: applications and general design methodology
- 5.4. Reverse osmosis: osmotic pressure and industrial applications

Description of teaching methods:

The courses are completed by tutorials where students are organized into smaller groups of ¼ of the students - The Practical work relative to this module take place in Semester S7 and are presented in the module "Reactive Systems & Industrial Processes III".

EVALUATION METHODS:

Three written exams, one on Heterogeneous Reactions Engineering (2h) and two others on Separations Engineering (2 x 1h30)

The evaluation will focus on the acquisition of basic knowledge in different areas and the student's ability to apply acquired skills and concepts to real problems. While carrying out a real case study, the student should predict the performance of a heterogeneous reactor and separation processes.

Resits: Written exam based on the 2 parts of the module.

USEFUL INFORMATION:

PREREQUISITES: Teaching Unit "Process and Reaction Engineering 1", notions of mass & energy balances, notions of transport phenomena.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: Distributed lecture notes

Advised: A list of recommended books is given in the course handout

CORE CURRICULUM			
COURSE TITLE:	REACTION ENGINEERING AND COMPUTER SCIENCES		MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
30	102	4	

AIMS:

The Reaction Engineering Project aims at teaching the students to size an industrial reactor by using different skills in Reaction Kinetics, Chemical Engineering and Computer Sciences.

Most of these lectures are given in semester 5, but it is necessary to introduce specific computer software (Matlab and VBA) considered as standard tools for engineers.

LEARNING OUTCOMES:

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

- Be capable of writing a code in VBA or Matlab;
- Understand and use sub-programs in Matlab or VBA;
- Be able to use MS-Excel for complex data processing;
- Be able to analyse reaction kinetic mechanisms and deduce important information for reactor sizing;
- Be able to implement a procedure to determine kinetic constants;
- Be able to model industrial reactors with mass and energy balances;
- Be able to design a computer program to simulate industrial reactors;
- Be able to analyse and criticise the simplifying assumptions;
- Have learnt how to work in a team and write a scientific report.

DESCRIPTION AND TEACHING METHODS:

Computer Sciences:

8 tutorials (2h) for Matlab learning: basis, matrix computation, integer, differential system integration, graph plot, interpolation

7 tutorials (2h) for VBA learning: computer language, data processing, graphical interfaces, event programming.

Reaction Engineering project:

Four students work in each team. The project is divided into two parts:

- The first part aims at analyzing a detailed kinetic mechanism and deducing stoichiometries and kinetic rate expressions. The students create a mathematical model of the reactor which is initially checked, on the basis of pseudo experimental data (generated by a black box software), and subsequently implemented in order to infer the rate coefficients, through the use of numerical methods and modern simulation packages.
- The second part aims at modelling and simulating an industrial reactor. The kinetic rate expressions obtained in the first step are implemented in appropriate mass balances coupled with an energy balance.

During the project, each team is supervised by 3 lecturers specialised in Chemical Kinetics, Chemical Engineering and Numerical Methods. There are 3 tutorial sessions.

EVALUATION METHODS:

VBA and Matlab skills are evaluated in a 2-hour exam.

The project is evaluated on the basis of 3 memos, one final report and an oral defence during which each group must present its work and results within 20 minutes. Subsequently, the members of the group are questioned by the three supervising lecturers for another 30 minutes (10 minutes each).

The overall average mark for the project is calculated from 5 individual marks: 3 memos (10% each), final report (50%) and oral defence (20%).

The resits consist of a new subject given to the students by the board of examiners. A written report is due 6 weeks later, followed by an oral presentation.

The final mark for this teaching module is the average between the Computer Sciences mark and the Reaction Engineering project

USEFUL INFORMATION:

PREREQUISITES: Learning outcomes corresponding to the following semester 5 teaching modules: Process and Reaction Engineering I, Computer Sciences and Applied Mathematics.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Compulsory:

- [1] SCACCHI, G., BOUCHY, M., FOUCAUT, J.F., ZAHRAA O. and FOURNET, R., 2011, *Cinétique et Catalyse*, Tec et Doc, Lavoisier;
- [2] CORRIOU, J.P., 2010 *Méthodes Numériques et d'Optimisation : théorie et pratique pour l'ingénieur*, Tec et Doc, Lavoisier.

Advised:

- [1] J. Villiermaux, *Génie de la Réaction Chimique*, Tec et Doc, Lavoisier, 1993.

CORE CURRICULUM			
COURSE TITLE: TRANSPORT PHENOMENA II			MANDATORY
TAUGHT HOURS 88	STUDENT WORKLOAD 183	ECTS CREDITS 5	SEMESTER 6

AIMS:

- Heat transfer by conduction, convection and radiation;
- Diffusion mass transfer and convective mass transfer.

LEARNING OUTCOMES:

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

- Carry out momentum, heat and mass balances in all unit operations of Chemical Engineering.

DESCRIPTION AND TEACHING METHODS:

- Heat transfer by conduction, Fourier's law;
- Mathematical methods for the solution of conduction problems;
- Forced convection, internal and external, in laminar and turbulent flow;
- Natural convection, hydrodynamic stability, mixed convection;
- Diffusive and convective mass transfer;
- Radiation basic principles. Heat exchangers design;
- Problem session.

EVALUATION METHODS:

Three examinations, a project and practical work

USEFUL INFORMATION:

PREREQUISITES: Transport Phenomena

LANGUAGE: French, English

BIBLIOGRAPHICAL REFERENCES

Needed:

- [1] SAATDJIAN, E., 2009, *Les bases de la mécanique des fluides et des transferts de chaleur et de masse pour l'ingénieur*, Editions Sapiaientia;
- [2] SAATDJIAN, E., 2000, *Transport Phenomena, equations and numerical solution*, John Wiley.

Advised: None

CORE CURRICULUM			
COURSE TITLE: MANAGEMENT AND ECONOMICS II			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
40	68	3	

AIMS:

- Identify human, industrial, economic and legal challenges for Occupational Health and Safety (OHS) in an organizational background;
- Incorporate the assessment and control of risks for OHS in daily practices and projects;
- Assess and model a workplace;
- Understand the core dimensions of business management by analysing its three major functions: Accounting and Financial Management, Marketing and Information Systems Management:
 - Describe and apply basics of accounting through accounting, recording and reporting on documents. Analyse items that impact accounts;
 - Analyse and understand how markets work, consumer behaviour and marketing strategies;
 - Learn how to introduce and incorporate information systems into an organizational structure by taking into account their impact on the other components of business activities.

LEARNING OUTCOMES:

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

- Conduct risk assessment in the workplace and select the best means of protection and risk prevention.
- Correct, set up and design workplace situations;
- Conduct a financial analysis by using the fundamental resources and tools available.
- Conduct a market survey and build up a marketing strategy;
- Design a conceptual and physical database model.

DESCRIPTION AND TEACHING METHODS:

Occupational Health and Safety

This part is mapped on the BES&ST data repository (Bases Essentielles en Santé et Sécurité au Travail - Basic Occupational Health And Safety Practices) established by The French National Council for Education in Occupational Health and Safety (Conseil National Pour l'Enseignement en Santé et Sécurité Au Travail - CNES&ST) comprising members of the General Directorate for Higher Education (Direction Générale de l'Enseignement Supérieur - DGES) and the French National Health Insurance Fund for Employees (Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés - CNAM-TS)

1. The Basic concepts in occupational health and safety have led to the creation of a general study framework, aka activity-centred work system, where taking activity into account is central in order to correct, set up and design workplace situations.
2. Assessing risks in organizations
3. Chemical risks. The European REACH and CLP regulations
4. Preparing industrial placements

Finance and accounting

1. Basic accounting principles
2. Accounting recording and reporting on documents. Analysis of account impacting items
3. Introduction to financial analysis (tools and resources), intermediary management balances, cash flow, functional analysis of balances and cash flow statements, budget balance and risk identification, diagnosis formalization

Marketing

1. Market analysis: the concept of market, market demand and market segmentation
2. Consumer behaviour study: behavioural factors, consumer buying process, consumer response patterns
3. Market surveys: qualitative, quantitative
4. Marketing strategies

Information systems

1. Fundamentals in information systems: introduction to information systems, IS types and their impact on business organization, incorporating ISs
2. Designing Databases: designing a conceptual and physical model DB

EVALUATION METHODS:

Exercises and case studies.

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHIC REFERENCES:

Needed:

Required:

- [1] Booklet by an INRS lecturer network (Institut National de Recherche et de Sécurité) to which ENSIC belongs, Repères pour le travail à l'usage des ingénieurs, élèves et débutants, designed on behalf of ANACT (Association Nationale d'Amélioration des Conditions de Travail)
- [2] INRS Briefing Notes;
- [3] Handouts for all classes;
- [4] Case studies and videos will be used in class to illustrate the methodological elements of risk analysis.

CORE CURRICULUM			
COURSE TITLE: FOREIGN LANGUAGES II			MANDATORY
TAUGHT HOURS 40	STUDENT WORKLOAD 70	ECTS CREDITS 3	SEMESTER 6

LANGUAGE 1: ENGLISH

AIMS:

- To enable students to become more responsible for their own learning;
- To consolidate and acquire linguistic and communicative skills in English. B1/B2/C1/C2 levels (See CEFR scales);
- To develop professional language skills needed when working in industry and research laboratories abroad;
- Develop 21st Century skills: learning skills, literacy skills and life skills.

LEARNING OUTCOMES:

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

- Analyse and evaluate their language level (B1/B2/C1/C2) and their general and professional skills in English;
- Manage their own learning objectives;
- Understand the main points of clear standard input on familiar matters regularly encountered in work, university, leisure, etc. ;
- Interact with a degree of fluency and spontaneity, in pairs and in a team;
- Describe the different steps of a process or system using Chemical Engineering specific vocabulary;
- Carry out a training period phone interview;
- Write a report.

DESCRIPTION AND TEACHING METHODS:

- Work in pairs or groups on a defined personal project and in workshops;
- Use of personal computer and various resources – written documents, videos, DVDs, CDs, internet sites;
- Discuss in pairs or small groups;
- Study Chemical Engineering vocabulary specific to the ENSIC;
- Study functional language to describe different steps of a process or system and describe a process in pairs;
- Expressions for making and answering calls. Recording and assessing a simulation of a training period telephone call;
- Write a personal project report.

EVALUATION METHODS:

Certification: Pass or fail

- 1) Written report on personal project and academic staff observation
- 2) Phone call

Level test: reading and listening comprehension

Resits: Personal work or phone call or level test

USEFUL INFORMATION:

PREREQUISITES: B1

LANGUAGES: English

BIBLIOGRAPHICAL REFERENCES:

NEEDED: None

ADVISED: None

LANGUAGE 2: GERMAN, SPANISH, FRENCH
NO DESCRIPTORS AVAILABLE FOR:
SPANISH AND GERMAN -SECOND LANGUAGE: BEGINNERS

AIMS:

- To consolidate and acquire linguistic and communicative skills in Spanish, German and French. A2/B1/B2 level. (See CEFR scales);
- To develop academic and professional language skills to study and work in industry and research laboratories abroad.

LEARNING OUTCOMES:

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

- Understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. Very basic personal and family information, shopping, local geography, employment);
- Communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters.

COURSE CONTENT AND TEACHING METHODS:

- Use of various resources – written documents, videos, DVDs, CDs, internet sites in different domains eg. Social, cultural, economic, scientific, environmental;
- Work either individually, in pairs or groups;
- Different speaking activities.

EVALUATION METHODS:

CERTIFICATION: Pass or fail - Class tests (per group)

Level test: reading and listening comprehension

RESITS: Personal work or tests based on class work

USEFUL INFORMATION :

PREREQUISITES: A2 level

LANGUAGE: Spanish // German // French

BIBLIOGRAPHICAL REFERENCES:

NEEDED: None

ADVISED: None

CORE CURRICULUM			
COURSE TITLE: INDUSTRIAL CONFERENCES I			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 6
12	21	1	

AIMS:

Illustrate different industrial domains with conferences by industrial specialists.

LEARNING OUTCOMES:

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

- Have a better understanding of the Chemical Engineering industry;
- Have a better understanding of what is expected from a Chemical Engineer in industry;
- Have a clearer vision of his/her career objectives.
-

DESCRIPTION AND TEACHING METHODS:

This course is composed of short conferences (1h30 to 2h) given by industrialists, grouped in 4 half-days. Generally, two different conferences are given at the same time so that students have a choice in the subject.

EVALUATION METHODS:

Multiple choice questions at the end of each conference.

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

NEEDED: None

ADVISED: None

SEMESTER 7: COURSE UNITS

Academic supervisor: Rainier HREIZ

SEMESTER OVERVIEW

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Polymer Chemistry	Anne JONQUIERES	52	13,5	8	28			2,5	3
<i>Polymer Chemistry</i>	Anne JONQUIERES		13,5	8				1,5	
<i>Polymer Chemistry: Practical Work</i>	Khalid FERJI				28			1	
Industrial Processes and Sustainable Development	Alain DURAND	103	43	28	24		3	5	7
<i>Safety</i>	Olivier DUFAUD		14,5	10				2	
<i>Industrial Process Design</i>	Laurence MUHR		19,5	12			3	2	
<i>Polymer Process Engineering</i>	Alain DURAND		9	6				1	
<i>Process and Reaction Engineering III: Practical Work</i>	Marie LEPAGE MOSTEFA				24				
Transport Phenomena III	Sabine RODE	56	11,5	17,5	24			3	3
<i>Fluid-Solid Unit Operations</i>	Sabine RODE		7	13				2	
<i>Mixing</i>	Souhila PONCIN		4,5	4,5				1	
<i>Transport phenomena III: Practical Work</i>	Marie LEPAGE MOSTEFA				24				
Thermal Separation Processes II	Sabine RODE	80	25	24	24	2		5	5
<i>Thermodynamics of Phase Equilibria</i>	Jean-Noël JAUBERT		13	8				2	
<i>Binary Distillation</i>	Sabine RODE		7	8				1,5	
<i>Psychrometry, Evaporative Cooling and Solids Drying</i>	Sabine RODE		5	8		2		1,5	
<i>Thermal Separation Processes : Practical Work</i>	Marie LEPAGE MOSTEFA				24				
Process systems engineering	Abderrazak LATIFI	68	19,5	42,5				6	5
<i>Computer-aided Process Design</i>	Abderrazak LATIFI		1,5	18				2	
<i>Optimization</i>	Abderrazak LATIFI		6	9,5				1,5	
<i>Process Dynamics and Control</i>	Jean Marc COMMENGE		12	15				2,5	
Management and Economics III	Véra IVANAJ	24	8	8			8		2
<i>Change Management</i>	Véra IVANAJ		6	6			8		
<i>Curriculum Vitae and Cover Letter</i>	Alexandra GIGANTE		2	2					
Foreign Languages III	Jude BOWDEN	40		40					3
<i>English</i>	Jude BOWDEN			20					
<i>Modern Languages</i>	Jude BOWDEN			20					
Elective	-	12							1
Industrialists' Conferences II	Guillain MAUVIEL	12					12		1
<i>Industrial Conferences</i>	Guillain MAUVIEL						12		
TOTAL		448							30

ELECTIVES III (to be chosen: one)

Electives III	Unit coordinators	Taught hours	Lectures	Tutorials	Practical Work	P	C	Ex	ECTS credits
<i>Drugs engineering</i>	Axelle ARRAULT	12	5	6				1	1
<i>Photophysics and Photochemistry</i>	Céline FROCHOT	12	5	6				1	1
<i>A Brief History of Science</i>	Arnaud FISCHER	12	5	6				1	1
<i>Financial and Budget Management</i>	Valerie HENRI	12	5	6		3			1
<i>Microfluidics</i>	Thibault ROQUES CARMES	12	5	6				1	1
<i>Biopolymers and biodegradable polymers</i>	Anne JONQUIERS	12	9,5				1,5	1	1
<i>Big data and artificial intelligence</i>	Jean-Marc COMMENGE	12	5	6				1	1
<i>Modelling tools at the Disposal of an Engineer</i>	Dimitrios MEIMAROGLOU	12	5	6				1	1
<i>Hydrometallurgical processes</i>	Marie LE PAGE MOSTEFA	12	5	6				1	1

CORE CURRICULUM			
COURSE TITLE: POLYMER CHEMISTRY			MANDATORY
TAUGHT HOURS 52	STUDENT WORKLOAD 84	ECTS CREDITS 3	SEMESTER 7

AIMS:

The polymer chemistry module aims at:

- Introducing the basics of polymers;
- Presenting the different types of polymerisation and their characteristics;
- Describing the different polymerisation kinetics and the corresponding calculations of polymer molecular weights.

LEARNING OUTCOMES:

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

- Understand the macromolecule specificity and their main characteristics;
- Choose the right polymerisation type to achieve a specific task;
- Identify the advantages and drawbacks of the different polymerisation types;
- Make the kinetics and molecular weight calculations which are pre-requisite for dimensioning polymerisation reactors;
- Perform simple polymerisations and have a basic knowledge of the most common polymerisation processes.

DESCRIPTION AND TEACHING METHODS:

The polymer chemistry module is structured in 4 chapters:

Chapter 1: Introduction to polymers

Chapter 2: Radical polymerisation

Chapter 3: Ionic and coordination/insertion polymerisations

Chapter 4: Step-growth polymerisations

The module involves 9 lectures of 1h30, the lecture textbook being the slides of the different presentations. The lectures, structured around the slides, provide a first approach to the subject using industrial examples and open questions to the audience. At the end of each chapter, an online interactive questionnaire is submitted to the students in order to allow an auto-assessment learning of the module fundamentals.

The lectures provide the basis for 5 tutorials (2h, and 4 x 1h30) which will follow the progression of the lectures. These tutorials have to be prepared by the students who have to know the main aspects under scrutiny of the corresponding chapter. These tutorials are based on active learning by problem-based pedagogy. Therefore, during these tutorials, different problems will be solved by small teams of students under the supervision of a member of the academic team.

The first four tutorials will propose several exercises related to the different chapters. The fifth tutorial will be an opportunity to reinforce knowledge of step-growth polymerisations, which are more difficult to master, before the final exam of 1h30.

28 hours of Practical work over 4 days will complete the basic polymer chemistry course by enabling the student confrontation with real life issues in polymerisation processes. The practical work will focus on the different polymerisation processes and their specificity (polymerisations in solution, in suspension and in emulsion, step-growth polymerisation etc.) and the main techniques used for polymer characterization, including molecular weight determination.

EVALUATION METHODS:

- A final exam corresponding to the lectures and tutorials (2/3 of the overall mark)
- An assessment of practical work done on the basis of brief lab reports on pre-formatted forms, the student work during the practical lessons and a final lab work exam, the total mark corresponding to the lab work accounting for 1/3 of the global mark.

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of organic chemistry

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed : The textbooks of lectures, tutorials and practical lessons are only needed in this module.

Advised : The following books, which are all available at the ENSIC library and are mainly in French, are recommended to the students wanting to broaden their knowledge in macromolecular chemistry :

- [1] FONTANILLE, M. and GNANOU, Y., 2010, *Chimie et physico-chimie des polymères*, 2nd édition, Editeur Dunod;
- [2] MERCIER, J-P. and MARECHAL, E., 1993, *Chimie des polymères : synthèses, réactions, dégradations*, 13th Volume du Traité des Matériaux, Editeur Presses polytechniques et universitaires romandes;
- [3] ODIAN, G., 1991, *Principles of Polymer Chemistry*, 3rd edition, John Wiley and Sons.

CORE CURRICULUM			
COURSE TITLE : INDUSTRIAL PROCESSES AND SUSTAINABLE DEVELOPMENT			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
103	174	7	

AIMS:

- To understand the methodology of analysis and design of industrial processes including environmental and safety aspects;
- To extend basic knowledge in Chemical Engineering to polymerisation processes by taking into account the link between the chemical structure, manufacturing processes and final material properties;
- An experimental study of homogeneous and heterogeneous reactors;
- To present working conditions, chemical hazards, regulations about work and process safety;
- To present the main risks related to industrial processes (fire, explosion, thermal runaway, dispersion in atmosphere);
- To introduce the fundamentals of sustainable development.

LEARNING OUTCOMES:

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

- Know how to design an industrial process including all unit operations (reaction, separation, compression...) and carry out an analysis of environmental and safety aspects;
- Be able to define the required operations for wastewater treatment;
- Be able to apply knowledge to process design and sizing of each unit operation;
- Know how to design polymerisation reactors as well as whole polymerisation processes taking into account the characteristics of the reaction;
- Know how to design polymerisation reactors taking into account the required performances for yield, productivity, cost, as well as targeted macromolecule characteristics (molar mass distribution) and material properties;
- Have experience of running lab-scale chemical reactors with detailed knowledge of all related technical and safety aspects;
- Know how to include safety, environmental and energy saving concerns when designing and running an industrial process;
- Know and be able to apply the main methods of risk analysis;
- Be able to take part in preliminary danger assessments and understand the objectives of an impact study.

DESCRIPTION AND TEACHING METHODS:

EC 1. Industrial Process Design (35.5 h)

Part I: Inorganic Chemistry Processes

Part II: Refining and Petrochemistry

Part III: Nuclear Processes

Wastewater treatment as well as gas effluents will be examined

EC 2. Polymer Process Engineering (15 h)

Part I: Introduction: relation between structure, process and properties

Part II: Polymerisation Processes

Part III: Design and modelling of reactors for radical polymerisation

EC 3. Safety and Sustainable Development (24 h)

This part deals with process safety at all stages: design (intrinsic safety), building, running, and shut down of

industrial processes. More specifically:

- Current regulations (ICPE, Seveso 3, IED...),
- Available methodologies (intrinsic safety, APR, HAZOP method...)
- Corresponding basic knowledge (fires, gas and vapor explosions, BLEVE, Boilover, dust explosions, dispersion in atmosphere, thermal runaway, etc.)

Fundamentals of sustainable development are also studied. Life Cycle Analysis as well as Product and Process Management are presented.

EC 4. Process and Reaction Engineering: Experimental study (28 h)

Crystallisation: population balance, model for crystalliser/measure of gas-liquid mass transfer coefficient in the presence of a chemical reaction (8h), estimation and experimental determination of residence time distribution in various reactors (4h), heterogeneous catalytic reactors (8h), autothermal reactor (4h), system dynamics (4h).

Teaching methods

EC 1. Lectures, tutorials, conferences (1 conference given by an industrialist) and case studies (4 classes)

EC 2. Lectures and tutorials

EC 3. Each class (3h) comprises 1h lecture and 2h exercises. Exercise topics are organized according to danger assessment of an industrial site

EC 4. Practical work – Theory is taught on the semesters 5 and 6 courses. “Process and reaction engineering I and II”

EVALUATION METHODS:

3 h written exam for EC 1 and EC 2: questions about several industrial processes studied during the course (no documents allowed) and exercises about a specific polymerisation process (all documents allowed).

1.5 h written exam for EC 3 and group project on danger assessment.

Written reports on practical work for EC 4.

The final evaluation of the course is obtained by calculating the average of individual evaluations, taking into account the relative workloads.

USEFUL INFORMATION:

PREREQUISITES: Courses « Process and Reaction Engineering I and II », « Macromolecular Chemistry », « Thermodynamics and Energetics ».

TEACHING LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Required:

- [1] LAURENT, A., 2011, *Sécurité des Procédés Chimiques - connaissances de base et méthodes d'analyse de risques*, 2nd edition, Paris, Tec&Doc Lavoisier.

Recommended:

- [1] CRAWLEY, F., PRESTON M. and TYLER, B., 2000, *HAZOP: guide to best practice: guidelines to best practice for the process and chemical industries*, Institution of chemical engineers;
- [2] DEGREMONT, 2005, *Memento Technique de l'eau*, 10th edition, Paris, Lavoisier;
- [3] DI NENNO, P.J. and Al., 1995, *SFPE handbook of fire protection engineering*, 2nd edition, National Fire Protection Association Society of Fire Protection Engineers;
- [4] ECKHOFF, R.K., 2005, *Explosion hazards in the process industries*, Gulf Publishing Company, Houston;
- [5] IchemE, 1988, *Preventing major chemical and related process accidents*, Symposium series - Rugby, UK: Institution of Chemical Engineers;
- [6] MANNAN S. and LEES, F.P., 2005, *Loss prevention in the process industries*, Elsevier;
- [7] MORTUREUX, Y., *Analyse Préliminaire de risques, Techniques de l'Ingénieur*, SE 4010 ;
- [8] VILLERMAUX, J., 1993, *Génie de la Réaction Chimique*, Tec et Doc, Lavoisier;
- [9] SCACCHI, G., BOUCHY, M., FOUCAULT JF. and ZAHRAA, O., 1996, *Cinétique et Catalyse*, Lavoisier, Tec et Doc.

[10]DURAND A., HOPPE S., MEIMAROGLOU D., SERRA C., RACHET R., WILSON J., Réacteurs homogènes de polymérisation radicalaire, Techniques de l'Ingénieur, AF 6046.

CORE CURRICULUM			
COURSE TITLE: TRANSPORT PHENOMENA III			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
56	92	3	

AIMS:

This course aims at:

- Acquiring fundamental knowledge in the description of multiphase solid-liquid flows, in fixed and fluidised beds;
- Acquiring fundamental knowledge in mechanical fluid-solid separations;
- Acquiring fundamental knowledge in stirring
- Providing students with the required capacities in the design of installations related to the above unit operations.

LEARNING OUTCOMES:

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

- Estimate flow and transfer characteristics and rates in fixed and fluidised beds;
- Select the suitable impeller and design the mechanical stirred vessel for a defined application;
- Select and design mechanical separation devices: settler, filter, centrifugation devices.

DESCRIPTION AND TEACHING METHODS:

Lectures and tutorials (32 h), as follows:

Flows in fixed beds and fluidization:

This part comprises 3 one-hour long lectures and 3 two-hour tutorial sessions: Sauter diameter of solid particles, Darcy's law and Ergun's equation, minimum fluidisation velocity and terminal velocity; classification of power materials, fluidisation regimes; similitudes and scaling up; industrial processes; 1 hour exam.

Stirring

Three 1h 30 minute lectures and three 1h 30 minute tutorials: radial and axial impellers; power number; recirculation and pumping flow rates, mixing times, heat transfers; 1 hour long exam.

Mechanical unit operations

The sub-unit comprises one 1 ½ hour, three 1h lectures and three 2h tutorial sessions: solid-liquid and gas-solid separations, settling, depth and support filtration, centrifugation, mechanical drying, dust removal.

Practical Work (28 hours)

Flow phenomena in plate or packed columns: flooding, priming, pressure drops (8 h); Gas-solid and liquid-solid fluidisations: minimum fluidisation velocity, transfer, bed expansion (8 h); Stirring: power characteristic curve, effect of the impeller geometry, gas-liquid stirring (4 h); Filtration: in press filters, resistance of cake and the layer stuff (4 h); Plate exchangers: enthalpy balances, efficiency curves, transfer coefficients (4 h).

EVALUATION METHODS:

Practical session reports; written exams on fixed / fluidised beds, stirring and mechanical separation.

USEFUL INFORMATION:

PREREQUISITES: Transfer Phenomena I and II

LANGUAGE: French

BIBLIOGRAPHIC REFERENCES:

Required: Photocopied transmitted documents

Additional references:

- [1] BEEK, W.J., MUTZALL, K.M.K. and VAN HEUVEN, J.W., 1999, *Transport Phenomena*, 2nd edition, New-York: John Wiley & Sons;
- [2] MC GRAW-HILL, Perry's Chemical Engineers' Handbook, 2007, *Heat and Mass Transfer*, Ch. 5; Ch. 6, *Fluid and Particle Dynamics*; Ch.18, *Liquid-Solid Operations and Equipment*, 8th edition, New York;
- [3] KUNII D. and LEVENSPIEL, O., 1991, *Fluidization Engineering*, 2nd. Edition, New-York: John Wiley;
- [4] WALLIS, G.B., 1969, One-dimensional two phase flow, New-York: Mc-Graw Hill;
- [5] YANG, W.C., 2003, *Handbook of fluidization and fluid-particle systems*, New-York: Marcel Dekker Inc.

CORE CURRICULUM			
COURSE TITLE: THERMAL SEPARATION PROCESSES			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
80	150	5	

AIMS:

- To present the formalism for describing multi-component systems with emphasis on the concept of chemical potential;
- To describe the phase diagrams of binary systems with a homogeneous liquid phase;
- To introduce the basic methods of sizing equilibrium-based separation operations involving coupled mass and heat transfer: binary distillation (continuous and batch operation), evaporative cooling and solids drying;
- To enable the student to design the corresponding facilities.

LEARNING OUTCOMES:

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

- Calculate an isothermal or isobaric phase diagram as well as the equilibrium curve of any binary system (positive or negative deviations from ideality, homogeneous azeotropic);
- Estimate the limiting operating conditions of a binary distillation column (minimum reflux ratio, minimum number of trays) and choose the optimal operating conditions of the column;
- Design distillation and evaporative cooling columns;
- Analyze drying curves and select and design solids drying equipment.

DESCRIPTION AND TEACHING METHODS:

Lectures and tutorials

Thermodynamics and phase equilibrium: equilibrium criteria, evaluating chemical potentials, vapour-liquid equilibrium relationships, properties change on mixing, ideal-mixture properties change on mixing, excess properties, low-pressure phase diagrams (classical, homogeneous positive and negative azeotropes).

Binary distillation: two lectures (1h:30): design of packed and tray towers ; 4 sessions of 3 hour tutorials prepared by the students: flash distillation, rectification, Fenske equation, design methods of Mac-Cabe Thiele and Ponchon-Savarit, batch distillation, Rayleigh equation; 1h30 written examination.

Psychrometry and evaporative cooling: two lectures (1h); 2 tutorial sessions (2h): wet bulb temperature, psychrometric calculations and charts, evaporative cooling towers.

Solids drying: 2 lectures (1h) – 2 tutorial sessions (2h), 2 tutorial sessions for homework (1h30): drying mechanisms, drying curves, industrial dryers, enthalpy balance, energy efficiency and related technologies; 1h30 written exam (with evaporative cooling).

Practical work	Student hours
Liquid-liquid extraction: extraction of methylene blue in an agitated column, aqueous two-phase system	8
Batch distillation, total and partial reflux ; water-ethanol and water-acetic acid separation	4
Spray Drying (sodium sulfite): material and enthalpy balances, wet bulb temperature	4
Thermodynamics of separation: heat of mixing, excess volume, ebulliometry	8
Absorption with chemical reaction and solvent regeneration: CO ₂ absorption in amino acids	4
SUM:	28

EVALUATION METHODS:

Written laboratory reports (20 %), written examination Thermodynamics (35%), written examination Binary Distillation (20%), written examination Psychrometry and Drying (15%), homework Psychrometry and Drying (10%)

Resits: 3 h written examination: 1h30 Thermodynamics, 1h30 Distillation, Psychrometry and Drying

USEFUL INFORMATION:

PREREQUISITES: Thermodynamics, Isothermal Separation Processes

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

NEEDED: distributed lecture notes

ADVISED:

CORE CURRICULUM			
COURSE TITLE: PROCESS SYSTEMS ENGINEERING (OR PSE)			MANDATORY
TAUGHT HOURS 68	STUDENT WORKLOAD 119	ECTS CREDITS 5	SEMESTER 7

AIMS:

The objective of the Process Systems Engineering courses is to give to the students the necessary tools for modelling, synthesis, analysis, optimization and control of systems that will allow them to design and manage complex and efficient processes. The tools consist mainly of Computer-Aided Process Design (or CAPD), Process Optimization, Dynamics and Control.

The CAPD course aims at:

- Introducing the general aspects of process simulation and flowsheeting software;
- Presenting the physical properties organization within the software;
- Explaining the computation and flowsheeting methods implemented within the software;
- Using the process flowsheeting software pro/ii for case studies.

The optimization course aims at:

- Showing how to formulate a steady-state optimization problem;
- Presenting direct search and gradient-based methods;
- Describing the constrained (equality and inequality constraints) optimisation methods as well as the computation algorithms.

The process dynamics and control course aims at:

- Introducing the system dynamics and the residence time distribution (rtd);
- Familiarising the student with the basics of control of siso continuous systems;
- Explaining the techniques of tracking and disturbance rejection based on pid controller and advanced methods;
- Showing the importance of control and its dynamic consequences on processes

LEARNING OUTCOMES:

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

- Simulate simple units and complex process flowsheets;
- Choose and size units;
- Understand different optimisation methods (direct, gradient-based, constrained, etc);
- Formulate and solve a constrained steady-state optimisation problem;
- Optimise process operations;
- Know how to describe the dynamic operation of linear systems;
- Define the performance indices of non-ideal reactors based on residence time distribution (or rtd) approach;
- Master the control concepts and methods based on Laplace transform, including the pid controller;
- Understand some advanced control methods with respect to PID controller.

DESCRIPTION AND TEACHING METHODS:

I. CAPD

1. General aspects of process simulation and flowsheeting software

Process simulation requirements

Flowsheeting software and their structure

Units frequently encountered in process simulations

2. Physical properties in flowsheeting software

Fixed data and temperature-dependent variables

Thermodynamic models and their choice

3. Numerical and flowsheeting methods implemented within software

Direct substitution method

Broyden method

Wegstein method
Recycle and tear streams

4. Case Studies using PRO/II

Use of different databanks
Regress data
Thermodynamic equilibria computation
Compressors/turbines
Chemical reactors
Distillation and liquid/liquid extraction columns
Heat integration
Exergetic analysis

II. **Optimisation**

1. Analytical optimisation methods
2. Numerical optimisation methods
3. Linear programs
4. Quadratic and non-linear programs

III. **Process Dynamics and Control**

1. Process dynamic modelling
 - State space representation
 - Transfer functions
 - Open-loop control study of linear systems
2. Open loop analysis of linear systems
 - Systems of first and second order
 - Delayed and distributed systems
3. RTD-based dynamic systems
 - Ideal reactors modelling and identification
 - Complex systems modelling
4. Feedback linear control
 - PID controller
 - Dynamics of feedback controlled processes
5. Stability analysis
 - Analysis in state space
 - Stability analysis of feedback controlled systems
6. Closed-loop design of controllers
 - Improvement of PID controllers
 - Internal model control
7. Frequency analysis
 - Bode and Nyquist diagrams
 - System characterisation by frequency analysis
 - Bode stability criterion
8. Improvement of control systems
 - Pure delay and zeros offset
 - Shared, selective and cascade feed forward control

SUPERVISOR :	M.ABDERRAZAK LATIFI
TEACHING STAFF :	Description
LATIFI A.	CAPD and Optimization
COMMENGE J.M.	Process Dynamics and Control
PORTHA JF.	CAPD, Optimization and Control
CONIGLIO JAUBERT L.	CAPD
JAUBERT JN.	CAPD
LESAGE F.	CAPD and Process Control
PRIVAT R.	CAPD
ADOUANI N.	CAPD
LEMAITRE C.	Optimization and Process Control

EVALUATION METHODS:

CAPD :	2h written exam in the computer room
Optimisation :	1h 30 minute written exam
Process Dynamics :	1h written exam
Process Control :	2h written exam

USEFUL INFORMATION:

PREREQUISITES:

CAPD: Thermodynamics – Chemical Reaction Engineering – Unit Operations – Numerical Analysis and Optimisation Methods

Optimisation: Numerical Analysis Methods – Use of a programmable calculator

Process Dynamics and Control: Mass and energy balances

LANGUAGE:

CAPD: French

Optimisation: French

Process Dynamics: French

Process Control: French

BIBLIOGRAPHICAL REFERENCES:

Needed:

- [1] CAPD : Course handout
- [2] Optimisation : Course handout
- [3] Process Dynamics : Course handout
- [4] CORRIOU, J-P., 2003, *Commande des procédés*, Process Control, Lavoisier Tec&Doc.

Advised:

- [1] BIEGLER, L.T., GROSSMANN, I.E. and WESTERBURG, A.W., 1997, *Systematic methods of chemical process design*, Prentice Hall PTR;
- [2] CORRIOU, J-P., 2010, *Méthodes numériques et optimisation: Théorie et pratique pour l'ingénieur*, Lavoisier Tec&Doc;
- [3] SEIDER, W.D. , SEADER, J.D. and LEWIN, D.R., 1998, *Process design principles : synthesis, analysis, and evaluation*, John Wiley & Sons;
- [4] VILLERMAUX, J., 1993, *Génie de la Réaction Chimique*, Tec et Doc, Lavoisier;
- [5] WESTERBERG, A.W., HUTCHINSON, W., MOTARD, R. and WINTER, P., 1979, *Process flowsheeting*, Cambridge University Press.

CORE CURRICULUM			
COURSE TITLE: CHANGE MANAGEMENT			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
24	42	2	

AIMS:

- Understand the challenges and core factors for successful organizational change;
- Identify and manage resistance to change;
- Analyse the laws for change dynamics and processes.

LEARNING OUTCOMES:

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

- Lead a change project by using a managerial approach and appropriate tools;
- Structure a project by identifying the major steps and actions to undertake in relation to the change issues encountered;
- Take into account the human component: handle values, culture, resistance to change by using a participative approach, communication and training/coaching with the aim of facilitating comprehension and acceptance by individuals of the “new rules” resulting from the change process.

DESCRIPTION AND TEACHING METHODS:

Management of change:

- Approaches to leading change;
- Change methods;
- Change factors;
- Steps towards change;
- Change resistance;
- Causes for failing change;
- The dynamic laws of change.

Case studies of organizational change

EVALUATION METHODS:

Case study of organizational change

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Required:

- [1] CARTON, G.D., 2004, *Éloge du changement*, 2ème édition, Village Mondial éd..

Recommended:

- [1] AUTISSIER, D. and MOUTOT, J-M., 2003, *Pratiques de la conduite du changement -Comment passer du discours à l'action*, Dunod;
- [2] DUPUY, F., 2004, *Sociologie du changement – Pourquoi et comment changer les organisations*, édition Dunod;
- [3] FAURIE, C., 2003, *Conduite et mise en œuvre du changement – l’effet de levier*, Maxima éd.;
- [4] VAILLANCOURT, R., 2003, *Le Temps de l'Incertitude - du changement personnel au changement organisationnel*, Presses de l’Université du Québec.

LANGUAGE 1: ENGLISH

CORE CURRICULUM			
COURSE TITLE: FOREIGN LANGUAGES III			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
40	70	3	

AIMS:

- To consolidate and acquire linguistic and communicative skills in English. B1/B2/C1/C2 levels (See CEFR scales) **(TOEIC: 785 /990 or TOEFL: 95/120 or IELTS: 5.5/9);**
- To develop professional language skills needed when working in industry and research laboratories abroad;
- To enable students to become more responsible for their own learning;
- Develop 21st Century skills: learning skills, literacy skills and life skills.

LEARNING OUTCOMES:

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

- Analyse and evaluate their language level (B1/B2/C1/C2);
- Manage their own learning objectives;
- Understand the main ideas of complex texts on both concrete and abstract topics;
- Interact with a degree of fluency and spontaneity;
- Option "Meetings" : facilitate and take part in meetings - express their ideas and opinions with precision, present and respond to arguments convincingly, take on role of facilitator / secretary (taking the minutes).

DESCRIPTION AND TEACHING METHODS:

- TOEIC /TOEFL /IELTS preparation. . Techniques for listening, reading, speaking, concentration and memory skills. Self assessment;
- Use of various exercises /books/internet;
- Working in pairs or groups on learning objectives;
- Improving databank of vocabulary in various contexts (business, industry, university, economy, culture...)

Meetings:

- 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;
- How to write the minutes and agenda;
- Case studies and role play simulations.

EVALUATION METHODS:

Certification: Pass or fail:

- 1) Written report on personal project and academic staff observation
- 2) Meetings and report

Resits: Personal work

Level test : Mock TOEIC (reading and listening comprehension)

Resits: Personal work or level test

USEFUL INFORMATION:

PREREQUISITES: B1 English

BIBLIOGRAPHICAL REFERENCES:

Needed: complete guide to the TOEIC test: Bruce Rogers, TOEFL prep books, test simulator in resource center, vocabulary and grammar book.

LANGUAGE 2: GERMAN, SPANISH, FRENCH

**NO DESCRIPTORS AVAILABLE FOR:
SPANISH AND GERMAN - SECOND LANGUAGE: BEGINNERS**

AIMS:

- To consolidate and acquire linguistic and communicative skills in Spanish, German and French A2/B1 /B2/C1 (See CEFR scales)
- To develop professional language skills required when working in industry and research laboratories abroad

LEARNING OUTCOMES:

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

- Understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialisation
- Interact with a degree of fluency and spontaneity
- Give a clear, systematically developed talk, with highlighting of significant points, and relevant supporting detail
- Understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc.
- Deal with most situations likely to arise whilst travelling in an area where the language is spoken
- Produce simple connected text on topics, which are familiar, or of personal interest
- Write their own cv, cover letter and e-mails
- Describe the different steps of a process or system

COURSE CONTENT:

- Analysis of various resources – written documents, videos, dvds, cds, internet sites in different domains (eg. Social, cultural, economic, scientific, environmental): listening, reading and speaking activities
- Working either individually, in pairs or groups
- Expressions to write essays, reports, notes, summaries
- Chemical Engineering vocabulary specific to the ENSIC

EVALUATION METHODS:

CERTIFICATION: Pass or fail - Class tests (per group)

RESITS: Personal work or tests based on class work

USEFUL INFORMATION:

PREREQUISITES: B1+

LANGUAGES: Spanish // German // French

BIBLIOGRAPHICAL REFERENCES:

NEEDED: None

ADVISED: None

CORE CURRICULUM			
COURSE TITLE: DRUGS ENGINEERING			ELECTIVE
12	STUDENT WORKLOAD 21	ECTS CREDITS 1	SEMESTER 7

AIMS:

An active substance is a molecule or a biomolecule, generally found in very small proportions in the drug compared to excipients, which induces a therapeutic effect in a drug. Recently, new techniques for preparing these active molecules have been developed. This optional teaching session will present the principle of drug engineering.

LEARNING OUTCOMES:

At the end of this option, students will be able to understand classical and emerging techniques used to develop biomolecules or active substances (R&D) in the pharmaceutical industry. They will also understand why few families of molecules are of special interest and be able to choose the optimal synthesis technique for their production.

DESCRIPTION AND TEACHING METHODS:

Description:

- Synthesis strategies: total, in fragments, classical, combinatorial or supported synthesis
- Applications to the synthesis of biomolecules (active substances) such as peptides, sugars, heterocycles
- Emerging synthesis techniques, online follow-up.

- The teaching will be composed of lectures concerning the:
 - different synthesis techniques
 - different classes of biomolecules and their pharmaceutical properties
 - and a microproject: a small group of students will choose and develop one of these techniques (oral presentation + technical form).

EVALUATION METHODS:

Type of evaluation:

Oral presentation + technical form

Remedial written exam

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: FRENCH

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE:	PHOTOPHYSICS AND PHOTOCHEMISTRY : APPLICATIONS		ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

Light possesses spectral, temporal and spatial resolutions. These exceptional qualities can be exploited for specific applications in Spectroscopies, Biology, Chemical Synthesis or for “new energies”. The aim of this course is to present the basics and concepts of Photophysics and Photochemistry and to analyse how they can be used to develop applications.

LEARNING OUTCOMES:

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

- Understand the mechanisms that take place in Photophysical and Photochemical processes;
- Use Photophysics as a spectroscopic method for chemical, biological analyses;
- Use Photophysics for industrial applications in particular in terms of “new energies”;
- Understand that this domain is a science of interface open to interdisciplinarity.

DESCRIPTION AND TEACHING METHODS:

The session will include lectures, laboratory visits and a project.

The project will consist of the analysis of a document dealing with Photophysics or Photochemistry.

Different lecturers will participate in this course.

EVALUATION METHODS:

Project.

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: A BRIEF HISTORY OF SCIENCE			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

Very scarcely mentioned during post-graduate studies, the history of science and technology nevertheless reveals the most pleasant aspects of otherwise dull theories and unveils details concerning the existence of inventors who, somehow, still haunt our everyday lives. The aim of this option is to convey a synoptic perspective of the development of some of the major scientific matters from their origins to today.

LEARNING OUTCOMES:

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

- Be familiar with the chronological highlights of theories and technological improvements dealing with different subjects such as Chemistry, Mathematics, Mechanics, Astronomy, Optics, Energy and Electromagnetism.

-

DESCRIPTION AND TEACHING METHODS:

The development of the aforementioned subjects will be presented using an illustrated Powerpoint slide show. A few short studies of texts will help discover genuine historic scientific literature. The students will be offered the opportunity to visit the historical collections from the libraries of both the Science and Technology and Medicine campuses in Nancy. An optional visit to the Musée des Arts et Métiers in Paris, an institution with a huge collection of historic scientific instruments, will take place one Saturday, allowing a more concrete perception of the history of technology.

EVALUATION METHODS:

Bibliographical project

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: FINANCIAL AND BUDGET MANAGEMENT			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

- To control the basic theoretical assets of a company;
- To correctly define the basic notions and concepts of a financial, and entrepreneurial economy;
- To produce a presentation of the mechanisms;
- To analyze and synthesise information;
- To collect and process data;
- To use knowledge, concepts and learned procedures to solve problems.

LEARNING OUTCOMES:

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

- Draw up a provisional budget;
- Identify and optimise the funding sources of an investment: leases, loans, or equities...;
- To know how to calculate the cost of a product.

DESCRIPTION AND TEACHING METHODS:

This course will consist of classes (case studies) and a micro project.

EVALUATION METHODS:

Two means of evaluation: A presentation by groups of 4 to 5 students on a topic about current financial affairs or an aspect dealt with during the course and a case study.

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: MICROFLUIDICS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

Microfluidics is a field that is currently growing. Its applications are highly varied ranging from intensified processes through medical testing to green chemistry and the encapsulation of active ingredients for pharmaceutical applications.

One of the main strong points of microfluidics is that operating conditions (temperatures, flows, concentration, residence time etc.) can be controlled very well. This means yields can be optimised while the quality of products obtained and the level of reproducibility cannot be equalled using other processes.

The aim of this module is (i) to give an overview of the possible applications of microfluidics and (ii) to increase students' awareness of emerging questions and problems for micro-scale flows and give the scales concerned (iii) to provide examples of industrial processes using microfluidics.

LEARNING OUTCOMES:

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

- Have knowledge of the current developments in microfluidics;
- Be aware of the particularities and the advantages of microfluidic devices such as: flows with low reynolds numbers, heat exchanges facilitated by a highly favourable surface/volume ratio, well controlled residence times, importance of interface tension and wetting;
- Be able to design and process microfluidic devices;
- Have knowledge of various microfluidic industrial processes.

DESCRIPTION AND TEACHING METHODS:

The course will be taught with classes and tutorials. Students will also be requested to carry out a microproject.

- Presentation of the different manufacturing methods;
- Droplet-handling / Use in medical applications;
- Hydrodynamics, transfers at micrometric scale and physical mechanisms involved;
- Microfluidics as reactors;
- Applications in the fields of analysis and health;
- Applications for industrial processes: certain industrial processes based on microfluidics will be covered in detail.

EVALUATION METHODS:

1st session: project + oral presentation

2^{eme} session: oral examination

USEFUL INFORMATION:

Prerequisites: None

Language: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: BIOPOLYMERS AND BIODEGRADABLE POLYMERS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

- To describe the main natural polymers (biopolymers) used as polymer materials, their advantages, limits and their impact on polymer processing for common applications;
- To present the main industrial developments to limit the environmental impact of polymer materials with biodegradable polymers based on petroleum or natural resources;
- To illustrate an exemplary industrial approach for developing bio-sourced technical polymers.

LEARNING OUTCOMES:

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

- Identify the important industrial biopolymers and biodegradable polymers;
- Take advantage of their specific advantages and limits for targeted applications;
- Define the main prospects and challenges for developing new biopolymers and biodegradable polymers in industry;
- Contribute to the development of new polymer materials within the framework of sustainable development.

DESCRIPTION AND TEACHING METHODS:

Natural polymers (biopolymers) will be presented first by focusing on biopolymers used as polymer materials. Synthetic biodegradable polymers also know an unprecedented growth, which should further intensify in the coming years. In particular, several of them can be obtained from renewable resources and could be interesting alternatives to petroleum-based polymers. The different types of synthetic biodegradable polymers recently developed in industry will be presented as well as their applications in key markets. The future prospects and industrial related challenges for biopolymers/biodegradable polymers will be discussed in the context of sustainable development.

This teaching will combine the presentation/discussion of lecture slides with that of several on-line contents, which have been selected on the internet sites on the leading industrial companies in the field of biopolymers/biodegradable polymers. An industrial conference will also illustrate the exemplary industrial developments recently achieved by the chemical company Arkema in the field of bio-sourced technical polymers.

EVALUATION METHODS:

Industrial case studies with documents (1h).

USEFUL INFORMATION:

PREREQUISITES: Basics on polymers and polymer chemistry.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: The textbook of lectures is only needed for this module.

Advised: The following books - which are all available at the ENSIC library and are mainly in English - are recommended to students willing to deepen their knowledge in biopolymers and biodegradable polymers:

- [1] RINAUDO, M., 2000, *Les polymères naturels : structure, modification, applications, Initiation à la Science des Polymères Vol 13*, du Groupe Français d'Etudes et d'application des Polymères;
- [2] SCOTT, G., 1999, *Polymers and the environment*, RSC Paperbacks, Cambridge: The Royal Society of Chemistry, 132;
- [3] STEVENS, E. S., 2001, *Green Plastics: An Introduction to the New Science of Biodegradable Plastics*, Princeton: Princeton University Press.

CORE CURRICULUM			
COURSE TITLE: BIG DATA AND ARTIFICIAL INTELLIGENCE			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER S7
12	21	1	

AIMS:

The "Big Data and Artificial Intelligence" option aims to:

- Present an overview of big data methods and machine learning, supervised or unsupervised.
- Describe some emblematic methods of dimension reduction (Principal Component Analysis, Auto-encoding Network), binary and multi-class classification (K-means, Nearest neighbors), model-free regression (Perceptrons) and machine learning (Neural networks).
- Implement these methods Process Engineering cases, using Matlab.

LEARNING OUTCOMES:

At the end of the option, students should be able to:

- Choose a method to process a batch of data according to a targeted objective (classification, regression, identification of trends) and available data (volume, variety, velocity),
- Understand the interest and the limits of these methods, depending on the context of their treatment and their use (bias-variance compromise, explainability of the model, need for extrapolability),
- Apply the main methods in a suitable software environment (K-means, Nearest neighbors, Perceptrons, etc.).

DESCRIPTION AND TEACHING METHODS:

The sessions are exclusively carried out on computer in the computer room, using the functions and toolbox dedicated to machine learning in the Matlab environment, according to the sequence:

- General introduction to Big Data and Artificial Intelligence
- Dimension reduction methods (PCA)
- Classification and clustering methods (Nearest neighbors, K-means)
- Single layer perceptrons for classification and regression
- Multilayer neural networks (Auto-encoder)

EVALUATION METHODS:

Individual control on machine (1h).

USEFUL INFORMATION:

PREREQUISITES: UE Informatique, méthodes numériques et statistiques (S5, EC Méthodes statistiques, EC Informatique pour l'ingénieur des industries chimiques I) et UE Systèmes réactifs et Informatique (S6, EC Informatique pour l'ingénieur des industries chimiques II).

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

1. Chloé-Agathe Azencott, « Introduction au machine learning », Ed. Dunod, 2018.
2. Stéphane Tufféry, « Big Data, Machine Learning et apprentissage profond », Ed. Technip, 2019.
3. Ian Goodfellow, « L'apprentissage profond », Massot Editions, 2018.
4. Charu C. Aggarwal, « Data mining – the textbook », Ed. Springer, 2015.

Needed: Distributed mimeographed documents, data files distributed via ARCHE.

Advised: See bibliographic references.

CORE CURRICULUM			
COURSE TITLE:	MODELLING TOOLS AT THE DISPOSAL OF AN ENGINEER		ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 7
12	21	1	

AIMS:

- To familiarise students with various modelling tools and approaches that will undoubtedly be useful during their career, without necessarily specialising in modelling;
- Explain the implementation of different modelling techniques that can be applied according to the specific nature of the problem at hand, their main advantages and inconveniences;
- To show the usefulness and meaning of a mathematical model through specific industrial case studies.

LEARNING OUTCOMES:

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

- Make connections between the different notions learned after following several courses at ENSIC;
- Understand why it is important to develop a model and which principal steps are to be followed;
- Distinguish and understand the meaning, the usefulness and the applicability of basic types of modelling approaches (e.g., empirical/mechanistic, deterministic/stochastic, etc.);
- Explain what a Neural Network is or what people mean when they speak about Monte Carlo modelling.

DESCRIPTION AND TEACHING METHODS:

Theoretical presentations are combined with practical sessions in PC rooms.

- Introduction: Objectives of model development, different types of models, generalised balances;
- Parameter estimation: possibility of identifying/estimating the values of the parameters of a model, an industrial case study;
- Design of Experiments: principles and utility, different design methods, examples and application in MATLAB®;
- Alternative modelling approaches: Data-Driven models, stochastic Monte Carlo modelling, Artificial Intelligence in mathematical modelling, advantages and limitations;
- Demonstration and applications: examples of model-based solutions to industrial problems of importance.

** The order of the above chapters is subject to variations.*

EVALUATION METHODS:

Written multiple choice exams

USEFUL INFORMATION:

PREREQUISITES: ENSIC courses on Informatics and applied mathematics

LANGUAGE: English / French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] LUYBEN, W.L. , 1996, *Process Modelling Simulation and Control for Chemical Engineers*, New York: McGraw Hill;
- [2] MYERS, R. H., MONTGOMERY, D. C. and ANDERSON-COOK, C. M., 2011, *Response surface methodology: process and product optimization using designed experiments*. New Jersey, Wiley;
- [3] RUTHERFORD, A., 1999, *Mathematical modelling: a chemical engineer's perspective*, London, Academic Press.

CORE CURRICULUM			
COURSE TITLE: HYDROMETALLURGICAL PROCESSES			ELECTIVE
TAUGHT HOURS 12	STUDENT WORKLOAD 21	ECTS CREDITS 1	SEMESTER 7

AIMS:

Presentation of the hydrometallurgical processes, in full expansion, in order to meet the needs initiated by the 3rd industrial revolution - the mineral revolution currently underway, in order to meet the needs of tomorrow. Several aspects will be discussed:

- The 3rd industrial revolution - industrial, economic, geopolitical, ecological, societal challenges, and the place of recycling,
- Precipitation processes, applied to hydrometallurgy,
- Liquid / liquid extraction applied to hydrometallurgy,
- Electrochemical processes applied to hydrometallurgy,
- Separation processes using ion exchange resins.

The lecturers are members of the PROMETHEE Research Group - gdr-promethee.cnrs.fr

LEARNING OUTCOMES:

At the end of the study of each of the topics covered, students should be able to:

- Have a global vision of the context, industrial, economic and geopolitical issues raised by the mineral revolution,
- Understand the different unit operations relating to hydrometallurgy: leaching, precipitation, electrodeposition, electrodeionization, liquid / liquid and liquid / solid extractions

DESCRIPTION AND TEACHING METHODS:

Courses and Tutorials

The 3rd industrial revolution - industrial, economic, geopolitical, ecological, societal challenges

2 hour lesson; 1h written exam.

Precipitation processes applied to hydrometallurgy

1 lesson session (30 min); 1 tutorial session (1h): equilibrium condition between liquid and solid phases, dimensioning of crystallization reactors by cooling and by evaporation; 1h written exam.

Liquid / liquid extraction applied to hydrometallurgy

1 lesson (1h); 1 tutorial (2h): metal separation by liquid-liquid extraction process; choice of extractants; 1h written exam.

Electrochemical processes applied to hydrometallurgy,

1 lesson (1h); 1 TD session (2h): electroplating processes, metal separations by electrochemical processes; 1h written exam.

Separation processes using ion exchange resins.

1 lesson session (30 min); 1 tutorial (1h): condition of balance between liquid and solid phases; liquid - solid extraction; examples of innovative processes; 1h written exam.

EVALUATION METHODS:

Written exam.

USEFUL INFORMATION:

PREREQUISITES: Mineral chemistry, Liquid / liquid extraction processes, Solution chemistry (thermodynamic equilibria), Material & mass balance, Mass transfer.

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed:

Advised:

CORE CURRICULUM			
COURSE TITLE: INDUSTRIAL CONFERENCE II			MANDATORY
TAUGHT HOURS 12	STUDENT WORKLOAD 21	ECTS CREDITS 1	SEMESTER 7

AIMS:

- Illustrate how the chemical engineer's skills are applied in industry;
- Introduce new applied skills that have not been studied by the students during the preceding semesters.

LEARNING OUTCOMES:

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

- Have a better understanding of the different industrial sectors;
- Understand what is expected from a chemical engineer in industry;
- Decide which specialty to choose in semester 8 at ENSIC.

DESCRIPTION AND TEACHING METHODS:

This module is based on short conferences (1h30) proposed by professional from industry. There are at least two conferences in parallel so that students can choose between two different topics.

EVALUATION METHODS:

Each student has to write down one question for each conference attended. The questions are then sent to the lecturer who will judge if the questions make sense. Generally, the lecturer answers all the students' questions. In this way, the lecturers get feedback on their conference.

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

NEEDED: None

ADVISED: None

SEMESTER 8: COURSE UNITS

Academic supervisor: Rainier HREIZ

SEMESTER OVERVIEW

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Management and Economics IV	Vera IVANAJ	40	16	16	8				2
Foreign Languages IV	Jude BOWDEN	44		44					2
<i>English</i>	Jude BOWDEN			24					
<i>Modern languages</i>	Jude BOWDEN			20					
Industrial Design Project	Sabine RODE - Jean-François PORTHA	30	2	9		18		1	6
<i>Industrial Design Project</i>	Sabine RODE					18			
<i>Techno-Economic Process Analysis</i>	Laurent FALK		2	9				1	
Operator Training period	Laurent PERRIN								4
Personal Project	Nicolas BASTIEN	26				6	20		3
Electives		18							1
Academic specialization path		156							12
TOTAL		314							30

ELECTIVES IV (to be chosen: one)

Electives IV	Unit coordinators	Taught hours	Lectures	Tutorials	Practical Work	P	C	Ex	ECTS credits
Surface Functionalization and Applications	Halima ALEM MARCHAND	18	7	8		2		1	1
Aerosols and Safety	Olivier DUFAUD	18	7	8		2		1	1
Supramolecular Organization and Materials	Guillaume PICKAERT	18	15			2		1	1
Advanced Thermodynamics of Solutions	Jean-Noël JAUBERT	18	7	8		2		1	1
Industrial Waste Treatment Methodologies	Alexandra GIGANTE	18	9	7		2		1	1
Products for Health	Cécile NOUVEL	18	10,5	3		2	1,5	1	1
Molecular Simulation	René FOURNET	18	7	8		1,5		1,5	1
Industrial Polymer Process Engineering	Alain DURAND	18	7	8		2		1	1
Polymeric Nano-Objects: Syntheses, Characterizations And Applications	Khalid FERJI	18	12	4	2				1

ACADEMIC SPECIALIZATION: Process Engineering for Energy and Environment

Academic supervisor: Sabine RODE

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Advanced Separation Processes and Multiphase Reactors	Eric SCHAER	60	26	29,5				4,5	4
<i>Catalytic Engineering</i>	Eric SCHAER		6	4,5				1,5	
<i>Multiphase Unit Operations</i>	Sabine RODE		8	14,5				1,5	
<i>Crystallization</i>	Marie LEPAGE		6	4,5				1,5	
<i>Chromatographic Processes</i>	Eric FAVRE		6	6					
Sustainable Processes	Laurent PERRIN	36	16,5	1,5		7,5	8	2,5	4
<i>Life Cycle Analysis</i>	Jean-François PORTHA		4,5	1,5			2	1	
<i>Process Safety and Environment</i>	Laurent PERRIN		12				6	1,5	
<i>LCA- Safety Project</i>	Laurent PERRIN					7,5			
Process Design and Simulation	Romain PRIVAT	60	20	36				4	4
<i>Advanced Thermodynamics and Machines</i>	Jean-Noël JAUBERT		9	20				1,5	
<i>Advanced Distillation</i>	Sabine RODE		6	10				1,5	
<i>Dynamic Simulation of Processes</i>	Abderrazak LATIFI		5	6				1	
TOTAL		156							12

ACADEMIC SPECIALIZATION: Innovative Products: from Chemistry to Process

Academic coordinator: Alain DURAND

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Micro- and Nanostructured Products	Véronique SADTLER	60	51	5,5			2	1,5	4
<i>Physical Chemistry and Formulation of Polyphasic Fluid Systems</i>	Véronique SADTLER		21	3,5			2	1,5	
<i>Processes for Fluid-Fluid Dispersed Systems</i>	Huai Zhi LI		17	2					
<i>Micro and Nanoparticles</i>	Laurent MARCHAL-HEUSSLER		13						
Introduction to Product Engineering	Alain DURAND	36	18	6		7,5	2	2,5	4
<i>Life Cycle Analysis</i>	Jean-François PORTHA		4,5	1,5			2	1	
<i>Batch processes</i>	Eric SCHAER		6	4,5				1,5	
<i>From Process to Product Engineering</i>	Alain DURAND		7,5			7,5			
From molecules to products	Cécile NOUVEL	60	16,5	17	24			2,5	4
<i>Products: Practical Work</i>	Véronique SADTLER				24				
<i>Rheology</i>	Cécile LEMAITRE		6	5				1	
<i>Molecular Structure and Functional Properties</i>	Cécile NOUVEL		10,5	12				1,5	
TOTAL		156							12

ACADEMIC SPECIALIZATION: Bioprocess Engineering

Academic coordinator: Nouceiba ADOUANI

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Introduction to Biological Sciences	Marie-Christine AVERLANT PETIT	60	46,5	10,5				3	4
<i>Biomolecules: Introduction to Biological Sciences</i>	Marie-Christine AVERLANT PETIT		24	4,5				1,5	
<i>Analytical Methods on a Laboratory Scale</i>	Cécile NOUVEL		22,5	6				1,5	
Biocatalysts and Bioreactors	Nouceiba ADOUANI	36	18	9		6		3	4
<i>Biocatalysts and Bioreactors</i>	Nouceiba ADOUANI		6	6				1,5	
<i>Multiphase Reactors and Rheology</i>	Eric OLMOS		12	3				1,5	
<i>Bioreactors: Project</i>	Nouceiba ADOUANI					6			
Bioseparations	Eric FAVRE	60	19,5	18	20			2,5	4
<i>Biotechnology: Practical Work</i>	Cécile NOUVEL/Nouceiba ADOUANI				20				
<i>Membrane Processes</i>	Eric FAVRE		6	6				1	
<i>Chromatographic Processes</i>	Christophe CASTEL/Laurence MUHR		9	7,5				1,5	
<i>Crystallisation</i>	Eric SCHAER		4,5	4,5					
TOTAL		156							12

CORE CURRICULUM			
COURSE TITLE: MANAGEMENT AND ECONOMICS IV			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
40	68	2	

AIMS:

- To describe and understand the technological innovation process in an industrial environment;
- To identify the factors which both favour and hinder technological innovation from strategic, organizational, cultural and scientific standpoints;
- To design and develop an innovative product or process using the right project management tools and principles;
- To construct a business plan by developing different aspects linked to the project: competition, suppliers, customers, provisional budgets, technology, legal issues etc.

LEARNING OUTCOMES:

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

- Master the process of the creation of a new product or service from the original idea right up to its creation;
- Construct a business plan, estimate and measure the main internal (human resources, supplies; financial matters etc.) and external (market, partners, regulations, etc.) parameters involved;
- Implement short, medium and long term development strategies.

DESCRIPTION AND TEACHING METHODS:

- Management of innovative projects;
- Simulation of a situation requiring the management of a new company start-up which will combine both design and creation. The simulation takes one whole week to complete.

EVALUATION METHODS:

Assessment of project work and oral presentation

USEFUL INFORMATION:

PREREQUISITES: Knowledge of companies

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: FOREIGN LANGUAGES IV			MANDATORY
TAUGHT HOURS 44	STUDENT WORKLOAD 77	ECTS CREDITS 2	SEMESTER 8

LANGUAGE 1: ENGLISH

AIMS:

- To consolidate and acquire linguistic and communicative skills in English. B2/C1/C2 levels (See CEFR scales);
- To develop professional language skills needed when working in industry and research laboratories abroad;
- Develop 21st Century skills: learning skills, literacy skills and life skills.

LEARNING OUTCOMES:

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

- Understand the main ideas of a complex text /recording on both concrete and abstract topics, including technical discussions in his/her field of specialisation;
- Interact with a degree of fluency and spontaneity in a social, academic and professional context;
- Understand the structure of a scientific publication;
- Write executive summaries, scientific reports;
- Describe the different steps of a process or system in a chemical engineering context;
- Give a clear, systematically developed presentation, with highlighting of significant points, and relevant supporting detail and self assess his/her own presentation;
- Take a series of follow up questions with a degree of fluency and spontaneity which poses no strain for either him/herself or the audience.

DESCRIPTION AND TEACHING METHODS:

- Study of the format and structure of a scientific report and articles: executive summaries, abstracts, introductions, results etc...);
- Study of specific chemical engineering vocabulary using original video/audio programmes;
- Individual presentation of a chemical engineering process poster (study of poster format, use of scientific/chemical language, answering questions);
- Taking notes and writing up two summaries of processes presented in the poster session;
- Study of how to make a good presentation: structure, body language, voice, use of visual aids;
- Expressions to structure a presentation; describe charts, graphs, results and to answer difficult questions;
- Presentation filmed and analyzed.

EVALUATION METHODS:

CERTIFICATION: Pass or fail

- 1) Poster presentation.
- 2) Written summaries of a process.
- 3) Power Point presentation.

RESITS: Power Point presentation or poster presentation or written summary of a process.

USEFUL INFORMATION:

PREREQUISITES: B2

LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

LANGUAGE 2: GERMAN, SPANISH, FRENCH
NO DESCRIPTORS AVAILABLE FOR:
SPANISH AND GERMAN -SECOND LANGUAGE: BEGINNERS

AIMS:

- Develop linguistic and communicative skills to reach or consolidate a B1/B2/C1 level;
- To develop professional language skills required when working in industry and research laboratories abroad.

LEARNING OUTCOMES:

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

- Understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc.;
- Deal with most situations regularly encountered in work, school, leisure, everyday situations with a degree of fluency and spontaneity;
- Produce simple connected text on topics, which are familiar, or of personal interest;
- Present a subject orally in front of an audience;
- Describe the different steps of a process or system;
- Write parts of a scientific report (abstract, intro etc);
- Write CV's, cover letters, e-mails;
- Take part in meetings;
- Carry out an effective work placement interview.

COURSE CONTENT:

- Use of various resources – written documents, videos, DVDs, CDs, internet sites in different domains eg. Social, cultural, economic, scientific, environmental;
- Working either individually, in pairs or groups;
- Expressions to write CV's, cover letters, e-mails and write own CV and cover letter;
- Presenting a subject on PowerPoint;
- Simulating a work placement interview;
- Preparing for international exams (e.g. Spanish : DELE).

EVALUATION METHODS:

CERTIFICATION: Pass or fail - Class tests (per group).

Level test: reading and listening comprehension.

RESITS: Personal work or tests based on class work.

USEFUL INFORMATION:

PREREQUISITES: B2

LANGUAGE: Spanish // German // French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: INDUSTRIAL DESIGN PROJECT			MANDATORY
TAUGHT HOURS 30	STUDENT WORKLOAD 201	ECTS CREDITS 6	SEMESTER 8

AIMS:

- Design an industrial-scale production process as a whole, working autonomously in teams;
- Interact effectively with academic experts as well as with engineers working in industry;
- Learn how to write a scientific report in English.

LEARNING OUTCOMES:

At the end of the project the student engineer should:

- Have an overview of the basic as well as the specialised courses studied in this semester and the preceding semester;
- Know how to find scientific information needed to solve a particular problem;
- Be able to select a methodology needed to design a process;
- Be able to exchange data and scientific results with peers;
- Be able to organise work with peers as a team;
- Be able to write a scientific report in English.

DESCRIPTION AND TEACHING METHODS:

The industrial process design course implements an integrated learning methodology addressing an open-ended problem, which is the design of an industrial-scale production process. It includes the following steps: process selection, choice of operating conditions, research of physical, chemical and technical data, overall balances, detailed sizing of selected equipment, health and safety considerations.

Several original subjects are defined each year in collaboration with industrial partners. Students work in groups of five.

The work is divided into two parts:

- Sizing of a reactor (25% of the time) supervised by academic staff (4 h tutorials for each group); software: Matlab©
- Sizing of the industrial production process as a whole (75% of the time), supervised by industrial partners (12h tutorials for each group); software: Proll©

The project is evaluated by an intermediate (40 minutes) and a final (60 min) as well as an intermediate and a final report, written in English. The industrial partners are involved in all the assessments. Linguistic quality is assessed by specialist academic staffs.

A specific subject is given to students specializing in the pharmaceutical industry.

EVALUATION METHODS:

Evaluation of written reports and oral presentations: progress report 10%, intermediate oral defence 10%, final Report 35%, final oral defence 35%, extended summary (assessment of English) 10%

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemical Engineering

LANGUAGE: French, English

BIBLIOGRAPHICAL REFERENCES:

Needed: dedicated documents distributed to students; scientific databases

Advised:

CORE CURRICULUM			
COURSE TITLE: OPERATOR TRAINING PERIOD			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
-	-	4	

AIMS:

This operator training period aims, primarily, to allow the student to gain experience from being in a working environment.

LEARNING OUTCOMES:

At the end of the training period the student engineer should:

- have knowledge of health and safety at work.

DESCRIPTION AND TEACHING METHODS:

Lectures preparing this training period are part of 5I15MGE (Management and Economics I - S5) and 5I16MGE (Management and Economics II - S6) modules.

120 hours supervised by an industrial tutor.

EVALUATION METHODS:

Training period report.

USEFUL INFORMATION:

PREREQUISITES: 5I15MGE (Management and Economics I - S5) and 5I16MGE (Management and Economics II - S6) modules.

LANGUAGE:

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: PERSONAL PROJECT			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
26	95	3	

AIMS:

This course aims at:

- Managing a project;
- Applying a practical case of the project management concept learned in class;
- Becoming a project manager: managing a budget, a schedule, a team;
- Testing one's own limits and getting to know oneself better;
- Putting forward one's innovation skills;
- Enriching one's CV.

LEARNING OUTCOMES:

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

- Define a project;
- Conceive a project as a whole, define its actors, schedule, budget and the expected results;
- Implement the action as project manager;
- Self-evaluate the work performed in written and spoken reports.

DESCRIPTION AND TEACHING METHODS:

An introductory conference presents the objectives of the course. Each student then defines, alone or in a team, their project. The course supervisor validates the project subject and attributes an academic tutor to each project.

Along the academic year, several conferences on different subjects are held, in order to broaden the students knowledge and their reflections on subjects in general.

Each student meets their tutor regularly to provide an update on the project progress, on the obtained results and on possible questions.

Introductory conference: Management of innovation

Other conferences (non-exhaustive list)

- To be a student or freshly graduated and an entrepreneur, the case of "self-entrepreneurs";
- Supply chain and purchasing;
- International trade;
- Ethics of the executive.

Courses: one week: discovery of other courses provided in departments of the University of Lorraine.

Interview simulations: learn how to introduce themselves.

EVALUATION METHODS:

Written report and oral presentation

USEFUL INFORMATION:

PREREQUISITES: Basics in project management

LANGUAGE: French // English

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: SURFACE FUNCTIONALIZATION AND APPLICATIONS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

Surface and volume properties of materials play a major role for the final applications of many devices. For example, in the case of biomedical material, its mechanical properties are very important but its biocompatibility is crucial. This latter functionality can be obtained by functionalizing the surface of this material. Indeed, many materials can present excellent mechanical, electrical or physico-chemical properties, but they still have no biocompatibility. The lectures aim at introducing students to the main processes of surface functionalization, to the methods developed and used for a complete characterization of these surfaces.

LEARNING OUTCOMES:

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

- Be able to propose a method to elaborate surfaces presenting specified properties and to be able to compare and discuss their advantages and disadvantages;
- Be able to propose characterization techniques suitable to characterise the structure and/or the properties of a modified/or not surface;
- Know how to synthesise and functionalise nanomaterials for targeted applications.

DESCRIPTION AND TEACHING METHODS:

This course is composed of lectures, exercise classes and related small projects.

Gustavo Luengo (L'Oreal) will present an overview dealing with the application of surface functionalization in Cosmetics (hair and skin).

Part I: Homogeneous surfaces

- General introduction on surface and their industrial challenges
- Surface properties and specificities
- Surface functionalization processes and their industrial applications
- Characterization technique related to surface diagnosis.

Part II: Nanomaterials

- Synthesis process used to obtain nanoparticles
- Surface functionalization of nanoparticles

Part II: Application of surface functionalization in Cosmetics (hair and skin) (conference given by G. Luengo from L'Oreal)

Project: Students focus on an application area of the surface functionalisation with the supervision of academic staff, carry out research and finally give a presentation.

EVALUATION METHODS:

First session:

- Small project (oral presentation)
- Written examination (1h30)

Resits:

- Written examination (1h30)

USEFUL INFORMATION:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised:

- [1] BUTT, H-J., GRAF, K. and KAPPL, M., 2003, *Physics and Chemistry of Interfaces*, Wiley-VCH Verlag GmbH & Co. KGaA.

CORE CURRICULUM			
COURSE TITLE: AEROSOLS AND SAFETY			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

The safety of people, goods and environmental protection are very important societal issues such as urban pollution with fine particles, the professional exposure to welding fumes or oil mist, or the Formosa Fun Coast explosion. At first glance, these examples seem to be disconnected, but they are related to the presence of aerosols and are sources of scientific and engineering questions.

In order to reduce risk at source and to improve the protection of employees and the environment, it is essential to develop new tools related to the study of the industrial processes and systems generating these aerosols. Technological and scientific developments in the field of aerosols therefore concern:

- The acquisition of knowledge for a better understanding of the physical and chemical processes governing the physics of aerosols, the transfer of matter to interfaces during their dispersal and inflammation;
- Measurement and / or visualization by advanced methods of these processes at different scales;
- Study, optimization, modelling of unit operations and combinations of operations (chemical reactions or separations - adsorption, filtration) for the design and optimization of clean and safe processes;
- Dust and hybrid mixtures explosions.

These optional courses give S8 students an overview of these issues and developments.

LEARNING OUTCOMES:

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

- Assess the main risks associated with aerosols (inflammation, auto-ignition, explosion, inhalation, dispersion and atmospheric pollution ...);
- Identify the techniques of analysis and metrology of liquid or solid aerosols, micrometric or nanometric and to be able to choose the appropriate technique according to their needs;
- Design processes for the separation and purification of biphasic gaseous effluents (filtration, bubble columns, granular beds, etc.);
- Propose relevant prevention and protection equipments.

DESCRIPTION AND TEACHING METHODS:

- Based on lectures by researchers and experts (eg INRS, INERIS);
- Visits to the laboratories of the LRGP SAFE research team (Safety, Aerosols, Filtration, Explosions);
- Tutorials using computer tools specific to the quantitative evaluation of risks related to aerosols.

TEAM:	Supervisor: O.DUFAUD	Hour Lectures	Hour Tutorials
O. DUFAUD (ENSIC)	Dust and hybrid mixtures explosions: advanced notions	1.5	
	Turbulent flame propagation in an heterogeneous media	1.5	
N. MONNIER (IUT Dpt GCGP Nancy)	CFD for dust/powders dispersion simulation	1.5	
L. PERRIN (ENSIC)	Case studies: use of specific softwares (Aloha, Marplot...)		1.5
	Lab. visit		1.5

D. THOMAS (IUT Dpt GCGP Nancy)	Aerosols metrology	3	
	Filtration	3	
A. CHARVET (IUT Dpt GCGP Nancy)	Aerosols filtration by bubble columns and granular beds	1.5	
S. CHAZELET (INRS)	Respiratory equipments	1.5	
A. VIGNES (INERIS)	Nanopowders: a SWOT analysis	1.5	

EVALUATION METHODS:

Short final examination with a proficiency test (1h)

USEFUL INFORMATION:

PREREQUISITES: S7 Process and Sustainable Development

LANGUAGE: French / doc in English

BIBLIOGRAPHICAL REFERENCES:

Needed:

Advised:

- [1] ECKHOFF, R., 2003, *Dust explosions in the process industries*, 3rd edition, Boston: Gulf Professional Publishing;
- [2] LAURENT, A., 2011, *Sécurité des Procédés Chimiques - connaissances de base et méthodes d'analyse de risques*, 2nd edition, Paris: Tec&Doc Lavoisier ;
- [3] RENOUX, A. and BOULAUD, D., 1998, *Les aérosols : physique et métrologie*, Paris : Tec&Doc Lavoisier.

CORE CURRICULUM			
COURSE TITLE: SUPRAMOLECULAR ORGANIZATION AND MATERIALS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

The aims of this course are:

- To introduce students to concepts and principles used in the construction of highly organized networks;
- To study their properties and their potential applications to materials with high added value.

LEARNING OUTCOMES:

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

- Know the contents of a supramolecular chemist toolbox in order to build super-molecule based materials (weak interactions, molecular recognition processes, molecular self-assembly...);
- Know the major application fields of materials made of supramolecular organization such as gels, liquid crystals and polymers;
- Know the advantages and opportunities given by these materials in an economic and industrial context.

DESCRIPTION AND TEACHING METHODS:

The teaching will be composed of lectures and projects.

EVALUATION METHODS:

Evaluation of students:

- One end-semester written examination (1h30)
- One oral presentation of the project

USEFUL INFORMATION:

Prerequisites: None

Language: French

Bibliographical references:

Advised:

- [1] LEHN, J-M., *La Chimie Supramoléculaire, Concepts et Perspectives*, DeBoeck Université;
- [2] STEED, J.W. and ATWOOD, J. L., *Supramolecular Chemistry*, Wiley;
- [3] STEED, J.W., *Core Concepts in Supramolecular chemistry*, Wiley.

CORE CURRICULUM			
COURSE TITLE: ADVANCED THERMODYNAMICS OF SOLUTIONS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

The course aims at:

- Detailing the different methods (gamma-phi approach and phi-phi approaches) to calculate a phase diagram, essential for the design of a separation unit (distillation, liquid-liquid-extraction, crystallization);
- Understanding stability analysis.

LEARNING OUTCOMES:

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

- Calculate an isothermal or isobaric phase diagram from an equation of state or an activity coefficient model. Such diagrams may include the existence of a positive, a negative or a heterogeneous azeotrope. They may also contain 3-phase lines and solid phase areas;
- Master the various algorithms to solve the phase equilibrium conditions;
- Select the correct thermodynamic model for a given problem;
- Master the classical mixing rules used with well-known equations of state;
- Calculate the excess properties and the mixing properties with an equation of state;
- Test the stability of a multi-component system in order to discriminate the stable, the metastable and the unstable states.

DESCRIPTION AND TEACHING METHODS:

- I. Phase equilibrium conditions
- II. Use of an equation of state to solve the fluid-fluid equilibrium conditions
- III. Solid-liquid and solid-solid equilibrium
- IV. Stability analysis
- V. Flash calculation
- VI. Advanced distillation

EVALUATION METHODS:

A written examination at the end of the course (1h 30 minutes)

A project

USEFUL INFORMATION:

Prerequisites: Separation Processes II (Prof. Jaubert's lectures)

Language: French

Bibliographical references (advised):

- [1] O'CONNELL, J.P. and HAILE, J.M., *Thermodynamics: Fundamentals for Applications*, Cambridge Series in Chemical Engineering;
- [2] PRAUSNITZ, J.M., LICHTENTHALER, R.N. and DE AZEVEDO, E.G., *Molecular Thermodynamics of fluid-phase equilibria*;
- [3] SMITH, J.M., VAN NESS, H. and ABBOTT, M., *Introduction to Chemical Engineering Thermodynamics*.

CORE CURRICULUM			
COURSE TITLE: PERSONAL INDUSTRIAL WASTE TREATMENT METHODOLOGY			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

“The best waste is the one we do not produce”. Presumably an ideal view since in all production factories, chemical or physical transformation of matter generates, inexorably, side-products, which are usually not valuable and can induce specific hazard. Waste management is a complex issue on any production site and two constraints have to be accounted for:

- Regulation and environmental constraints, since waste cannot be disposed in natural areas;
- Sustainable production also means profitable production: to recycle parts of the waste optimally.

LEARNING OUTCOMES:

The objective of this elective module is to combine various types of competences acquired in the core curriculum in Chemistry, Physical Chemistry, Thermodynamics, Kinetics, Chemical Reaction Engineering, Mechanical or Thermodynamic Unit Operations to:

- Define the waste in terms of chemical compositions and physical state (single or multiple phase);
- Determine the specifications of the overall treatment;
- Imagine the sequence of operations, of technical and financial viability to respond to the defined objectives.

Considering the diversity of the concepts used, this elective lecture does not aim to make the students specialists of all the techniques dealt with, but to provide them all the necessary information to develop a logical analysis of the problem to be solved and to propose the most pertinent solution.

Students will therefore become aware of the industrial reality so that they will be able to make use of their knowledge to imagine the operations to be designed and implemented to respond to economical and environmental constraints.

DESCRIPTION AND TEACHING METHODS:

This optional course relies upon very diverse disciplines. For any waste, considered globally, various strategies can be considered, but only one has to be selected. Teaching methodology is in accordance with this principle and the module is developed as follows:

Part 1: Definition of objectives considering the waste nature and the overall strategy of treatment. The next two parts deal more particularly with waste management for which the continuous phase is an aqueous medium.

Part 2: Treatment of insoluble pollution: physical chemistry of multiphase systems and related processes of mechanical separation;

Part 3: Treatment of dissolved pollutants: chemistry of transformation of soluble pollutants, processes of mechanical separation at the (sub)colloidal scale

Part 4: Thermal treatments of waste for energy and chemical recovery:

- Characteristics of waste in thermal treatment: LHV, HHV, analysis of fuels and waste;
- Incineration processes (combustion equation, formation of gaseous pollutants, description of side products (slags, emission of incineration towers), energy recovery and beneficiation with the water/vapour cycle
- Units for off-gas treatment

Other thermal treatment processes e.g. pyrolysis, methanisation, gasification

EVALUATION METHODS:

- Case studies, with documents (1h 30)
- Mini-project

USEFUL INFORMATION:

PREREQUISITES: Ground knowledge of the content of the core curriculum modules

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: PRODUCTS FOR HEALTH			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

The design of products for health care (new drugs, biomaterials, ...) is a major issue in our modern societies. Their development requires a strict requirement specification depending on the aimed biomedical application and induces drastic constraints, in particular concerning their biocompatibility.

The polymers used are more and more from natural origins, bio-based/biodegradable products, but they can also be synthesised. In particular, there is an increasing interest in stimuli-sensitive products, called "smart". The aim of this course is to provide an introduction to the development of specific products for biomedical applications and to show the latest advances and the main issues (development strategy, requirements...) in this field. The most important products in the biomedical field will be presented. Commercially available examples found in Cosmetics, Medicine will be chosen as well as others still under development.

LEARNING OUTCOMES:

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

- Understand and discuss the requirement specifications of products for health care;
- Understand the development procedure of pharmaceutical products from design to market;
- Describe the potential use of polymers in the biomedical field and in particular their interest to design biomaterial.

DESCRIPTION AND TEACHING METHODS:

This course will consist of lectures (including a conference by industrialists from the pharmaceutical world) and a group project (including tutorial sessions and a final presentation). It is divided into two parts:

Part 1: From molecule to drug design (4.5h)

Part 2: Polymers for biomedical applications (6h)

In the first part, strategies to design new drugs are presented. Numerous steps and years are necessary to attain this goal: study of the biological target, synthesis, effect of the drug on target cell and clinical assays. The presentation of these different steps give a basic overview of drug development in the pharmaceutical industry.

In the second part, the interest of using polymers (especially bio-based ones) for biomedical applications are presented. Strict specifications have to be defined for the design of new biocompatible materials for biomedical use (as surgical device or in drug delivery). Such specifications depend a lot on the aimed application and induce numerous challenges especially in terms of biocompatibility. A general introduction of the problematic is firstly to define the concept of biomaterial thanks to a few examples. The economical challenges and the main constraints associated to the related specifications are presented and a few examples of biomaterials are detailed:

- Materials for surgery (osteosynthesis screw, endoprothesis);
- Nanomedicine (Drug delivery system, medical diagnostic...);
- Hydrogels for drug delivery, tissue repair and wound dressing;
- Biomaterials for tissue engineering.

EVALUATION METHODS:

Small Project on one study case: report and oral presentation

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemistry/Physical-Chemistry

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised:

- [1] DUMITRI, S., 1996, *Polysaccharides in medicinal Applications*, Ed. Marcel Dekker, 779 p.;
- [2] KEWAL, J. K., 2008, *Drug Delivery Systems*, Ed. Human Press, 251 p.;
- [3] LI, S., TIWARI, A., PRABAHARAN, M. and ARYAL, S., 2010, *Smart polymer materials for biomedical applications*, Ed., Collection, 405 p.;
- [4] RAMAKRISHNA, S., RAMALINGAM, M. and SAMPATH KUMAR, T.S., 2010, *Biomaterials: a nano approach*, Ed. CRC Press, 350 p.

CORE CURRICULUM			
COURSE TITLE: MOLECULAR SIMULATION			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	44	1	

AIMS:

This course is aimed at introducing molecular modelling techniques to students and showing how these tools can be used to describe and quantify physical chemistry and reactive phenomena.

To do so, time and size scales covered by molecular simulation will be described. This course will focus more specifically on three kinds of techniques:

- Quantum scale: ab initio;
- Microscopic scale: molecular dynamics;
- Microscopic scale: Monte Carlo.

LEARNING OUTCOMES:

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

- List some application fields and present the main molecular simulation techniques;
- Discuss the interest and limitations of such techniques;
- Explain the theoretical concepts at the basis of the techniques;
- Implement molecular simulation calculations using dedicated software.

DESCRIPTION AND TEACHING METHODS:

Teaching methods: (interactive) lectures; tutorials and project

Contents:

- General introduction: what molecular simulation can provide for chemical-process engineers?
- Quantum chemistry concepts for ab initio calculations;
- Statistical physics concepts for molecular dynamics and Monte Carlo techniques;
- Description of molecular interactions and models for their quantification;
- Ab initio calculation;
- Molecular dynamics;
- Monte Carlo.

EVALUATION METHODS:

Molecular dynamics & Monte Carlo: written examination and practical examination (computer)

Ab initio: project

USEFUL INFORMATION:

PREREQUISITES: UE Thermodynamics and Energetics, UE Process and Reaction Engineering

LANGUAGE: French and English

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] ALLEN, M. P. and TILDESLEY, D. J., *Computer Simulation of Liquids*, Oxford Science Publications, ISBN-13: 978-0198556459
- [2] SCACCHI, G., BOUCHY, M., FOUCAUT, J.F., ZAHRAA, O. and FOURNET, R., 2011, *Cinétique et Catalyse*, Chapitre 12, 2^e édition, Lavoisier, éditions Tech et Doc.

CORE CURRICULUM			
COURSE TITLE: INDUSTRIAL POLYMERISATION PROCESSES			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
18	48	1	

AIMS:

During this course, students examine the main theoretical and technological aspects of several industrial polymerisation processes. The approach focuses on the links between end use properties, macromolecular/microscopic structure and polymerisation process. The main idea is to use the basic knowledge of polymer chemistry and chemical engineering to study several examples and identify the main technological bottlenecks of polymerisation processes in relation to targeted end use properties.

LEARNING OUTCOMES:

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

- Know the main engineering aspects related to common polymerisation processes;
- Be able to relate some macroscopic properties of common polymeric materials to their macromolecular/microscopic characteristics;
- Know the main differences between polymerisation processes involving chain polymerisations and step polymerisations.

DESCRIPTION AND TEACHING METHODS:

The course takes place in the form of lectures, conferences by industrialists, and team work on a topic chosen by the students. The team work takes place in sessions during which academic staffs discuss with the teams. In addition there is a visit to an industrial site where polymers are manufactured.

EVALUATION METHODS:

Evaluation of students:

- A final individual test in the form of multiple choice questions;
- Oral presentation by teams of the results of their work to all students.

USEFUL INFORMATION:

PREREQUISITES:

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: POLYMERIC NANO-OBJECTS: SYNTHESSES, CHARACTERIZATIONS AND APPLICATIONS			ELECTIVE
TAUGHT HOURS 18	STUDENT WORKLOAD 48	ECTS CREDITS 1	SEMESTER 8

AIMS:

Currently, nano-objects based on polymers are widely used in various applications including nanomedicine, food, and cosmetics. The advanced chemical and physical properties of (co)polymers allow preparing smart nano-objects with large set of morphologies (spherical micelles, worm-like micelles, and vesicles) responding to external stimuli (pH, light, and temperature). In addition, the novel methodologies of self-assembly make such nano-objects more attractive for large scale production. The main objective of this teaching module is to present the recent research progress in the field of formulation of polymeric nano-objects. Processes that can be upgraded to an industrial scale will be favored. The physico-chemical characterization (light scattering and microscopy) of nano-objects will be also presented.

LEARNING OUTCOMES:

At the end of this teaching module, the student engineer will be familiar with:

- The preparation of amphiphilic copolymers.
- The self-assembly of amphiphilic copolymers.
- The characterization of the physico-chemical properties of nano-objects (light scattering and microscopy).

DESCRIPTION AND TEACHING METHODS:

This course will be composed of lectures (12h), tutorials (4h), and laboratory work (2h) where the techniques of formulation and characterization of nano-objects will be used.

EVALUATION METHODS:

Project + oral presentation.

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge in polymer chemistry

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

ACADEMIC SPECIALIZATION: PROCESS ENGINEERING FOR ENERGY AND ENVIRONMENT			
COURSE TITLE: ADVANCED SEPARATION PROCESSES AND MULTIPHASE REACTORS			MANDATORY
TAUGHT HOURS 60	STUDENT WORKLOAD 105	ECTS CREDITS 4	SEMESTER 8

AIMS:

- Increase knowledge of catalytic engineering and in the design of multiphase reactors;
- To analyze and design multiphase contactors implementing a multiphase reaction;
- To analyze and design crystallization, precipitation and chromatographic processes.

LEARNING OUTCOMES:

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

- Develop original models of catalytic reactors and catalytic reactions, taking into account the mass and thermal transport limitations, the phenomena of catalyst deactivation. Be able to understand and implement a catalytic process including catalyst regeneration, describe and design the hydrodynamic behaviour of fixed bed fluidised bed reactors;
- Understand and design the coupled mass transfer and reaction gs, gl, gls systems;
- Select and design a reactor:
 - Choose a suitable reactor for the considered reaction,
 - Derive a suitable model describing the chosen reactor, including the transport limitations,
 - Estimate the physical chemistry and transfer data necessary for the problem resolution,
 - Solve the system and find the optimal operating condition for a given objective.

DESCRIPTION AND TEACHING METHODS:

Catalytic Engineering: heterogeneous fixed bed and fluidised-bed catalytic reactors, catalytic kinetics, transport limitations, catalyst deactivation

Absorption with chemical reaction: choice of the absorber, reaction regimes, acceleration factor, Hatta criterion.

Multiphase reactors: choices of contactor, hydrodynamics of two-phase flow and triphasic phase flow, transfer limitations, reactor designs.

Crystallization: kinetics and mechanisms of crystallization, population balances, industrial crystallisers, precipitation.

Chromatographic Processes: transfer modelling, simulated moving bed, chromatographic reactors.

EVALUATION METHODS:

Two projects, 3 written examinations

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemistry, Chemical Engineering and Transfers

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: Course handouts in Chemical Engineering,

Advised:

- [1] VILLERMAUX, J., 1993, *Génie de la Réaction Chimique*, Paris: Tech & Doc, Lavoisier.

ACADEMIC SPECIALIZATION: PROCESS ENGINEERING FOR ENERGY AND ENVIRONMENT			
COURSE TITLE: SUSTAINABLE PROCESSES			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
36	125	4	

AIMS:

The course is aimed at providing an understanding of the key principles to integrate process safety and sustainable development in order to make the process cleaner and safer.

LEARNING OUTCOMES:

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

- Be able to conduct a risk analysis on a complex industrial system;
- Know the regulations and specifications of industrial water treatment;
- Be able to use environmental management;
- Know how to implement a life cycle analysis.
-

DESCRIPTION AND TEACHING METHODS:

Life cycle analysis: object and field of study, analysis of the life cycle inventory, impact assessment of the life cycle, interpretations

Process Safety: MOSAR methodology (risk analysis), nuclear safety.

Environment: Environmental Management, ISO Standards 1400X, Eco-audit, gas treatment, industrial water treatment

EVALUATION METHODS:

Multiple Choice Question tests, Project on major industrial accidents, study using the MOSAR methodology
Project report and oral presentation

USEFUL INFORMATION:

PREREQUISITES:

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

ACADEMIC SPECIALIZATION: PROCESS ENGINEERING FOR ENERGY AND ENVIRONMENT			
COURSE TITLE: ADVANCED PROCESS SIMULATION AND PROCESS DESIGN			MANDATORY
TAUGHT HOURS 60	STUDENT WORKLOAD 105	ECTS CREDITS 4	SEMESTER 8

AIMS:

- To understand base concepts of engineering thermodynamics and exergy analysis;
- To be able to implement methodologies for sizing and simulation of separation processes of complex mixtures using distillation techniques;
- To know the bases of dynamic simulation of chemical and energy processes.

LEARNING OUTCOMES:

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

Advanced engineering thermodynamics

- Apply energy conversion principles;
- Describe power, heat-pump and refrigeration cycles;
- Describe energy conversion processes;
- Implement exergy analysis tools;
- Elaborate relationships between exergy and economy;
- Implement pinch technology and analysis tools;
- Understand the design of classical energy conversion processes.

Advanced distillation methods

- Understand when and how residue curves can be used to design advanced distillation processes;
- Understand azeotropic, extractive and pressure-swing distillation techniques;
- Design and simulate advanced distillation processes.

Dynamic simulation of processes

- Understand process dynamic models that are models described by ordinary differential equations (ODE), by differential-algebraic equations (DAE) or by partial differential-algebraic equations (PDAE);
- Specify adequate initial conditions;
- Understand and implement simple and higher order integration formulae (combined BDF and Newton methods, prediction-correction steps);
- Understand index and high index systems of DAE;
- Use gPROMS or Dynsim software for simulation of batch and fedbatch reactors.

DESCRIPTION AND TEACHING METHODS:

Advanced engineering thermodynamics

Lectures and tutorials

Case study (study of a process illustrating concepts introduced in any of the sub-courses of the ADVANCED PROCESS SIMULATION AND PROCESS DESIGN course): computer-aided practical work

Advanced distillation methods

Lectures, tutorials and computer-aided practical work

Dynamic simulation of processes

Lectures and computer-aided practical work

EVALUATION METHODS:

Advanced Engineering Thermodynamics

Final examination (1h30)

Final report (case study)

Advanced Distillation Methods

Final examination (1h30)

Dynamic Simulation of Processes

Final examination (1h00)

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of:

- Chemical Engineering Thermodynamics
- Separation Process Design And Simulation
- Process System Engineering

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] KOTAS, T.J., 1985 *The Exergy Method of Thermal Plant Analysis*, Florida: Krieger Publishing Company, Malabar;
- [2] MORAN, M.J., SHAPIRO, H.N., BOETTNER, D.D. and BAILEY, M.B., *Fundamentals of Engineering Thermodynamics*, 7th Edition, Wiley;
- [3] SEIDER, W.D., SEADER, J.D., LEWIN, D.R. and WIDAGDO, S., 2009, *Product and Process Design Principles: synthesis, analysis and evaluation*, 3rd edition, Wiley;
- [4] Wankat, P.C., *Separation Process Engineering: Includes Mass Transfer Analysis*, International Edition Broché;
- [5] *Distillation de mélanges non idéaux – Courbes de résidu et autres outils de conception*, Techniques de l'Ingénieur, Vol. J 2611, 2010;
- [6] *Distillation de mélanges non idéaux – Distillation azéotropique et distillation extractive*. Choix de l'entraîneur, Techniques de l'Ingénieur, Vol. J 2612, 2010.

ACADEMIC SPECIALIZATION: INNOVATIVE PRODUCTS – FROM CHEMISTRY TO PROCESS			
COURSE TITLE: MICRO- AND NANOSTRUCTURED PRODUCTS			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
60	105	4	

LEARNING OUTCOMES:

The development and design of micro and nano products is becoming more and more important. Many new technologies are being developed and they create many visions for new products and applications. The aim of this course is to present the basics and concepts of the fabrication of micro and nano-structured products such as emulsions, colloidal dispersions and foams. This course will describe the different dispersing agents, in particular, surfactants, which are necessary for the stabilization of the various interfaces.

AIMS:

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

- Analyze the behaviour of the dispersing agents used in formulated products (surfactants) in solution and at the interfaces;
- Choose the most appropriate surfactant for the formulation of a product;
- Fabricate micro and nano-structured products such as emulsions, colloidal dispersions and foams;
- Study the unit operations for producing micro and nano-structured products: emulsification, granulation ;
- Master the concept of chemical product engineering and performance products;
- Understand that this domain is a science of interdisciplinarity and innovation.

DESCRIPTION AND TEACHING METHODS:

- The session will be composed of lectures and 2 projects;
- The projects will consist of the analysis of various documents dealing with 1) Processes applied to disperse fluid systems;
- (multiphase fluid systems) and 2) Processes applied to solid dispersion systems;
- Different academic staffs will take part in this course.

EVALUATION METHODS:

- I. **Physical Chemistry of interfaces and Molecular Self-Assembly systems: written examination**
- II. **Processes applied to disperse fluid systems (multiphase fluid systems): project**
- III. **Processes applied to solid dispersion systems: project**

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemistry and Chemical Engineering

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] ADAMSON, A.W., *Physical Chemistry of Surfaces*, John Wiley and Sons.

ACADEMIC SPECIALIZATION: INNOVATIVE PRODUCTS – FROM CHEMISTRY TO PROCESS			
COURSE TITLE: INTRODUCTION TO PRODUCT ENGINEERING			MANDATORY
TAUGHT HOURS 36	STUDENT WORKLOAD 125	ECTS CREDITS 4	SEMESTER 8

AIMS:

Chemical industries nowadays are increasingly involved in specialty chemicals (small quantity, batch production, high added value) as well as formulated products (complex mixtures targeted to confer specific end-use properties). In addition to process design and optimization which are the major concerns of commodity production, the specialty and formulated product industries also face new technical as well as marketing challenges (time to market, smart product design, choice or adaptation of generic, not dedicated plants etc.).

Moreover, in place of the classical unit operations found in commodity production (distillation, absorption, extraction etc.), more specific unit operations such as emulsification, spray cooling, extrusion, coating and granulation are relevant for formulated product elaboration. This situation calls for an examination of the possibilities and limitations of Chemical Engineering methodology within a product oriented framework. The aim of this course is to identify some of the challenges of what is termed Chemical Product Engineering. The distinctive features of product design (particularly in contrast to process design, a more familiar topic for chemical engineers) are outlined.

LEARNING OUTCOMES:

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

- Master the concept of Chemical Product Engineering and performance products;
- Use batch operation and batch production;
- Study the life cycle analysis of a product;
- Understand that this domain is a science of interdisciplinarity and innovation.

DESCRIPTION AND TEACHING METHODS:

The session will be composed of lectures, conferences from industrial partners and a project. The project will consist of the analysis of various documents dealing with Chemical Product Engineering. Different academic staffs and industrial lecturers will take part in this course.

EVALUATION METHODS:

- I. **Introduction to Chemical Product Engineering: oral presentations of team work (3-4 persons)**
- II. **Batch operation and batch production: written examination**
- III. **Life cycle analysis: Multiple Choice Question test**

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemistry and Chemical Engineering

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] CUSSLER, E.L., *Chemical Product Design*, 2nd edition, Cambridge Series in Chemical Engineering, Cambridge University Press;
- [2] VILLERMAUX, J., *Génie De La Réaction Chimique - Conception et Fonctionnement Des Réacteurs*, Lavoisier Tech & Doc.

ACADEMIC SPECIALIZATION: INNOVATIVE PRODUCTS – FROM CHEMISTRY TO PROCESS			
COURSE TITLE: FROM MOLECULES TO PRODUCTS			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
60	99	4	

AIMS:

This course aims to:

- Going from product design by the choice of molecule/formulation and their shape up to its specific fabrication process and its characterization;
- Highlight the crucial effect of chemical structures in formulation and its links with the physical properties of the formulation and the resulting end-use properties of the product;
- Give basic knowledge in rheology and understand rheology as a tool to characterise complex systems.

LEARNING OUTCOMES:

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

- Develop a reverse strategy of product design including the choice of the molecules and their shape (linked to the specifications and the aimed end-use properties) as well as the specific fabrication process;
- Analyze the chemical structure of molecules and establish the link with some end-use properties in the final product;
- Explain the behaviour of complex molecular system depending on their environment;
- Justify the use of specific functionalities in a product formulation;
- Design, process and characterise formulated products;
- Master rheology as a tool to characterise complex systems.

DESCRIPTION AND TEACHING METHODS:

Products: Practical Work (24h): Design of formulated Products - from process to final product characterization: Molecule synthesis, production of particles, gels, emulsions and dispersions; wetting phenomena; product characterization (granulometer, interfacial tension, rheology...)

Rheology (11h) : Fundamental equation in rheology; Description of the main non-Newtonian behaviors (shear-thinning, yield stress, thixotropic) based on examples found in cosmetics, hygiene, coating industries.; Description of solid-liquid ambivalence of formulated product , particularly in case of gels; Description of measurement apparatus depending on their use ; Systemic rheology, Industrial study cases.

Molecules structures and end-use properties (22,5h)- : Study cases assisted by interactive courses on the following subjects: Product Stability/Lability (Main functions - Influence of environment/Prevention methods); Activity –Toxicity (Active centre and relation with chemical structure, Introduction to synthetic pathway to active ingredient); Properties on demand and « Smart » Materials » ; Complexity of property-structures relation ; Introduction to some prediction methods.

EVALUATION METHODS:

1. Products: Practical Work: Practical work reports
2. Rheology: Written examination 1h
3. Molecules structures and end-use properties: Oral presentation and written examination (1h 30). Each one counts 50%.

The final Mark is the weighted average at prorata temporis.

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Chemistry and Chemical Engineering

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] BROCKEL, U., MEIER, W. AND WAGNER, G., *Product Design and Engineering: Formulation of Gels and Pastes*, Wiley;
- [2] BROCKEL, U., MEIER, W. AND WAGNER, G., *Product Design and Engineering*, 2 Volume Set, Editor, Wiley;
- [3] COUSSOT, P. and GROSSIORD, J.L., *Comprendre la rhéologie*, EDP Sciences ;
- [4] CUSSLER, E.L., *Chemical Product Design*, 2nd edition, Cambridge Series in Chemical Engineering, Cambridge University Press;
- [5] WEI, J., 2007, *Product engineering: molecular structure and properties*, Oxford University Press.

ACADEMIC SPECIALIZATION: BIOPROCESS ENGINEERING			
COURSE TITLE: INTRODUCTION TO BIOLOGICAL SCIENCES			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
60	105	4	

AIMS:

- Insight into classification and occurrence of microorganism, cell structure, metabolism;
- Molecular biology;
- Insight into immunology and immunological techniques;
- Biomolecules (proteins, lipids, carbohydrates, nucleic acids) structure/function relationships and purification;
- Insight into enzymology.

LEARNING OUTCOMES:

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

- Describe the different biomolecule types and discuss their function;
- Have an overview of lipids and carbohydrates degradation and biosynthesis;
- Explain the principles underlying protein structure;
- Describe enzyme kinetics;
- Describe the major purification and separation methods for biomolecules.

DESCRIPTION AND TEACHING METHODS:

Teaching methods: (interactive) lectures (49h); tutorials (9h)

Content:

1. Biomolecules: an introduction to Biochemistry
 Cell structure: lipids and membranes;
 Cell metabolism (glycolysis, citric acid cycle, lipids biosynthesis), bioenergetics and ATP production.
 Description of biomolecules: aminoacids, proteins, lipids, carbohydrates, nucleic acid
 Overview of protein structure and function
 Enzymes: enzyme activity, catalysis, kinetics, regulation
2. Methods
 biophysics methods (NMR/XRD, circular dichroism, infrared spectroscopy)
 characterization of biomolecules (PCR, Elisa, westernblot)
 molecular interaction (surface plasmon resonance, ITC)
 purification of biomolecules (precipitation, chromatography, centrifugation, electrophoresis, strategies).

EVALUATION METHODS:

Written examination

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Organic Chemistry is required

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Advised:

- [1] CHRISTER, J. and LARS RYDEN, J., 1989, *Protein Purification: Principles, high Resolutions Methods and Applications*, VCh Publishers;
- [2] VOET,D. and VOET,J-G., *Biochemistry*, 4th Ed., Wiley.

ACADEMIC SPECIALIZATION: BIOPROCESS ENGINEERING			
COURSE TITLE: BIOCATALYSTS AND BIOREACTORS			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 8
36	112	4	

AIMS:

This course aims to give students scientific and technical skills in Biotechnology Engineering. They will learn about enzymatic and microbial kinetics and different kinds of bioreactors. Hydrodynamics as well as mass and heat transfer aspects will be discussed. Students will also be initiated to bioreactor modelling and to the basic principles of scaling-up.

LEARNING OUTCOMES:

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

- Represent enzymatic and microbial kinetics with the appropriate equations;
- Establish mass and heat balance equations taking into account hydrodynamic parameters;
- Model biological reactors (enzymatic and microbial);
- Master scaling-up procedures from laboratory data to industrial application.

DESCRIPTION AND TEACHING METHODS:

Biocatalysis: Characterization of enzymatic mechanisms (Michaelis-Menten, enzymatic inhibition) and microbial mechanisms (Monod).

Bioreactors:

- Continuous, batch and fed-batch reactors, global mass balances;
- Multiphase (gas-liquid and gas-liquid-solid) reactors: hydrodynamics (flow regimes, mixing of the phases, effect of operating parameters), mass and heat transport phenomena, modelling and scale-up for different types of bioreactors.

Lectures (16h 30) and tutorials (10h 30).

Micro project: carried out by groups of 5 students, modelling a biological process with Matlab (6h).

EVALUATION METHODS:

Written examination and Micro Project oral presentation.

USEFUL INFORMATION:

PREREQUISITES: Matlab software

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

ACADEMIC SPECIALIZATION: BIOPROCESS ENGINEERING			
COURSE TITLE: PERSONAL BIOSEPARATION			MANDATORY
TAUGHT HOURS 60	STUDENT WORKLOAD 100	ECTS CREDITS 4	SEMESTER 8

AIMS:

The series of lectures is aimed at:

- Providing students the required background in the various separation techniques employed in biotechnological production;
- Teaching students a structured approach for possible analysis of the involved phenomena in bioseparation processes;
- Providing the required competences for the design and dimensioning of the various separation processes currently used in biotechnology;
- Providing students the criteria to select suitable equipment, and the required elements to implement a global separation approach e.g. combined concentration and purification.

LEARNING OUTCOMES:

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

- Know the main processes used in bioseparation with their operation principles;
- Know how to select a separation process depending on specified multi-criteria constraints e.g. nature of the mixture to be separated, targeted performance, operating conditions;
- Be able to design a process for a specified application taking into account the specificities of the biomolecules;
- Understand the interactions between the various types of processes involved in a system combining the concentration and purification of a biological molecule.

DESCRIPTION AND TEACHING METHODS:

Centrifugation / Filtration: 2 (1h30) lecture sessions and 2 (1h30) tutorial sessions

Membrane processes: 5 (2h) lecture sessions and 4 (2h) tutorial sessions

Concept of selectivity, rejection rate and permeability ; various types of membranes processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, dialysis, pervaporation, membrane contactors); membrane materials and modules; mass transfer rates and fluxes, concentration polarisation, osmotic effects; industrial case studies (discontinuous concentration of a complex mixture, design of a ultrafiltration module for protein separation, solution treatment by reverse osmosis, dialysis separation; degassing of liquid mixtures by contactors).

Chromatographic processes: 6 (1h30) lecture sessions and 6 (1h30) tutorial sessions

Various adsorbent types; various operation models (elution, front chromatography) - General mass balances - Concept of concentration wave front - Solutions of general equations using analytical or numerical techniques - Cyclic operations - Application to biomolecules - Enantiomeric separation by simulated moving bed - Sequential and continuous multicolumn processes.

Crystallisation: 3 (1h30) lecture sessions and 3 (1h30) tutorial sessions

Nucleation, growth, aggregation and breaking mechanisms - Influence of physicochemical conditions and of operating parameters in a process - Discontinuous crystallization operation - Population balances - Industrial case study.

EVALUATION METHODS:

Written examination

USEFUL INFORMATION:

PREREQUISITES:

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

SEMESTER 9: COURSE UNITS

SEMESTER OVERVIEW

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
<i>Management and Economics V</i>	Vera IVANAJ	40	20	20					2
<i>Foreign Language V</i>	Jude BOWDEN	48		48					3
	<i>English</i> Jude BOWDEN			48					
<i>Research and Development Project</i>	Eric SCHAER								10
<i>Electives</i>		19							3
<i>Academic specialization path</i>		Ab. 145							12
TOTAL		Ab. 250							30

ELECTIVES V (to be chosen: one)

Electives V	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
<i>Polymer-based Processes and Products</i>	Sandrine HOPPE	19	8	8		3			3
<i>Materials and Nanomaterials for Catalysis</i>	Halima ALEM-MARCHAND	19	8	8		3			3
<i>Kinetics of Fuel Combustion</i>	Olivier HERBINET	19	8	8		3			3
<i>Biorefinery</i>	Guillain MAUVIEL	19	8	8		3			3
<i>Numerical Solution Of Transport Equations</i>	François LESAGE	19	7	7		3		2	3

ACADEMIC SPECIALIZATION: Process Engineering for Energy and Environment

Academic coordinator: Sabine RODE

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
<i>Process Engineering and Energy</i>	Olivier HERBINET	60	14	10			33	3	4
<i>Industrialists' Conferences</i>	Olivier HERBINET						33		
<i>Combustion</i>	Olivier HERBINET		6	6				1,5	
<i>Exergy Analysis</i>	Romain PRIVAT		8	4				1,5	
<i>Dynamic Optimization and Advanced Control</i>	Abderrazak LATIFI	46	30	10		6			4
<i>Dynamic Optimization</i>	Abderrazak LATIFI		20				3		
<i>Advanced Control</i>	Jean-Marc COMMENGE		10	10			3		
<i>Process Intensification and Innovation</i>	Jean-Marc COMMENGE	33	12	9		9		3	4
<i>Process Intensification</i>	Jean-Marc COMMENGE		6	4,5			1,5		
<i>Membrane Processes</i>	Eric FAVRE		6	4,5			1,5		
<i>Innovation Project</i>	Jean-Marc COMMENGE					9			
TOTAL		139							12

ACADEMIC SPECIALIZATION: Innovative Products: from Chemistry to Process

Academic coordinator: Thibault ROQUES-CARMES

Course units and their components	Unit coordinators	Taught hours	Lectures	Tutorials	Practical work	P	C	Ex	ECTS credits
Specialty Products	Alain DURAND	60	45	6			3	6	4
<i>Copolymers: from Processes to Applications</i>	Anne JONQUIERES		10,5	4,5				1,5	
<i>Plastics Formulation</i>	Sandrine HOPPE		9				3	1,5	
<i>Polymers in Solutions, at Interfaces and in Emulsions</i>	Alain DURAND		25,5	1,5				3	
Product Properties and Quality	Alain DURAND	61,5	38	18				5,5	4
<i>Process for Health Products</i>	Laurent MARCHAL-HEUSSLER		8	6				1	
<i>Experimental Design</i>	Graciela CARES		6	6					
<i>Physical Properties of Polymers</i>	Anne JONQUIERES		19,5	1,5				4,5	
<i>Crystallization</i>	Eric SCHAER		4,5	4,5					
Case Study - Innovative Product Design Project	Laurent MARCHAL-HEUSSLER	33	18	3		9		3	4
<i>Innovative Product Design Project</i>	Laurent MARCHAL-HEUSSLER		9			9		3	
<i>Manufacturing Processes of Inorganic Solids</i>	Mohammed BOUROUKBA		9	3					
TOTAL		154							12

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

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: FOREIGN LANGUAGE V			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
48	84	3	

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	ECTS CREDITS	SEMESTER 9
-	300	10	

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 unless the placement takes place abroad in which case English is the preferred language.

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: POLYMER-BASED PROCESSES AND PRODUCTS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
19	58	3	

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:

PREREQUISITES: None

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: MATERIALS AND NANOMATERIALS FOR CATALYSIS			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
19	58	3	

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: French

BIBLIOGRAPHICAL REFERENCES:

Needed: None

Advised: None

CORE CURRICULUM			
COURSE TITLE: KINETICS OF FUEL COMBUSTION			ELECTIVE
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
19	58	3	

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: French (English possible if there is a demand)

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	STUDENT WORKLOAD	ECTS CREDITS	S9
19	58	3	

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: French (English language is possible on demand and agreement of all students)

BIBLIOGRAPHICAL REFERENCES:

Needed:

Advised:

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

ACADEMIC SPECIALISATION: PROCESS ENGINEERING FOR ENERGY AND ENVIRONMENT			
COURSE TITLE: PROCESS ENGINEERING AND ENERGY			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
60	105	4	

AIMS:

- Awareness of technological and societal challenges related to energy production, through conferences by industrialists and visits of power plant units;
- Understand the main chemical phenomena involved in combustion for applications to industrial processes (boilers, engines, gas turbines ...);
- Understand how to perform exergy analysis in order to reduce energy wastes in chemical processes.

LEARNING OUTCOMES:

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

- Understand the global context of production and energy demand;
- Have knowledge of the main processes dedicated to the transformation of energy;
- Be able to analyze combustion parameters and to calculate the associated main chemical parameters;
- Be able to build combustion diagrams and to apply these diagrams to the combustion in boilers;
- Be able to evaluate exergy of pure components or mixtures using appropriate property data;
- Be able to apply exergy balances to closed and open systems at steady state involving reacting and non-reacting species.

DESCRIPTION AND TEACHING METHODS:

Combustion: 4 lectures (1h30), 4 tutorials (1h30): definition and calculation of physical chemistry properties involved in combustion, thermodynamic approach of the combustion: diagrams of combustion Wobbe index, combustion efficiency and energy loss, practical applications to the combustion in industrial boilers and in engines, ideal thermodynamic cycles.

Exergy analysis: 5 lectures = (1h30), 3 tutorials (1h30): definition of exergy, exergy balances in closed and open systems, estimation of multicomponent-system exergy through the gamma-phi and phi-phi approaches, exergy analysis in reacting systems, application to chemical-engineering processes.

Conferences and visits: 11 sessions (3h). Themes: world energy outlook; oil recovery; oil & gas processes; carbon capture and storage; wind power and hydroelectricity; photovoltaic; biomass and energy; nuclear power; radioactive waste management; bio-methane from anaerobic digestion.

EVALUATION METHODS:

Two written exams of 1h30mins (40 % each), mandatory attendance at conferences, abstract writing and multiple choice question test (20%)

USEFUL INFORMATION:

PREREQUISITES: Basic knowledge of Thermodynamics, Kinetics and Chemical Engineering

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES:

Needed: Course handouts

Advised: none

ACADEMIC SPECIALISATION: PROCESS ENGINEERING FOR ENERGY AND ENVIRONMENT			
COURSE TITLE: DYNAMIC OPTIMIZATION AND ADVANCED CONTROL			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
46	130	4	

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: French

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*, 2^{ème} 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	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
33	132	4	

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: French

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: French

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	STUDENT WORKLOAD	ECTS CREDITS	SEMESTER 9
60	108	4	

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: French and 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, *Vieillesse 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

SEMESTER 10: COURSE UNITS

Course unit	Unit coordinator	Taught hours	Lectures	Tutorials	Laboratory	P	C	Ex	ECTS credits
<i>Industrial placement</i>	Oliver HERBINET								30
TOTAL									30

CORE CURRICULUM			
COURSE TITLE: INDUSTRIAL PLACEMENT			MANDATORY
TAUGHT HOURS	STUDENT WORKLOAD	ECTS CREDITS 30	SEMESTER 10

AIMS:

This is a professional work placement in a company or in a public agency with an industrial or commercial aspect for 4 months minimum and 6 months maximum and to be carried out in France or abroad.

The student will gain experience working in a professional environment. They will encounter technical and human management aspects and safety requirements.

LEARNING OUTCOMES:

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

- Complete a mission by solving complex technical problems (with objectives, timelines, cost and quality);
- Use their imagination and creativity; be proactive and demonstrate independence;
- Present findings and proposals; provide technical expertise and support of decisions made; convey a message with strength and conviction;
- Write a report meeting the academic and industrial expectations.

DESCRIPTION AND TEACHING METHODS:

The subject of the Industrial placement must be defined in advance and must be approved by the Head of Studies. The subject must relate to the courses taught in ENSIC and should enable students to use their knowledge and skills acquired during the first two years of training.

An industrial supervisor (the company) and a university tutor are appointed for each trainee.

EVALUATION METHODS:

At the end of the Industrial placement, the student must produce a written report with the objectives of the work carried out and the achievements. There will also be an oral presentation with a panel composed of the industrial supervisor, the university tutor and an academic staff of the school who did not follow the work.

Evaluation of the Industrial placement: the mark takes into account the following criteria (each rated on 5 points):

- The quality of the written report;
- The quality of the oral presentation;
- The work done during the placement;
- The assessment of the industrial supervisor.

USEFUL INFORMATION:

PREREQUISITES:

- Have a defined career plan;
- Know how to write a curriculum vitae and a cover letter;
- Job interview skills;
- Report writing skills;
- Master all the concepts taught at the School.

LANGUAGE: /

BIBLIOGRAPHICAL REFERENCES:

Needed: Work Placement guide is available on the ENT (Bureau > Diffusion de Documents > Scolarité ENSIC > Stages)

Advised: