CHEMICAL ENGINEERING SCHOOL
SINCE 1887

SYLLABUS

CHEMICAL ENGINEERING M.ENG DEGREE

2024-2025 (CLASS OF 2027)

ENSIC

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ENSIC

Chemical Engineering M.Eng Degree Syllabus 2024 - 2025

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HISTORY

The ENSIC celebrated its 130th anniversary in 2017. Created in 1887 under an agreement between the City of Nancy and the Ministry of Education, the Nancy Chemical Institute was inaugurated by President Sadi Carnot in 1892. Half a century later, a bold reform, known as the Travers reform, introduced the competitive entrance examination reserved for Special Mathematics students, which is still in force today.
The name was changed to "Ecole Supérieure des Industries Chimiques". Finally, in early 1948, following a decree creating the Ecoles Nationales Supérieures d'Ingénieurs, the school became the Ecole Nationale Supérieure des Industries Chimiques, graduating process engineers who would meet the expectations of industry and society.

In 1997, the original Chemical Industry Engineering programme, for which the School holds accreditation dating back to 1936, was extended to include a new programme, also accredited by the Commission des Titres d'Ingénieur: the "Industrial Techniques Engineering programme". This course, which focuses on chemical engineering, works with industrialists in the professional sectors to train its engineers on a sandwich course basis.

ENSIC Nancy is a component of the University, its parent institution being the Institut National Polytechnique de Lorraine between 1971 and 2011, and the Université de Lorraine since 2012. Within this framework, ENSIC engineering students have the possibility of obtaining an additional Master's degree during their 3ème 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 some 140 new Engineering students in these two courses.

CHEMICAL ENGINEERING M.Eng DEGREE SYLLABUS

I. TRAINING OBJECTIVES

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 (I^2C)"* (Chemical Engineering Syllabus) are either based on a national competitive exam "C*oncours 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 I^2C 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 I^2C 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.

Diploma skills reference framework

SCIENTIFIC AND TECHNICAL KNOWLEDGE AND MASTERY OF ITS APPLICATION	
Skill no. 1	**Knowledge and understanding of a wide range of fundamental and applied sciences, and the ability to analyse and synthesise them, which is associated with them**
Level a	Name and describe the basic principles of fundamental and applied science.
Level b	Explain and demonstrate the fundamentals of mathematics, physics and chemistry in order to achieve the objectives of the training programme.
Level c	Handling and experimenting with the fundamentals of mathematics, physics and chemistry for problem solving.
Level d	Analysing and synthesising scientific knowledge and work, on the basis of extensive and in-depth knowledge of mathematics, physics and chemistry, to provide a coherent overall view of a subject of study in order to to develop.
Level e	Develop original approaches that contribute to the contribution of new knowledge and innovation in the basic sciences.
Skill no. 2	**The ability to mobilise and integrate resources from several fields specific scientific and technical knowledge.**
Level a	Identify the scientific fields whose exploration involves the integration of several fundamental disciplines in the physical and chemical sciences.
Level b	Explain the links between transfer phenomena, thermodynamics and the chemical kinetics appearing in the process engineering sciences.
Level c	Use process engineering methodologies to describe the processes involved in transporting matter, energy and momentum. Use this knowledge to design heat transfer installations. matter and energy.
Level d	Know, evaluate and be able to implement the coupling between physical and chemical sciences in complex, multiphase and multidisciplinary environments. to optimise plant operation.
Level e	Develop methods that draw on knowledge from a number of scientific and technical disciplines in order to advance the frontiers of engineering. processes.
Skill no. 3	**Mastery of engineering approaches, methods and tools: identification, modelling and resolution of even unfamiliar and incompletely defined problems, a systemic, holistic and interdisciplinary approach, use of digital approaches and tools, etc. analysis and design of computer systems**
Level a	Identify the conceptual basis and methodologies of process engineering and combine them with appropriate numerical and statistical tools.
Level b	Distinguish between and describe dimensioning problems and differentiate between levels of complexity for problem solving.
Level c	Solve problems formulated at different levels of complexity, by using appropriate methods.
Level d	Identify problems and formulate them at the required level of complexity. Analysing products and processes using process engineering methods, integrating socio-ecological aspects.
Level e	Evaluating, equating and solving unfamiliar and difficult problems incompletely defined. Develop original and innovative approaches based on fundamental principles.

Skill no. 4	**The ability to design, put into practice, test and validate innovative solutions, methods, products and processes, with a prior appraisal of their effectiveness. questioning uses**

Level a	Name and identify products or processes for a given application.
Level b	Compare and select products and processes to meet specifications charges.
Level c	Analyse products and processes by selecting and applying methods and taking into account aspects related to their use.
Level d	Design, develop and size new products and processes, based on fundamental aspects and incorporating aspects relating to the socio-ecological transition.
Level e	Develop and validate innovative product and process design methods, incorporating the most recent developments in the field, on the basis of a critical analysis taking into account technological and economic aspects, environmental and social issues.
Skill no. 5	**The ability to carry out fundamental or applied research, to set up experimental devices; the ability to master orders of magnitude based on substantiated data; the ability to present research work**
Level a	Apply an experimental protocol and give the order of magnitude of the main physico-chemical parameters.
Level b	Use existing experimental equipment wisely, identify the parametric field that can be explored, carry out measurements, use and present the results results and uncertainties in an appropriate scientific format.
Level c	Link theory and experiment. Develop an experimental methodology to validate a model or to regress some of its parameters, and estimate the uncertainty.
Level d	Organise a fundamental or applied research project: develop models, choose appropriate experimental set-ups, draw up an experimental plan and analyse the results. Identify the predominant phenomena and the major associated impacts in order to deduce the order of magnitude of the phenomena. waiting.
Level e	Devising a strategy for exploring a new field. Identify the scientific and/or technological obstacles and the resources needed to overcome them. Develop innovative experimental strategies. Report on progress using in the form of scientific papers.
Skill no. 6	**The ability to find relevant information, analyse and evaluate it, and to exploit it**
Level a	Identify and list the different types of bibliographic resources and basic bibliographic tools.
Level b	Select the most relevant publications on a given subject using basic bibliographic tools. Organise them and cite them correctly as bibliographical references.
Level c	Adopt a rigorous and reasoned approach to extracting relevant publications, patents and scientific works using different tools bibliography. Identifying and analysing the key points of a scientific document.
Level d	Carry out a bibliographical study, interpret published results and analyse the state of the art on a specific subject. Use various bibliographic and reference management tools. Write a report or a presentation summary bibliography.

Level e	To produce the most comprehensive bibliographic review possible on a particular topic, using expertise and a critical eye combined with in-depth knowledge and experience in the field.
ADAPTING TO THE SPECIFIC REQUIREMENTS OF THE COMPANY AND A SUSTAINABLE SOCIETY	

Skill no. 7	**The ability to take account of the company's challenges and report on its actions: economic dimension, compliance with requirements, etc. social and environmental issues, quality, competitiveness and productivity, commercial requirements, economic intelligence**
Level a	List the QHSE rules, performance indicators and functional requirements of a process.
Level b	Identify the QHSE and economic requirements of a process.
Level c	Monitor performance indicators for a process or product and check compliance with standards.
Level d	Ensuring compliance with QHSE rules, carrying out a technical and economic analysis of a process or product and suggesting areas for improvement.
Level e	Preventing and managing risks associated with processes or products, planning and organising control and maintenance activities. Monitor performance indicators and implement optimisation measures.
Skill no. 8	**The ability to integrate ethical and professional responsibilities into one's conduct and to take account of the challenges of workplace relations, health and safety at work and diversity**
Level a	Describe the principles of ethical responsibility and health and safety in the workplace. Distinguish between the concepts of Diversity, Equality, Inclusion and Respect.
Level b	Discuss the principles of ethics and professional responsibility. Apply the health and safety rules and the principles of Diversity, Equality, Inclusion and Respect.
Level c	Apply the principles of ethics and professional responsibility. Applying health and safety rules in the workplace. Apply the principles of Diversity, Equality, Inclusion and Respect.
Level d	Defending and organising the principles of ethics, workplace relations, health and safety at work and diversity in all its professional activities, particularly in its scientific and technical practices, communication, management and decision-making.
Level e	Organising change, advancing the above principles in your professional environment.

Skill no. 9	**The ability to take action for the energy and ecological transition of companies**
Level a	Describe the technical development of industry and its growing need for materials and energy.
Level b	Identify and characterise the different natural resources used by industry. Understand the problems associated with their use. Detail the energy/material requirements of industry and their carbon impact.
Level c	Distinguish between the different types of industrial pollution. Identify the technologies that make it possible to reduce resource requirements and environmental and social damage. Carry out a simplified LCA.
Level d	Quantify and analyse the resource requirements and environmental and societal impacts of an existing process or product (LCA extended to societal advantages and disadvantages). Evaluate, together with all stakeholders, the interest in of a new technology through a systemic and forward-looking approach.
Level e	Managing change towards greener industrial systems. Anticipating socio-ecological needs and constraints when developing processes and products

Skill no. 10	**The ability to act for the emergence of a sustainable society and the dissemination of knowledge science**
Level a	Define the issues and needs of society, examine the diversity of Man-Nature relationships and describe the principles of a scientific approach.
Level b	Describe the concepts of planetary limits, biodiversity, ecosystem services and societal objectives (SDGs). Illustrate the principles and contributions of scientific approach.
Level c	Examine society's needs and challenges in the context of the socio-ecological transition. Analyse the causes and consequences of climate change and the collapse of biodiversity. Establish the link between science & technology and a sustainable society. Act as a citizen and scientific engineer.
Level d	Co-construct diagnoses and solutions for mitigating and adapting to the depletion of resources, biodiversity and climate change. Disseminate knowledge and share experience as part of a civic-minded approach.
Level e	Supporting technological and societal progress towards a sustainable world. Designing socially responsible innovation by integrating new challenges.

TAKING ACCOUNT OF THE ORGANISATIONAL, PERSONAL AND CULTURAL DIMENSIONS	
Skill no. 11	**The ability to fit into professional life, to integrate into an organisation, to lead it and to help it evolve: exercising responsibility, commitment and leadership, project management, the ability to collaborate and communicate within diverse and dynamic teams. multidisciplinary**

Level a	Describe the main functions of a company and distinguish the main roles in a work team.
Level b	Identify a company's strategy, values and missions, and pinpoint its methods of growth. Contribute to group work, taking personal responsibility. Coordinate your activities with those of other team members.
Level c	Be a driving force within a work organisation, using communication and interpersonal cooperation techniques. Know how to manage conflict in order to facilitate decision-making.
Level d	Manage people and entrepreneurial and business projects. Make career choices that take account of the company's strategic vision and its own aspirations.
Level e	Leading and managing multi-disciplinary teams and projects, anticipating difficulties and encouraging dialogue. Initiating and supporting organisational and technical change. Designing and managing complex, multi-partner projects.
Skill no. 12	**The ability to undertake and innovate, through personal projects or through initiative and involvement within the company in entrepreneurial projects**
Level a	Name the basic principles of how a company operates and list its main activities.
Level b	Describe the issues involved in running and managing a company. Identify the major challenges to a company's socio-economic performance.
Level c	Develop your entrepreneurial and creative potential and use it t o build your personal and professional project.
Level d	Identify the main tools and methods of business management and apply them to the management of an entrepreneurial and/or innovation project.
Level e	Design and implement entrepreneurial and innovation projects within a company or on an individual basis. Suggest possible avenues for business development.

Skill no. 13	**The ability to work in an international and multicultural context: mastery of one or more foreign languages and associated cultural openness, ability t o adapt to international contexts and to work in a multicultural environment. cooperation on collective global issues**
Level a	Understand one or more foreign languages and identify cultural specificities.
Level b	Reporting on your work in written and oral form using more than one language, including English, and being able to work in an international context.
Level c	Presenting the results of work in written and oral form, communicating effectively with specialists and non-specialists, using multimedia tools. Work in a multicultural team, using more than one language, including English.
Level d	Work effectively in national and international contexts, as a member or leader of a multidisciplinary and multicultural team. Use appropriate communication tools and techniques to communicate in your own language. mother tongue, in French and English.
Level e	Communicate with peers, the international scientific community and society about their work or expertise in their mother tongue, in French and in English. Anticipate and adapt to cultural differences in order to manage international groups and projects.
Skill no. 14	**The ability to know oneself, to assess oneself, to manage one's skills (particularly with a view to lifelong learning), to make career choices**
Level a	Identify the fundamental needs of individuals at work and distinguish between the physical, cognitive and emotional dimensions.
Level b	Understand the importance of the human dimension at work. Identify differences in values and work culture.
Level c	Distinguish between the different personality profiles, their strengths and weaknesses, and take them into account when managing interpersonal relationships. Identify your personality profile to help you make the right career choices.
Level d	Choose and argue in favour of a professional and personal project, taking account of technical and human skills. Consider the need for lifelong learning.

Level e	Develop and structure your personal and professional development plan. Imagine possible career paths and train or reorientate accordingly.

OVERVIEW OF STUDIES

S10	**4 to 6 month engineering internship**					IFP School apprenticeship	French National Institute for Nuclear Science and	PROCEDIS course (15-month sandwich
S9	**Specialisation courses** **Innovation Project**	*Research and Development project*	Double degree with ENSAIA or ENSG	Studying at another Fédération Gay Lussac school	Studying at a foreign university			
	3-month work placement or stay abroad: June to September							
S8	**Specialisation courses**	*Design project*						
S7	**Common Core**							
	Work experience **1 month: July or August**							
S6	**Common Core**	*Reactive systems project*						
S5		*Modelling project*						

IV. Development and elaboration of the student's career plan. Mentoring

A range of teaching and support activities, integrated into the compulsory modules of the syllabus, enable all students to prepare their career plans in line with their personal development. In addition to these compulsory modules, there is a mentoring scheme run jointly with ENSIC Alumni, in which students can take part on a voluntary basis.

The aim of the career development programme, which takes place over the first two years, is to enable students to better define their personality, identify their real skills and aptitudes, present all the possible outlets for an ENSIC engineer and give them as many tools as possible to find a first job corresponding to their aspirations.

At the end of the core curriculum and Semester 7, a personalised assessment is carried out with each student to check the progress of their career plan. This should enable them to choose their speciality pathway in S8 and shape the content of their third year (S9 and S10).

Description of the objectives of the career development programme

Defining your personality, getting to know yourself and your skills and aptitudes

During Semester 5, specific teaching aims to make students aware of their own personality: their strengths, weaknesses and the way they function in relation to others. This teaching also highlights the behavioural differences between individuals and provides the main tools for managing them, in particular the Myers Briggs test (MBTI). This learning is supplemented and applied in S8 during the opening project, which enables students to test their own limits and get to know themselves better as part of the management of a personal project carried out outside the classroom.

Career opportunities for ENSIC engineers

The diversity of industrial sectors and professions is studied and presented from many angles:

- The meaning of the profession of "engineer" and reflection on ethical concepts: organisation of a conference as part of the societal outreach project
- Presentation of the industrial world and the typology of companies
- Presentation of the different engineering professions

Numerous events are organised to expose students to industry professionals: visits to industrial sites, company presentations at ENSIC, in particular during the "Companies Day" organised in Semesters 5, 7 and 9, organisation in Semesters 6 and 8 of the "Careers Day" with ENSIC Alumni, meetings with industrialists on site or at ENSIC via conferences, participation in forums such as Forum Horizon Chimie. This should enable students to choose their career path: small or large companies, preferred sector of activity, production or research profession, etc.

Finding your first job

Intensive preparation for job interviews is carried out using a variety of methods, including learning how to write CVs and covering letters, and role-playing through simulated interviews.

Mentoring scheme co-sponsored with ENSIC Alumni
At the beginning of the academic year, new entrants receive information about the mentoring scheme run jointly with ENSIC Alumni. On a voluntary basis, an engineering student is assigned a mentor and, like the mentor, signs the mentoring charter, which includes a commitment to minimal interaction during the academic year. Details of exchanges between mentor and mentee are confidential. The aims of mentoring are: to help students better situate themselves in the professional world and to help them better situate themselves in the world of engineering.

the content of their training in relation to its expectations, help students to define their career plans and identify how to build their training pathway accordingly. Participation in mentoring can, if the student so wishes, contribute to the acquisition of skills (see above, "pedagogical organisation and overview of studies").

V. CORE EDUCATION UNITS (Semesters 5 to 7)

Semester 5 teaching units	***ECTS***	***CM/TD***	***TP***	***Tutoring***	***Total On-site***
Organic chemistry I	5	60	28		88
Reactive systems and processes I	6	72	32		104
Thermodynamics and energy	4	60			60
Transfer phenomena I	3	48			48
Computer science, numerical methods and statistics	6	88		6	94
Management and Economics I	3	40			40
Languages I	3	40			40
TOTAL	**30**	**408**	**60**	**6**	**474**
Teaching units in Semester 6	***ECTS***	***CM/TD***	***TP***	***Tutoring***	***Total On-site***
Inorganic chemistry	5	52	28		80
Chemistry and analytical engineering	5	48	32		80
Reactive systems and processes II	4	60			60
Reactive systems and IT	4	24		6	30
Transfer phenomena II	5	51,5	32	4,5	88
Management and Economics II	3	34	6		40
Languages II	3	40			40
Industry, Society & Environment Conferences I	1	21			21
TOTAL	**30**	**330,5**	**98**	**10,5**	**439**
Semester 7 teaching units	***ECTS***	***CM/TD***	***TP***	***Tutoring***	***Total On-site***
Polymer chemistry	3	23	29		52
Industrial processes and sustainable development	7	79	24		103
Transfer phenomena III	3	32	24		56
Thermal separation processes	5	56	24		80
Process systems engineering	5	68			68
Management and Economics III	2	24			24
Languages III	3	40			40
Options	1	12			12
Industry, Environment & Society II	1	16			16
TOTAL	**30**	**350**	**101**	**0**	**451**
TOTAL COMMON TRACK SEMESTERS 5 to 7	***90***	***1088,5***	***259***	***16,5***	***1364***

CM: lectures; TD: tutorials; TP: practical work:
1 hour of classroom-based CM/TD corresponds to 1.75 hours of personal student work, 1 hour of classroom-based TP corresponds to 1.5 hours of personal student work,
1 hour of face-to-face tutoring corresponds to 10 hours of personal student work,

The number of hours of personal work per student is approximately 2,480 for the entire core curriculum.

VI. SPECIALISATION COURSE EDUCATION UNITS (Semesters 8 to 10)

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

Teaching units in Semester 8	*ECTS*	*CM/TD*	*TP*	*Tutoring*	*Total On-site*
Management and Economics IV	2	32	8		40
Languages IV	2	44			44
Industrial project	6	17,5		18	35,5
Work experience	4				
Opening project	3	20		6	26
Options	1	16		2	18
Specialisation pathway: Processes for energy and the environment					
Reactors and multiphase separations	4	60			60
Sustainable Processes	4	28,5		7,5	36
Process design and simulation	4	58,5			58,5
Specialisation: Innovative products: from chemistry to processes					
Micro and nanostructured products	4	60			60
Introduction to product engineering	4	28,5		7,5	36
From molecules to products	4	36	24		60
Specialisation: Biotechnology processes					
Introduction to biological sciences	4	60			60
Biocatalysts and bioreactors	4	30		6	36
Bioseparations	4	40	20		60

TOTAL	**30**				**319**

Semester 9 teaching units	*ECTS*	*CM/TD*	*TP*	*Tutoring*	*Total On-site*
Management and economics V	2	40			40
Language V	3	48			48
Option	3	16		3	19
Research and development project	10				
Specialisation pathway: Processes for energy and the environment					
Process engineering and energy	4	60			60
Dynamic optimisation and advanced control	4	40		6	46
Process intensification and innovation	4	24		9	33
Specialisation: Innovative products: from chemistry to processes					
Speciality products	4	59,5			59,5
Product properties and quality	4	62,5			62,5
Case study - innovative product design project	4	24		9	33

TOTAL	**30**				**Approx. 254[a]**

Semester 10 teaching unit	*ECTS*
Engineering internship	**30**

PRESENTIAL FULL COURSE: SEMESTERS 5 to 10	***Approximately 1935 h[a]***

CM: lectures; TD: tutorials; TP: practical work

[a] The exact number depends on the specialisation path chosen (the difference being 16hrs)

Timetable by teaching unit and by pathway :

COMMON MODULES:
Manager: Olivier HERBINET

Teaching units	***Manager***	***H***	***ECTS***
Management and economics V	Vera IVANAJ	40	2
Languages V	E. KASMAREK/M. ADRIAN	48	3
Research and Development Project	Olivier HERBINET	238/ 193,5[1]	9
Specialisation courses (see details in the tables below)		75,5/ 120[1]	8
Batch process engineering	Olivier HERBINET	66	4
Design and operation of multi-product facilities	Olivier HERBINET	92,5	4
PROCEDIS engineer internship	Olivier HERBINET		30
TOTAL		**560**	**60**

[1] *According to specialisation path*

SPECIALISATION COURSE: Processes for energy and the environment
Manager: Sabine RODE

Teaching units	***Manager***	***H***	***ECTS***
Process engineering and energy	Olivier HERBINET	42,5	4
Process intensification and innovation	Jean-Marc COMMENGE	33	4
TOTAL		**75,5**	**8**

SPECIALISATION COURSE: Innovative products: from chemistry to processes
Manager: Cécile NOUVEL

Teaching units	***Manager***	***H***	***ECTS***
Speciality products	Alain DURAND	59,5	4
Product properties and quality	Anne JONQUIERES	62,5	4
TOTAL		**122**	**8**

Educational objectives of the PROCEDIS course in semesters 9 and 10:

The **part common** to both courses aims to reinforce the skills acquired in previous semesters, both in technical and scientific aspects and in economic and managerial aspects:

- Use language effectively and flexibly in social, professional or academic life / Be able to reconstruct facts from written or oral sources in a coherent and detailed manner, demonstrating a solid command of a vast lexical and semantic repertoire / Use techniques and tools to use creative thinking in the context of chemical engineering / Lead a meeting, taking the initiative in a job interview, broadening and developing their ideas / working in a team in English and using 21ème century skills and "soft skills".

- Managing a fictitious company in competition with other companies in a simplified economic market.

- Simulate batch chemical reactors with the aim of defining the operating conditions that lead to optimum management of the process / Simulate a process described by ordinary differential, algebraic-differential or partial algebraic-differential equations / Formulate a dynamic optimisation problems / Designing, sizing and analysing the operation of crystallisation and precipitation equipment.

- Applying the methodology for designing a batch unit, which involves building a discontinuous installation on an industrial scale from a chemical synthesis protocol carried out on a laboratory scale / Optimising production in a batch workshop / Mastering the sizing techniques for discontinuous, semi-continuous and continuous equipment forming part of a discontinuous production workshop / Planning and leading a simple project to design an innovative chemical product / Structuring and optimising the creativity of a project team.

- Fulfil an engineering mission by solving complex technical problems (with objectives set in terms of deadlines, costs and quality) / Demonstrate imagination and creativity; be proactive and show autonomy with regard to the mission entrusted / Present concrete conclusions and proposals; provide technical expertise and decision-making assistance; convey a message with force and conviction / Write a report that meets academic and industrial expectations.

Objectives specific to the ***Processes for Energy and the Environment*** *specialisation pathway*

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

- Be capable of analysing and proposing improvements for a given process (determination of limiting phenomena, implementation of an intensification strategy) / Know how to select a membrane separation process according to a set of constraints (nature of the mixture to be separated, target performance, operating conditions) / Be capable of sizing a membrane process for a given application and comparing its performance with other technologies (energy efficiency, productivity) / Understand the importance and interaction between the three pillars of innovation: creativity (generating new ideas); value (in terms of esteem, use and exchange); socialisation (managing change).

Specific objectives of the ***Innovative products: from chemistry to processes*** *specialisation pathway*

- Understanding the specificity and interest of copolymers compared with simple homopolymer mixtures / Performing kinetic calculations, which are prerequisites for sizing copolymerisation reactors / Designing and implementing radical copolymerisation reactors / Formulating and shaping plastics / Taking advantage of the properties of polymers in solution, at interfaces and in emulsion for formulation applications in a variety of fields / Understanding the link between the structural characteristics and the behaviour of products, particularly at interfaces.

- Implement an experimental design / Optimise production in a batch workshop / Design and size a reactor leading to the desired product and address the process-structure-properties relationships / Identify the cause of degradation of a polymer on the basis of information collected in the field / Define a strategy for preventing degradation and implement stabilisers in an appropriate way / Stabilise a polymer in a batch workshop properties / Identify the cause of polymer degradation on the basis of information collected in the field / Define a strategy for preventing degradation and implement stabilisers appropriately / Stabilise a polymer effectively for shaping or during its lifetime / Understand transport in polymers and gels / Model crystallisation processes using population balances, understanding transport in polymers and gels / modelling crystallisation, aggregation and fracture processes using population balances / knowing and applying the main laws of colloid behaviour to the design of a product containing nanoparticles / integrating and actively participating in a project to develop a new product with a specific use function / designing and implementing specific unit operations in the production of nanoparticles.

manufacture of medicines and cosmetics (solid, liquid and cream forms): mixing and granulation, compaction and coating, nano-emulsification and microencapsulation, freeze-drying.

Assessments - Diploma

Assessment of knowledge will take the form of continuous assessment over the entire duration of the course. The research and development project and the end-of-study internship will be specifically assessed in the form of two written reports and a joint oral presentation before a jury made up of at least two members of the ENSIC teaching staff and the industrial tutor.

DETAILED PRESENTATION OF THE COURSE

The course is presented in chronological order of semesters.

For each semester, a summary table indicates the teaching units and their possible division into components. This table gives the names of the teachers responsible for the teaching units and components, as well as the breakdown of hours into lectures (CM), tutorials (TD), practical work (TP), project follow-up (P), industrial conference (C) and assessment (Ex). The number of ECTS credits allocated to the teaching units is indicated.

The syllabus sheets describing the teaching content of the various semester units are presented after the summary table, in the order in which they appear in the table. In addition to the general and specific objectives of the teaching unit, the content and teaching methods are described. The type of assessment is indicated for information purposes, with details of the assessment procedures given in a separate document (assessment procedures, MCC). Useful information on prerequisites and bibliographical references is also provided. Lastly, the number of ECTS credits awarded for the validation of the course and the contribution of the course to the acquisition of competences are indicated in each sheet. Summary tables, semester by semester, are also included.

COURSES IN SEMESTER 5

Pedagogical Supervisor: Axelle ARRAULT

GENERAL ORGANISATION

Title of teaching unit and its components	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Organic chemistry I	Axelle ARRAULT	88[1]	34,5[1]	22,5[1]	28[1]			3[1]	5
Organic chemistry: beginners	Axelle ARRAULT		34,5	22,5				3	
Organic chemistry: advanced	Guillaume PICKAERT		27	18				3	
Organic chemistry support	Axelle ARRAULT		9	3					
TP Organic Chemistry	Guillaume PICKAERT				28				
Reactive systems and processes I	René FOURNET	104	21	46,5	32			4,5	6
Adsorption and heterogeneous catalysis	Laurent MARCHAL-HEUSSLER		2	20,5				1,5	
Homogeneous chemical kinetics	René FOURNET		9,5	13				1,5	
Chemical reaction engineering	Jean-François PORTHA		9,5	13				1,5	
TP Reactive systems and processes I	Yves SIMON				32				
Thermodynamics and energy	Jean-Noël JAUBERT	60	31,5	24,5				4	4
Thermodynamics and energy	Jean-Noël JAUBERT		27,5	17,5				3	
Process engineering reports	Laurence MUHR		4	7				1	
Transfer phenomena I	Huai-Zhi LI	48	20	25				3	3
Computer science, numerical methods and statistics	Jean-Marc COMMENGE	94	31	51,25		6		5,75	6
Computer Science for chemical industries I	Romain PRIVAT		3	19,25				2,75	
Numerical methods	Jean-Marc COMMENGE		10,5	10,5				2	
Statistics	Jean-Marc COMMENGE		5,5	9,5				1	
Modelling project	Dimitrios MEIMAROGLOU					6			
Mathematics support	François LESAGE		12	12					
Management and Economics I	Vera IVANAJ	40	22	14				4	3
Management of people and organisations	Vera IVANAJ		14	14				4	
Hygiene, health and safety at work	Laurent PERRIN		8						
Languages I	E. KASMAREK/M. ADRIAN	40		40					3
English	E. KASMAREK/M. ADRIAN			20					
LV B	E. KASMAREK/M. ADRIAN			20					
TOTAL		**474**							**30**

[1] Volume given for the "Baby" group

EDUCATIONAL UNIT TITLE: **Organic Chemistry I - Level 1**		MANDATORY
	ECTS CREDITS 5	S5

GENERAL OBJECTIVES OF THE TEACHING UNIT

This module aims to :

- Basic knowledge of organic chemistry (knowledge of the properties and reactivity of the various functions present in organic molecules).
- Provide the basic concepts essential for understanding the reactivity of organic compounds (detailed reaction mechanisms for each function)
- To provide food for thought that will lead to a better understanding of the mechanisms studied

SPECIFIC OBJECTIVES

At the end of this module, students should be able to:

- Predicting the reactivity of organic molecules
- Using commercial products to design high added-value organic molecules
- Predict or also explain the formation of by-products during a chemical reaction
- Know how to modify the result of a chemical reaction by changing the parameters
- Predict the reaction mechanism of a chemical reaction and its outcome.
- Know and analyse the parameters influencing the result of a reaction
- Know how to use the appropriate tools to analyse and deduce the result of a reaction
- Analysing organic molecules (NMR, IR).

CONTENT AND TEACHING METHODS

Teaching takes the form of lectures, tutorials and practical work. Lecture content :

- Reactivity and properties of organic molecules (classified by function)
- Study of solvents and their influence on the course of a chemical reaction
- Introduction to the tools available to organic chemists for understanding reaction mechanisms. (Hammond postulate, HSAB theory, kinetic and thermodynamic control, etc.).
- Spectroscopic methods for identifying and characterising organic molecules (NMR, infra-red, etc.)

The aim of the tutorials will be to illustrate certain points of the lecture using exercises involving the synthesis and characterisation of organic molecules.

The practical work will enable students to understand the scientific approach required to synthesise an organic molecule. They will have to carry out a multi-stage synthesis of a target molecule. Under the guidance of a teacher, the students will have to synthesise, purify and characterise all the intermediates in each stage.

TYPE OF ASSESSMENT

- Two written exams of 1h30 each (E1 and E2).
- Practical work report to be written in English (TP) Mark = (2E1 + 2E2 + TP)/5

Make-up exam: written exam (1h30)

USEFUL INFORMATION

PREREQUISITE: Organic Chemistry (compulsory support - introduction to organic chemistry - 12h)
TEACHING LANGUAGE: French
Recommended bibliography: Chimie Organique, K. Peter C. Vollhardt, DeBoeck Université

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 4, 5, 8, 11 and 13.

EDUCATIONAL UNIT TITLE: Organic Chemistry I - Level 2		MANDATORY
	ECTS CREDITS 5	S5

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this module is to:

- Give a general overview of reactivity in organic chemistry
- Make students aware of the main fundamental principles that explain a large number of reactions in organic chemistry
- Involve students in the study of real-life industrial applications

SPECIFIC OBJECTIVES

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

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

CONTENT AND TEACHING METHODS

Teaching will take the form of lectures, tutorials, projects and practical work.

The organic chemistry lecture (27 hrs) will be structured in three parts, one for each major class of reaction: addition reactions, substitution reactions, elimination reactions. The course will also be supplemented by the study of five fundamental tools for understanding the principles of reactivity in organic chemistry: Hamond's postulate, kinetic and thermodynamic control, stereochemistry of dynamic processes, solvents and HSAB theory. Finally, an introduction to IR-TF and NMR spectroscopy will also be included in this course.

The tutorials (12 h) will be designed to illustrate certain points of the lecture by means of exercises relating to the synthesis and characterisation of organic molecules.

Tutored projects (6 hours) will give students the opportunity to work in small groups on a bibliographical subject related to the industrial applications of organic molecules.

The practical work (28 hours) will enable students to understand the scientific approach required to synthesize an organic molecule. They will have to carry out a multi-stage synthesis of a target molecule. Under the guidance of a teacher, the students will synthesize, purify and characterise all the intermediates in each stage using NMR and IR-FT spectroscopy.

TYPE OF ASSESSMENT

- Two written exams of 1h30 each (E1 and E2).
- Practical work report to be written in English (TP) Mark = (2E1 + 2E2 + TP)/5

Make-up exam: written exam (1h30)

USEFUL INFORMATION

PREREQUISITES: equivalent organic chemistry option and Baby modules
TEACHING LANGUAGE: French
REFERENCES :

Recommended:

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

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 4, 5, 8, 11 and 13.

EDUCATIONAL UNIT TITLE: **Reactive Systems and Processes I**		MANDATORY
	ECTS CREDITS 6	S5 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The main objectives of the "Reactive Systems and Industrial Processes" module are:

- Analyse industrial processes in terms of material and energy balances
- Study the kinetics of a homogeneous reaction
- Implement this type of chemical reaction in ideal reactors (closed, RPA, piston)
- Acquire basic knowledge of heterogeneous catalysis
- Present and explain the mechanisms involved in surface interactions between solid, liquid and gas phases

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Formulate material and energy balances
- Choosing and sizing a suitable reactor for a given homogeneous chemical transformation
- Know and identify how a reactor works (with or without chemical reactions, type of flow, transient/permanent regime, how material and energy flows are introduced and removed).
- Optimising conversions, yields and selectivity
- Identify the conditions for the stability of exothermic reactors
- Measure the velocity in an ideal reactor and determine the velocity law
- Construct detailed kinetic mechanisms for simple homogeneous reactions
- Be familiar with the main kinetic theories used to calculate the rate constants o f elementary processes
- Identify the presence of interfacial phenomena in material transformation and formulation processes
- Use and interpret gas-solid and liquid-solid sorption isotherms
- Define a catalyst and find out about its properties
- Demonstrate the value of heterogeneous catalysis in controlling the environmental impact of industrial synthesis processes
- Be familiar with the main models of heterogeneous catalytic kinetics
- Knowing, identifying and taking into account the different stages of limitation of a heterogeneous catalytic reaction
- Establishing a rate law for heterogeneous catalysis

CONTENT AND TEACHING METHODS

I. Homogeneous chemical kinetics
    1. General definition and measurement of velocity in different types of reactor
    2. Laws of speed (orders, activation energies)
    3. Speed theories and kinetic principles
    4. Reaction mechanisms in the gas and liquid phases

II. Chemical reaction engineering
    1. Material balances in ideal reactors
    2. Conversion optimisation
    3. Optimising efficiency and selectivity
    4. Energy balances and stability of exothermic reactors

III. Heterogeneous catalysis

1. Definition and structural characteristics of catalysts
2. Stages of a catalytic reaction
3. Ways of expressing the rates of a catalytic reaction
4. Modelling catalytic reactions

Description of teaching methods

The lectures are supplemented by TD sessions organised by ¼ of the class for GRC and catalysis. For the kinetics part, the sessions devoted to TDs correspond to problem-based learning sessions and make it possible to approach certain parts of the course in the form of tutorials. In this case, the sessions are organised by ½ promotion.

The practical sessions last 4 hours and cover the following points:

- Gas-phase kinetics
- Photolysis of pyridine
- Enzymatic catalysis
- Liquid phase kinetics: solvent effect
- Ionic reaction in the liquid phase: salt effect
- Closed adiabatic reactor
- Comparison of closed, perfectly stirred and piston reactors
- Physisorption (BET) and chemisorption (dispersion)
- Photocatalysis
- Hydrogenolysis of butane
- Hydrogenation of butene

TYPE OF ASSESSMENT

Course part: The aim of the assessment carried out as part of this teaching unit is to check the knowledge and skills acquired by the student in the field of chemical reaction engineering, homogeneous kinetics and catalysis applied to industrial processes. A 1.5 hour test is carried out at the end of each unit, i.e. 3 tests in total (kinetics, GRC, catalysis). A make-up test is carried out under the same conditions.
Practical part: Assessment of practical work based on written reports or posters.

The main aim of this written assessment is to measure a student's ability to carry out a practical task aimed at studying the kinetics of a reaction or the operation of a reactor, using the knowledge acquired in class or at the beginning of the practical work, and to assess his/her ability to write a scientific document highlighting the main results obtained.

Share in the final assessment :

Joint assessment:	3/4 of the final mark with the following coefficients for the different subjects: Homogeneous kinetics: coefficient 1; Chemical reaction engineering: coefficient 1; Catalysis: coefficient 1.
Practical work:	1/4 of the final mark

USEFUL INFORMATION

PREREQUISITES: teaching of physical chemistry, mathematics, preparatory school level
LANGUAGE OF TEACHING: French
REFERENCES :
Recommended:

- Livre de Cinétique et Catalyse, G. Scacchi, M. Bouchy, J.F. Foucaut, O. Zahraa, R. Fournet, Tec et Doc, Lavoisier, 2011.
- Livre de Génie de la Réaction Chimique, J. Villermaux, Tec et Doc, Lavoisier, 1993.
- Physical chemistry of surfaces - A.W. Adamson - John Wiley and Sons
- GRC online course: https://sites.cnam.fr/industries-de-procedes/ressources-pedagogiques-ouvertes/GRChomogene/co/0module_GRChomogene.html

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 4, 5, 8, 11 and 13.

EDUCATIONAL UNIT TITLE: **Thermodynamics and Energy**		MANDATORY
	ECTS CREDITS 4	S5 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

Process Engineering Balance Sheet is an introductory course which aims to :

- Introduce the basics of process engineering
- Present the general principles of process diagrams
- Propose a methodology for carrying out material and energy balances
- Raising awareness of the environmental impact of processes through material balances (carbon balance)

More broadly, the Thermodynamics and Energy CE aims to :

- Detail and clarify the principles of thermodynamics and highlight the usefulness of fundamental quantities such as internal energy, enthalpy, entropy, Gibbs energy and Helmholtz energy.
- Learn to estimate the properties of a pure substance (vapour pressure, boiling temperature, quantities of change of state, heat capacities, enthalpy, entropy, etc.) using an equation of state, a diagram, a correlation or the law of corresponding states.
- Explain the operation of a thermal or refrigeration machine
- Describe subsonic and supersonic flows

SPECIFIC OBJECTIVES

At the end of this teaching unit, the student should be able to :

- Understand the basic concepts of process engineering (continuous and batch processes, reactions, separations, recycling)
- Understand and analyse a process from the diagram
- Be able to write and solve a material balance and a heat balance in steady state/transient state, for non-reactive/reactive systems

- Carry out an energy and/or entropy balance on any system (open, closed, steady state or transient)
- Estimate the properties of a pure substance in solid, liquid or vapour form or in two-phase equilibrium.
- Handle the main equations of state used in the chemical industries and the corresponding tables of states
- Know the characteristics of the various elements involved in basic thermodynamic cycles (valve, turbine, compressor, heat exchanger, pump)
- Master the evolution of a fluid flowing in a nozzle (convergent, divergent, Laval) or in a straight-section pipe.

CONTENT AND TEACHING METHODS

I. EC: Process engineering balances

1. Process classification
2. Drawing up industrial process diagrams
3. Material balances for unit processes
4. Calculations for multi-unit processes
5. Material balances in reaction processes
6. Process energy balances
    a. Non-reactive processes
    b. Reactive processes
7. Material balances under transitional conditions

Carrying out a carbon assessment of a lime kiln introduces a few notions about LCA (example of the use of lime).
This course comprises 4 hours of lectures and 7 hours of tutorials. During tutorials, students work in groups of 4 or 5. The teachers circulate to help and guide the students. A detailed answer sheet is distributed to students at the end of the session.

II. EC: Thermodynamics and energy
1. Introduction to the study of thermodynamic systems
2. The first principle for closed and open systems, steady-state and transient conditions
3. The second principle for closed and open systems, steady-state and transient conditions
4. Formalism in thermodynamics :
    4.1. Variations in state functions (VFE)
    4.2. Customs balance sheet concepts
    4.3. Characteristic functions
    4.4. Chemical potential
5. The pure perfect gas
6. Notion of variance
7. The liquid-vapour equilibrium of a pure substance
8. Introduction to energy thermodynamics
    8.1. Compression, expansion, heating and cooling of fluids
    8.2. Simple thermal and refrigeration machines
9. The equations of state for pure real fluids
    9.1. Explicit equations of state in v and P
    9.2. Calculating fluid properties from an equation of state and the c_P of the perfect gas
    9.3. Solving the equilibrium conditions between phases using an explicit equation of state in P
10. The law of corresponding states
11. Chemical reaction
12. Subsonic, sonic and supersonic fluid flows

TYPE OF ASSESSMENT

I. EC: Process engineering balances
- A 1-hour written test.

II. EC: Thermodynamics and energy
- A final test lasting 1 hour 30 minutes or 2 hours.
- Two intermediate tests, each lasting between 30 and 45 minutes.

USEFUL INFORMATION

PREREQUISITES :
- Thermodynamics level BAC+2
- Mathematical tools: differential calculus, integral calculus and functions of several variables.

LANGUAGE OF TEACHING: French

BIBLIOGRAPHICAL REFERENCES :

Recommended:

1. Ghasem, Henda, Material and energy balances for chemical engineering, Principles and practical applications, Ed. De Boeck, 2012
2. J. M. Smith, Hendrick C Van Ness, Michael Abbott. *Introduction to Chemical Engineering Thermodynamics*. The Mcgraw-Hill Chemical Engineering Series.
3. Bruce E. Poling, John M. Prausnitz, and John P. O'Connell. *The Properties of Gases and Liquids*. The Mcgraw-Hill Chemical Engineering Series.
4. Richard E. Sonntag , Gordon J. Van Wylen , Pierre Desrochers. *Applied Thermodynamics*. Published by Erpi.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 2, 3 and 4.

The lessons in this unit contribute indirectly (as resources) to competences 1, 9, 10 and 11.

EDUCATIONAL UNIT TITLE: **Transfer Phenomena I**		MANDATORY
	ECTS CREDITS 3	S5 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The fluid mechanics course aims to :

- Consolidate basic concepts in physics associated with mathematical formalisms
- Acquire knowledge of fluid mechanics in the context of process engineering applications
- Prepare students to have a solid basis for dealing with all types of flows during and after their studies at ENSIC.

SPECIFIC OBJECTIVES

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

- Describe a flow using appropriate tools and, wherever possible, apply an analytical formalism
- Propose a strategy to find a solution in different forms
- Reason and justify the proposed solution in the context of process engineering

CONTENT AND TEACHING METHODS

Description of the different parts of the course (CM)

1. Introduction. Fluid statics. Isobaric surfaces and pressure sensors.
2. Velocity fields, trajectories and streamlines. Eulerian and Lagrangian approach. Differential balances for incompressible fluids. Conservation, Euler and Bernoulli equations.
3. Reynolds' theorem and the integral balances of matter, momentum and energy.
4. Application of fundamental balances (driving accidents, flow measurement, etc.).
5. Newtonian viscosity and friction. Navier-Stokes equations. Notion of non-Newtonian behaviour.
6. Notion of dimensional analysis. Buckingham's theorem. Navier-Stokes dimensionalization and demonstration of similarities. Dimensionless numbers. Models and scaling laws.
7. Laminar, Poiseuille, Stokes and trickle flows. Analytical solutions.
8. The concept of turbulence. The main characteristics. Fluctuations and different scales.
9. Turbulent tangential stresses. Turbulence in pipes. Wall friction and pressure drop.
10. Pipe components. Singularities, manual and servo valves, flowmeters, pumps.
11. Boundary layers and wakes.
12. Friction and drag coefficients. Terminal displacement speed.
13. Notions of two-phase flows. Understanding complex fluid flows.

Organisation of tutorial sessions in line with the progress of lectures with 4 groups of students

TD 1: Molecular phenomena. Hydrostatics. Internal pressure and gravity. TD 2:
Hydrodynamics of perfect fluids.
Task 3: Application of Bernoulli's equation.
Task 4: Principle of dimensional analysis. Task
5: Application to model theory. Task 6:
Laminar flows.
Task 7: Turbulent flows. TD 8:
Circuit elements.
TD 9: Ageing of pipes and pumps.

Task 10: Operation of pumps and fans. TD 11: External
flows and boundary layers.

TYPE OF ASSESSMENT

Assessment of two 1.5 hour part-exams in the form of a written examination with all documents authorised.

USEFUL INFORMATION

PREREQUISITES: basic concepts in physics
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :
Required: handout and exercise book supplied
Recommended:

1. Physical hydrodynamics (E. Guyon, J-P. Hulin and A. Petit, EDP Sciences 2001)
2. Transport phenomena (R. Byron Bird, Warren E. Stewart and E.N. Lightfood, John Wiley & Sons, Inc. 2002).

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skill no. 2

The lessons in this course contribute indirectly (as resources) to Competency 1

TITLE OF EDUCATIONAL UNIT: **Computer Science, Numerical Methods and statistics**		MANDATORY
	ECTS CREDITS 6	S5 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of the computer science and numerical methods courses is to enable students to solve an engineering problem using numerical calculation. This involves:

- Learning the basics of algorithms
- Familiarising students with languages that enable them to programme the resolution of numerical or data processing problems
- Teaching basic programming techniques, in particular the use of the debugger
- Knowledge of the numerical methods available for obtaining the numerical solution of a physical problem

The main aim of the Modelling Project is to consolidate the concepts covered in the Computer Science and Applied Mathematics course through practical work. Secondarily :
- If the subject lends itself to it, students will be introduced to one or more stages of the modelling approach in the physical sciences (creation of a model, parameterisation, simulation, validation of the model, etc.).
- This project should enable students to discover group work and project management. Finally, it also aims to improve students' ability to present and promote their personal work.

The Statistical Methods course aims to :

- Explain the main statistical concepts and laws of probability involved in the work of a process engineer,
- Understand hypothesis testing and confidence intervals,
- Introduce experimental designs, the associated calculation methods and their interpretation.

SPECIFIC OBJECTIVES

On completion of the IT course, students should be able to:

- Be able to design simple algorithms.
- Produce a calculation code tailored to engineering needs
- Writing a calculation code in Fortran 90
- Understanding and using existing subroutines The

specific objectives of the Modelling Project are :

- Discover how to manage a project with several people: concepts of stages, time management, etc.
- Design a medium-scale computer programme
- Be able to propose a personalised approach and treatment for the subject (demonstrate creativity).
- Writing a report
- Presenting work orally
- Defending and criticising the choices made in terms of programme design and implementation
- If the subject lends itself to it: analyse the results of the calculation, discuss orders of magnitude, the quality of a model, a numerical method, etc.

On completion of the Numerical Methods course, students should be able to:

- Analyse a physical problem and deduce the class of numerical methods required to solve it,
- Transform a physical problem into a numerical solution,
- Know which numerical methods are necessary and available to solve a given physical problem,
- Choose from the available methods according to your objectives: speed, robustness, accuracy.

By the end of the Statistical Methods course, students should:

- Know how to carry out hypothesis tests and estimate confidence intervals,
- Implement experimental designs to obtain a meaningful statistical model.

CONTENT AND TEACHING METHODS

I. IT :

- 3 hours of lectures on the basics of algorithmics and procedural programming
- 20 hours of programming tutorials in Fortran 90 on a PC. The course and the previous tutorials must have been assimilated at each session, which will be verified by a mid-course assessment.
    - Approximately 5 language learning TDs
    - Approximately 5 numerical methods programming tutorials, the algorithms for which will be taken from the course and the numerical methods tutorials.

II. Numerical methods :

1. Interpolation and approximation
2. Digital integration
3. Solving equations using iterative methods
4. Numerical operations on matrices
5. Solving systems of algebraic equations
6. Numerical integration of ordinary differential equations
7. Numerical integration of partial differential equations Each

chapter will be covered in 1? hours of lectures and 1? hours of

tutorials.

III. The Modelling project will be carried out in groups of 2 or 3 students, except in exceptional cases decided by the supervisory team. The technical objectives of the project will be set at the beginning of the course, and will describe the programme specifications. Each group will be allocated a supervisor. The students will then be free to make their own choices within the various parts of the project:

- The first part will be devoted to designing the structure of the programme and, if the subject lends itself to it, to implementing one or more stages of the modelling approach (establishing the model, setting parameters, calculating orders of magnitude, etc.).
- The second part consists of programming the structure defined in part 1 in the language seen in the computer science tutorial. The results obtained will be analysed critically.
- In the third part, students will present their project in writing (through a report) and orally.
- Interim reports (around two) will be written during the project and presented at meetings with the supervisor.

IV. Statistical Methods

- Probability laws, normal, chi2, Student, Fisher-Snedecor
- Hypothesis testing
- Estimation and confidence intervals
- Linear and multi-linear regression
- Design of experiments, analysis of variance

TYPE OF ASSESSMENT

- 1 written computer test of 45 or 50 minutes at mid-course.
- Short quizzes may be given during tutorials to check that the course has been learned.
- 1 final written IT test of 2 hours (TD)
- 1 final written test in numerical methods
- For the Modelling project, the assessment is carried out by the supervisor during the validation stages and meetings, as well as through a written report and a final oral presentation. The assessment covers the quality of the design and programming, as well as project management and personal contributions.
- Statistical methods: Mini-test at the beginning of each tutorial from the second tutorial onwards, counting for 50% of the total assessment.
- Statistical methods: Final exam lasting one hour, 50% of which is counted as part of the course.

USEFUL INFORMATION

PREREQUISITES :

- For numerical methods: mathematical knowledge such a s integration of functions, linear algebra, integration of differential equations, partial differential equations.
- For the Modelling project: computer science and numerical methods courses
- For statistical methods: Matrix operations. Use of a programmable calculator. LANGUAGE OF

TEACHING: French (or English for volunteers)

REFERENCES :

Required:

Use of a programmable calculator in numerical and statistical methods. Numerical and optimisation methods", Jean-Pierre Corriou

Course handouts

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 3, 11 and 12.

The lessons in this course contribute indirectly (as resources) to Competency 4.

EDUCATIONAL UNIT TITLE: Management and Economics I		MANDATORY
	ECTS CREDITS 3	S5 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Identify the human, social, economic and legal issues involved in occupational health and safety (OHS) in the company.
- Incorporating S&ST risk assessment and control into day-to-day practices and projects.
- Explaining differences in individual behaviour, based on Carl Jung's theory of psychological types, using the Myers and Briggs Type Inventory (MBTI).
- Recognising the main dimensions and tools of interpersonal communication (verbal and non-verbal).
- Identifying the content of a CV and covering letter
- Describing and analysing the main aspects of an organisation's operations
- Addressing intercultural issues in the broadest sense, and their implications for a study period or a job in an international context (in France or abroad).

SPECIFIC OBJECTIVES

- Carry out an industrial risk assessment and implement prevention and protection strategies
- Master the variables of personal and professional development, in particular by managing strengths and weaknesses
- Be able to work with others and in a team made up of people with different behavioural preferences
- Ability to speak in public, conduct face-to-face interviews and lead meetings, depending on the people and professional situations encountered
- Be able to put together and adapt an application in response to an internship or job offer
- Carry out an organisational analysis and diagnosis of a company in its sector of activity
- Prepare your international project by being aware of intercultural differences and better understanding intercultural issues

CONTENT AND TEACHING METHODS

Management of people and organisations

1. Self-knowledge :
2. Attitudes and personality; self-image; value system.
3. Interpersonal communication: the registers of verbal and non-verbal communication; basic oral communication techniques;
4. The main professions and sectors of activity in the chemical industry
5. The organisation and how it works: organisational structure, strategy, management system, stakeholders, culture, technology, internal environment, external environment, performance.

Hygiene, Health and Safety at Work

This section is based on the BES&ST (Bases Essentielles en Santé et Sécurité au Travail) reference framework drawn up by the CNES&ST (Conseil national pour l'enseignement en santé et sécurité au travail), which includes representatives of the DGES (Direction Générale de l'Enseignement Supérieur) and the CNAM-TS (Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés).

1. Introduction to health and safety at work.
   - 1.1 History and development of regulations (Labour Code)
   - 1.2 The European REACH and CLP regulations
   - 1.3 Risk assessment methodology
2. The human, social, economic and legal issues involved in OH&S.

    2.1 Employee representative bodies
    2.2 French and European safety agencies
3 The mechanisms behind an accident at work.
4 Preparation for the industrial integration placement: Discovery of the business world during a day organised jointly by the Research, Industrial Relations and External Relations Departments. It gives new students the opportunity to discover the business world through round tables attended by a number of industrialists.

"Cultural Sensitisation
Definition of "Culture". Study of intercultural aspects: the notion of time, body language, proxemics (Edward T. Hall), kinesics. Study by John Mole: "Organisation and Leadership" in European companies. Discussion in small groups.

TYPE OF ASSESSMENT

Case studies; Written report and oral presentation; Written examination

USEFUL INFORMATION

PREREQUISITES: None
TEACHING LANGUAGE: French and English
BIBLIOGRAPHICAL REFERENCES
Required:

1. Repères pour le travail à l'usage des ingénieurs, élèves et débutants" booklet designed for ANACT (Association Nationale d'Amélioration des Conditions de Travail) by an educational network of INRS (Institut National de Recherche et de Sécurité), of which ENSIC is a member.
2. Notes documentaires de l'INRS.
3. Handouts for all courses
4. Case studies and videos illustrate the methodological elements of risk analysis

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 8, 11 and 12.

EDUCATIONAL UNIT TITLE: Languages I		MANDATORY
	ECTS CREDITS 3	S5 COMMON CORE

LVA: English

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Enable students to take greater responsibility for their own learning.
- Develop language skills to reach/maintain level B1/B2/C1/C2 cfr: CEFR or CTI 2010 description.
- Develop the professional skills needed to work in a company or research laboratory in an international context (in France or abroad).
- Develop the skills of the 21e century: learning and innovation skills, information, media and technology skills, social and professional skills.
- Aspects of sustainable development dealt with in the project according to the objectives and choices of the students. (Describe the concepts of planetary limits, biodiversity, ecosystem services, societal objectives (SDGs), Illustrate the principles and contributions of the scientific approach).

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Identify their level of English and their needs in order to communicate in English.
- Self-assessment.
- Use tools to manage their personal project.
- Understand the essential content of concrete or abstract topics in complex text, including technical discussions in their field.
- Communicate with a degree of spontaneity and ease such that a conversation with a native speaker involves no strain for either party.
- Express yourself clearly and in detail on a wide range of subjects.
- Writing CVs and emails.
- Write a chemical engineering laboratory report.

CONTENT AND TEACHING METHODS

- Analyse and evaluate their own level of English on entry to ENSIC (B1/B2/C1/C2) and their skills in English in everyday and professional life.
- Define their needs to improve their level of English and develop their general and professional skills in English.
- Working in pairs/teams on their objectives, finding the right documents and analysing the results achieved.
- Use a tool to guide their work.
- Presentation of different types of CV (chronological, functional, etc.), functional language for writing letters, formal and informal e-mails. Vocabulary and terms specific to ENSIC.
- Presentation of chemical engineering and scientific practical work reports. Functional language for describing a chemical engineering laboratory experiment.

TYPE OF ASSESSMENT

- Validation (grade between 3-5): 1) Personal project report and teacher's assessment 2) CV
- Resit exam: Personal work or CV

USEFUL INFORMATION

PREREQUISITE: minimum level: B1 (cfr: CTI 2010 Description, or CEFR)
TEACHING LANGUAGES: English
REFERENCES :

Required:

LVB

GENERAL OBJECTIVES OF THE TEACHING UNIT

- To consolidate and acquire a solid level of competence and a good command of German, Spanish, Italian and French in the four skills: oral and written comprehension and expression. Level A2/B1/B2 cfr: CEFR or CTI 2010 description
- Developing professional skills.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Understand isolated sentences and frequently used expressions related to areas of most immediate relevance (e.g. simple personal and family information, shopping, local environment, work).
- Communicate in simple and routine tasks requiring only a simple and direct exchange of information on familiar and routine matters.
- Using simple means, describe your background and immediate environment and talk about subjects that correspond to your immediate needs.
- Deepen your knowledge to master lexical, semantic and grammatical fields,
- Understand and summarise authentic written and spoken documents in a variety of fields: social, cultural, professional and economic.
- (specific to French courses) Benefit from an intercultural experience by setting acculturation objectives to be achieved over the course of the year.

CONTENT AND TEACHING METHODS

- Use of a variety of documents - written, video, audio, websites - with oral training through "peer work", discussions, role-playing and simulations, covering a range of areas: social, cultural, economic, scientific and professional life.

TYPE OF ASSESSMENT

- Validation: validation of skills acquired: various continuous assessment tests (oral, written)
- Remedial: oral and written test

USEFUL INFORMATION

PREREQUISITE: minimum level: A1 (in LVB) (cfr: CTI 2010 description, or CEFR) TEACHING LANGUAGES: German / Spanish / Italian / French
REFERENCES :
Required:

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 13

The lessons in this course contribute indirectly (as resources) to Skill 10

COURSES IN SEMESTER 6

Pedagogical Supervisor: Axelle ARRAULT

GENERAL ORGANISATION

Title of teaching unit and its components	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Inorganic chemistry	Mohammed BOUROUKBA	80	33	16	28			3	5
Inorganic chemistry	Mohammed BOUROUKBA		33	16				3	
TP Inorganic Chemistry	Dominique PETITJEAN				28				
Chemistry and analytical engineering	Véronique SADTLER	80	10	33	32		2	3	5
Ion chemistry in solution	Fabrice MUTELET		2	12				0,75	
Electrochemistry and corrosion	Cornélius SCHRAUWEN		4	10				0,75	
Methodology - Spectrophotometry - Chromatography	Véronique SADTLER		4	11			2	1,5	
TP Chemistry and Analytical Engineering	Véronique SADTLER				32				
Reactive systems and processes II	Eric SCHAER	60	22	32				6	4
Heterogeneous reaction engineering	Eric SCHAER		8	14				2	
Separation processes I	Eric FAVRE		14	18				4	
Reactive systems and IT	Guillain MAUVIEL	30		22		6		2	4
Reactive systems project	Guillain MAUVIEL					6			
IT II	Boris ARCEN/Nicolas BLET			22				2	
Transfer phenomena II	Alexandra GIGANTE	88	18,5	30	32	4,5		3	5
Material and heat transfer	Alexandra GIGANTE		17,5	28				3	
Heat exchanger	Eric SCHAER		1	2		4,5			
TP Transfer phenomena II	Rainier HREIZ				32				
Management and Economics II	Vera IVANAJ	40	24	8	6			2	3
Languages II	E. KASMAREK/M. ADRIAN	40		40					3
English	E. KASMAREK/M. ADRIAN			20					
LVB	E. KASMAREK/M. ADRIAN			20					
Conferences Industry, Environment & Company I	Axelle ARRAULT	21					21		1
TOTAL		**439**							**30**

EDUCATIONAL UNIT TITLE: Inorganic Chemistry		MANDATORY
	ECTS CREDITS 5	*S6* *COMMON*

The inorganic chemistry course aims to :

- Acquire the concepts of inorganic physical chemistry
- By systematically using physico-chemical and thermochemical data, engineering students will be able to predict the reactivity of chemical systems and the stability and compatibility of materials used in furnaces, crucibles and reactors.
- Understand the relationship between the chemical and physical properties of solids and their structure

SPECIFIC OBJECTIVES

At the end of this module the student should be able to :

- Establish the link between the structure of matter and the resulting chemical and physical properties
- Understanding, analysing and predicting chemical reactions at different stages of a process.
- Choosing the right materials for a reactor, oven or any part of an installation

CONTENT AND TEACHING METHODS

1. INTRODUCTION TO RADIOACTIVITY (course)
   1.1. Constitution and stability of the core
   1.2. Natural radioactivity and nuclear reactions
   1.3. Artificial radioactivity

2. CRYSTALLOGRAPHY: PRINCIPLES AND USE (lecture/DD)
   2.1. Geometric crystallography
   2.2. Diffraction phenomena, the case of X-rays
   2.3. Experimental equipment and use

3. CHEMICAL REACTIVITY OF MINERAL ELEMENTS AND COMPOUNDS (lecture/DD)
   3.1. Study of the main chemical properties of the elements in the classification
   3.2. Study of chemical reactions in aqueous phases, solids and molten media
   3.3. Use of thermodynamic representations (E-pH, E-pX^-, Ellingham)
   3.4. The main principles of hydrometallurgy
   3.5. Chemical analysis of industrial processes (compound production, metal separation and recycling)

4. EXTRACTIVE METALLURGY/MINERAL PROCESSING AND METAL EXTRACTION (lecture/DD)
   4.1. General: historical and economic aspects
   4.2. Ore characteristics and processing
   4.3. Extractive metallurgy processes
   4.4. Study of equilibria between phases in metallic solutions
   4.5. Thermochemistry of oxides, sulphides and other compounds (chlorides, carbides, nitrides, etc.)
   4.6. Pyrometallurgical transformations in solid and liquid phases
   4.7. Study and analysis of extraction processes for a number of metals (Cu, Ni, Zn, Pb, Al)

5. RELATIONSHIP BETWEEN PROPERTIES AND STRUCTURE OF SOLIDS (lecture/DD)
   5.1. Nature of bonds and cohesive energy of solids
   5.2. Crystal lattice and periodicity of physical properties.
   5.3. Charge and energy transport in solids
   5.4. Metals: Free electron gas model

5.5. Semiconductors and insulators: Electron-lattice interaction and energy bands

PRACTICAL WORK :
A participative teaching approach is used, with bibliographical research to set up an experimental protocol and the writing of a practical report.

The subjects covered are often related to industrial processes. They cover the 4 main synthesis routes in inorganic chemistry:

- High-temperature dry process
- Chemical route in solution
- Electrochemical route in solution or molten medium
- Metallothermy.

Raising awareness of safety and environmental issues:

- Search for information on the toxicity and hazards associated with the chemicals handled
- Taking into account the treatment of gaseous effluents from manipulations in the experimental protocol.
- Management of solid and liquid residues at the end of handling

TYPE OF ASSESSMENT

Continuous assessment (written: 1er part in April (2h), 2ème part in June (2h))
Graded practical work reports: The practical work grade takes into account the student's work in the laboratory, their compliance with safety and environmental instructions and their bibliographical research on the subject.

Overall mark for the module = (Test mark x 0.75 + Practical work mark x 0.25)

A 3-hour written exam covering the entire programme is required.

USEFUL INFORMATION

PREREQUISITES :
Notion of chemical elements, periodicity of physico-chemical properties and periodic classification, electronic structure of atoms and chemical bonding. Basics of chemical reactions, the Acid/Base and Red/Ox concepts and notions of thermochemistry.

LANGUAGE OF TEACHING: French

REFERENCES :

Required: Handouts provided
Recommended: Indicated at the end of the course handouts

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 2, 5, 6, 8, 11 and 13.

The lessons in this unit contribute indirectly (as resources) to competences 3, 4 and 5.

EDUCATIONAL UNIT TITLE: Chemistry and Analytical Engineering		MANDATORY
	ECTS CREDITS 5	S6 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

Acquire basic knowledge of chemical and physico-chemical analysis methods in order to master the various aspects of an analytical process, from sampling to the exploitation of results. Apply this methodology to the analysis of a real system.
To provide the basic concepts essential for a phenomenological understanding of corrosion

SPECIFIC OBJECTIVES

At the end of this module, the student should be able to apply the concepts of analytical methodology, which implies:

- Determine the relevant chromatographic methods and conditions
- Choose the appropriate spectroscopic techniques for the analytes in question and implement the quantification methods, taking account of sample matrix effects where necessary
- Understand chemical equilibria in aqueous solution and solve problems involving these equilibria
- Using current-potential curves
- Carry out analyses using volumetric and instrumental methods (chromatography, spectroscopy, electrochemistry)
- Choosing materials for chemical industry processes, taking into account their resistance to corrosion, diagnosing a number of forms of corrosion and choosing appropriate anti-corrosion methods.

CONTENT AND TEACHING METHODS

1. Chemistry of ions in solution (CIS): (12h)

    1.1 Activity and activity factor
    1.2 Electrodes and Batteries
    1.3 Chemical equilibria (precipitation, complexation, acid-base, oxidation-reduction)

2. Chromatography: (5h)

    2.1 Theoretical basis of analytical chromatography
    2.2 Gas chromatography, instrumentation and applications
    2.3 Liquid chromatography, instrumentation and applications
    2.4 Supercritical phase chromatography Industrial
    conference: preparative chromatography

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

    3.1 Electrochemical kinetics
    3.2 Building a network of curves
    3.3 Applications - choosing an electrochemical analysis technique

4. Corrosion: (8h)

    4.1 Uniform corrosion
    4.2 Corrosion piles
    4.3 Corrosion protection methods

5. Analytical Methodology (14h)

    5.1 The different stages of chemical analysis
    5.2 Spectroscopic methods
    5.3 Analytical chemistry applications

5.4 Industrial conference: the role of analytical chemistry in industry

6. Practical work: 32 hours for students

This is work in the form of a group project, consisting of determining the chemical composition of a real product under the supervision of a referent teacher. The systems studied concern the environment (water, fertilisers) and nutrition (food supplements), as well as materials (alloys). After a preliminary bibliographical search for applicable analytical methods, the practical project consists of using or setting up experimental protocols, carrying out multiple analyses (volumetric, spectroscopic, gravimetric, electrochemical, chromatographic) and processing the results statistically. At the end of the project, an oral presentation will be given to all the students, showing the methods used and the results obtained. A written report of all the experiments and results will also be produced.

TYPE OF ASSESSMENT

Written exams (3h)
Group work
Practical work (assessment of preparation; assessment of experimental practice and theory - written assessment of results and their interpretation / discussion) - oral presentation

USEFUL INFORMATION

PREREQUISITE : Basic chemistry
TEACHING LANGUAGE : French
BIBLIOGRAPHICAL REFERENCES :
Required:
Recommended:

1. Analytical Chemistry by Skoog/West/Holler; publisher: DeBoeck Université
2. Electrochimie analytique et réactions en solution by B. Tremillon; publisher: Masson
3. Chromatographie en phase liquide et supercritique by R. Rosset; publisher: Masson
4. Manuel pratique de chromatographie en phase gazeuse by J. Tranchant, publisher: Masson

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this unit contribute directly to the acquisition of competences 1, 2, 3, 5, 8, 11 and 13 The lessons in this unit contribute indirectly (as resources) to competency 6.

EDUCATIONAL UNIT TITLE: Reactive Systems and Processes II		MANDATORY
	ECTS CREDITS 4	S6 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Reactive Systems and Processes II module aims to :

- Understanding the coupled transport and reaction processes observed in catalytic and heterogeneous reactions
- Explain the concepts used to describe these phenomena
- Understanding and choosing reactors that reduce the need for resources and environmental impact
- Design and optimise reactors for catalytic and heterogeneous reactions

- Acquire basic knowledge of isothermal separation processes (absorption, liquid-liquid extraction, adsorption, membranes), both simple and staged.
- Explain the concepts behind the various separation operations
- To enable students to choose and size the appropriate type of separator for a given situation

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Understand, identify and take into account the various transport processes involved in a heterogeneous gas-solid or fluid-fluid reaction,
- Apply the concepts used to design heterogeneous and catalytic reactors

- Understanding the main separation processes used in industry
- Master the principles on which they are based, as well as the concepts and models that enable them to be analysed
- Apply sizing methods for the main types of process

CONTENT AND TEACHING METHODS

Description of the different parts of the course

1. Heterogeneous Reaction Engineering
   1.1. Presentation of the main industrial heterogeneous reactors,
   1.2. Heterogeneous gas-solid catalytic reactions,
      1.2.1. Coupling transport & reaction
      1.2.2. Notions of external and internal diffusional limitations
      1.2.3. Calculation of catalyst efficiency factors
   1.3. Implementation of non-catalytic gas-solid reactions, Shrinking core model,
   1.4. Implementation of gas-liquid reactions, Hatta criterion & Acceleration factor.

2. Separation Engineering
   2.1. Introduction
   - Classification of operations, separating agents,
   - Notion of minimum separation work
   2.2. Break-even floor operations :
   - Notion of theoretical floor
   - Multi-stage devices (crosscurrents, countercurrents): analytical and graphical resolution,
   - minimum solvent flow rate
   - Tray efficiency and material transfer
   - Progressive exchanger
   - Methodology for sizing an installation

2.3. Gas-liquid absorption and stripping :
- Industrial applications
- Elements of plant technology
- Absorption with solvent regeneration

2.4. Liquid-liquid extraction :
- Industrial applications
- Theoretical single-stage extraction (graphic resolution)
- Sizing a counter-current column (operating curve, theoretical number of stages),
- minimum solvent flow rate)
- Basics of supercritical solvent extraction

2.5. Adsorption & chromatography :
- Types of adsorbent and main applications
- Notion of resolution factor
- General equation (differential balance) and notion of front propagation speed
- Adsorption in plug flow: Rosen's analytical solution

2.6. Membrane separation :
- Typology of membrane separations
- Notion of ideal separation factor
- Gas permeation: applications and methodology for sizing an installation
- Reverse osmosis: the concept of osmotic pressure and industrial

applications Description of teaching methods :

Classes are supplemented by practical sessions. Each class session is supplemented by (at least!) one tutorial session, organised by class quarter.
The practical sessions relating to these courses take place in Semester 7 and are presented in the "Industrial processes and sustainable development" module sheet.

TYPE OF ASSESSMENT

Three written exams, one on Heterogeneous Reaction Engineering (2 hrs), and two others on Separation Engineering (2 x 1h30).

The aim of the assessment will be to check the acquisition of basic knowledge in the various fields, and the skills acquired by applying the concepts to a real problem. Through this real case, the student will have to predict the performance of a heterogeneous reactor and then separation processes.

USEFUL INFORMATION

PREREQUISITE: - "Reactive systems and processes I" teaching unit
- Notions of material balances and transfer phenomena TEACHING

LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES: Online HRM course: HTTPS://GPIP.CNAM.FR/RESSOURCES-PEDAGOGIQUES-OUVERTES/GRH_ENSIC/CO/0MODULE_GRCPOLYPHASIQUE.HTML

Required:
- Course handouts
- A list of recommended books is given in the course handout.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skills 2, 4 and 5.

The lessons in this course contribute indirectly (as resources) to Competency 9.

EDUCATIONAL UNIT TITLE: Reactive Systems and Computing		MANDATORY
	ECTS CREDITS 4	S6 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of the Reactive Systems project is to enable students to design a complex industrial reactor using a combination of skills in kinetics, GRC, numerical methods and computer science. Although most of this teaching is carried out in the previous semester (S5), it is nevertheless necessary to introduce new computer software (Matlab and VBA) which have become standard tools for process engineers.
This project integrates historical and prospective dimensions to place the reactor in question in its industrial and societal context.

SPECIFIC OBJECTIVES

On completion of this course, students should be able to :

- Writing calculation code in VBA and Matlab
- Understand and use existing sub-programs (in VBA and Matlab)
- Using MS-Excel to process complex data (requiring programming)
- Analyse a detailed chemical kinetic mechanism and deduce the relevant kinetic information for sizing the reactor
- Use optimisation methods to determine speed constants
- Modelling the industrial reactor by formulating coupled material/energy balances
- Design a complex computer programme to simulate the industrial reactor by numerically solving the model
- Analyse and criticise the simplifying assumptions proposed in the project
- Working in a group and writing a multidisciplinary scientific report

CONTENT AND TEACHING METHODS

IT tools :

- 5 tutorials (2h) on using and programming Matlab: concepts, matrix calculation, integration, integration of differential systems, function plotting, optimisation, etc.
- 6 tutorial sessions (2 hours) on using and programming MS-Excel (VBA): learning the language, complex data processing, graphical interfaces, event-driven programming basics, etc.

Reactive Systems Project :
The project is carried out in groups of 4 students. The project is divided into 2 parts:

- The first part involves studying the complex reaction scheme from which the students must deduce a certain amount of kinetic information (stoichiometries and rate laws). Using pseudo-experiments corresponding to a theoretical reactor (provided to the students) and by running a Matlab computer programme, they carry out a numerical optimisation procedure to determine the rate constants of the stoichiometries obtained previously.
- In the second part, the students model and simulate an industrial reactor that implements the reaction scheme studied in the first part.

Throughout the project, the students can discuss the problems they encounter with three referent teachers who are specialists in one of the areas covered (kinetics, GRC, IT). These discussions are supervised during 3 follow-up sessions.

TYPE OF ASSESSMENT

Skills in VBA and Matlab are assessed in a 2-hour exam.

The project is assessed on the basis of two interim reports, an individual MCQ and a final report, as well as an oral presentation during which the students in the same team take it in turns to summarise their work (20 min) and answer questions from three teachers. The final mark for the project is calculated as the average of 5 marks corresponding to the 2 RCs (10% each), the individual MCQs (25%), the final report (35%) and the oral presentation (20%).

The final grade for the UE is the average of the 2 constituent elements: IT tools (2 ECTS) and Reactive Systems Project (2 ECTS).

The make-up session for the Reactive Systems project consists of a subject provided to the student concerned at the end of the exam in semester 6. This project is the subject of a single individual report submitted to the teaching staff. The make-up session for the Computer Tools CE consists of a 2-hour examination.

USEFUL INFORMATION

PREREQUISITES: S5 courses on reactive systems, computer science and applied mathematics. TEACHING LANGUAGE: French

REFERENCES :

Required:

1. Cinétique et Catalyse, G. Scacchi, M. Bouchy, J.F. Foucaut, O. Zahraa, R. Fournet Tec et Doc, Lavoisier, 2011.
2. Méthodes Numériques et d'Optimisation: théorie et pratique pour l'ingénieur, J.P. Corriou, Tec et Doc, Lavoisier, 2010.

Recommended:

1. Génie de la Réaction Chimique, J. Villermaux, Tec et Doc, Lavoisier, 1993.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 2, 3, 4 and 11.

EDUCATIONAL UNIT TITLE: Transfer Phenomena II		MANDATORY
	ECTS CREDITS 5	S6 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The heat and mass transfer course aims to :

- Learn to draw up an energy balance for a physical process and an industrial installation, taking into account heat transfer by convection, conduction and radiation.
- Learn to draw up a balance sheet for each chemical species in an industrial installation, taking into account diffusive and convective transfers.
- Detailing and understanding radiative transfers
- Detail and understand the analogy between heat transfer and matter transfer
- Detail the operation and sizing of a heat exchanger

SPECIFIC OBJECTIVES :

At the end of this module the student should be able to :

- Draw up a heat and mass balance for an industrial installation, focusing on the most important phenomena and ignoring secondary phenomena.
- Choosing and sizing an industrial heat exchanger.

CONTENT AND TEACHING METHODS :

1. Heat transfer by diffusion, Fourier's law, examples of one-dimensional heat diffusion, transient diffusion, numerical methods for solving the diffusion equation. 6 h of lectures, 6 h of tutorials, 1 h of assessment

2. Forced convection determination of heat transfer coefficients in internal and external flows in laminar or turbulent regime. Natural convection, Grashof and Rayleigh numbers, hydrodynamic stability, critical Rayleigh number in certain simple cases. Mixed convection. 7.5 h of lectures, 9 h of tutorials and 1 h of assessment.

3. Radiative transfers, black body concept, Planck's law. Calculation of the form factor between two bodies. Notion of grey bodies. Radiative calculations in absorbing media. 1.5 h lecture, 1.5 h tutorial

4. Matter transfer by diffusion, Fick's law, steady-state and transient diffusion. Diffusion in solids. 6hrs lecture, 6hrs tutorial, 1hr assessment.

5. Description and operation of heat exchangers, 1hr lecture, 3hrs practical work, 5hrs project

TYPE OF ASSESSMENT :

The Heat and Matter Transfer course is assessed by exams throughout the semester (3*1 h of assessment), continuous assessment. The heat exchanger project counts for ¼ of the final grade. The practical work counts for ¼ of the final mark.

USEFUL INFORMATION :

PREREQUISITES: S5 Fluid Mechanics course
LANGUAGE OF TEACHING: French or English
BIBLIOGRAPHICAL REFERENCES :
Required:

1. Les bases de la mécanique des fluides et des transferts de chaleur et de masse pour l'ingénieur, E. Saatdjian, Editions Sapientia, 2009.
2. Transport Phenomena, equations and numerical solution, E. Saatdjian, John Wiley, 2000

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 2, 4, 8, 11 and 13.

The lessons in this course contribute indirectly (as resources) to competences 3, 9 and 14.

EDUCATIONAL UNIT TITLE: **Management and Economics II**		MANDATORY
	ECTS CREDITS 3	S6 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Identify the human, social, economic and legal issues involved in occupational health and safety (OHS) in the company.
- Incorporating S&ST risk assessment and control into day-to-day practices and projects
- Knowing how to analyse and model a workstation
- Introduction to quality (different types of audits, standardisations usually encountered, cost of quality and non-quality)
- Corporate social responsibility (CSR), code of conduct (managing conflicts of interest), ethics and professional conduct.
- Understand the main dimensions of company management by analysing its three main functions: accounting and financial management, marketing and information systems management.
  - Describe and apply the basic principles of accounting through accounting records and summary documents. Analyse the factors influencing the accounts
  - Know how to analyse and understand how markets work, the specific characteristics of consumer behaviour and marketing strategy
  - Learn how to introduce and integrate information systems into an organisational structure, taking into account their impact on the organisation's other activities.

SPECIFIC OBJECTIVES

At the end of this module the student should be able to :

- Carry out a risk analysis at the workstation and choose the best means of prevention and protection
- Correct, adapt or design work situations
- Conducting a financial analysis by mastering the main tools and means of analysis
- Conducting market research and developing a marketing strategy
- Develop a conceptual and physical database model

CONTENT AND TEACHING METHODS

Hygiene, Health and Safety at Work

This section is based on the BES&ST (Bases Essentielles en Santé et Sécurité au Travail) reference framework drawn up by the CNES&ST (Conseil national pour l'enseignement en santé et sécurité au travail), which includes representatives of the DGES (Direction Générale de l'Enseignement Supérieur) and the CNAM-TS (Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés).

1. The basic concepts of health and safety at work lead us to draw up a general framework for study known as the "activity-centred work system"; taking activity into account is essential for correcting, adapting or designing work situations.
2. Risk assessment in the workplace
3. Chemical risk and the European REACH and CLP regulations.
4. Preparation for the industrial integration course

Finance and accounting

1. The basic principles of accounting.
2. Accounting records and summary documents. Analysis of factors affecting the accounts.

3. Introduction to financial analysis (tools and means of analysis), intermediate management balances, cash flow, functional analysis of the balance sheet and the cash flow statement, financial equilibrium and identification of risks, formal diagnosis.

Marketing
1. Market analysis: the concept of the market, market demand, market segmentation
2. Studying the consumer: factors that explain behaviour, the consumer buying p r o c e s s , consumer response methods, etc.
3. Market research: qualitative and quantitative studies
4. Marketing strategy

Information Systems
1. The foundations of information systems: introduction to information systems, types, their impact on the activities of organisations, IS integration.
2. Database design: developing a conceptual and physical database model.

Exercises and case studies

Discovering engineering professions: Careers Day
This event is organised jointly by the School's Director of Studies, the Alumni Association and student representatives. A series of round tables involving many of the school's industrial alumni gives new students a first glimpse of the various engineering professions available to them.
Manager: Alexandra Gigante

TYPE OF ASSESSMENT

Exercises and company case studies

USEFUL INFORMATION

PREREQUISITES: none
TEACHING LANGUAGE: French BIBLIOGRAPHICAL REFERENCES :
Required:
1. Repères pour le travail à l'usage des ingénieurs, élèves et débutants" booklet designed for ANACT (Association Nationale d'Amélioration des Conditions de Travail) by an educational network of INRS (Institut National de Recherche et de Sécurité), of which ENSIC is a member.
2. Notes documentaires de l'INRS.
3. Handouts for all courses
4. Case studies and videos illustrate the methodological elements of risk analysis

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 7, 8, 11 and 12.

EDUCATIONAL UNIT TITLE: Languages II		MANDATORY
	ECTS CREDITS 3	*S6* *COMMON*

LVA: English

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Enabling students to take greater responsibility for their own learning
- Develop language skills to achieve/maintain level B1/B2/C1/C2 (see CTI 2010 description, or CEFR)
- Develop the professional skills needed to work in a company or research laboratory in an international context (in France or abroad).
- Developing skills for the 21^{e} century: learning and innovation skills, information, media and technology skills, social and professional skills
  - Aspects of sustainable development dealt with in the project according to the objectives and choices of the students. (Describe the concepts of planetary limits, biodiversity, ecosystem services, societal objectives (SDGs), Illustrate the principles and contributions of the scientific approach).

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Identify their level of English and what they need to communicate in English.
- Self-assessment.
- Use tools to manage their personal project.
- Understand the essential content of concrete or abstract topics in a complex text.
- Communicating with a degree of spontaneity and ease.
- Express yourself clearly and in detail on a wide range of subjects.
- Describe the different phases of a process - a scientific process in chemical engineering - using appropriate vocabulary and syntax.
- Conducting a telephone job interview

CONTENT AND TEACHING METHODS

- Analyse and evaluate their own level of English on entry to ENSIC (B1/B2/C1/C2) and their skills in English in everyday and professional life.
- Define their needs to improve their level of English and develop their general and professional skills in English.
- Working in pairs/teams on their objectives, finding the right documents and analysing the results achieved.
- Use a tool to guide their work.
- Functional language for describing the different phases of a chemical engineering process or system.
- Telephone: Study and acquisition of the specific language used in telephone conversations, training in the use of the telephone; - Role-playing and simulations of job interviews. Recorded simulations of conversations, deciphering and analysis.

TYPE OF ASSESSMENT

- <u>Validation (mark between 3-5)</u>: 1) Personal project presentation and teacher's assessment 2) Telephone simulation.
- Level test: listening comprehension, reading comprehension.

- Remedial: Level test (CO,CE) or homework or telephone simulation.

USEFUL INFORMATION

PREREQUISITE: Minimum level B2 in English (cfr: CTI 2010 Description, or CEFR)
LANGUAGE OF TEACHING: English
REFERENCES :
Required:

LVB

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Consolidate level A2 // B1 (weak groups), reach B2 (strong groups) (cfr: CTI 2010 description, or CEFR)
- Developing professional skills.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Understand and render any written and audio/video document relating to various fields: social, cultural, economic, scientific and professional life
- Writing summaries and brief notes
- Interacting orally in groups, sub-groups or pairs (feedback, exchanges, debates, opinions, analysis), presenting a PowerPoint presentation
- Express themselves clearly and in a well-structured way on complex subjects or in everyday life, express an opinion on a problem, use the language effectively and flexibly in academic and social life.
- Describe the different phases of a scientific process, using appropriate vocabulary and syntax (according to group level).

CONTENT AND TEACHING METHODS

- Use of a variety of documents - written, video, audio, websites - with oral training through "peer work", discussions, role-playing, simulations, covering various areas: social, cultural, economic and scientific life.

TYPE OF ASSESSMENT

- *Validation: validation of skills acquired: various tests and continuous assessment (oral, written)*
- *Level tests: oral and written comprehension.*
- Remedial tests: Oral and written tests or level tests

USEFUL INFORMATION

PREREQUISITE: minimum level: A1 (in LVB) (cfr: CTI 2010 description, or CEFR)
TEACHING LANGUAGES: German / Spanish / French / Italian
REFERENCES :
Required:

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 13.

The lessons in this course contribute indirectly (as resources) to Competency 10.

EDUCATIONAL UNIT TITLE: Industry, Environment & Energy Conferences Company I		MANDATORY
	CREDITS ECTS 1	*S6*

GENERAL OBJECTIVES OF THE TEACHING UNIT

Discover and exchange with external professionals (academic or industrial):

- Certain socio-environmental issues
- The various industrial fields linked to ENSIC.

SPECIFIC OBJECTIVES

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

- Identifying certain socio-environmental issues
- Understanding the diversity of the industrial world
- Visualise the engineer's involvement in the socio-economic world
- To steer your academic career in the right direction

CONTENT AND TEACHING METHODS

The course is based on :

- A 3-hour workshop on certain socio-environmental issues, led by small groups in the form of a metaplan, followed by a presentation in the amphitheatre.
- 12 hours of compulsory lectures by professionals on socio-environmental subjects. For example :
    - Anthropocene & Planetary Limits
    - Social issues & Sustainable Development Objectives
    - Energy supply
    - Climate change: Consequences, Mitigation & Adaptation
    - Water resources (drinking water, river transport, process water, treatment)
    - Corporate Social Responsibility
- 6 hours of industrial lectures to be chosen from various sectors (e.g. Energy, Health, Chemicals, Safety, Cosmetics, Waste treatment, etc.).

TYPE OF ASSESSMENT

Attendance compulsory. Table-top project (if resit exam).

USEFUL INFORMATION

PREREQUISITES: none
LANGUAGE OF TEACHING: French
BIBLIOGRAPHICAL REFERENCES: none

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of competences 9, 14, 15 and 16.

The lessons in this course contribute indirectly (as resources) to Competency 10.

COURSES IN SEMESTER 7

Pedagogical Supervsor: Rainier HREIZ

GENERAL ORGANISATION

Title of teaching and learning unit its constituent parts	***Manager***	***H***	***CM***	***TD***	***TP***	***P***	***C***	***Ex***	***ECTS***
Polymer chemistry	Anne JONQUIERES	52	13,5	8	29			1,5	3
Polymer chemistry	Anne JONQUIERES		13,5	8				1,5	
TP Polymer Chemistry	Carole ARNAL-HERAULT				29			0	
Industrial processes and development sustainable	Alain DURAND	103	43	27,5	24		3	5,5	7
Security	Olivier DUFAUD		14,5	10				2	
Industrial process design	Laurence MUHR		19,5	12			3	2	
Polymerisation process engineering	Alain DURAND		9	5,5				1,5	
TP Reactive systems and processes III	Yann LE BRECH				24				
Transfer phenomena III	Sabine RODE	56	11,5	17,5	24			3	3
Fluid-solid unit operations	Sabine RODE		7	13				2	
Agitation	Cécile LEMAITRE		4,5	4,5				1	
TP Transfer phenomena III	Yann LE BRECH				24				
Thermal separation processes	Guillain MAUVIEL	80	22,5	28,5	24			5	5
Thermodynamics of equilibria between phases	Jean-Noël JAUBERT		13	8				2	
Binary distillation	Guillain MAUVIEL		5,5	9,5				1,5	
Humid air and drying	Guillain MAUVIEL		4	11				1,5	
TP Thermal separation processes	Yann LE BRECH				24				
Process systems engineering	Abderrazak LATIFI	68	19,5	42,5				6	5
CPAO	Abderrazak LATIFI		1,5	18				2	
Optimisation	Abderrazak LATIFI		6	9,5				1,5	
System dynamics and control	Jean-Marc COMMENGE		12	15				2,5	
Management and Economics III	Véra IVANAJ	24	8	8			8		2
Change management	Véra IVANAJ		6	6			8		
Curriculum vitae and covering letter	Alexandra GIGANTE		2	2					
Languages III	E. KASMAREK/M. ADRIAN	40		40					3
English	E. KASMAREK/M. ADRIAN			20					
LVB	E. KASMAREK/M. ADRIAN			20					
Options		12							1
Industry, Environment & Energy Conferences Company II	Guillain MAUVIEL	16					16		1
Industry conferences	Guillain MAUVIEL						16		
TOTAL		**451**							**30**

Options

Option title	***Manager***	***H***	***CM***	***TD***	***TP***	***P***	***C***	***Ex***	***ECTS***
Drug engineering	Axelle ARRAULT	12	5	6				1	1
Photophysical and photochemical engineering	Céline FROCHOT	12	5	6				1	1
A short history of science	Arnaud FISCHER	12	5	6				1	1
Financial and budgetary management	Valérie HENRY	12	5	6		3		1	1
Microfluidics	Thibault ROQUES CARMES	12	5	6				1	1

Biopolymers and biodegradable polymers	Anne JONQUIERES	12	9,5				1,5	1	1

AI for process engineering - First contact	Dimitrios MEIMAROGLOU	12	5	6				1	1
Hydrometallurgical processes	Marie LE PAGE MOSTEFA	12	5	6				1	1
The energy and industrial transition	Guillain MAUVIEL	12	5	7				0	1

TEACHING UNIT TITLE: **Polymer Chemistry**		MANDATORY
	ECTS CREDITS 3	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The polymer chemistry module aims to :

- Introduce the basic concepts of polymers
- Present the different types of polymerisation and their main characteristics
- Describe the polymerisation kinetics and calculate the molar masses obtained

SPECIFIC OBJECTIVES

On completion of the polymer chemistry module, students should be able to:

- Understanding the specificity of macromolecules and their main characteristics
- Choose the type of polymerisation to be used to achieve a given objective
- Identify the advantages and limitations of each type of polymerisation
- Carry out the kinetic and molar mass calculations required to design polymerisation reactors
- Know how to carry out simple polymerisations and be familiar with the most common polymerisation processes

CONTENT AND TEACHING METHODS

The polymer chemistry course will be divided into 4 chapters:

Chapter 1: General information on polymers
Chapter 2. Radical polymerisation
Chapter 3. Ionic and coordination-insertion polymerisations Chapter 4. Step-by-step polymerisation

It will comprise 9 lecture sessions of 1,5 hour, with the course handout corresponding to the slides presented. The lectures will enable students to go into greater depth on the basis of these slides, concrete examples and open questions with the audience. At the end of each chapter, students will be given an unmarked quiz which will be corrected immediately to enable them to self-assess the fundamental knowledge acquired during the course.

The lectures will be used as a basis for problem-based learning during active pedagogy tutorials. The first tutorial will take 2 hours for introducing problem-based learning. It will then be followed by 4 tutorials of 1,5 hour, , which will be spread out according to the progress of the course. The tutorial sessions must be prepared by the students, who must have acquired the main concepts of the corresponding course. The first 4 tutorial sessions will include exercises on the different chapters to be solved by student teams with the teacher. The fifth tutorial session will be used to reinforce the acquisition of knowledge by means of an exercise session focusing on step-by-step polymerisation, a subject that is more difficult for students to grasp, before the 1.5 hour final exam.

29 hours of practical work, spread over 4 days, will complete the polymer chemistry course by enabling students to confront field problems related to polymerisation processes. Practical lessons will focus on the different polymerisation methods and their specific features (emulsion polymerisation, suspension polymerisation, step polymerisation, etc.), and the most common techniques for characterising polymers, particularly their molar masses.

TYPE OF ASSESSMENT

- A final test of 1,5 hours corresponding to the lectures and tutorials, accounting for 2/3 of the final mark.

- Practical work will be assessed by means of multi-skills evaluation forms based on laboratory work, calculations made during lab work and related fundamental aspects, involving individual Multiple-Choice Quizzes. The overall mark allocated to the assessment of practical work will count for 1/3 of the final mark.

USEFUL INFORMATION

PREREQUISITES: basic knowledge of organic chemistry. LANGUAGE OF TEACHING: French

REFERENCES :

Required:

None, as the course handouts, tutorials and practical exercises are the only documents required to follow the Polymer Chemistry course.

Recommended:

1. Chemistry and physical chemistry of polymers, 2ème edition, Michel Fontanille and Yves Gnanou, Dunod, 2010.
2. Chemistry of polymers: synthesis, reactions, degradation, 13ème Volume of the Traité des Matériaux, Jean- Pierre Mercier and Ernest Maréchal, Publisher Presses polytechniques et universitaires romandes, 1993.
3. Principles of Polymer Chemistry, G. Odian, 3ème edition, John Wiley and Sons, 1991.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 4, 5, 8, 11 and 13.

EDUCATIONAL UNIT TITLE*: Industrial Processes and Sustainable Development*		MANDATORY
	ECTS CREDITS 7	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

This teaching unit aims to:

- Acquire a methodology for the multidisciplinary analysis and design of industrial material transformation processes, with an integrated approach that takes account of environmental and safety aspects.
- Complements the basic knowledge acquired in chemical reaction engineering with polymerisation process engineering, integrating the link between polymer structure, process and application properties.
- Experimental approach to the operation and characteristics of homogeneous and heterogeneous reactors.
- Present working conditions, chemical risks, occupational health and process safety regulations.
- Present the main risks associated with industrial processes (fires, explosions, thermal runaway, atmospheric dispersion).
- Introduce the fundamentals and principles of sustainable development.

SPECIFIC OBJECTIVES

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

- To design a complex industrial process in its entirety, including all types of unit operations (reaction, separation, compression, etc.) and integrating environmental and safety constraints from the outset.
- Choosing effluent treatment processes.
- Use the knowledge acquired in different disciplines to carry out an analysis based on physical reasoning and prepare the dimensions of each of the unit operations thus defined.
- Choose a type of reactor and select a polymerisation process to carry out a particular polymerisation reaction.
- Choose the operating parameters for a polymerisation reactor, taking into account performance in terms of yield, productivity and cost, on the one hand, and the characteristics of the macromolecules in relation to the desired properties, on the other.
- Describe the concepts involved in the operation of chemical reactors in a concrete, experimental way.
- Knowing the measures to be taken at the various stages of the design and operation of a process to make it cleaner, more sober and safer.
- To be familiar with and able to apply the main risk analysis methodologies.
- Participate in a hazard study and understand the issues involved in an impact assessment.

CONTENT AND TEACHING METHODS

CE 1. Major industrial processes (35.5 h classroom)

Part I: Inorganic chemical processes Part II:
Refining and petrochemicals
Part III: The nuclear fuel cycle

Water management and off-gas treatment will be integrated into the study of these processes.

CE 2. Polymerisation process engineering (15 h classroom)

Part I: Introduction: structure-process-properties relationship Part
II: Different polymerisation processes
Part III: Design and modelling of radical homopolymerisation reactors

EC 3 Safety and sustainable development (24 h classroom)

The aim of the "safety" section is to teach all the measures to be taken at all stages of the design (intrinsic safety), construction, operation and shutdown of a process in the field of risk prevention and protection. These provisions are studied through :

- different existing legislation (ICPE, Seveso 3, IED, etc.),
- methodologies that can be used (intrinsic safety principle, RPA, HAZOP method, etc.)
- associated basic knowledge (fires, gas and vapour explosions, BLEVE, Boilover, dust explosions, atmospheric dispersion, thermal runaway, etc.)

The section dealing with "sustainable development" aims to teach the fundamentals and principles of Life Cycle Analysis and Product and Process Management during this same life cycle.

CE 4. Reactive systems and processes (24 h classroom)

Crystallisation: population balance, crystalliser model or measurement of the gas-liquid mass transfer coefficient in the presence of a chemical reaction (8h); estimation and experimental determination of the residence time distribution in different types of reactor (4h); study of heterogeneous catalytic reactors (8h); system dynamics (4h); filtration: filter press filtration, cake and cloth resistance (4h). Absorption with and without chemical reaction: absorption of CO_2 in amino acids, absorption of oxygen in water (8h).

Teaching methods

EC 1. takes the form of lessons, tutorials, lectures (1 lecture given by an industrialist) and case studies (4 problem-solving sessions).

EC 2. is given in the form of lectures and tutorials. Tutorial sessions are organised by class quarter.

EC 3. is given in the form of short lectures (1 hour) and long tutorials (2 hours). The tutorial sessions are organised by class quarter and follow a common thread which is the hazard study of an industrial site. EC 4. is given in the form of practical work. The related theoretical concepts are presented in the form of lectures and tutorials in semesters 5 and 6 in the "Reactive Systems and Processes I and II" modules.

TYPE OF ASSESSMENT

- Written test of 3 hours covering EC 1 and EC 2. The assessment will focus on questions that are transversal to several industrial processes covered (without documents) as well as on the analysis of a specific polymerisation process (with documents).
- 1.5 hour written test for EC 3 combined with a group project on part of a hazard study.
- Writing reports on practical work for EC 4.
- The final assessment of the module is based on the intermediate assessments of the four parts, using a weighting based on the number of hours of work per student (face-to-face work, etc.). + personal work).
- A single make-up session will be offered per semester.

USEFUL INFORMATION

PREREQUISITE: Reactive Systems and Processes I and II, Macromolecular Chemistry, "Thermodynamics and energy.

TEACHING LANGUAGE: French

BIBLIOGRAPHICAL REFERENCES :

Required:

1. Laurent A. (2011). Sécurité des Procédés Chimiques - connaissances de base et méthodes d'analyse de risques, Tec&Doc Lavoisier, 2ème edition, Paris.

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. Degrémont, Memento Technique de l'eau, Lavoisier, Paris, 2005, 10th edition.
3. Di Nenno P.J. et 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). Lees loss prevention in the process industries, Elsevier.
7. Mortureux Y., Analyse Préliminaire de Risques, Techniques de l'Ingénieur, SE 4010
8. Génie de la Réaction Chimique, J. Villermaux, Tec et Doc, Lavoisier, 1993.
9. Cinétique et Catalyse, G. Scacchi, M. Bouchy, JF. Foucault, O. Zahraa, Lavoisier, Tec et Doc, 1996.
10. Durand A., Hoppe S., Meimaroglou D., Serra C., Rachet R., Wilson J., Réacteurs homogènes de polymérisation radicalaire, Techniques de l'Ingénieur, AF 6046.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of competences 2, 4, 7, 8, 11 and 13 The lessons in this course contribute indirectly (as resources) to competences 3, 9, 10 and 11.

TEACHING UNIT TITLE: **Transfer Phenomena III**		MANDATORY
	ECTS CREDITS 3	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Transfer Phenomena III module aims to :

- Acquire basic knowledge of the description of multiphase fluid-solid flows: fixed beds and fluidised beds
- Acquire basic knowledge of mechanical fluid-solid separations
- Acquire basic knowledge of agitation
- To enable the student to size the installations associated with the various unit operations mentioned above

SPECIFIC OBJECTIVES

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

- Estimate the hydrodynamic and transfer characteristics of a flow in a fixed bed and in a fluidised bed
- Choosing a stirrer and sizing a mechanically stirred tank for a given task
- Choosing and sizing mechanical separation equipment: decanter, filter, centrifuge, etc.

CONTENT AND TEACHING METHODS

Lectures and tutorials (32h)

Fixed-bed flow and fluidisation

3 lecture sessions (1h) - 3 practical sessions (2h): Sauter diameter of a divided solid, Darcy's law and Ergun's equation; minimum fluidisation velocity and terminal falling velocity; classification of pulverulent materials; fluidisation regimes; similarities and extrapolation; industrial processes; 1h written exam.

Agitation

3 lecture sessions (1h30) -3 practical sessions (1h30): axial and radial motions; power number; circulation and pumping flow rates; mixing time; heat transfer; 1h written exam.

Mechanical Unit Operations

4 lessons (1 x 1.5 hours, 3 x 1 hour) - 3 practical sessions (2 hours): liquid-solid and gas-solid separations, decantation, filtration on support and in depth, centrifugation, dewatering, dust removal.

Practical work (24h)

Hydrodynamics of a tray or packed column: clogging, priming, pressure drops (8h); gas-solid or liquid-solid fluidisation: minimum fluidisation speed, transfers, bed expansion (8h); agitation: power curves, influence of the geometry of the mobile, gas-liquid agitation (4h); spray drying: material and enthalpy balances, wet temperature (4h). Study of an autothermal reactor (4 hrs).

TYPE OF ASSESSMENT

Practical work reports, written exams, fixed and fluidised beds, agitation, mechanical separations.

USEFUL INFORMATION

PREREQUISITES: Transfer Phenomena I and Transfer Phenomena II

LANGUAGE OF TEACHING: French

BIBLIOGRAPHICAL REFERENCES :

Required:

Opération polyphasiques en génie des procédés, hydrodynamique, transferts, réactions, séparations mécaniques. Paris ; éditions Ellipses, 2e éd. 2023

Handouts Recommended:

1. Wallis, G.B. One-dimensional two phase flow. New York: Mc-Graw Hill, 1969.
2. Perry's Chemical Engineers' Handbook. New York: Mc Graw-Hill, 2007, 8th edition. Ch. 5, Heat and Mass Transfer; Ch. 6, Fluid and Particle Dynamics; Ch.18, Liquid-Solid Operations and Equipment.
3. Yang, Wen-Ching, [ed.]. Handbook of fluidization and fluid-particle systems. New York: Marcel Dekker Inc, 2003.
4. D. Kunii, O. Levenspiel. Fluidization Engineering. [John Wiley. 2nd. New York: s.n., 1991.
5. W.J. Beek, K.M.K. Mutzall, J.W. van Heuven. Transport Phenomena. 2nd. New-York: John Wiley & Sons, LTD, 1999.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of competences 2, 5, 8, 11 and 13 The lessons in this course contribute indirectly (as resources) to competency 9

TEACHING UNIT TITLE: **Thermal Separation Processes**		MANDATORY
	ECTS CREDITS 5	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The thermal separation processes module aims to :

- Present the formalism used to describe multi-constituent systems, emphasising the concept of chemical potential
- Describe the phase diagrams of binary systems with a homogeneous liquid phase.
- Present methods for sizing balanced separation operations involving coupled heat and mass transfer: binary distillation, operations on moist air, drying, etc.
- To enable students to design the installations associated with the above processes

SPECIFIC OBJECTIVES

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

- Calculate an isothermal or isobaric phase diagram and the equilibrium curve of any binary system (positive or negative deviations from ideality, homogeneous azeotropy).
- Determine the limit operating conditions for a binary distillation column (minimum reflux rate, minimum number of plates) and choose the optimum operating conditions for this column.
- Sizing distillation columns and direct contact cooling columns
- Analyse drying curves and select and size dryers

CONTENT AND TEACHING METHODS

Courses and tutorials

Thermodynamics of phase equilibria

13 h lecture, 8 h practical work: equilibrium conditions between phases, chemical potential expressions, liquid-vapour equilibrium relations, mixing quantities, ideal mixing quantities and excess quantities, description of fluid phase diagrams at low pressure; 2 h written examination.

Distillation fundamentals

5h30 of lectures: Flash distillation and fractional distillation, McCabe and Thiele methdoe, Fenske, Underwood and Gilliland equations, thermodynamic dimensioning of columns using the MESH method and the NUT method, hydrodynamic dimensioning of packed and tray columns; discontinuous distillation. 9.5 hours of lectures; 1.5 hours of written exams.

Humid air and drying

4 lessons (1 hour each); 4 practical sessions (2 hours each); 2 homework sessions (1 hour 30 minutes each): wet temperature, psychrometric diagrams, direct contact cooling processes, humidification processes, drying mechanisms, drying characteristic curves, industrial dryers, enthalpy balances, energy performance, associated technologies; 1 hour 30 minutes written examination (with moist air).

Practical work (24h)

Liquid-liquid extraction: extraction of methylene blue in a stirred column (8h); binary distillation: working with total and partial reflux, water-ethanol and water-acetic acid separation (8h); thermodynamics of separations: enthalpy of mixing, volume of excess, ebulliometry (8h).

TYPE OF ASSESSMENT

Practical work reports, Thermodynamics written exam, Distillation written exam, Drying - moist air written exam, Drying - moist air in-house work

USEFUL INFORMATION

PREREQUISITES: UE Thermodynamics and Energy and UE Separation Processes I TEACHING LANGUAGE: French

REFERENCES :

Required:

Séparations thermiques en génie des procédés, distillation, air humide, séchage. Paris ; éditions Ellipses, 2021

Handouts Recommended:

1. W.L. McCabe, J.C. Smith, P.Harriott. Unit Operations of Chemical Engineering. 7. New York: Mc-Fraw-Hill, 2005.
2. Perry's Chemical Engineers' Handbook. New York: Mc Graw-Hill, 2007, 8th edition. Ch.12, Psychrometry, Evaporative Cooling and Solids Drying ; Ch. 13, Distillation ; Ch. 14, Equipment for Distillation, Gas Absorption, Phase Dispersion and Phase Separation.
3. Mujumdar, A.S., [ed.]. Handbook of industrial drying. 3rd. Boca Raton: CRC Press, 2007.
4. Arlabosse, P. Séchage industriel, aspect pratiques. s.l. Techniques de l'Ingénieur, 2008, Vol. J 2, 455.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 1, 2, 3, 4, 5, 8 and 11. and 13

The lessons in this course contribute indirectly (as resources) to Competency 9.

EDUCATIONAL UNIT TITLE: **Process Systems Engineering (PSE)**		MANDATORY
	ECTS CREDITS 5	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of the 'Process Systems Engineering' or PSE UE is to provide students with the elements they need to model, synthesise, analyse, simulate, optimise and control systems, with the aim of designing and managing complex, high-performance processes. These elements mainly concern computer-aided process design (CAPD), optimisation, process dynamics and control.

The CPAO course aims to:

- Present a general overview of simulation and process simulators
- Demonstrate the organisation of physico-chemical properties in simulators
- Explain the numerical resolution methods used by simulators
- Using PRO/II static simulation software for applications The

Optimisation course aims to:

- To show how to pose a problem using static optimisation
- Describe analytical methods for optimisation problems with equality and inequality constraints
- Explain the principles of direct search and gradient methods. Provide resolution algorithms

The Process Dynamics and Control course aims to:

- Acquire the notion of system dynamics and Residence Time Distribution
- Familiarise the student with the basic automatic control of continuous-time monovariable systems
- Explain control and tracking techniques based on PID and improved techniques
- Demonstrate the importance and dynamic consequences of control on processes

SPECIFIC OBJECTIVES

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

- Simulate simple units and complex processes
- Choosing and sizing units
- Understand the classification of optimisation problems
- Be able to pose and solve a static optimisation problem with constraints
- Optimising the operation of processes
- Know and be able to describe the dynamic operation of linear systems
- Establish performance criteria for real reactors based on the concept of DTS
- Master the vocabulary and concepts of basic automatic control based on the Laplace transform
- Be able to design a feedback loop and adjust a PID controller
- Learn about improved methods compared to the PID controller

CONTENT AND TEACHING METHODS

I. CPAO

1. General information on simulation and process simulators
   1.1. Elements required for process simulation
   1.2. Simulation software and its structure

1.3. Interpretation of simulation results
1.4. Units frequently used in process simulation
2. Physico-chemical properties in simulators
2.1. Constant and temperature-dependent data
2.2. Thermodynamic models and their choice
3. Numerical resolution methods used by simulators
3.1. Direct substitution method
3.2. Broyden method
3.3. Wegstein method
4. Applications on PRO/II static simulation software
4.1. Consultation of various databases
4.2. Data regression
4.3. Calculating liquid/vapour equilibria
4.4. Compressor/turbine trains
4.5. Chemical reactors
4.6. Distillation and liquid/liquid extraction columns
4.7. Thermal integration
4.8. Energy analysis

II. Optimisation

1. Analytical optimisation methods
2. Numerical optimisation methods
3. Linear programming
4. Quadratic and non-linear programming III Continuous-time

III. process dynamics and control

1. Dynamic process modelling
    - 1.1. State representation
    - 1.2. Transfer functions
    - 1.3. Frequency analysis
    - 1.4. Bode diagrams
    - 1.5. System characterisation using frequency analysis
2. Study of standard linear open-loop systems
    - 2.1. First-order systems
    - 2.2. Second-order systems
    - 2.3. Pure delay systems
    - 2.4. Distributed parameter systems
3. Notion of System Dynamics applied to SDR
    - 3.1. Characterisation and identification of ideal reactors
    - 3.2. Modelling complex systems
4. Linear feedback control
    - 4.1. PID controller
    - 4.2. Dynamics of feedback-controlled processes
5. Stability analysis
    - 5.1. Analysis in state space
    - 5.2. Stability analysis of feedback systems
    - 5.3. Bode and Nyquist stability criteria
6. Loop controller overview
    - 6.1. Choosing and setting PID controllers
    - 6.2. Improving PIDs
    - 6.3. Internal model control
7. Improving control systems
    - 7.1. Pure delay compensation, inverse response
    - 7.2. Cascade, selective, shared, feedforward control

TYPE OF ASSESSMENT

CPAO:2-hour written exam in a computer room
Optimisation: 1.5-hour written exam Dynamics: 1-hour written exam
Order: 1.5 hour written exam

USEFUL INFORMATION

PREREQUISITES :
CPAO: Thermodynamics - Chemical reaction engineering - Unit operations - Numerical analysis and optimisation methods
Optimisation: Numerical analysis methods. Use of a programmable calculator Process Dynamics and Control : Material and energy balances
LANGUAGE OF INSTRUCTION :
CPAO: French Optimisation: French
Process Dynamics and Control: French
BIBLIOGRAPHICAL REFERENCES :
Required:
CPAO : Course handout Optimisation : Course handout
Systems Dynamics: course handout
Commande des Procédés : Book "Commande des procédés", Jean-Pierre Corriou, Lavoisier Tec&Doc (2003)
Recommended:

1. Process flowsheeting (A.W.Westerberg, W.Hutchinson, R.Motard, P.Winter /Cambridge University Press, 1979)
2. Systematic methods of chemical process design (L.T.Biegler, I.E.Grossmann, A.W.Westerburg / Prentice Hall PTR, 1997)
3. Process design principles: synthesis, analysis, and evaluation (W.D. Seider, J.D. Seader, D.R. Lewin /John Wiley & Sons, 1998)
4. Génie de la Réaction Chimique (J. Villermaux, Tec et Doc, Lavoisier, 1993)
5. Numerical methods and optimisation (J.P.Corriou, Lavoisier Tec&Doc, 2010)

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skill no. 3

The lessons in this course contribute indirectly (as resources) to Competency 4.

EDUCATIONAL UNIT TITLE: Management and Economics III		MANDATORY
	ECTS CREDITS 2	*S7* *COMMON*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The teaching aims to :

- Understand the issues at stake and the main factors influencing the success of organisational change.
- Identifying and managing resistance to change
- Analyse the laws governing the dynamics and process of change

SPECIFIC OBJECTIVES

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

- Support a change project using a managerial approach and appropriate tools
- Structuring a change project by identifying the main phases and actions to be undertaken according to the change issues encountered
- Taking into account the human dimension: taking into account values, culture and resistance to change through a participative, communicative and training/coaching approach, the aim of which is to enable individuals to understand and accept the "new rules of the game" resulting from the change process.

CONTENT AND TEACHING METHODS

Change management :

- Approaches to change management
- Methods of change
- Factors for change
- The phases of change
- Resistance to change
- Causes of failure to change
- The dynamic laws of change
- Industrial property law and change management Case study of

organisational change

Company knowledge: Company day organised jointly by the Research and Industrial Relations Departments and the External Relations Department (see "Management and Economics I" UE sheet). This day enables second-year students to learn more about companies in the various industrial sectors in which our engineers are recruited: energy, pharmaceuticals, design and expertise offices, polymer chemistry, chemistry of large intermediates, speciality chemistry, eco-environment and agri-food.

TYPE OF ASSESSMENT

Change case study

USEFUL INFORMATION

PREREQUISITES: none
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :
Required:

1. Gérard Dominique CARTON, Éloge du changement, Village Mondial éd, 2nd edition, 2004.

Recommended:

1. Christophe FAURIE, Conduite et mise en œuvre du changement - l'effet de levier, Maxima ed, 2003.
2. Raymond VAILLANCOURT, Le Temps de l'Incertitude - du changement personnel au changement organisationnel, Presses de l'Université du Québec, 2003.
3. David AUTISSIER & Jean-Michel MOUTOT, Pratiques de la conduite du changement -Comment passer du discours à l'action, Dunod, 2003
4. François DUPUY, Sociologie du changement - Pourquoi et comment changer les organisations, Dunod, 2004.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 6, 11, 12 and 14.

EDUCATIONAL UNIT TITLE: Languages III		MANDATORY
	ECTS CREDITS 3	S7 COMMON

LVA: English

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Enabling students to take greater responsibility for their own learning
- Preparation for the TOEIC/TOEFL/IELTS test. Develop language knowledge and skills to obtain a minimum level of B2. (C1: TOEIC 945+, TOEFL 95/120, IELTS 7)
- Develop the professional skills needed to work in a company or research laboratory in an international context (in France or abroad).
- Develop the skills of the 21e century: learning and innovation skills, information, media and technology skills, social and professional skills.
- Examine society's needs and challenges in the context of the socio-ecological transition. Analyse the causes and consequences of climate change and the collapse of biodiversity. Establish the link between science & technology and a sustainable society. Act as a citizen & scientific engineer through the English language.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Identify their level of English and what they need to do to reach a minimum level of B2
- Work in pairs/teams on their objectives and analyse the results achieved
- Use a tool to manage their work
- Understand the essential content of concrete or abstract subjects in a complex text
- Communicating with a degree of spontaneity and ease.
- Express yourself clearly and in detail on a wide range of subjects.
- Optional Meeting management module: leading a meeting, taking minutes and using the specific language of meetings

CONTENT AND TEACHING METHODS

- Define their needs to improve their level of English and develop their general and professional skills in English.
- Work in pairs/teams for TOEIC/TOEFL/IELTS test preparation/training and self-assessment.
- Create activities and exercises to learn and memorise vocabulary, grammar and expressions.
- Optional Module: Conducting meetings :
- Quality of communication: analysing participation in a meeting, studying the specific language of meetings (the agenda, functional language), taking minutes, simulations, case studies.
- Write a work report.

TYPE OF ASSESSMENT

- Validation (grade between 3-5) : Personal project report and teacher's assessment, conducting a meeting.
- TOEIC mock test.
- Make-up: TOEIC mock test, or homework.

USEFUL INFORMATION

PREREQUISITE: minimum level B1. (cfr: CTI 2010 description, or CEFR)

LANGUAGE OF TEACHING: English
BIBLIOGRAPHICAL REFERENCES :: Preparation For Toeic ,Bruce Rogers

LVB

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Consolidate level A2 // B1 (weak groups), reach B2/C1 (strong groups) (cfr: CTI 2010 description, or CEFR)
- Developing professional skills.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to:

- Understand and reconstruct written and audio/video documents on a variety of subjects: social, cultural, economic, scientific, etc.
- Writing summaries and brief notes
- Interacting orally in groups, sub-groups or pairs (feedback, exchanges, debates, opinions, analysis), presenting a PowerPoint presentation
- Express themselves clearly and in a well-structured way on complex subjects or everyday life, express an opinion on a problem, use the language effectively and flexibly in academic and social life,
- Understand a discussion in his/her professional field, understand the content of concrete or abstract subjects - in a text, an audio and/or video programme - using a foreign language.
  "standard
- Write down the different phases of a scientific process, using appropriate vocabulary and syntax *(depending on the level of the group).*
- Summarise any "authentic" written and spoken document in a variety of fields: social, cultural and professional life.

CONTENT AND TEACHING METHODS

- Listening comprehension: Various authentic audio and video documents, websites, news channels.
- Written comprehension: summaries, press articles, extracts from scientific articles, grammar and vocabulary exercises.
- Oral expression: presentations, debates, role-playing, exchanges, points of view using audio/video and written documents as sources, description of the different phases of a process, scientific process, presentations.
- Written expression: summaries, reports, emails, essays.

TYPE OF ASSESSMENT

- Assessment: validation of skills acquired: Continuous assessment tests (oral and written)
- Remedial: Oral and written test

USEFUL INFORMATION

PREREQUISITE: minimum level B1. (cfr: CTI 2010 Description, or CECRL)
TEACHING LANGUAGE: German / Spanish / French / Italian BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 13.

EDUCATIONAL UNIT TITLE: Drug Engineering		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

An active ingredient is a molecule or biomolecule which, in a medicinal product, has a therapeutic effect. This substance may be of different types and is generally present in a very small proportion in the medicine compared to the excipients.
In recent years, new techniques for synthesizing these active ingredients have been developed. The optional teaching unit will present the principle of drug engineering.

SPECIFIC OBJECTIVES

At the end of this option, students will be able to understand and master both traditional and emerging techniques for the production of biomolecules and active ingredients used in research and development in the pharmaceutical industry.

They will also be able to understand the advantages of developing certain families of molecules and choosing the optimum synthesis technique for producing certain families of biomolecules.

CONTENT AND TEACHING METHODS

The content will be as follows:

- Synthesis strategies: total synthesis, fragment synthesis, classical synthesis, combinatorial synthesis, supported synthesis, etc.
- Applications to the synthesis of biomolecules (active ingredients) such as peptides, sugars and heterocycles for therapeutic purposes.
- Emerging synthesis techniques, online monitoring.

The course will be based on two classroom sessions and a micro-project carried out in small groups:

- Course presenting the different synthesis techniques by category
- Course presenting the different families of biomolecules and some of their pharmaceutical properties
- Micro-project with a technical sheet: a small group of students will choose one of the techniques presented, which they will develop at the end of the session in an oral presentation; they will also summarise their work in the form of a technical sheet for distribution to the whole group.

TYPE OF ASSESSMENT

Oral defense and drafting of a technical report
Resit exam: written exam

USEFUL INFORMATION :

PREREQUISITES :
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :

EDUCATIONAL UNIT TITLE: **Photophysical and Photochemical Engineering**		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

Light has the potential for spectral, temporal and spatial resolution. These qualities can be exploited for specific applications in spectroscopy, biology, synthesis or for "new energies". The aim of this course is to present the concepts in the field and to examine how they fit into the development of applications (without forgetting the limits).

SPECIFIC OBJECTIVES :

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

- Understand the mechanisms involved in photophysical and photochemical processes
- The use of photophysics as a spectroscopic method for chemical and biological analysis...
- Tackling industrial photochemical applications for new energies
- Illustrate the field as an interface science open to interdisciplinarity

CONTENT AND TEACHING METHODS :

The course is based on classroom sessions and a micro-project.
The microproject consists of analysing an application of photophysics or photochemistry.
External speakers are called upon to pass on their experience to the student engineers.

TYPE OF ASSESSMENT :

- Development of a microproject on the theme of photophysics or photochemical engineering
- Final exam on part of the course (1h30)
- Make-up exam: written exam

USEFUL INFORMATION :

PREREQUISITES: *none*
LANGUAGE OF TEACHING: French
BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

EDUCATIONAL UNIT TITLE: **A Brief History of Science**		**OPTIONAL**
	ECTS CREDITS **1**	***S7***

GENERAL OBJECTIVES OF THE TEACHING UNIT

Rarely mentioned in post-baccalaureate courses, the history of science and technology makes theories much less arid and gives a more sympathetic face to the scientists who, in their own way, still live alongside us in our everyday lives. The aim of this option is to provide a comprehensive overview of the history of the development of some of the major scientific disciplines from their origins to the present day.

SPECIFIC OBJECTIVES

At the end of this module, the student-engineer should be able to situate the chronological articulations of theories and practical applications relating to the various fields considered, including chemistry, mathematics, mechanics and astronomy, light and colours, heat and energy as well as electricity and magnetism.

CONTENT AND TEACHING METHODS

The teaching content will be organised around a chronological and illustrated presentation of the development of ideas and techniques in each field considered, with certain parts of the programme giving rise to various close-ups. Some very specific text studies will be added to the sessions. Students will be given the opportunity to discover period works in the old collections of the libraries of the Faculties of Science and Technology and Medicine in Nancy. An optional visit to the Musée des Arts et Métiers in Paris, an institution that houses a large number of historical scientific objects, will also be offered on a Saturday, providing a more practical introduction to the history of technology to complement the course.

TYPE OF ASSESSMENT

Microproject :
Presentation in a small group (3 or 4 students) on a subject from the history of science and technology, chosen from a list suggested by the teacher or proposed spontaneously by the students themselves according to their preferred subjects.

Make-up exam: written exam (1h30)

USEFUL INFORMATION

PREREQUISITES: none
LANGUAGE OF TEACHING: French

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 10

EDUCATIONAL UNIT TITLE: **Financial and Budgetary Management**		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Master the basic theory of business knowledge
- Correctly define the basic notions and concepts of financial and business economics.
- Gathering and processing information for research purposes
- Produce a correct presentation of the mechanisms involved in microeconomic and financial news
- Analysing and summarising information
- Solve problems for which the knowledge, concepts and procedures learned have been mastered

SPECIFIC OBJECTIVES

At the end of the module, the student should be able to:

- Draw up a provisional budget
- Identify and optimise the sources of finance for an investment: leasing, loans or equity capital, etc.
- Be able to calculate the cost of a product (good or service)
- Identify and understand the nature of financial crises around the world

CONTENT AND TEACHING METHODS

The course is based on lectures/DD sessions (with case studies) and a micro-project.

TYPE OF ASSESSMENT

The various assessment tests: presentations by groups of 4 or 5 students on a topical financial theme or a point from the course, **and** assessment of knowledge and understanding of the course in the form of a case study, are designed to check whether the various skills and knowledge derived from current economic, financial and commercial events have been acquired.

USEFUL INFORMATION

PREREQUISITES: none
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :
Gestion financière de l'entreprise (Dov Ogien Dunod), and PQN in finance

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 12

TEACHING UNIT TITLE: **Microfluidics**		OPTIONAL
	ECTS CREDITS 1	S7

GENERAL OBJECTIVES OF THE TEACHING UNIT

Microfluidics is a rapidly developing field. It has a wide range of applications, from intensified processes to medical analysis, green chemistry and the encapsulation of active ingredients for pharmaceutical applications. One of the major advantages of microfluidics lies in the excellent control of operating conditions (temperature, flow rate, concentration, residence time, etc.), which allows us to optimise yields and achieve product quality and reproducibility that are unmatched by other processes.
The aim of this module is (i) to give an overview of the range of possible applications of microfluidics (ii) to make the participant aware of the new problems arising for micro-scale flows and to give the orders of magnitude involved (iii) to give a few examples of industrial processes using microfluidics.

SPECIFIC OBJECTIVES

- To provide a real understanding of what is being done in the field of microfluidics and, in particular, to highlight the breadth of the areas concerned
- Using examples, we will try to give the orders of magnitude encountered: flows often with low Reynolds numbers, heat exchanges facilitated by a very favourable surface/volume ratio, well-controlled residence times, problems of interfacial tension and wetting, etc.
- Process engineering on a microfluidic scale
- Specific examples of industrial microfluidic processes

CONTENT AND TEACHING METHODS

The teaching method will be based on lectures/DDs. A micro-project will also be required.
- Presentation of the different manufacturing methods
- Handling drops / usefulness for medical applications
- Hydrodynamics, micrometric-scale transfers and the physical mechanisms involved
- Microfluidics as a reactor
- Applications in the field of analysis and health
- Applications to industrial processes: a number of industrial processes based on microfluidics will be covered in detail

TYPE OF ASSESSMENT

Exam and Microproject

USEFUL INFORMATION

PREREQUISITES: None
LANGUAGE OF TEACHING: French (or English)
BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

TEACHING UNIT TITLE: **Biopolymers and Biodegradable Polymers**		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE COMPONENT

The "Biopolymers and biodegradable polymers" option focuses on :

- Describe the most important polymers of natural origin (biopolymers) in the field of materials and their main applications
- Present the main biodegradable polymers developed i n industry from petrochemical resources or, more recently, renewable resources.
- Illustrate an exemplary approach to the development of bio-based technical polymers

SPECIFIC OBJECTIVES

At the end of this module, students will be able to :

- Identify the most important biopolymers and biodegradable polymers in industry
- Knowing how to take advantage of their specific advantages and limitations for a given application
- Defining the issues and challenges involved in developing new biopolymers and biodegradable polymers for industry
- Contribute to the development of new polymer materials in the context of sustainable development

CONTENT AND TEACHING METHODS

Polymers of natural origin (biopolymers) will first of all be presented, limiting ourselves to the field of materials, where they generally represent major challenges. Synthetic biodegradable polymers are also undergoing unprecedented development, which should intensify in the coming years. In particular, some of these polymers can be obtained from renewable resources, and could ultimately represent interesting alternatives to petrochemical-based polymers. The main classes of synthetic biodegradable polymers recently developed by industry will be presented, along with their main applications in key sectors. Finally, the prospects and industrial challenges of new biosourced and/or biodegradable plastic materials that have less impact on the environment will be discussed from the perspective of sustainable development.

This teaching will combine the presentation/discussion of course slides with that of several contents available online and selected in particular from the websites of leading manufacturers in the field of biopolymers and/or biodegradable polymers. An industrial conference will also present the exemplary industrial developments achieved by Arkema in the field of biosourced technical polymers.

TYPE OF ASSESSMENT

Industrial case study with authorised documents in 1 hour.

USEFUL INFORMATION

PREREQUISITE: Basic knowledge of polymers and polymerisation chemistry TEACHING LANGUAGE: French
PORTABLE TELEPHONES: Unauthorised use
REFERENCES AVAILABLE AT THE ENSIC MEDIATHEQUE :

- Scott G., Polymers and the environment, RSC Paperbacks, The Royal Society of Chemistry, Cambridge, 1999, 132.

- Stevens, E. S., Green Plastics: An Introduction to the New Science of Biodegradable Plastics, Princeton University Press, Princeton, 2001.
- Rinaudo M., Les polymères naturels : structure, modification, applications, Initiation à la Science des Polymères Vol 13 du Groupe Français d'Etudes et d'application des Polymères, 2000.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 4, 10 and 11.

EDUCATIONAL UNIT TITLE: **Artificial Intelligence (AI) for Business Engineering processes - First contact**		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The "AI for Process Engineering - First Contact" option aims to :

- Explain the design of the various modelling techniques (e.g. data-based, phenomenological, etc.) that can be applied depending on the problem being addressed and illustrate their main advantages and disadvantages.
- Give an overview of what is currently being done in industry as part of the "industry of the future".
- Present an overview of supervised and unsupervised data processing and machine learning methods (Artificial Intelligence, Machine Learning, Deep Learning).
- Describe some emblematic regression and classification methods.
- Implement these methods on concrete Process Engineering cases, using the Matlab environment.

SPECIFIC OBJECTIVES

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

- Have an overview of machine learning approaches.
- Understand the characteristics and main steps involved in processing a dataset.
  - Understand the reasons for developing a learning model and the steps to follow.
  - Distinguish and understand the principle, usefulness and applicability of different modelling approaches (e.g. empirical/mechanistic, deterministic/stochastic, etc.).
  - Understand what a neural network is and what its main characteristics are.
- Apply the main methods in an appropriate software environment.

CONTENT AND TEACHING METHODS

The sessions are carried out exclusively on a computer in a computer room, using the functions and toolboxes dedicated to machine learning in the Matlab environment.

TYPE OF ASSESSMENT

Individual test on machine or MCQ (1 hour)

USEFUL INFORMATION

PREREQUISITES: UE Informatique, méthodes numériques et statistiques (S5, EC Méthodes statistiques, EC Informatique pour l'ingénieur des industries chimiques I) and UE Systèmes réactifs et Informatique (S6, EC Informatique pour l'ingénieur des industries chimiques II).
LANGUAGE OF TEACHING: French or English
BIBLIOGRAPHICAL REFERENCES :

1. Chloé-Agathe Azencott, "Introduction to machine learning", Ed. Dunod, 2018.
2. Stéphane Tufféry, "Big Data, Machine Learning and deep learning", Ed. Technip, 2019.
3. Ian Goodfellow, "Deep learning", Massot Editions, 2018.
4. Charu C. Aggarwal, "Data mining - the textbook", Ed. Springer, 2015.

Required: Handouts or slides distributed, data files distributed via ARCHE. Recommended: See bibliographical references.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 3

The lessons in this option contribute indirectly (as resources) to Skill 4

EDUCATIONAL UNIT TITLE: **Hydrometallurgical Processes**		OPTIONAL
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

Introduce students to hydrometallurgical processes, which are undergoing rapid 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 techniques and elements will be covered:

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

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

SPECIFIC OBJECTIVES

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

- A comprehensive understanding of the context and the industrial, economic and geopolitical issues raised by the mineral revolution,
- Understand the various unit operations involved in hydrometallurgy: leaching, precipitation, electrodeposition, electrodeionisation, liquid/liquid and liquid/solid extraction, etc.

CONTENT AND TEACHING METHODS

Courses and tutorials

The 3rd industrial revolution - industrial, economic, geopolitical, ecological and societal issues 2 h lecture; 1 h written exam.

Precipitation processes applied to hydrometallurgy

1 lecture (30 min); 1 practical session (1 hr): equilibrium conditions between liquid and solid phases, sizing of cooling and evaporation crystallization reactors; 1 hr written exam.

Liquid/liquid extraction applied to hydrometallurgy

1 lecture (1h); 1 practical session (2h): separation of metals by liquid-liquid extraction; choice of extractants; 1h written exam.

Electrochemical processes applied to hydrometallurgy,

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

Separation processes using ion exchange resins.

1 lecture (30 min); 1 practical session (1 hr): equilibrium conditions between liquid and solid phases; liquid-solid extraction; examples of innovative processes; 1 hr written exam.

TYPE OF ASSESSMENT

Written examination

USEFUL INFORMATION

PREREQUISITES: Inorganic chemistry, Liquid/liquid extraction processes, Chemistry in solution (thermodynamic equilibria), Matter & mass balance, Matter transfer.
LANGUAGE OF TEACHING: French
BIBLIOGRAPHICAL REFERENCES :
Required:
Handouts Recommended:

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 4, 10 and 11.

EDUCATIONAL UNIT TITLE: Energy and Industrial Transition		OPTIONAL
	ECTS CREDITS 1	S7

GENERAL OBJECTIVES OF THE TEACHING UNIT

Understand the causes and consequences of global warming, and in particular the links between climate, energy, industry and the economy.
Understand the energy, industrial and economic transition needed to mitigate global warming.
Clarifying the role of engineers and companies in decarbonising the process industry

SPECIFIC OBJECTIVES

Students should be able to:

- Develop a scientific, systemic and critical vision:
  - the challenges of global warming,
  - of the energy and industrial transition,
  - technical means to decarbonise industry: energy and materials conservation, energy efficiency, cogeneration/refrigeration, waste recycling/recovery, alternatives to fossil fuels for materials and energy supply (bio-economy, low-carbon H_2, electrification).
- Present one of these subjects in a concise, convincing manner that is open to debate

CONTENT AND TEACHING METHODS

Workshops and presentations :

La Fresque du Climat workshop (based on the scientific work of the IPCC, La Fresque du Climat is the benchmark collaborative workshop for collective understanding of the challenges of climate change).
3-hour participatory workshop with ENSIC teachers.

MIT En-Roads workshop (computer tool that simulates the consequences of our political, economic and technical choices on the climate)
3-hour participatory workshop with a speaker from the University of Lorraine.

Group oral presentation :
Two 3-hour sessions are organised as follows: a 30-minute presentation on a particular subject by a group of 3 or 4 students, followed by a 30-minute debate between the students, several teachers and outside guests. The different topics of these presentations will be defined in advance (at least 6 weeks in advance). At the end of each session, the groups of students concerned are assessed.

TYPE OF ASSESSMENT

Oral defence: The assessment covers a range of skills, including the quality of the bibliographical review, the scientific and systemic approach to the subject, the ability to synthesise, critical thinking, rhetoric and the ability to organise the debate and answer questions.

USEFUL INFORMATION

PREREQUISITES: THERMODYNAMICS, BALANCES, PROCESSES.
LANGUAGE OF TEACHING: French
REFERENCES :
Necessary:
Recommend
ed :

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 9

EDUCATIONAL UNIT TITLE: **Industry, Environment & Energy Conferences Company II**		MANDATORY
	ECTS CREDITS 1	*S7*

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Find out from external professionals (academic or industrial) :
  - Certain socio-environmental issues
  - Various industrial fields linked to ENSIC.
- Illustrate the use of chemical engineering skills in the industrial world
- Introduce the courses in semester 8 (processes, products, biotechnology) with lectures by industrialists working in these 3 sectors

SPECIFIC OBJECTIVES

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

- Identifying certain socio-environmental issues
- Understand the diversity of the industrial world and its professional practices
- Determining the role of engineers in the socio-economic world
- Guide your academic career accordingly, as well as your choice of internship or further studies

CONTENT AND TEACHING METHODS

The course is based on :
- 8 hours of compulsory lectures by professionals on socio-environmental subjects. For example :
  - Soil, Food resources, Agrochemicals
  - Mineral and metallurgical resources
  - Biodiversity & Ecosystem Services
  - Environmental regulations
- 8 hours of industry conferences to choose from (e.g. Energy, Health, Chemicals, Safety, Cosmetics, Waste treatment, etc.).

TYPE OF ASSESSMENT

Attendance compulsory. If resit exam: table-top project.

USEFUL INFORMATION

PREREQUISITES: none
LANGUAGE OF TEACHING: French
BIBLIOGRAPHICAL REFERENCES: none

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of competences 9, 14, 15 and 16.

The lessons in this course contribute indirectly (as resources) to Competency 10.

COURSES IN SEMESTER 8

Pedagogical Supervisor: Rainier HREIZ

GENERAL ORGANISATION

Title of teaching unit and its components building blocks	*Manager*	*H*	*CM*	*TD*	*TP*	*P*	*C*	*Ex*	*ECTS*
Management and Economics IV	Vera IVANAJ	40	16	16	8				2
Languages IV	E. KASMAREK/M. ADRIAN	44		44					2
English	E. KASMAREK/M. ADRIAN			24					
LV B	E. KASMAREK/M. ADRIAN			20					
Industrial project	Sabine RODE / Jean-François PORTHA	35,5	4,5	12		18		1	6
Industrial project	Sabine RODE					18			
Technical and economic evaluation of processes	Laurent FALK		2	9				1	
Pinch analysis	Romain PRIVAT / Jean-François PORTHA		2,5	3					
Work experience	Laurent PERRIN								4
Opening project	Valérie Henry	26				6	20		3
Options		18							1
Specialisation courses		156							12
TOTAL		**319**							**30**

OPTIONS

Option title	*Manager*	*H*	*CM*	*TD*	*TP*	*P*	*C*	*Ex*	*ECTS*
Surface functionalization and applications	Halima ALEM MARCHAND	18	7	8		2		1	1
Aerosols and safety	Olivier DUFAUD	18	7	8		2		1	1
Intelligent organic materials: concepts and industrial applications	Guillaume PICKAERT	18	7	8		2		1	1
Thermodynamics of advanced solutions	Jean-Noël JAUBERT	18	7	8		2		1	1
Waste treatment methodology manufacturers	Alexandra GIGANTE	18	7	8		2		1	1
Health products	Cécile NOUVEL	18	7	8		2		1	1
Industrial polymerisation and sustainable development	Alain DURAND	18	7	8		2		1	1
Polymer nano-objects: synthesis, characterisation and applications	Khalid FERJI	18	7	8		2		1	1
General installation	Gilles CARN	18	7	8		2		1	1
AI for process engineering - Introduction	Jean-Marc COMMENGE	18	7	8		2		1	1
Strategy: sustainable development for industry	Christian BOUIGEON	18	7	8		2		1	1

SPECIALISATION COURSE: Processes for energy and the environment
Manager: Sabine RODE

Title of Teaching and Learning Unit its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Reactors and multiphase separations	Eric SCHAER	60	26	29,5				4,5	4
Catalytic engineering	Eric SCHAER		6	4,5				1,5	
Multi-phase unit operations	Sabine RODE		8	14,5				1,5	
Crystallization	Marie LE PAGE MOSTEFA		6	4,5				1,5	
Chromatographic processes	Eric FAVRE		6	6					
Sustainable Processes	Laurent PERRIN	36	15,5	4		7,5	6	3	4
Life cycle analysis	Jean-François PORTHA		3,5	4				1,5	
Process safety and the environment	Laurent PERRIN		12				6	1,5	
Safety project	Laurent PERRIN					7,5			
Process design and simulation	Romain PRIVAT	58,5	20	34				4,5	4
Advanced energy thermodynamics	Jean-Noël JAUBERT		6,5	17				1,5	
Advanced distillation	Sabine RODE		8,5	11				2	
Dynamic process simulation	Abderrazak LATIFI		5	6				1	
TOTAL		**154**							**12**

SPECIALISATION COURSE: Innovative products: from chemistry to processes
Head: Cécile NOUVEL

Title of teaching and learning unit its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Micro and nanostructured products	Véronique SADTLER	60	51	5,5			2	1,5	4
Physical chemistry and formulation of multiphase fluid systems	Véronique SADTLER		21	3,5			2	1,5	
Processes for fluid systems scattered	Huai-Zhi LI		17	2					
Micro and nanoparticles	Laurent MARCHAL-HEUSSLER		13						
Introduction to product engineering	Alain DURAND	36	17	8,5		7,5		3	4
Life cycle analysis	Jean-François PORTHA		3,5	4				1,5	
Batch processes	Eric SCHAER		6	4,5				1,5	
From process engineering to products	Alain DURAND		7,5			7,5			
From molecules to products	Cécile NOUVEL	60	18	15,5	24			2,5	4
TP formulated products	Véronique SADTLER				24				
Rheology	Cécile LEMAITRE		7,5	3,5				1	
Molecule structure and properties of use	Cécile NOUVEL		10,5	12				1,5	
TOTAL		**156**							**12**

SPECIALISATION COURSE: Biotechnology processes
Head: Nouceiba ADOUANI

Title of teaching and learning unit its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Introduction to biological sciences	Marie-Christine AVERLANT PETIT	60	39	18				3	4
Biomolecules: Introduction to science biological	Marie-Christine AVERLANT PETIT		24	3				1,5	

Analytical methods at laboratory	Cécile NOUVEL		15	15				1,5	
Biocatalysts and bioreactors	Nouceiba ADOUANI	36	18	9		6		3	4
Biocatalysts and bioreactors	Nouceiba ADOUANI		6	6				1,5	
Multiphase reactors and rheology	Eric OLMOS		12	3				1,5	
Bioreactor project	Nouceiba ADOUANI					6			
Bioseparations	Eric FAVRE	60	19,5	18	20			2,5	4
TP Biotechnology	Cécile NOUVEL//Carole ARNAL-HERAULT				20				
Membrane processes	Eric FAVRE		6	6				1	
Chromatographic processes	Christophe CASTEL/Laurence MUHR		9	7,5				1,5	
Crystallization	Eric SCHAER		3	4,5				1.5	
TOTAL		**156**							**12**

EDUCATIONAL UNIT TITLE: Management and Economics IV		MANDATORY
	ECTS CREDITS 2	S8 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Describe and understand the process of technological innovation in an industrial environment
- Identify the factors favourable and unfavourable to the success of a technological innovation from a strategic, organisational, cultural and scientific point of view
- Design and develop an innovative product or process using the tools and principles of project management
- Draw up a business plan covering the various aspects of the project: competition, suppliers, customers, estimated budget, technology, legal aspects, etc.

SPECIFIC OBJECTIVES

- Master the process of creating a new product or service, from the emergence of an idea through to its realisation.
- Build a business plan, estimate and measure the main internal (human, material and financial, etc.) and external (market, partners, regulations, etc.) parameters.
- Implement a short, medium and long-term business development strategy

CONTENT AND TEACHING METHODS

-Management of innovative projects
The project: definition, objectives,
players Financing plan / Project strategy
Project construction
Communication / Project funding Project
evaluation
Presentation of projects

Simulation of a business start-up project management situation over the course of a week, combining design and implementation.

<u>The various engineering professions: Careers Day</u>
This day is organised jointly by the Director of Studies, the Alumni Association and student representatives (see "Management and Economics II" module).
Round-table discussions and one-to-one interviews with a number of industry partners enable second-year students to find out more about the careers and professions open to them after graduation.

TYPE OF ASSESSMENT

Evaluation of the project prepared and presented orally

USEFUL INFORMATION

<u>PREREQUISITE:</u> Business knowledge
<u>TEACHING LANGUAGE:</u> French

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 11.

EDUCATIONAL UNIT TITLE: Languages IV		MANDATORY
	ECTS CREDITS 2	S8 COMMON

LVA: English

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Develop language skills to reach/maintain level B1/B2/C1/C2 (see CTI 2010 description, or CEFR)
- Develop the professional skills needed to work in a company or research laboratory in an international context (in France or abroad).
- Developing skills for the 21^{e} century: learning and innovation skills, information, media and technology skills, social and professional skills.
- Oral presentations of industrial processes, with emphasis on the environmental context.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- Understand any written document relating to the scientific field, know how to write an "extended summary".
- Give a time-limited oral presentation of a scientific poster in their future professional field,
- Presenting a subject with a power point in a clear and methodical way and answering difficult questions

CONTENT AND TEACHING METHODS

- Articles, scientific publications (chemical engineering, process engineering, product engineering, other sciences) describing processes, presenting "extended summaries", abstracts, methods, results, graphs: style, tenses, sequential markers, linking words, vocabulary etc.... Application exercises.
- Use of audio and video documents, generally from industry, presenting systems/processes. Analysis of posters used at scientific conferences.
- Study the structure of a presentation, use your voice, learn to make transitions between the different parts of your presentation, use visual aids: talk about figures; trends; forecasts; results; describe a graph, expressions for a good conclusion. Mastering how to answer questions.
- Making a presentation: filming and viewing will enable you to assess yourself and become aware of your weaknesses so that you can work on them: language, body posture, elocution.
- Write a summary of a process for poster presentations.

TYPE OF ASSESSMENT

- Validation (grade 3-5): 1) powerpoint presentation, 2) presentation of a scientific poster, 3) written summaries of a process.
- Remedial: Poster or powerpoint presentation or written summary of a process.

USEFUL INFORMATION

PREREQUISITES: B2 level minimum.
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :
Required:

LVB

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Develop language skills to achieve/maintain level B1/B2/C1/C2 (see CTI 2010 description, or CEFR)
- Developing professional skills.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to:

- Mastering lexical, semantic and grammatical fields,
- Understand and reconstruct written and audio/video documents in a variety of fields: cultural, social and economic life, and be able to write summaries and brief notes,
- Interacting orally in groups, sub-groups or pairs (feedback, exchanges, debates, opinions, analysis), expressing yourself on complex subjects in a clear, well-structured way and controlling the tools of organisation, articulation and cohesion of discourse,
- Understand any written document relating to the field of science and know how to write parts of it (introduction, conclusion or abstract, for example), with an appropriate choice of semantics and good grammatical, lexical and semantic control,
- Presenting a subject clearly and methodically using a power point
- Writing a CV, covering letter or e-mail.
- Describe the different phases of a process or system.
- Preparing for a job interview

CONTENT AND TEACHING METHODS

- Use of a variety of documents - written, video, audio, websites - with oral training through "peer work", discussions, role-playing and simulations, covering a range of areas: social, cultural, economic and scientific life.
- Presenting a subject using power point
- Simulating a job interview
- Functional language for CVs, covering letters, formal and informal emails.
  Vocabulary and terms specific to ENSIC
- Functional language to describe the different phases of a process or system
- Various exercises to prepare and practice for international diplomas (e.g. Instituto Cervantes) in all skills,
- Preparation for public speaking, using documents (written and audio) to work on structure, the necessary expressions, describing a graph, the content and use of Powerpoint slides and managing non-verbal communication.

TYPE OF ASSESSMENT

- Validation: validation of skills acquired: various continuous assessment tests (oral and written)
- Level tests: oral and written comprehension
- Resit exam: Oral and written test

USEFUL INFORMATION

PREREQUISITE: minimum level B2 (cfr: CTI 2010 Description, or CEFR)
TEACHING LANGUAGE: German, Spanish, Italian.

References: Necessary :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 13.

The lessons in this course contribute indirectly (as resources) to Competency 10.

EDUCATIONAL UNIT TITLE: **Industrial Project**		MANDATORY
	ECTS CREDITS 6	S8 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The project aims to:

- Design an industrial production process as part of a team working independently
- Interact with academic experts and engineers working in industry
- Learn to write a scientific document in English

SPECIFIC OBJECTIVES

At the end of the project the student should be able to:

- An overview of the core curriculum
- Find the scientific information you need to solve a problem
- Choosing a methodology for designing a process
- Exchanging scientific data and results with peers
- Organising with peers in a group context
- Writing a scientific document in English

CONTENT AND TEACHING METHODS

The design project implements an integrated learning methodology, proposing an open problem. It involves the design of an industrial production process comprising the following stages: choice of process, choice of operating conditions, data research (technical, physico-chemical), overall balances, detailed sizing of selected equipment, techno-economic analysis.
Several subjects are proposed each year in collaboration with industrial partners. Students work in groups of five.

The work is largely supervised by engineers working in industry. The project is

assessed by a report written in English and a viva.
Language quality is assessed by language teachers A dedicated
subject is offered to students following the Pharma plus pathway.

TYPE OF ASSESSMENT

Assessment based on written reports and oral presentations.

USEFUL INFORMATION

PREREQUISITES: knowledge of chemical engineering
TEACHING LANGUAGE: French, English
BIBLIOGRAPHICAL REFERENCES :
Required: Documents distributed to students; scientific databases

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 3, 4 and 7.

The lessons in this course contribute indirectly (as resources) to competences 6, 10 and 13.

TITLE OF TEACHING UNIT: **Work placement**		MANDATORY
	ECTS CREDITS 4	S8 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

This work placement takes the form of an on-the-job training course, the main aim of which is to enable the student engineer to come into contact with working life and to gauge his or her own ability to adapt. The main aim of this work placement is to put the student engineer in the position of a privileged observer of all aspects of company life, but in a participative situation.

SPECIFIC OBJECTIVES

The main theme of the course is health and safety at work.

CONTENT AND TEACHING METHODS

The courses preparing for the work placement are part of the Management and Economics I and II modules. This placement corresponds to 120 hours of personal work supervised by an industrial tutor.

TYPE OF ASSESSMENT

Internship report

USEFUL INFORMATION

PREREQUISITE: UE Management and Economics I - S5 and Management and Economics II - S6

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 2, 6, 7, 8, 11, 13 and 14.

EDUCATIONAL UNIT TITLE: **Community outreach project**		MANDATORY
	ECTS CREDITS 3	S8 COMMON

GENERAL OBJECTIVES OF THE TEACHING UNIT

The module aims to :

- To enable students to get out of the classroom and manage a project that is close to their hearts. This project will have a societal dimension, taking into account the needs of society and including environmental and/or social and/or ethical aspects.
- Apply the project management tools learned in class to a practical case study
- Becoming a project manager: supervising a group, managing a budget and a schedule, monitoring and making adjustments
- Test your own limits and get to know yourself better
- Showcasing its capacity for innovation and inventiveness
- Enrich and differentiate your CV with original experience

SPECIFIC OBJECTIVES :

At the end of the project the student should be able to:

- Define a project in brief
- Designing a project as a whole, defining the players involved, the planning, budgeting and expected objectives, the risks, prioritising them and preventing them
- Implement the action as project manager
- Self-evaluate the actions undertaken and the results delivered, develop a critical mind and summarise feedback
- Enhance the value of the work carried out, both in writing (report) and orally (presentation)

CONTENT AND TEACHING METHODS :

Conference on project management :

- An introductory lecture to present the module's expectations and project management tools
- Each student then defines, alone or in a group, the project they wish to work on. The course leader approves the project definition and assigns a tutor to each project.
- Throughout the year, a number of conferences on a variety of themes enable students to broaden their knowledge and provide food for thought about their project.
- Each student or group of students meets the project tutor on a regular basis to discuss the progress of the project, the results obtained and any questions they may have.

Interview simulations :

- Learn how to present yourself and identify and promote your skills in two workshops "Pitch and Skills
- Job interviews: based on an application to a job vacancy selected by the students, two job interviews are simulated with industry professionals. These interviews are followed by feedback including a summary and advice.

TYPE OF ASSESSMENT :

Written report and oral presentation in front of a jury

USEFUL INFORMATION :

PREREQUISITES: none
LANGUAGE OF TEACHING: French

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This UE contributes directly to the acquisition of competences 10, 12, 14

TEACHING UNIT TITLE: **Surface Functionalisation and Applications**		OPTIONAL
	ECTS CREDITS 1	S8

GENERAL OBJECTIVES OF THE TEACHING UNIT

In all areas of materials applications, surface and volume properties play a vital role in the functionality of a device. For example, in the case of a biomedical material, not only are its mechanical properties important, but its biocompatibility is also essential, and this depends on its surface functionality. Many materials may have excellent mechanical, electrical or physico-chemical properties, but their surface properties remain inadequate. The aim of this course is to introduce students to the concepts of surface properties, describe surface functionalisation processes and methods for diagnosing these surfaces, i.e. their complete characterisation using experimental techniques.

SPECIFIC OBJECTIVES

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

- Propose a method for producing surfaces with specific properties and discuss the advantages and disadvantages of the method.
- Suggest a suitable characterisation technique for a given surface modification
- Knowledge of methods for synthesising and functionalising nanoparticles

CONTENT AND TEACHING METHODS :

This teaching will be based on lectures, tutorials and micro-projects relating to the subject of this course. Gustavo Luengo (L'Oréal) will share his experience of skin and hair in a 2-hour session.

TYPE OF ASSESSMENT :

First session:
- Microproject (defence)
- Exam (1h30)

USEFUL INFORMATION :

PREREQUISITES: none
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :
Recommended:

1. Physics and Chemistry of Interfaces, Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl; 2003 Wiley-VCH Verlag GmbH & Co. KGaA.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

EDUCATIONAL UNIT TITLE: Aerosols and Safety		OPTIONAL
	ECTS CREDITS 1	S8

GENERAL OBJECTIVES OF THE TEACHING UNIT

The safety of processes, goods and people, the treatment of gaseous effluents and the assessment of the impact of industrial processes on the environment are very important social issues. Examples include urban pollution episodes involving fine particles, exposure to welding fumes or oil mists at workstations, and even the explosion of hybrid gas/solid mixtures in biorefineries. All these issues are linked to the presence of aerosols and are a source of scientific and engineering questions.

In order to reduce the risk at source and improve the protection of employees and the environment (local residents and the natural environment), it is essential to develop new tools for studying the industrial processes and systems that generate these aerosols. Technical and scientific developments in the field of aerosols therefore focus on :

- acquiring knowledge to improve understanding of the physical and chemical processes governing the physics of aerosols, the transfer of matter at interfaces during their dispersion and their ignition,
- advanced methods for measuring and/or displaying these processes at different scales,
- the study, optimisation and modelling of unit operations and combinations of operations (chemical reactions or separations - adsorption, filtration - for the design and optimisation of clean and safe processes.

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

SPECIFIC OBJECTIVES

The aim of this module is to enable student engineers :

- Assess the main risks associated with aerosols (ignition, self-ignition, explosion, inhalation, dispersion and atmospheric pollution, etc.)
- Be familiar with techniques for analysing and metrology of liquid or solid, micrometric or nanometric aerosols (optical granulometry, impactors, condensation nucleus counters, electrical mobility analysers, etc.) and be able to choose the appropriate characterisation technique depending on the needs expressed.
- Design separation and purification processes for two-phase gaseous effluents (filtration, bubble columns, granular beds, etc.)
- Propose prevention and protection equipment adapted to the risks associated with aerosol generation (masks, filters, ventilation, vents, etc.).

CONTENT AND TEACHING METHODS :

- The course will be based on applied lessons given by teacher-researchers working in the field of aerosols, as well as a visit to the laboratories of the LRGP's SAFE (Safety, Aerosols, Filtration, Explosions) research team.
- External speakers will be asked to pass on their experience to the student engineers (e.g. INRS, INERIS).
- TDs using specific computer tools for the quantitative assessment of risks linked to atmospheric dispersion and explosion will be used

Teaching team :

O. DUFAUD (ENSIC)	Explosion of solid, liquid and hybrid aerosols
	Advanced concepts of dust explosion, interaction turbulence/combustion
	Hazard studies: case studies (use of software dedicated to hazard analysis) dispersion : Aloha, Marplot...)
L. PERRIN (ENSIC)	Self-ignition of aerosols and thermal runaway in storage facilities
	Visit to LRGP aerosol filtration/explosion facilities
D. THOMAS (IUT Dpt GCGP Nancy)	Aerosol metrology
	Filtration
A. CHARVET (IUT Dpt GCGP Nancy)	Alternative aerosol separation processes
S. CHAZELET (INRS)	Respiratory protection equipment
A. VIGNES (INERIS)	Risks associated with nanoparticles / nanomaterials

Head: O.DUFAUD

TYPE OF ASSESSMENT :

- Board examination: Short final examination
- A make-up session consisting of a single assignment covering all the topics covered will be offered each semester.

USEFUL INFORMATION :

PREREQUISITE : UE Industrial Processes and Sustainable Development - S7
TEACHING LANGUAGE : French
REFERENCES :
See also:

1. Laurent A. (2011). Sécurité des Procédés Chimiques - connaissances de base et méthodes d'analyse de risques, Tec&Doc Lavoisier, 2nd edition, Paris.
2. Eckhoff R. (2003). Dust explosions in the process industries, 3rd edition, Gulf Professional Publishing, Boston.
3. Renoux A., Boulaud D. (1998). Les aérosols : physique et métrologie, Tec&Doc Lavoisier, Paris.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 4, 7 and 8.

The lessons in this option contribute indirectly (as resources) to Skill 3

TEACHING UNIT TITLE: Intelligent Organic Materials: Concepts and industrial applications		OPTIONAL
	ECTS CREDITS 1	S8

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this module is to:

- Introduce students to the concepts and principles of highly organised structures, and study their applications in the development of high added-value materials.

SPECIFIC OBJECTIVES

At the end of the module, students will:

- Master the contents of the "toolbox" for building materials based on super-molecules (weak interactions, molecular recognition processes, molecular self-organisation, etc.).
- Understand the various fields of application of materials derived from supramolecular organisations such as low-molecular-weight gels, liquid crystals and polymers.
- Putting the advantages and opportunities offered by these speciality materials into an economic and industrial context

CONTENT AND TEACHING METHODS

Teaching will take the form of lectures, presentations by industrialists and tutorials.

TYPE OF ASSESSMENT

Individual written assessment and presentation, in the form of a poster, of a publication to be submitted during the first session. This work will be done in pairs.

USEFUL INFORMATION

PREREQUISITES: none
LANGUAGE OF INSTRUCTION: FRENCH
REFERENCES :
Recommended:

1. La Chimie Supramoléculaire, Concepts et Perspectives, Jean-Marie Lehn, DeBoeck Université.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

EDUCATIONAL UNIT TITLE: Advanced Thermodynamics of Solutions		OPTIONAL
	ECTS CREDITS 1	S8

GENERAL OBJECTIVES OF THE TEACHING UNIT

The advanced solution thermodynamics course aims to present the different approaches for calculating a phase diagram, which is essential for sizing a separation unit (distillation, liquid-liquid extraction, crystallisation).

SPECIFIC OBJECTIVES

At the end of the module, students will:

- calculate any isothermal or isobaric phase diagram (positive or negative deviations from ideality, homogeneous or heterogeneous azeotropy, double azeotropy, liquid-liquid demixing, presence of solid phases) from an equation of state or an activity coefficient model
- Master the various algorithms for resolving the conditions of equilibrium between phases
- How to choose a thermodynamic model (activity coefficient model or equation of state) depending on the problem to be addressed
- Master the various mixing rules and the theoretical concepts on which the models are based
- Calculate the properties of a multi-constituent system (total molar quantities, excess quantities, mixing quantities, etc.) using an equation of state.
- Know how to test the stability of a multi-constituent system in order to distinguish stable states from metastable or unstable states.

CONTENT AND TEACHING METHODS

Courses and tutorials

TYPE OF ASSESSMENT

Written exam (1.5 h), Project

USEFUL INFORMATION

PREREQUISITE: thermal separation processes (Jean-Noël JAUBERT's course) TEACHING LANGUAGE: French

REFERENCES :

1. Molecular Thermodynamics of fluid-phase equilibria (J.M. Prausnitz, R.N. Lichtenthaler, E.G. De Azevedo)
2. Introduction to Chemical Engineering Thermodynamics (J.M. Smith, Hendrick Van Ness, Michael Abbott)
3. Thermodynamics: Fundamentals for Applications (Cambridge Series in Chemical Engineering) (J. P. O'Connell, J. M. Haile)

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

EDUCATIONAL UNIT TITLE: **Waste Treatment Methodology manufacturers**		OPTIONAL
	ECTS CREDITS 1	S8

GENERAL OBJECTIVES OF THE TEACHING UNIT

"The best waste is the waste we don't produce! In any manufacturing industry, the transformation of matter (physical or chemical) inexorably generates by-products (commonly known as waste) which cannot be directly recycled and some of which may also represent a danger.
Waste management is therefore a complex issue for any production site and meets two requirements overall:

- The first is legislative and environmental: you can't just dump anything and everything into the natural environment.
- the second is that sustainable production is synonymous with profitable production; recycling a fraction of waste and/or recovering it (it should be noted that this may involve material recovery or energy recovery) is therefore desirable.

In this context, and in order to meet both of the above requirements simultaneously, we need to put in place a genuine waste treatment **strategy**, or rather waste treatment strategy(ies).

SPECIFIC OBJECTIVES

The aim of this optional module is therefore to combine all the knowledge acquired in the core curriculum in the fields of chemistry, physical chemistry, thermodynamics, kinetics, chemical reaction engineering, mechanical and thermal unit operations in order to:

- qualify the waste in terms of both its composition (species present) and its physical nature (single or multi-phase system),
- determine the purpose(s) of the overall processing operation,
- devise a technologically and economically viable chain of operations in response to the objectives.

Given the diversity of the concepts involved, the aim of this optional module is not to make the auditor a specialist in every technique or technology mentioned, but rather to provide them with all the information they need to develop constructive thinking based on common sense and aimed at envisaging the most appropriate solution in a given context.

Our sole avowed aim is to confront the student-engineer with industrial realities and to enable him to apply his knowledge to the development of a coherent process plan, taking into account environmental and economic constraints.

CONTENT AND TEACHING METHODS

By its very nature, this optional module calls on a very wide range of disciplines. For each waste, taken as a whole, there are many possible strategies, but choices have to be made. Our teaching methodology is in line with this principle, and is also based on choices. We will therefore develop our approach according to the following points:
Part 1: Definition of objectives for the type of waste in question, overall treatment strategy
The following 2 sections deal more specifically with the management of waste where the continuous phase is an aqueous phase.
Part 2: Treatment of insoluble pollution: physico-chemistry of multiphase systems and associated mechanical separation processes
Part 3: Treatment of soluble pollution: chemistry of soluble pollution transformation, mechanical separation processes on a sub-colloidal scale
Part 4: Thermal treatment of waste for product or energy recovery:

- Characterisation of waste for thermal treatment - HCV, ICV, Analysis of fuels and waste,
- Study of the incineration process (combustion equations, formation of gaseous pollutants, presentation of by-products (bottom ash and refiom), interest in energy recovery with description of the steam/water cycle, etc.).
- Presentation of flue gas treatment units
- Presentation of other heat treatment methods (pyrolysis, methanisation, gasification, etc.)

TYPE OF ASSESSMENT

- Case study with documents (approx. 1? hours)
- Mini-project

USEFUL INFORMATION

PREREQUISITE: Fundamental knowledge covered in all core curriculum units LANGUAGE OF TEACHING: FRENCH
REFERENCES :

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 9

EDUCATIONAL UNIT TITLE: **Health Products**		OPTIONAL
	ECTS CREDITS 1	*S8*

GENERAL OBJECTIVES OF THE TEACHING UNIT

The design of new medicines and products for use in the healthcare sector is a major issue in modern society. The development of new products requires very precise specifications, depending on the biomedical application envisaged, and entails major constraints, particularly in terms of biocompatibility. The (macro)molecules used are increasingly of natural origin, biosourced and/or biodegradable, but they can also be synthesised. Interest is also growing in so-called 'intelligent' stimulable products. In this context, the aim is to familiarise students with the design of products for health applications and to show them the latest advances and challenges in this field (specifications, development strategy, etc.). Examples of commercial products will be studied, as well as those still under development in high-stake areas (pharmaceuticals, cosmetics, biomaterials, etc.).

SPECIFIC OBJECTIVES

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

- Understand and explain the specifications to be met when designing a health product
- Understand the process used to design a drug, from the synthesis of the molecule to its marketing.
- Understand the potential uses of polymers in the healthcare sector, and in particular their interest in the design of biomaterials

CONTENT AND TEACHING METHODS

This course will be based on lecture sessions including a lecturer, and on a micro-project associated with project presentation sessions/DDs/tutorials (3.5h) and will end with a final presentation to all the project groups (2h). Apart from the lecture, project and introduction, the course will be structured in 2 parts:

Part 1. From molecule to drug (4.5 hrs): the aim is to explain how a synthesised molecule can become a drug. Several stages and, above all, many years are needed to achieve this objective: the study of biological targets, synthesis, the action of a molecule on the target and clinical studies. These different stages will be presented in such a way as to lay the foundations for a career in the pharmaceutical industry.

Part 2. Polymers for biomedical applications (6 h) :

a. General introduction - concept of biomaterials - main constraints linked to their specifications, types of polymers used

b. A more detailed presentation of a number of examples of biomaterials: materials for surgery (osteosynthesis screws, endoprostheses, etc.), polymers for galenics and nanomedicine (drug delivery systems, medical diagnostics, etc.), hydrogels for drug delivery, tissue repair and dressings, biomaterials for tissue engineering, etc.

TYPE OF ASSESSMENT

- Mini-project: oral presentation

USEFUL INFORMATION

MAXIMUM NUMBER OF PARTICIPANTS: 25
PREREQUISITE: Basic knowledge of chemistry and physical chemistry
TEACHING LANGUAGE: French

REFERENCES :

Recommended:

1. Dumitri S., Polysaccharides in medicinal Applications, Ed. Marcel Dekker, 1996, 779 p
2. Li S., Tiwari A., Prabaharan M. and Aryal S., Smart polymer materials for biomedical applications, Ed. collection, 2010, 405 p.
3. Ramakrishna, S., Ramalingam, M., Sampath Kumar T. S. et al, Biomaterials: a nano approach, Ed. CRC Press, 2010, 350 p.
4. Kewal J. K. Drug Delivery Systems, Ed. Human Press, 2008, 251 p.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

The lessons in this option contribute indirectly (as resources) to skills 1, 6 and 11.

TITLE OF EDUCATIONAL UNIT: **Industrial Polymerisation and Polymerisation Processes sustainable development**		OPTIONAL
	ECTS CREDITS 1	*S8*

GENERAL OBJECTIVES OF THE TEACHING UNIT

Polymerisation processes are designed using process engineering methodology. However, polymers differ from the usual products of the chemical industry in several specific ways: they are products with distributed characteristics (molar mass, chemical composition, branching, etc.); the progress of the polymerisation reaction generally leads to a significant variation in the physical properties of the reaction medium (viscosity, thermal diffusivity, etc.), with consequences for the performance of the reactor; and finally, the application properties (particularly the shaping properties) depend closely on the shape of the distribution of the characteristics of the macromolecules (which is itself closely linked to the operation of the reactor and the kinetic scheme).
In addition, the production and use of polymers raises a number of issues relating to their environmental impact and the notion of sustainable development. These issues are addressed using specific examples.
The aim of this module is to extend the basic concepts covered in the core curriculum, by combining presentations by industrialists, classroom sessions and a visit to an industrial site.

SPECIFIC OBJECTIVES

At the end of this course, students should know and understand:

- The principle of designing a chain and step polymerisation process
- The main links between process design and the characteristics of the polymers obtained
- How polymerisation reactors work
- Sustainable development issues in the polymer life cycle

CONTENT AND TEACHING METHODS

The module will alternate classes and lectures by industrialists. This module will be supplemented by a visit to an industrial polymer production site.

TYPE OF ASSESSMENT

Individual assessment in the form of MCQs based on the content of the course sessions and lectures. Mini-project carried out in groups and presented orally. Students must work as a group to design a polymerisation process and explain the issues relating to sustainable development in the case of the polymer they have studied.

USEFUL INFORMATION

PREREQUISITES: none
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES:
Recommended:

1. Génie de la Réaction Chimique, J. Villermaux, Tec et Doc, Lavoisier, 1993.
2. Cinétique et Catalyse, G. Scacchi, M. Bouchy, JF. Foucault, O. Zahraa, Lavoisier, Tec et Doc, 1996.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 4, 9 and 13.

The lessons in this option contribute indirectly (as resources) to Skill 14

TEACHING UNIT TITLE: **Polymeric nano-objects: syntheses, characterisation and applications**		OPTIONAL
	ECTS CREDITS 1	*S8*

GENERAL OBJECTIVES OF THE TEACHING UNIT

Polymer-based nano-objects are now widely used in a variety of applications, including the pharmaceutical, food and cosmetics industries. The chemical and physical properties of polymers are becoming increasingly varied, and it is now possible to develop intelligent nano-objects that respond to external stimuli such as pH, light or temperature. In addition, new, faster and more economical methodologies for accessing nano-objects with advanced morphologies (spherical, cylindrical and vesicular) are being developed, making them more attractive for industrial production. The main objective of this course is to expose engineering students to the latest methodologies developed in the academic world for the formulation of polymeric nano-objects. Emphasis will be placed on processes that can be transposed or potentially used on an industrial scale. The physico-chemical characterisation of these nano-objects will be presented, with particular emphasis on light scattering and microscopy.

SPECIFIC OBJECTIVES

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

- Learn about new processes for producing amphiphilic copolymers.
- Learn about new self-assembly technologies for amphiphilic copolymers.
- Knowledge of characterisation methods using light scattering and microscopy.

CONTENT AND TEACHING METHODS

This course will be based on lectures (12h), tutorials (4h) and a practical session (2h) where techniques for formulating and characterising nano-objects will be used.

TYPE OF ASSESSMENT

Project and oral presentation by team.

USEFUL INFORMATION

PREREQUISITE: Basic knowledge of polymer chemistry.
LANGUAGE OF TEACHING: French.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 1

EDUCATIONAL UNIT TITLE: **General Installation**		OPTIONAL
	ECTS CREDITS 1	*S8*

GENERAL OBJECTIVES OF THE TEACHING UNIT

At the heart of a multi-skilled project organisation, the General Installation business line designs buildings housing chemical and/or mechanical processes for the entire nuclear fuel cycle, from uranium mining to the recycling of fuel elements from nuclear power plants.
Through a series of presentations, we invite you to discover this profession, its roles and responsibilities, its interfaces with other professions, including the Process, and its main deliverables.

SPECIFIC OBJECTIVES

At the end of this module, the student-engineer will have a better understanding of:

- Input data (process, safety, etc.) that is crucial to building design,
- Building design principles (how to go from a process diagram to a 3D model)
- The engineering documents produced and the level of detail adapted to each phase of the project.
- Means of transferring radioactive fluids used at La Hague.
- Introduction to the world of 1D/2D/3D using the AVEVA software suite (Engineering, Diagrams, E3D)

CONTENT AND TEACHING METHODS

18h of training spread over 6 sessions, based on 12 presentations:

- Nuclear fuel cycle (chemical and mechanical processes)
- Introduction to general installation
- Industrial risks (definition)
- Safety requirements
- Building ventilation: interfaces, input/output data
- Civil engineering: interfaces, input/output data
- Electricity: interfaces, input/output data
- Process equipment and piping (including means of transferring radioactive solutions)
- Defining the layout: the main principles of facility design
- Specification of piping materials and fittings
- P&ID: Specificity of the schematic at ORANO Projects
- Estimating piping contracts.

TYPE OF ASSESSMENT

Final exam on part of the course (1h)

USEFUL INFORMATION

PREREQUISITES: none
LANGUAGE OF TEACHING: French.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

COURSE UNIT TITLE: **Artificial Intelligence (AI) for Business Engineering processes – Initiation**		**OPTIONAL**
	ECTS CREDITS 1	***S8***

GENERAL OBJECTIVES OF THE TEACHING UNIT

The "IA for Process Engineering - Initiation" option aims to :

- Present an overview of methods for processing massive data ("Big Data") and automatic learning ("Artificial Intelligence", "Machine Learning", "Deep Learning"), both supervised and unsupervised.
- Describe a few emblematic dimension reduction, clustering and regression methods from the family of machine learning methods.
- To illustrate the value of surrogate models and their characteristics.
- Provide an initial introduction to deep learning.
- Implement these methods on concrete Process Engineering cases, using the Matlab environment.

This option is a continuation of the S7 option entitled "IA for Process Engineering - First Contact", without the latter being a prerequisite. A summary of the concepts covered in S7 will be given at the beginning of each session.

SPECIFIC OBJECTIVES

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

- Have a complete understanding of machine learning approaches.
- Apply a number of methods typical of each category of problem, depending on the objective (regression, clustering, dimension reduction, etc.), including the pre-processing of available data.
- Understand the advantages and weaknesses of these methods.
- Get an initial idea of the benefits and capabilities of deep learning methods.
- Apply the main methods in an appropriate software environment.

CONTENT AND TEACHING METHODS

The sessions are carried out exclusively on a computer in a computer room, using the functions and toolboxes dedicated to machine learning in the Matlab environment.

TYPE OF ASSESSMENT

Individual test on machine or MCQ (1 hour)

USEFUL INFORMATION

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

1. Chloé-Agathe Azencott, "Introduction to machine learning", Ed. Dunod, 2018.
2. Stéphane Tufféry, "Big Data, Machine Learning and deep learning", Ed. Technip, 2019.
3. Ian Goodfellow, "Deep learning", Massot Editions, 2018.
4. Charu C. Aggarwal, "Data mining - the textbook", Ed. Springer, 2015.

Required: Handouts or slides distributed, data files distributed via ARCHE.

Recommended: See bibliographical references.

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 3

The lessons in this option contribute indirectly (as resources) to Skill 4

COURSE TITLE: STRATEGY: SUSTAINABLE DEVELOPMENT FOR INDUSTRY		OPTIONAL
	ECTS CREDITS 1	SEMESTER 8

AIMS:

This course aims to:

- Understand the definitions and principles of Sustainable Development and CSR,
- Understand all the challenges raised by Sustainable Development in industry,
- Be able to analyse and contribute to corporate strategy,
- Integrate Sustainable Development as a winning factor in corporate strategy, particularly in terms of added value.

LEARNING OUTCOMES:

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

- Identify and use the main sustainable development levers that can be applied in industry,
- Understand the implications for each corporate function (in particular HR and Purchasing),
- Know how to read a company's CSR report,
- Integrate the communication dimension to convince stakeholders and avoid greenwashing,
- Become involved in their company's CSR approach as soon as they start to work / Put in place the CSR foundations when setting up their company.

DESCRIPTION AND TEACHING METHODS:

The course is based on:

- Lectures/lessons,
- Exercises on real case examples,
- A business case to be carried out in teams,
- A contribution to the ENSIC RAISPIR project.

EVALUATION METHODS:

Oral presentation following group work

USEFUL INFORMATION:

PREREQUISITES: NONE
LANGUAGE: FRENCH

BIBLIOGRAPHICAL REFERENCES:
Needed: DOCUMENTS DISTRIBUTED
Advised:

TEACHING UNIT TITLE: **Reactors and Multiphase Separations**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

This course aims to:

- Deepen knowledge of catalytic engineering and multiphase reactors
- Be capable o f analysing and sizing a multiphase contactor implementing a reaction
- Be able to analyse and size crystallisation and precipitation processes and chromatographic processes

SPECIFIC OBJECTIVES

At the end of the course, students must:

- Develop original models of catalytic reactions and reactors
- Knowing how to take into account catalyst deactivation phenomena
- Understanding and implementing catalyst regeneration processes
- Understand and describe the hydrodynamic operation of fixed-bed and fluidised-bed reactors.
- Understanding transfer-reaction coupling modelling in G-S, G-L, G-L-S systems
- Estimate the terminal velocity of a fluid inclusion
- Be able to estimate the pressure drop in a gas-liquid flow line
- Analyze the hydrodynamics of flows in bubble columns and trickling fixed-bed catalytic reactors.
- Be able to select and size a heterogeneous reactor
- Be able to choose and size a separation by crystallisation
- Be able to choose and size a chromatographic separation system

CONTENT AND TEACHING METHODS

Catalytic engineering: fixed-bed and fluidised-bed heterogeneous catalytic reactors, catalytic kinetics, transfer limitations, catalyst deactivation.

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

Multiphase reactors: choice of contactor, hydrodynamics of two-phase and three-phase flows, transfer limitations, reactor models.

Crystallisation: crystallisation kinetics and mechanisms, population balances, industrial crystallisers, precipitation.

Chromatographic processes: transfer modelling, simulated moving bed, chromato-graphic reactors.

TYPE OF ASSESSMENT

Homework (2) Written exams (3)

USEFUL INFORMATION

PREREQUISITE: Basic knowledge of chemistry, chemical engineering and transfers
TEACHING LANGUAGE: French
REFERENCES :
Required: Chemical engineering course handouts,
Opérations polyphasiques en génie des procédés, hydrodynamique, transferts, réactions, séparations mécaniques. Paris ; éditions Ellipses, 2^{e} éd. 2023
Recommended:

1. Génie de la Réaction Chimique, J. Villermaux, Tech & Doc, Lavoisier, 1993, Paris.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skills 2, 4 and 5.

The lessons in this unit contribute indirectly (as resources) to competences 4, 9 and 11.

EDUCATIONAL UNIT TITLE: **Sustainable Processes**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this teaching unit is to provide appropriate, reasoned responses to health, safety, environmental protection and sustainable development concerns during the various phases in the life of a process.

SPECIFIC OBJECTIVES

At the end of the course, students must:

- Be able to carry out a risk analysis on a complex industrial system
- Knowing the regulations and specificities of industrial water treatment
- Be able to implement an environmental management system
- How to carry out a life cycle analysis

CONTENT AND TEACHING METHODS

Life cycle assessment: definition of the object and scope of the study, analysis of the life cycle inventory, assessment of life cycle impacts, interpretations.

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

Environment: Environmental management, ISO 1400x standards, Eco-audit, Treatment of gaseous effluents, Treatment of industrial water.

TYPE OF ASSESSMENT

Continuous assessment (MCQs at the end of the course), Project using the MOSAR methodology on major industrial accidents. Project report and oral presentation.

USEFUL INFORMATION

PREREQUISITES :
TEACHING LANGUAGE: French
BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this unit contribute directly to the acquisition of competences 4, 6, 7, 8, 9 and 11 The lessons

in this unit contribute indirectly (as resources) to competences 3 and 10.

EDUCATIONAL UNIT TITLE: **Process Design and Simulation**		MANDATORY
	ECTS CREDITS 4	**S8 COURSE** PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this course is to extend and complement the general courses on process simulation and design. The teaching unit aims to :

- Introduction to the basic concepts of energy thermodynamics and exergy analysis
- Describe the methodologies used to approach the separation of complex mixtures by distillation
  Present the basics of dynamic process simulation

SPECIFIC OBJECTIVES

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

- Recognise and differentiate between the main types of energy system
- Carry out an energy balance, whatever the complexity of the process studied
- Performing a pinch analysis
- Construct and interpret a distillation residue curve
- Envision thermal integration strategies for distillation processes
- Identify the possible distillation sequences for separating a given complex mixture
- Moving from a steady-state process model to a transient model
- Simulate a process described by systems o f ordinary differential equations, algebraic differentials or partial algebraic differentials.

CONTENT AND TEACHING METHODS

<u>Teaching methods: lectures and tutorials</u>

<u>Contents:</u>
<u>Advanced energy thermodynamics</u>

Operating modes of the various components of an engine or refrigeration cycle Thermal machines, refrigeration production processes, gas liquefaction.
Introduction to exergy analysis and thermo-economics. Pinch analysis and technology.
Optimising process architecture
Case study (processes linking the concepts presented in the other elements of the module).

<u>Distillation of complex mixtures</u>

Construction and interpretation of residue curves
Azeotropic distillation and extractive distillation
Thermal integration of distillation
Development of distillation trains

<u>Dynamic process simulation</u>

Presentation of processes whose model is described by ordinary differential, algebraic-differential or algebraic-differential equations.
Specification of initial conditions
Simple and advanced integration methods (BDF combined with Newton's method) Notion of indexes and systems of high-index algebraic-differential equations
Use of Dynsim or gPROMS software for process simulation (flash, reactors, distillation)

TYPE OF ASSESSMENT

Written tests (thermodynamics, distillation, dynamic simulation) and written report (thermodynamics: case study)

USEFUL INFORMATION

PREREQUISITES: UE Thermodynamics and energy, UE Thermal separation processes, UE Process systems engineering and UE Reactive systems and processes II (EC: separation processes I)
LANGUAGE OF TEACHING: French
BIBLIOGRAPHICAL REFERENCES :
Required:
Séparations thermiques en génie des procédés, distillation, air humide, séchage. Paris ; éditions Ellipses, 2021Handouts Recommended:

1. Separation Process Engineering: Includes Mass Transfer Analysis: International Edition Paperback - Phillip C. Wankat
2. Fundamentals of Engineering Thermodynamics 7th Edition - Wiley - Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner, Margaret B. Bailey
3. The Exergy Method of Thermal Plant Analysis, Krieger Publishing Company, Malabar, Florida, 1985, T.J. Kotas.
4. Product and Process Design Principles: synthesis, analysis and evaluation, 3rd edition, Wiley, 2009 W.D. Seider, J.D. Seader, D.R. Lewin, S. Widagdo
5. Distillation of non-ideal mixtures - Residue curves and other design tools, Techniques de l'Ingénieur, 2010, Vol. J 2611
6. Distillation of non-ideal mixtures - Azeotropic distillation and extractive distillation. Choice o f entrainer, Techniques de l'Ingénieur, 2010, Vol. J 2612

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 3, 4 and 5.

The lessons in this unit contribute indirectly (as resources) to competences 9, 11 and 12.

TEACHING UNIT TITLE: **Micro- and Nanostructured Products**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The course aims to:

- Discover micro and nano structured products (emulsions, colloidal dispersions, microparticles).
- Acquire knowledge of the characterisation and behavioural analysis of molecules used in formulated products.
- Understand the link between structural characteristics and product behaviour, particularly at interfaces.
- Describe the main laws of behaviour of micro- and nanoparticles and use them in the design process (formula, process, use) of a product with a specific function.

SPECIFIC OBJECTIVES

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

- Analysing product formulations and understanding, in particular, the behaviour of the surfactant molecules used in these products.
- Choose and justify the choice of a compound (surfactant) in the formula of a product.
- Integrating the ecological transition into product formulation.
- Make the link between the structural and behavioural characteristics of products, particularly at interfaces.
- Studying processes for dispersed systems
- Design manufacturing processes for products with a specific function containing micro- or nanoparticles.
- Analyse the process of microplastic pollution and devise strategies for replacing non-biodegradable micro- and nanoparticles with biodegradable systems in formulated products

CONTENT AND TEACHING METHODS

<u>1. Physico-chemistry and formulation of multiphase fluid systems</u>
- Physical chemistry of interfaces
- Sprawl dynamics
- Formulation and manufacture of foams
-
- Classes, specificity and behaviour of surfactants in solution
- Micellisation, adsorption at interfaces, liquid crystal phases
- Emulsions : definition, formulation rules, manufacturing processes
- Deformulation: analysis of formulated productsProduct reformulation : adapting products to the ecological transition and integrating them into the circular economy
- Lecture by a speaker from the world of industry

<u>2. Processes for dispersed fluid systems</u>
- Mechanically assisted emulsification, equipment
- An attempt to model spatio-temporal phenomena; examples of semi-empirical modelling
- Micro-technology for controlled emulsification, nucleation and growth: basic principles and mechanisms
- Relationship between the quality of a dispersed system and the energy cost
- Atomisation: characterisation of dispersions and atomisation d e v i c e s ; atomisation mechanisms and characteristics

3. Processes for dispersed solid systems

- Characterisation of dispersed systems: granulometry, energies and surface potentials
- Qualitative and quantitative description of Brownian motion, physical and physico-chemical instabilities (DLVO), controlled release mechanism, filmification mechanism
- Study of nanoparticle and microparticle manufacturing technologies
  - Analysis of a PID batch manufacturing scheme: solvent emulsification-evaporation
  - By descriptive analysis o f other processes: sol-gel processes, solvent diffusion, atomisation, pyrolysis, spray-drying, interfacial polymerisation, etc.

TYPE OF ASSESSMENT

1. Physico-chemistry and formulation of multiphase fluid systems: a written test at the end of the module
2. Processes for dispersed fluid systems: homework mini-project
3. Processes for dispersed solid systems: MCQs

USEFUL INFORMATION

PREREQUISITES: L3 level, basic knowledge of chemical engineering and chemistry
TEACHING LANGUAGE: French
REFERENCES :
Recommended:

1. Physical chemistry of surfaces, *A.W. Adamson*, John Wiley and Sons
2. Fundamentals of Interfacial Engineering, *Robert J. Stokes*, *D. Fennell Evans*, Wiley 1996

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this unit contribute directly to the acquisition of skill no. 4

EDUCATIONAL UNIT TITLE: **Introduction to Product Engineering**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Introduction to Product Engineering course aims to:

- Understanding the organisation of the chemical industry and the positioning of the formulated products industry
- Highlight the specific characteristics of these industries
- Understanding the particularities of batch processes
- Present and explain a product life cycle analysis

SPECIFIC OBJECTIVES

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

- Addressing the many facets of product engineering
- Choosing and justifying the choice of a batch process
- Analysing a product's life cycle

CONTENT AND TEACHING METHODS

1. From process engineering to product engineering
    - Positioning the theme
    - Notion of ownership by use
    - Specific methodologies
    - Intellectual property
    - Eco-design

2. Batch processes
    - Material and heat balances in batch reactors
    - Optimising efficiency and selectivity
    - Thermal stability and runaway in batch reactors
    - Controlling heterogeneous reactions in batch reactors
    - Batch mode crystallisation

3. Life cycle analysis
    - Definition of the subject and field of study
    - Life cycle inventory analysis
    - Life cycle impact assessment, interpretations
    - Lecture by a speaker from the world of industry

TYPE OF ASSESSMENT

1. From process engineering to product engineering: Documentary research and presentations in groups of 3-4 people
2. Batch processes: A written test at the end of the module
3. Life cycle analysis: MCQs

USEFUL INFORMATION

PREREQUISITES: L3 level, basic knowledge of chemical engineering and chemistry
TEACHING LANGUAGE: French

References :

Recommended:

1. Chemical Product Design (Cambridge Series in Chemical Engineering), E.L. Cussler; Cambridge University Press; 2nd edition
2. Génie De La Réaction Chimique - Conception et Fonctionnement Des Réacteurs , Jacques Villermaux ; Lavoisier Tech & Doc

Contribution of the teaching unit to the acquisition of skills

This course contributes directly to the acquisition of skills 2, 4, 9 and 13.

The lessons in this course contribute indirectly (as resources) to competences 10, 14 and 16.

TEACHING UNIT TITLE: **From Molecules to Products**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Introduction to Product Engineering course aims to:

- From the product design strategy, through the choice of molecules and form (linked to the specifications and targeted properties of use), to the specific manufacturing process and characterisation of the finished product.
- To highlight the importance of the chemical structure of the molecules used in the formulation of a product and its link with the resulting physical properties and, ultimately, with the expected properties of use for this product.
- Acquire a basic understanding of rheology. Understand rheology as a tool for characterising complex systems in industry.
- Produce products on a laboratory scale and characterise the products produced.

SPECIFIC OBJECTIVES

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

- in a "reverse engineering" approach, to develop a product design strategy from the choice of molecules and product shape (linked to the specifications and targeted properties of use) through to the specific manufacturing process
- analyse the chemical structure of molecules and link their physico-chemical properties with some of the expected properties of use for the final product
- explain the behaviour of complex molecular systems as a function of their environment.
- justify the use of certain functionalities in the formulation of a product
- design and apply formulated products
- characterise the finished product
- master rheology as a tool for characterising complex systems

CONTENT AND TEACHING METHODS

1. TP-Formulated Products - 24h: Design and implementation of formulated products- manufacturing and characterisation of the finished product:
   - Synthesis of molecules
   - Development of particles, gels, emulsions and dispersions
   - Study of the wetting phenomenon
   - Product characterisation (particle size, interfacial tension, rheology, etc.)
   - Optimising efficiency and selectivity

2. Rheology (11h)
   - Introduction to the basic concepts and equations of rheology
   - Description of the main rheological behaviours (Newtonian, rheofluid, threshold, thixotropic) using examples from the cosmetics, hygiene and coatings industries
   - Description of t h e solid-liquid ambivalence of formulated systems and viscoelastic behaviour, with particular emphasis on gels.
   - Measuring instruments and methods classified according to their purpose: tools for quality control or research & development
   - Systemic rheology
   - Industrial case studies

3. Structure of molecules and properties for use (22.5 hrs)

This course is structured around 3 case studies on the following themes.

- Stability/Lability of a product: Main functions - Influence of the environment/Prevention
- Stimulation and properties triggered on demand: Formation/destruction of reversible or non-reversible interactions/bonds under stimulus action
- Activity -Toxicity: Notion of active site/Active centre in relation to chemical structure-Introduction to the main methods of obtaining an active product.

The teaching shows the complexity of structure-property relationships and, at the end of the session, makes the student-engineer aware of certain prediction methods.

TYPE OF ASSESSMENT

1. TP Formulated Products: TP reports
2. Rheology: Final exam 1h
3. Structure of molecules and properties for use: Intermediate presentations on case studies - Final exam 1.5h. The average mark for the case study presentations and the examination each count towards the ½ grade of the component

The Final grade is the weighted average of the grades for each CE, calculated in proportion to the time spent in attendance, i.e. 2/1/2.

USEFUL INFORMATION

PREREQUISITE: Basic knowledge of chemical engineering and chemistry TEACHING LANGUAGE: French

REFERENCES :

Recommended:

1. Chemical Product Design (Cambridge Series in Chemical Engineering), E.L. Cussler; Cambridge University Press; 2nd edition
2. Product Design and Engineering: Formulation of Gels and Pastes, U. Brockel -W. Meier (Editor), G. Wagner, Wiley
3. Product Design and Engineering, 2 Volume Set , U. Brockel -W. Meier (Editor), G. Wagner , Wiley
4. Product engineering: molecular structure and properties, J. Wei, Oxford University Press, 2007
5. Comprendre la rhéologie, P. Coussot, J.L. Grossiord, EDP Sciences

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 4, 8, 11 and 13.

The lessons in this course contribute indirectly (as resources) to competences 3, 5 and 6.

EDUCATIONAL UNIT TITLE: **Introduction to Biological Sciences**		MANDATORY
	ECTS CREDITS 4	S8 COURSE BIOTECHNOLOGIES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this module is to acquire basic notions of biology and biochemistry as well as a vocabulary that will enable students to understand their biologist colleagues and thus facilitate collaboration. The cell, how it works and its main constituents will be covered, along with their functions and the uses that can be made of them in biotechnology. This last point will just be an introduction to the following modules. Finally, techniques for the structural and physico-chemical characterisation and separation of biomolecules on a laboratory scale will be presented.

SPECIFIC OBJECTIVES

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

- Understanding the main components of the cell and their functions
- Understand how the cell functions, in particular the basic principles of metabolism, replication and enzymology
- Be familiar with the main techniques for the structural and biochemical characterisation and separation of biomolecules

CONTENT AND TEACHING METHODS

1) Biomolecules: Introduction to the biological sciences (27h)

First, the cell and its components - membranes, organelles and biomolecules - will be described. The functioning of a cell will be discussed in order to understand how the cell works: what are its needs? What biochemical reactions are involved? A few examples of metabolic pathways will be chosen for energy production and biomolecule synthesis (glycolysis, Krebs cycle, biomolecule biosynthesis, etc.).

Two families of biomolecules in particular will be addressed, nucleic acids and proteins (enzymes, antibodies), which are the main players used in transgenesis, for example, or ink in agri-food processes. Several approaches will be developed: first of all a descriptive approach; the chemical structures will be described but also the three-dimensional structures which are essential in understanding the mechanisms of these molecules. Various biophysical methods will also be described. The second approach will describe the cellular functions that are important in biotechnologies. In particular, cell replication will be dealt with, using examples from current developments in transgenesis and the use of genetic engineering, and the foundations of enzymology will be laid.

2) Analytical methods at laboratory level (30h)

In this second part, we describe the various analytical techniques available in the laboratory, whether they are (a) biophysical and dedicated to structural analysis (infrared spectroscopy, circular dichroism, NMR, crystallography, artificial intelligence and molecular modelling, etc.), (b) biochemical for characterising biomolecules (Elisa; PCR; westernblot; etc.) or studying molecular interactions, or (c) separative for purifying biomolecules: precipitation, filtration, centrifugation, various chromatographies (reverse phase, steric exclusion, hydrophobic interaction, ion exchange, affinity, etc.), electrophoresis (capillary, SDS page, etc.).
The ethical aspects of biotechnology will be addressed and debated, in conjunction with social responsibility and sustainable development.

Teaching methods include lectures and tutorials, but also new teaching methods such as flipped lectures and role-playing.

TYPE OF ASSESSMENT

3-hour written exams and oral presentations

USEFUL INFORMATION

PREREQUISITE: basic knowledge of chemistry
TEACHING LANGUAGE: French

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 1, 4 and 5.

The lessons in this unit contribute indirectly (as resources) to competences 3, 8 and 11.

TEACHING UNIT TITLE: **Biocatalysts and Bioreactors**		MANDATORY
	ECTS CREDITS 4	S8 COURSE BIOTECHNOLOGIES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim of this module is to acquire the basics of biological process engineering. Firstly, the fundamentals of enzymatic and bacterial kinetics will be mastered, followed by the writing of material balances in closed, continuous and semi-continuous biological reactors. Part of the course will deal with hydrodynamics and heat and mass transfer phenomena for the main reactor technologies used in the industry. Finally, the module will provide an introduction to the modelling of bioprocesses and the sizing of the main specific equipment used, and will lay the foundations for scaling up from the laboratory to industry.

SPECIFIC OBJECTIVES

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

- Represent enzymatic and microbial reactions using the appropriate kinetic laws
- Write material balances for different types of enzymatic and microbial biological reactors and master the modelling of biological reactors
- Represent the hydrodynamics of biological reactors, taking into account heat and matter transfer phenomena
- Dealing with the complexity of scaling up a process from the laboratory to the pilot plant and then to industry

CONTENT AND TEACHING METHODS

1. Biocatalysis and bioreactors: from the scale of the cell to that of the reactor and process a) Characterisation of enzymatic (Michaela kinetics) and microbial (Monod's law) biocatalysis mechanisms. The course will be supported by tutorials in the form of exercises as well as online tests in order to facilitate learning retention. b) Enzymatic and microbial reactor engineering: flows, continuous, closed and semi-continuous reactors, material balances. Modelling tutorials in a computer room will familiarise students with modelling in biotechnology. Aspects of instrumentation, control and data processing will also be covered.

2. Fixed-bed reactors and gas-liquid and gas-liquid-solid reactors: studying these reactors will enable students to study the hydrodynamics of a reactor and understand the transfers of matter and heat that take place there, the rheology of biological media and thus write detailed balances.

3. Scale-up: this section will deal with the problems of moving from laboratory scale to industrial scale and will give the student an insight into this know-how.

TYPE OF ASSESSMENT

- Written exam (3 hours)
- Micro-project with written report and oral presentation (6 hours classroom-based)

USEFUL INFORMATION

PREREQUISITES: knowledge of Matlab software.
TEACHING LANGUAGE: French

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The teaching in this unit contributes directly to the acquisition of skills 1, 2, 4 and 6.

The lessons in this course contribute indirectly (as resources) to competences 3, 7, 9 and 11.

TEACHING UNIT TITLE: **Bioseparations**		MANDATORY
	ECTS CREDITS 4	S8 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The course aims to:

- Raising awareness among engineering students of the various separative technologies used in biotechnology production
- Train students in a structured approach leading to analysis of the phenomena involved in bioseparation processes
- Provide the basic knowledge needed to calculate the various separation processes used in biotechnology
- Make students aware of the criteria for choosing equipment and the importance of a global approach (concentration/purification chain).
- Implement bioreactions and characterisation adapted to proteins at different scales

SPECIFIC OBJECTIVES

At the end of the module the student must:

- Be familiar with the main processes used in bioseparation and the principles on which they are based
- How to select a separation process according to a set of constraints (nature of the mixture to be separated, target performance, operating conditions)
- Be able to design a process for a given application, taking into account the specific characteristics of biomolecules
- Understand the interactions between the different types of process involved in a concentration/purification chain for a biological molecule.

CONTENT AND TEACHING METHODS

Centrifugation / Filtration: 2 class sessions (1h30) - 2 practical sessions (1h30)

Membrane processes: 5 class sessions (2h00) - 4 practical sessions (2h00)
Notion of selectivity, rejection rate and permeability; different types of membrane processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, dialysis, pervaporation, membrane contactors); membrane materials and modules; matter transfer/flow law, concentration polarisation ; osmotic effects; industrial case studies (batch concentration of a complex mixture; sizing of a protein ultrafiltration unit; treatment of a solution by reverse osmosis; separation by dialysis; degassing of a liquid mixture by contactor).

Chromatographic processes: 6 class sessions (1h30) - 6 practical sessions (1h30)
Different types of adsorbent. Different methods of implementation (elution, frontal). General material balances. Concept of concentration wavefront. Solving general equations (analytical and numerical). Cyclic processes. Application to biomolecules. Separation of enantiomers by Simulated Moving Bed. Sequential and continuous multicolumn processes.

Crystallization: 2 class sessions (1h30) - 3 practical sessions (1h30) – 1 examination (1h30)
Nucleation, growth, aggregation and fracture mechanisms. Influence of physico-chemical conditions and process parameters. Discontinuous crystallisation process. Population balances. Industrial case studies.
Practical work in biotechnology :

1. Characterisation of unknown proteins by SDS-Page.
2. Implementation and analysis of enzymatic kinetics
3. Preparing a cell culture

4. Use of a cell culture in a bioreactor/pilot fermenter

TYPE OF ASSESSMENT

Examination
TP-biotechnology: TP reports

USEFUL INFORMATION

PREREQUISITES :
LANGUAGE OF INSTRUCTION :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 4, 5, 8, 11 and 13.

COURSES IN SEMESTER 9

GENERAL ORGANISATION

Title of Teaching and Learning Unit its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Management and economics V	Vera IVANAJ	40	20	20					2
Language V	E. KASMAREK/M. ADRIAN	48		48					3
English				48					
Research and development project	Khalid FERJI								10
Options		19							3
Specialisation courses		Approx. 147							12
TOTAL		**Approx 254**							**30**

OPTIONS

Title of option V	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Plastics recycling: technologies, issues and challenges	Dimitrios MEIMAROGLOU	19	8	8		3			3
Materials and nanomaterials for catalysis	Halima ALEM-MARCHAND	19	8	8		3			3
Fuel combustion kinetics, biofuels and e-fuels	Olivier HERBINET	19	8	8		3			3
Numerical resolution of transport	François LESAGE	19	7	7		3		2	3
Electrochemical engineering applied to energy and environmental protection	Emmanuel MOUSSET	19	7	7		3		2	3
Glasses, metals, céramics	Christian BOUIGEON	20	8	12					3
Technological solutions for capturing, storing and using CO2	Bouchra BELAISSAOUI	19	9			8		1,5	3

SPECIALISATION COURSE: Processes for energy and the environment
Head: Sabine RODE

Title of the Teaching Unit and its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Process engineering and energy	Olivier HERBINET	60	14	10			33	3	4
Industry conferences	Olivier HERBINET						33		
Combustion	Olivier HERBINET		6	6				1,5	
Energy analysis	Jean Noël JAUBERT		8	4				1,5	
Dynamic optimisation and advanced control	Abderrazak LATIFI	46	30	10		6			4
Dynamic optimisation	Abderrazak LATIFI		20			3			
Advanced control	Jean-Marc COMMENGE		10	10		3			
Intensification of processes and innovation	Jean-Marc COMMENGE	33	12	9		9		3	4
Process intensification	Jean-Marc COMMENGE		6	4,5				1,5	
Membrane processes	Eric FAVRE		6	4,5				1,5	

Innovation project	Jean-Marc COMMENGE					9			
TOTAL		**139**							**12**

SPECIALISATION COURSE: Innovative products: from chemistry to processes
Head: Cécile NOUVEL

Title of the teaching unit and its constituent parts	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Speciality products	Alain DURAND	59,5	45	6			3	5,5	4
Copolymers: from processes to applications	Anne JONQUIERES		10,5	4,5				1,5	
Plastics formulation	Cécile NOUVEL		9				3	1	
Polymers in solution at interfaces and emulsion	Alain DURAND		25,5	1,5				3	
Product properties and quality	Anne JONQUIERES	62,5	36,5	18				8	4
Processes for health products	Laurent MARCHAL-HEUSSLER		8	6				1	
Design of experiments	Graciela CARES		6	6				1	
Thermophysical properties of polymers	Anne JONQUIERES		19,5	1,5				4,5	
Crystallization	Eric SCHAER		3	4,5				1.5	
Case study - design project for innovative products	Laurent MARCHAL-HEUSSLER	33	18	3		9		3	4
Product design project innovative	Laurent MARCHAL-HEUSSLER		9			9		3	
Solids manufacturing processes inorganic	Mohammed BOUROUKBA		9	3					
TOTAL		**155**							**12**

COURSES IN SEMESTER 10

Title of teaching unit	Manager	H	CM	TD	TP	P	C	Ex	ECTS
Engineering internship	Laëtitia CESARI								30
TOTAL									**30**

TITLE OF CURRICULUM UNIT : *Management and Economics V*		MANDATORY
	ECTS CREDITS 2	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

Practise a simulation of global business management, enabling students to make rapid strategic and operational choices, based on changes in the market, the competition and other economic factors.

SPECIFIC OBJECTIVES :

Managing a fictitious company in competition with other companies in a simplified economic market (computer simulation).

CONTENT AND TEACHING METHODS

1. Estimating a market: potential and the impact of conjecture
2. Production and sales management
3. Financial risks and investments
4. Personnel management
5. Marketing strategy

Finalising your personal and professional project: Company day

The format of this day (see "Management and Economics I" and "Management and Economics III" modules) enables final-year students to finalise their personal and professional plans: finding an industrial placement for S10, individual meetings with professionals from targeted industrial sectors.

Manager: Cornélius Schrauwen

TYPE OF ASSESSMENT

Evaluation of the management results obtained by the group in a simulation situation and oral presentation of the results obtained.

USEFUL INFORMATION

PREREQUISITES: Business management: accounting, finance, marketing, human resources management
TEACHING LANGUAGE: French
REFERENCES :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 12.

TITLE OF TEACHING UNIT : *Languages V*		MANDATORY
	ECTS CREDITS 3	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Consolidate level B2/ C1 (cfr: CTI 2010 description, or CEFR)
- Develop the professional skills needed to work in a company or research laboratory in an international context (in France or abroad).
- Developing skills for the 21e century: learning and innovation skills, information, media and technology skills, social and professional skills.
- Study of case studies dealing with environmental issues.
- Co-constructing diagnoses and solutions for mitigating & adapting to the depletion of resources, biodiversity & climate change through the English language.

SPECIFIC OBJECTIVES

At the end of this module, students should be able to :

- To use the language effectively and flexibly in social, professional and academic life.
- Be able to reconstruct facts from written or oral sources in a coherent and detailed manner, demonstrating a solid command of a vast lexical and semantic repertoire.
- Use techniques and tools to apply creative thinking in the context of chemical engineering.
- Leading a meeting, taking minutes and using the specific language of meetings.
- Take the initiative in a job interview, broaden and develop their ideas.
- Working in a team in English and using 21st century skillse and "soft skills".

CONTENT AND TEACHING METHODS

Students follow 2 modules and a 'Creativity' course (compulsory: 'meetings' module and 1 module chosen from a range of subjects), as well as a week's intensive session (21h). Below are a few examples of modules/workshops.

- **Meetings**" **module**: Study and acquisition of the specific language used during meetings, quality of communication and observation/analysis of participation, behaviour, attitudes and reactions during meetings. Written work: agenda, minutes. Oral training through role-playing, case studies and simulations.
- **Ad it up**: The course objective is to familiarize students with the world of advertising through the analysis of examples. The course will be covering basic terms and concepts such as slogans and catchphrases. The topic will also be tackled from other angles such as media, celebrity endorsement as well as subliminal advertising. Past and current trends will also be discussed during debates and students will be given a chance to show their creativity with the creation of an ad campaign.
- **Science Facts and Science Fictions" module:** This module is devoted to the study of different areas of science that are more or less controversial today. Activities include examining video documents, group debates and role-playing.
- **TOEIC preparation module or personal project:** Define their needs to improve their level of English. Work in pairs/teams for TOEIC preparation and self-assessment or work on a personal project.
- Job interview: Study and acquisition of the specific language used in job interviews. Job interview simulation: filmed and viewed. This role-play will enable you to assess yourself and become aware of your weaknesses: deciphering language, body posture and elocution.
- Intensive session: projects in small groups and powerpoint presentation.

- 2 work reports (one for each module)

TYPE OF ASSESSMENT

- Validation (grade between 3-5): 1) 2 work reports and teacher assessment, 2) professional interview, 3) presentation of session project.
- Resit exam: Personal work with powerpoint presentation and report.

USEFUL INFORMATION

PREREQUISITE: B2+ level TEACHING
LANGUAGE: ENGLISH BIBLIOGRAPHICAL
REFERENCES :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of Competency 13.

EDUCATIONAL UNIT TITLE: Research and Development Project (RDP)		MANDATORY
	ECTS CREDITS 10	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

This is an individual research and development placement, which may take place either in a company or in a university laboratory. The subject of the work must be scientific or technological. It lasts 2 months at the end of S9 and takes place in France or abroad.

The aim of this research and development project is to introduce engineering students to the research and development process.

SPECIFIC OBJECTIVES

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

- Produce a detailed and comprehensive bibliography on a given research topic
- Join a university or industrial Research and Development team
- Write a summary report of the work carried out
- Have an informed scientific opinion on your research topic
- Demonstrate autonomy in relation to the research topic assigned to them

CONTENT AND TEACHING METHODS

Each year, during S9, the school distributes a list of PRD subjects proposed by the site's research laboratories. Student engineers following the 'advanced process engineering', 'process engineering for products' and 'biotechnology process engineering' courses are invited to choose from these proposals. Student engineers can also propose research and development topics to the Research Department, which will be carried out in a dedicated department within a company (as part of an engineering internship, etc.).
The list of allocated subjects is published.

TYPE OF ASSESSMENT

Assessment is based on a research report, the content, length and submission date of which are to be agreed with the supervisor. Oral examinations are organised during the last week of the PRD. The examination panel is made up of at least three people, including one member from outside the research team. The oral presentation lasts 20 minutes, followed by 20 minutes of questions. The jury's mark takes into account the work done (25%), the approach taken by the student to complete the project (25%), as well as the quality of the written report (25%) and the oral presentation (25%).

USEFUL INFORMATION :

PREREQUISITES :
- Have defined a career plan.
- Know the best practices for writing a report.
- Mastering all the concepts taught during training at the School.

LANGUAGE OF TEACHING: French, unless the course takes place abroad (in which case English is preferred).
BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 2, 3, 5, 6, 7, 8 and 10, 11, 13

Title of Curriculum Unit: *Recycling Plastics: Technologies, issues and challenges*		Optional
	ECTS credits 3	S9

General objectives of the teaching unit

- Present an overview of the plastics recycling issue.
- Present the different technologies and solutions for a circular economy for plastic materials and illustrate the main inhibiting factors involved.
- Analyse the different points of view surrounding the debate on banning plastic products, using purely scientific arguments.

Specific objectives

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

- Knowing the different technologies for recycling plastics
- Know the main stages of each technology, its advantages and disadvantages Be able to understand the dangers, benefits and alternatives associated with the use of different plastic products in everyday life

Content and teaching methods

The teaching takes the form of general and more specific courses, as well as case studies. A visit to a recycling centre is also envisaged. The course covers the following topics:

- Circular economy models for plastics; State of the art on the legal framework
- Recycling/recovery processes
- The role of additives
- Collection and sorting technologies; labelling and tracing
- Biopolymers or recyclable-by-design?
- The full picture; information and misinformation; dangers vs. benefits

Type of assessment

Individual assessment in the form of multiple-choice questions
Possibility of supplementing with a bibliographic watch on a subject (to be agreed with the teaching team)

Useful information

PREREQUISITES: none
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :

Contribution of the option to skills acquisition

The lessons in this option contribute directly to the acquisition of skills 3, 9 and 10

TITLE OF TEACHING UNIT: *Materials and nanomaterials for the catalysis*		OPTIONAL
	ECTS CREDITS 3	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

In recent years, catalysis has undergone a major boom with the development of new (nano)-materials. These have improved the efficiency of many chemical processes, from fine chemistry to the abatement of liquids and gases.

SPECIFIC OBJECTIVES

- Materials and associated characterisation techniques
- Organometallic complexes and nanoparticles used in homogeneous or heterogeneous catalysis
- Materials for photocatalysis

CONTENT AND TEACHING METHODS

Materials and associated characterisation techniques.
Organometallic complexes and nanoparticles used in homogeneous or heterogeneous catalysis Materials

for photocatalysis

TYPE OF ASSESSMENT

1ère session: project + oral presentation
2ème session: examination

USEFUL INFORMATION

PREREQUISITES: basic notions of catalysis
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 4

TITLE OF CURRICULUM UNIT: *Kinetics of fuel combustion, biofuels and e-fuels*		OPTIONAL
	ECTS CREDITS 3	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

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

SPECIFIC OBJECTIVES

Master the nature of the elementary processes involved in combustion reactions in order to :

- Understand the specific phenomena observed during these reactions (cold flame, negative temperature coefficient, self-ignition)
- Be able to construct a combustion mechanism for simple model molecules
- Be able to carry out a kinetic analysis of a model to identify the main reagent consumption pathways and the most sensitive reactions
- Be familiar with the various experimental techniques used to carry out kinetic studies so as to be able to choose the most appropriate technique for a given problem (measurement of self-ignition times, flame speed, species profiles, etc.).

CONTENT AND TEACHING METHODS

Fundamental concepts will be presented in the form of lectures. Exercises on concrete problems will be used to illustrate the fundamental concepts covered in class. One exercise will involve constructing a detailed kinetic mechanism for a small alkane using systematic construction rules. Software will be used to carry out a simulation with a detailed kinetic model and to carry out the kinetic study of this model.

TYPE OF ASSESSMENT

Individual assessment in the form of multiple choice questions and exercises.

USEFUL INFORMATION

PREREQUISITE: basic knowledge of kinetics TEACHING
LANGUAGE: English
REFERENCES :
Recommended:
G. Scacchi, M. Bouchy, J.F. Foucaut, O. Zahraa, Cinétique et catalyse, Lavoisier-Tec & Doc
F. Battin-Leclerc, J. M. Simmie, E. Blurock, Cleaner Combustion, Springer

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skill no. 3

TITLE OF CURRICULUM UNIT: *Numerical Solving of the Equations of transport*		OPTIONAL
	ECTS CREDITS 3	S9

GENERAL OBJECTIVES OF THE TEACHING UNIT

The aim is to provide a short introduction to numerical solution techniques for coupled diffusive and convective flows and transfers. This course should provide training in professional tools (e.g. Ansys Fluent), and in programming calculation codes for simple problems.

SPECIFIC OBJECTIVES

In particular, these include:

- Be familiar with the methods and main algorithms for the numerical resolution of coupled flows and transfers
- Know how to implement these methods in a calculation code (in reasonably simple cases)
- Take a critical approach to numerical results, and be able to discern in particular the influence of the discretisation method, the mesh, the numerical resolution methods, the settings of these methods, etc.
- Knowing how to exploit the results obtained (post-processing)

CONTENT AND TEACHING METHODS

The fundamental concepts (discretisation, solution algorithms, etc.) will be presented in the form of lectures. A project using all the concepts presented will be distributed at the beginning of the course, and will evolve as the course progresses. Exercise sessions may be either simple examples illustrating concepts seen in class, or project follow-up.

TYPE OF ASSESSMENT

Collective evaluation with the project

USEFUL INFORMATION

PREREQUISITES :
- Good knowledge of at least one programming language
- Good knowledge of classical numerical methods
- Good knowledge of fluid flow and transfer physics

In the ENSIC curriculum, this corresponds to the "Computer Science and Numerical Methods" and "Information Technology" modules.
"Transfer phenomena I and II
- Students who have taken "Numerical Fluid Mechanics 1" in S8 are not allowed to register for this module, as the training provided is very similar.

TEACHING LANGUAGE: English

BIBLIOGRAPHICAL REFERENCES :

Mandatory :
1. E. Saatdjian, "Les bases de la mécanique des fluides et transferts de chaleur et de masse pour l'ingénieur". "2009, Ed. Sapientia

Advised:
1. H.K. Versteeg and W. Malalasekera, "An introduction to computational fluid dynamics", 1995, Longman Scientific & Technical

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 2, 3 and 4.

EDUCATIONAL UNIT TITLE: **Electrochemical Engineering Applied to Energy and the Environment** **environmental protection**		**OPTIONAL**
	ECTS CREDITS **3**	**S9**

GENERAL OBJECTIVES OF THE TEACHING UNIT

- Acquire basic knowledge of theoretical electrochemistry and electrochemical engineering
- An overview of the application of electrochemical engineering in the fields of energy and environmental protection

SPECIFIC OBJECTIVES

At the end of the course, students should:
- Be familiar with electrochemical processes
- Evaluate charge transfer and material transport kinetics by determining the charge transfer and material transport constants respectively.
- Know how to establish material balances in ideal electrolysers.
- Be able to size
    1. A membrane fuel cell or water electrolyser
    2. An electrochemical cell for anodic oxidation applied to water treatment.

CONTENT AND TEACHING METHODS

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

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

The general electrochemistry course is followed by a presentation of the two targeted applications:
- Energy: dimensioning of batteries and electrolysers and overall energy balances,
- Environmental protection: material balance in ideal electrolysers, application of electrolysis to water treatment (electrode materials, oxidants formed, reaction parameters and control), application of anodic oxidation to disinfection and wastewater treatment (methodology, kinetic models, sizing, equipment used, costs, health and safety aspects).

This training, in the form of practical sessions integrated into the course (Cours/TD), is delivered by two CNRS researchers who are developing these themes within the Reactions and Process Engineering Laboratory (LRGP).

TYPE OF ASSESSMENT

Final written exam in 2 hours (100%)

USEFUL INFORMATION

PREREQUISITE: Knowledge of Chemical Engineering
LANGUAGE OF TEACHING: English
REFERENCES :
Required: Documents distributed to students; scientific databases Recommended:

CONTRIBUTION OF THE OPTION TO SKILLS ACQUISITION

The lessons in this option contribute directly to the acquisition of skills 3, 9 and 10.

COURSE TITLE: GLASSES, METALS, CÉRAMICS		Optional
	ECTS CREDITS 3	SEMESTER 9

AIMS:

This course aims to:

- Understand the different aspects of the heavy industry (glasses, metals, ceramics), including raw materials and sustainable development topics,
- Understand the logic behind glass formulation and the continuum of properties,
- Use examples to understand the interactions between products, properties, processes and markets,
- Understand chemical reactions and reactors at very high temperatures,
- Understand the main characteristics of these emblematic products and the resulting market applications (e.g. glass ceramics),

LEARNING OUTCOMES:

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

- Interact with industrial actors who design, produce and market these materials,
- Master the basic structures of these materials, which are also used in the chemical industry for reactor implementation,
- Be familiar with the various aspects of the formulator's job,
- Know the analogies between glasses/polymers/metals/ceramics,
- Understand the world of raw materials and how they are processed,
- Be familiar with glass processing (forming, machining, moulding, etc.) and surface treatment,
- Be aware of customer requirements.

DESCRIPTION AND TEACHING METHODS:

The course is based on:

- Lectures: structure of products (presentation of samples), chemical reactions at high temperature (often incorrectly called “melting”), chemical reactors,
- Real case studies (markets, industries),
- Case studies: students will work on market size determination, design products, sustainable development, formulation, etc,
- A visit to an industrial site (heavy industry) is organised.

EVALUATION METHODS:

MCQs and exercises similar to those covered in class.

USEFUL INFORMATION:

PREREQUISITES: NONE

LANGUAGE: ENGLISH

BIBLIOGRAPHICAL REFERENCES:

Needed: DOCUMENTS DISTRIBUTED

Advised:

Title of Curriculum Unit: Technological solutions for the capture, storage and use of CO2		Optional
	ECTS credits 3	S9

General objectives of the teaching unit

The general objectives of the teaching unit are as follows:

- Understanding the different technological aspects of Carbon Capture Utilization and Storage (CCUS),
- Understand the energy demand, cost and environmental impact of CCUS technology options,
- Understand the challenges involved in their industrial deployment.

Specific objectives

The specific objectives of the teaching unit are as follows:

- Gain an overview of carbon capture, use and storage strategies,
- Understanding the strategic choice of capture technology depending on the sources of CO_2 and the ways in which it is used,
- Be able to design a CO capture unit$_2$ using process simulation software,
- Analyse the impact of operating conditions on process performance (purity of H_2 and CO recovery rate$_2$) using a parametric study,
- Evaluate and discuss the energy requirements of CO capture$_2$ (OPEX)

Content and teaching methods

Lectures: (Total 9h)

- Introduction to CCUS
- Pre-treatment of post-combustion fumes
- Carbon dioxide capture
- Use of carbon dioxide

Supervised dimensioning work (Total 8h): four project monitoring sessions of 2 hours each

Oral presentation of the design work (1,5 hrs)

Type of assessment

Students design a CO capture unit$_2$ using simulation software for processes. The students' project report and oral presentation are each assessed by one mark.

Useful information

Prerequisites: general basics of process engineering: transport and transfer phenomena, hydrodynamics, separations engineering, heat exchangers, computer-aided process design.

Language of instruction : English

References :

Required:

Recommended:

Contribution of the option to skills acquisition

The lessons in this option contribute directly to the acquisition of skill no. 9

The lessons in this option contribute indirectly (as resources) to Skill 14

EDUCATIONAL UNIT TITLE : **Process Engineering and Energy**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The courses aim to :

- Raising students' awareness of the technological and societal challenges associated with energy production, through lectures given by industrial speakers and visits to energy production sites.
- Understanding the main chemical phenomena involved in combustion for industrial applications (boilers, engines, gas turbines, etc.). Consequences of the emergence of new fuels (biofuels and e-fuels) and new combustion methods on processes.
- Understand how to carry out an exergy analysis of a process in order to reduce energy losses

SPECIFIC OBJECTIVES

At the end of the module the student should:

- Understanding the global context of energy production and demand
- Understanding the main energy conversion processes
- Know how to analyse combustion parameters and calculate the main associated chemical parameters
- Know how to construct combustion diagrams and apply them to practical cases
- Be able to evaluate the exergy of pure fluids or mixtures using appropriate data
- Be able to carry out exergy balances on closed (reactive or non-reactive) and open steady-state systems.

CONTENT AND TEACHING METHODS

Combustion: 4 lessons (1.5 hours), 4 exercise sessions (1.5 hours); awareness of the issues involved in the energy transition (conservation of resources, new types of fuel, new modes of combustion), definition and determination of the physico-chemical parameters involved in combustion; thermodynamic approach to combustion: combustion diagrams; Wobbe index, combustion efficiency and the concept of losses through combustion products, application to combustion in boilers and internal combustion engines, ideal thermodynamic cycles; 1.5 hours exam.

Exergy analysis: 8 h lecture, 4 h lab; definition of exergy; exergy balances in closed and open systems; calculation of the exergy of multiconstituent systems using the gamma-phi and phi-phi approaches; exergy analysis of reactive systems; practical applications to chemical industry processes, 1h30 exam.

Industrial lectures and visits: 11 3-hour slots (5 slots for Procédis); topics covered: global energy context, oil extraction and oil & gas processes, CO_2 capture and storage, wind and hydroelectric energy, solar energy, biomass and energy, nuclear energy and nuclear waste management, methanisation processes; Assessment: final MCQ, writing of summaries and attendance.

TYPE OF ASSESSMENT

Compulsory attendance at conferences, final MCQs and abstract writing (20%); combustion exam (40%), exergy analysis exam (40%)

USEFUL INFORMATION

PREREQUISITES: knowledge of chemical engineering, kinetics and thermodynamics
TEACHING LANGUAGE: English for Combustion and French for Conférences industrielles and Analyse exergétique

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 4, 8 and 9.

EDUCATIONAL UNIT TITLE: **Dynamic Optimization and Control advance**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Dynamic Process Optimisation course aims to:

- Recall the different types of dynamic process models (differential, algebraic-differential and partial algebraic-differential) and the resolution methods commonly used
- Define and formulate a dynamic optimisation problem
- Present the CVP resolution method combined with the sensitivity method
- Using the gPROMS software for some applications

The advanced control course aims to:

- Discover parametric identification methods to determine transfer function models
- Discover transfer function control methods for monovariable systems and state-space control methods for multivariable systems

SPECIFIC OBJECTIVES

At the end of both courses, students should be able to:

- Simulate a process described by ordinary differential, algebraic differential or partial algebraic differential equations
- Formulating a dynamic optimisation problem
- Use gPROMS software to solve dynamic optimisation problems, with and without constraints
- Identify a monovariable system using a transfer function
- Develop transfer function control for monovariable systems and state-space control for multivariable systems, for examples taken from the field of process engineering.

CONTENT AND TEACHING METHODS

I. Dynamic optimisation

1. Dynamic process models
   - Models described by ordinary differential equations (ODE)
   - Models described by differential algebraic equations (DAE)
   - Models described by partial algebraic differential equations (PDAE) and their transformation into ODE or DAE
2. Dynamic simulation
   - Specification of initial conditions
   - Simple and higher-order integration formulas (BDF combined with Newton's method, prediction-correction)
   - Notion of index and systems of high-index algebraic-differential equations
   - Using gPROMS software to simulate batch and fedbatch reactors
3. Dynamic optimisation
   - A reminder of static optimisation
     - Karush-Kuhn-Tucker (KKT) optimality conditions
     - Successive quadratic optimisation (SQP)
   - Definition and mathematical formulation of a dynamic optimisation problem

- Calculation of gradients using the sensitivity method
- Resolution using the "control variable parameterisation" (CVP) method
- Using gPROMS software to optimise batch reactors 4.Project
- Process description and modelling (distillation columns, reactors, etc.)
- Simulation using gPROMS software
- Definition and formulation of dynamic optimisation problems
- Resolution using gPROMS software

II. Advanced control

- Use of the Matlab Simulink environment to study linear dynamic systems in state space and synthesise controllers
- Synthesis of improved regulators
- Multivariable control in continuous time
- Monovariable control in discrete time

Project: development of a monovariable or multivariable control system for a model reactor using Matlab.

TYPE OF ASSESSMENT

Optimisation project (50%); advanced control project (50%)

USEFUL INFORMATION

PREREQUISITES: chemical engineering methods, balance sheet writing, numerical analysis and optimisation methods, IT (programming)
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :
Required: Handouts
Recommended:

1. Applied Optimal Control: Optimization, Estimation, and Control, Arthur E. Bryson and Yu-Chi Ho, Taylor & Francis Inc; Revised Edition, (1988)
2. Nonlinear Programming: Theory and Algorithms, Mokhtar S. Bazaraa, Hanif D. Sherali , C. M. Shetty , Wiley; 2nd edition, (1993)
3. Commande des Procédés, Jean-Pierre Corriou, Lavoisier Tec & Doc, 2ème edition (2003)

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skill no. 3

The lessons in this course contribute indirectly (as resources) to Competency 11.

TITLE OF TEACHING UNIT : **Process Intensification and Innovation**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PROCESSES

GENERAL OBJECTIVES OF THE TEACHING UNIT

The Process Intensification and Innovation course aims to :

- Raising students' awareness of equipment and technologies for process intensification
- Train students in a structured approach leading to process intensification and innovation
- Provide the basic knowledge required to calculate membrane separation processes
- Raise students' awareness of the importance of innovation and the associated methodologies

SPECIFIC OBJECTIVES

At the end of the module the student should

- Be capable of analysing and proposing improvements for a given process (determining limiting phenomena, implementing an intensification strategy).
- Knowing how to select a membrane separation process according to a set of constraints (nature of the mixture to be separated, target performance, operating conditions)
- Be able to design a membrane process for a given application and compare its performance with other technologies (energy efficiency, productivity)
- Understand the importance of and interaction between the three pillars of innovation: creativity (generating new ideas); value (in terms of esteem, use and exchange); socialisation (managing change).

CONTENT AND TEACHING METHODS

Process intensification: 4 lecture sessions (1h30) - 3 practical sessions (1h30); definition of intensification; existing technologies (rotating disc reactor, reactive distillation, etc.); intensification by microstructuring; generalisation of the choice of intensification strategy by analysis of limitations (transfer, equilibrium, risk, saturation, etc.) and identification of technologies to overcome these limitations; industrial case studies on synthesis or effluent treatment processes.

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

Innovation project: Work on the different facets of innovation and implementation of an innovative approach based on an example from the chemical industries (in collaboration with our industrial partners).

TYPE OF ASSESSMENT

Written exam on intensification and membrane processes (25%), innovation project (75%).

USEFUL INFORMATION

PREREQUISITES: knowledge of chemical engineering, kinetics and thermodynamics TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES: course documents

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 2, 4, 6 and 9.

The lessons in this course contribute indirectly (as resources) to competences 11, 12 and 13.

TITLE OF TEACHING UNIT: **Speciality Products**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The course aims to:

- Introduce the basic concepts of radical copolymerisation
- Illustrate the main types of copolymers and their characteristics
- Describe the calculation of radical copolymerisation reactors
- Introduce students to the plastics processing industry and the various processes involved in shaping plastic materials
- Introduction to the physical chemistry of polymers in solution, at interfaces and in emulsion
- Acquire knowledge of the characterisation and behavioural analysis of polymers used in formulated products
- Describe the main water-soluble polymers (neutral, charged and amphiphilic) for formulation applications in various fields

SPECIFIC OBJECTIVES

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

- Understand the specificity and interest of copolymers compared with simple homopolymer mixtures
- Carry out the kinetic calculations required to design copolymerisation reactors
- Design and implement radical copolymerisation reactors
- Formulating and shaping plastics
- Take advantage of the properties of polymers in solution, at interfaces and in emulsion for formulation applications in a variety of fields
- Understanding the link between structural characteristics and product behaviour, particularly at interfaces

CONTENT AND TEACHING METHODS

1. Copolymers: from processes to applications

- Introduction to radical copolymerisation
- Copolymerisation kinetics
- Main types of copolymer produced on an industrial scale and their characteristics
- Modelling and design of copolymerisation reactors
- Introduction to controlled radical polymerisation for the synthesis of copolymers with controlled architecture
- Examples of applications for the development of copolymers with controlled architecture, focusing on the outstanding applications developed by French manufacturers Arkema and Solvay in recent years.

2. Formulation and shaping of plastics

- An introduction to the plastics industry and the various processes used to shape plastics: extrusion, injection, calendering, thermoforming, rotational moulding, high-pressure moulding of thermosets, etc.
- Sizing of an extrusion process: relationship between flow rate and pressure drop during extrusion, calculation of self-heating of polymers during extrusion, relationship between operating conditions of the process and the structure of the finished product.
- Formulation of plastics: concepts and methodology, planning of formulation experiments, choice of base resins, fillers, additives, adjuvants.

3. Polymers in solution, at interfaces and in emulsion

- Polymers in solution :
- Physico-chemistry of neutral and charged polymers in solution
- General information on polymers in solution: solubility, different concentration regimes and critical solubility temperatures
- Thermodynamics of dilute polymer solutions
- Polymer characterisation methods: osmometry, tonometry, viscometry, light scattering, steric exclusion chromatography and their coupling in advanced polymer characterisation systems
- General information on water-soluble polymers for formulation applications in various fields (cosmetics, pharmaceuticals, fine chemicals, etc.).
- Polymers at interfaces :
- Importance of the concept of polymers at interfaces in formulated products
- Conformation of polymers at interfaces
- Kinetic and thermodynamic aspects of macromolecule adsorption
- Emulsion polymers :
- Application of latex in formulated products
- Links between latex formulation and macroscopic properties
- Mechanism of an emulsion polymerisation reaction: general and borderline cases
- Influence of reaction conditions on the properties of the latex formed
- Emulsion copolymerisation

TYPE OF ASSESSMENT

1. Copolymers: from processes to applications: a 1.5 hour written final test at the end of the module
2. Formulation and shaping of plastics: a 1.5 hour written final test at the end of the module
3. Polymers in solution, at interfaces and in emulsion: a written test at the end of the module

USEFUL INFORMATION

PREREQUISITES: Basic chemistry and physical chemistry of interfaces and macromolecules. General knowledge of chemical engineering. Basic knowledge of polymer chemistry.
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :
Required: none
Recommended:
1. Copolymers: from processes to applications

1. Principles of Polymer Chemistry, G. Odian, 3ème edition, John Wiley and Sons, 1991, Chapter 6 "Chain copolymerization", pages 452-531.
2. Polymer Chemistry - An introduction, R.B. Seymour, C.E. Carraher, 6ème edition, Marcel Dekker, 2003, Chapter 9 "Copolymerization", pages 332-367.

2. Formulation and shaping of plastics

1. Matières plastiques - Propriétés, mise en forme et applications industrielles des matériaux polymers, Marc Carrega, Vincent Verney, 3rd edition, Dunod, 2012.
2. Polymer Extrusion, Pierre G. Lafleur Bruno Vergnes, Wiley, First published: 8 May 2014.

3. Polymers in solution, at interfaces and in emulsion

1. Chemistry and physical chemistry of polymers, M. Fontanille and Y. Gnanou, 2ème edition, Dunod, 2010.
2. Initiation à la chimie et à la physico-chimie des polymères, volume 1, Physico-chimie des polymères, published by the Groupe Français d'études et d'applications des polymères (GFP).
3. Initiation à la chimie et à la physico-chimie des polymères, volume 5, exercices et travaux dirigés, published by the Groupe Français d'études et d'applications des polymères (GFP).

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this unit contribute directly to the acquisition of skill no. 4

The lessons in this course contribute indirectly (as resources) to Competency 11.

TITLE OF EDUCATIONAL UNIT : **Properties and qualities of products**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The course aims to:

- Understanding experimental design and its use
- Introduction to batch planning
- Make the link between the macroscopic properties of polymers and the associated structural and morphological characteristics
- Introduce the different types of degradation possible for polymers and the impact on their properties
- Present the polymer stabilisation methods used to shape polymers and their applications
- Understanding transport phenomena in polymers and gels
- Understanding and modelling the crystallisation process
- Analysing the process of shaping a medicinal product in accordance with the specific requirements of the pharmaceutical and/or cosmetics industry, using the "Quality by Design" (QbD) approach.

SPECIFIC OBJECTIVES

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

- Implementing an experimental design
- Optimising batch workshop production
- Designing and sizing a reactor leading to the desired product and addressing process-structure-property relationships
- Identify the cause of polymer degradation on the basis of information gathered in the field
- Define a strategy to prevent deterioration and apply stabilisers appropriately
- Efficiently stabilise a polymer for shaping or during its service life
- Understanding transport in polymers and gels
- Using population balances to model the crystallisation, aggregation and cracking process
- Designing and implementing specific unit operations in the manufacture of medicines and cosmetics:
    - Mixing and granulation
    - Compaction and coating
    - nano-emulsification and micro-encapsulation
    - Freeze-drying

CONTENT AND TEACHING METHODS

<u>1. Design of experiments</u>

- Introduction: history, knowledge acquisition process, terminology, a priori mathematical modelling of the response
- Experimental design methodology: definition of the problem, construction of the model, selection of factors and responses (mnemonic)
- Types of Designs: Screening matrices, factorial designs, fractional designs, response surface designs
- Interpretation of results: Hadamard matrices, significance of coefficients and interactions, effects diagram.
- Notion of Statistics: Modelling, dispersion of coefficients, influential factors and interactions
- Case studies using a tool: Excel and Design-Expert®.

<u>2. Polymers: thermophysical properties, degradation and stabilisation</u>

<u>Thermophysical properties of polymers</u>

- General information on polymer materials: chemical structure, morphology, properties
- Glass transition temperature and melting temperature: definition, measurement and estimation methods
- Relationship between chemical structure and thermomechanical transitions: interpretation based on physical considerations, consequences for applications and materials shaping

Degradation and stabilisation of polymers

- Consequences of polymer degradation on their properties
- Presentation of the different types of degradation: physical, mechanical and chemical
- Different mechanisms of chemical degradation: thermal, oxidative thermal, photo-oxidative, hydrolytic, radiochemical, biodegradation, etc.
- Different classes of stabilisers: thermal, photochemical, fungicidal and bactericidal, fire retardant, etc.
- Impact of stabilisers on the environment and health

3. Transport in polymers, controlled release

- Notion of permeability and solution-diffusion model
- Experimental methods for determining transport coefficients
- Mechanisms and models of diffusion in polymers and gels
- Controlled release of active ingredients (reservoir systems / matrix systems): processes and modelling of release kinetics
- Production processes, products and examples of applications

4. Crystallization

- Crystallisation, aggregation and cracking processes
- Modelling using population balances (DLVO theory)

5. Health products

- Nature and content of ICH and GLP recommendations: Validation vs QbD
- Principles, technologies and sizing of pharmaceutical unit operations (OUPs)
- Problem-based learning (PBL)

TYPE OF ASSESSMENT

Experimental design: intermediate test (online test carried out during the 3rd session of the class) + final written test
Crystallization: written assessment (1h30)
Polymers: thermophysical properties, degradation and stabilisation: written test at the end of the module
Transport in polymers, controlled release: Project followed by an oral presentation
Health products: MCQs

USEFUL INFORMATION

PREREQUISITE: Basic macromolecular chemistry and physical chemistry. Basic knowledge of polymer chemistry. General knowledge of fluid mechanics and the thermal properties of continuous media.
TEACHING LANGUAGE: English
BIBLIOGRAPHICAL REFERENCES :
Required: none
Recommended:

1. Chemical ageing of plastics: general aspects, J. Verdu, Les techniques de l'ingénieur, Traité plastiques et composites, Volume AM 3 151, 2002.
2. Stabilisation of plastics: general aspects, S. Girois, Les techniques de l'ingénieur, Traité plastiques et composites, Volume AM 3 232, 2004.
3. La stabilisation des polymères, J. Ecole, Nathan, Encyclopédie technique pratique, 1991.

Polymers and the environment, G. Scott, RSC Paperbacks, The Royal Society of Chemistry, Cambridge, 1999.

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

The lessons in this course contribute directly to the acquisition of skills 4, 5, 6 and 13 The lessons in this

course contribute indirectly (as resources) to skill 3

TEACHING UNIT TITLE: **Case study - design project for innovative products**		MANDATORY
	ECTS CREDITS 4	S9 COURSE PRODUCTS

GENERAL OBJECTIVES OF THE TEACHING UNIT

The objectives are :

- Develop and apply creative thinking by virtually creating an innovative product
- Build and execute an innovative product design plan, from idea to pilot workshop
- To mobilise existing chemical engineering skills in the design process of a speciality chemical product with a specific use function
- Know and adapt a tool for assessing the potential profitability of a new product at the various stages of design
- Integrating the environmental and social impact of the project and the product into the design process

SPECIFIC OBJECTIVES

The more specific objectives are :

- Use the scientific, technical and organisational knowledge and skills acquired in previous semesters to design an innovative product from idea to proof of concept.
- Calculate the project's potential profitability and include this criterion in the project's phase transition criteria
- Calculate the environmental and social impact of the project using appropriate tools and include this criterion in the project phase transition criteria.
- Integrate quickly and effectively as a scientific expert in a structured project group activity
- Analyse the intellectual property relating to the innovative product and implement a strategy to circumvent it if necessary

CONTENT AND TEACHING METHODS

- Content
  - Innovative processes, their organisation, key success factors and planning
  - Structure-property relationships of complex dispersed products
  - Tools for managing innovative projects: investment, costs, profitability
  - The human side of a project group

- Teaching methods
  - Team working
  - Case studies
  - Experiential learning
  - Problem-based learning

EVALUATION

- Proof of concept report and oral presentation of the project

USEFUL INFORMATION

PREREQUISITES: knowledge and skills in chemical engineering at M1 level
TEACHING LANGUAGE: English and/or French

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This course contributes directly to the acquisition of skills 4, 6, 7, 9, 11 and 13.

TITLE OF CURRICULUM UNIT: *Engineering Internship*		MANDATORY
	ECTS CREDITS 30	S10

GENERAL OBJECTIVES OF THE TEACHING UNIT

This is a work placement of a professional nature, which must take place in a company or in a Public Industrial and Commercial Establishment, lasting a minimum of 5 months and a maximum of 6 months. The work placement takes place in France or abroad. This placement is the student's first significant experience in the professional world. Its aim is to bring the student engineer face to face with the reality of the engineering profession, both in its technical aspects and in its human, organisational and regulatory dimensions.

SPECIFIC OBJECTIVES

At the end of the engineering placement, students should be able to :

- fulfil an engineering role by solving complex technical problems (with objectives set in terms of deadlines, cost and quality),
- show imagination and creativity; be proactive and demonstrate autonomy in relation to the assignment,
- present concrete conclusions and proposals; provide technical expertise and decision-making support; convey a message with force and conviction,
- write a report that meets academic and industrial expectations.

CONTENT AND TEACHING METHODS

The subject of the internship is defined in advance and must be approved by the Dean of Studies. The work required of the trainee must correspond to the professions for which the school is preparing and must enable the student-engineer to mobilise the knowledge acquired during the previous 5 semesters of the course and to continue acquiring skills. An industrial tutor (from the company) and an academic tutor (a teacher-researcher from the school) are appointed for each trainee.

TYPE OF ASSESSMENT :

At the end of their work placement, student engineers must produce a written report setting out the purpose of their work and the results obtained. They must also make an oral presentation of their work to a panel made up of the industrial tutor, the university tutor and a teacher-researcher from the school who did not supervise the work. The placement is assessed on the basis of a skills reference framework. For each skill, a required reference level will be necessary to validate the placement. A list of assessment points is also drawn up for the final report and the oral presentation. Any skill assessed at a lower level than the required reference level will be deemed not to have been acquired for this placement. The trainee's acquisition of skills must be clearly and precisely explained in the placement report and in the oral presentation. The trainee is also required to carry out a self-assessment.

USEFUL INFORMATION :

PREREQUISITES :

- Have defined a career plan.
- How to write a Curriculum Vitae and covering letter.
- Mastering the keys to a successful job interview.
- Know the best practices for writing a report.
- Mastering all the concepts taught during training at the School.

LANGUAGE OF TEACHING: French, unless the course takes place abroad (in which case English is preferred).
RESOURCES: internship offers and practical information sheets available on the JOBTEASER CAREER CENTER

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This UE contributes directly to the acquisition of skills 2, 3, 4, 6, 7, 8, 9, 10, 11, 13 and 1

TEACHING IN SEMESTERS 9 and 10 - PROCEDIS COURSE

(sandwich course under a vocational training contract)

CORE CURRICULUM:
Head: Olivier HERBINET

Title of the Teaching Unit and its constituent parts	*Manager*	*H*	*ECTS*
Management and economics V	Vera IVANAJ	40	2
Languages V	E. KASMAREK/M. ADRIAN	48	3
Research and Development Project	Olivier HERBINET	238/ 191.5[1]	9
Specialisation courses (see details in the tables below)		75.5/ 122[1]	8
Batch process engineering	Olivier HERBINET	66	4
Simulation of batch reactions	Olivier HERBINET	18	
Dynamic process optimisation	Abderrazak LATIFI	18	
Industrial crystallisation	Hervé MUHR	30	
Design and operation of multi-product facilities	Olivier HERBINET	92.5	4
Management and design of multi-product facilities	Olivier HERBINET	88	
Introduction to management and project management	Laurent MARCHAL-HEUSSLER	4.5	
PROCEDIS engineer internship	Olivier HERBINET		30
TOTAL		**560**	**60**

[1] *According to specialisation path*

SPECIALISATION COURSE: Processes for energy and the environment
Head : Sabine RODE

Title of the Teaching Unit and its constituent parts	*Manager*	*H*	*ECTS*
Process engineering and energy	Olivier HERBINET	42.5	4
Industry conferences	Olivier HERBINET	15.5	
Combustion	Olivier HERBINET	13.5	
Energy analysis	Jean Noël JAUBERT	13.5	
Process intensification and innovation	Jean-Marc COMMENGE	33	4
Process intensification	Jean-Marc COMMENGE	12	
Membrane processes	Eric FAVRE	12	
Innovation project	Jean-Marc COMMENGE	9	
TOTAL		**75.5**	**8**

SPECIALISATION COURSE: Innovative products: from chemistry to processes
Head: Cécile NOUVEL

Title of the Teaching Unit and its constituent parts	*Manager*	*H*	*ECTS*
Speciality products	Alain DURAND	59.5	4
Copolymers: from processes to applications	Anne JONQUIERES	16.5	
Plastics formulation	Sandrine HOPPE	13	
Polymers in solution, at interfaces and in emulsion	Alain DURAND	30	
Product properties and quality	Anne JONQUIERES	62.5	4
Processes for health products	Laurent MARCHAL-HEUSSLER	15	
Design of experiments	Graciela CARES	13	
Thermophysical properties of polymers	Anne JONQUIERES	25.5	
Crystallization	Eric SCHAER	9	
TOTAL		**122**	**8**

Links to detailed teaching unit descriptions

Common core:

Management and economics V
Languages V
Research and Development Project
Batch process engineering
Design and operation of multi-product facilities
PROCEDIS engineer internship

SPECIALISATION COURSE: Processes for energy and the environment

Process engineering and energy
Process intensification and innovation

SPECIALISATION COURSE: Innovative products: from chemistry to processes

Speciality products
Product properties and quality

TITLE OF TEACHING UNIT: Research and Development Project (RDP)		MANDATORY
	ECTS CREDITS 9	S9 AND S10 PROCEDIS PATHWAY

GENERAL OBJECTIVES OF THE TEACHING UNIT

This is an individual research and development placement that takes place during the school term. The subject of the project must be scientific or technological.

The aim of this research and development project is to introduce engineering students to the research and development process.

The subject is proposed at the beginning of the year by the company hosting the student-engineer, according to the following main criteria:

- the proposed subject must be of interest to the company and must be different from the tasks assigned during the work placement, although it may be directly related,
- the work required of the trainee must correspond to the professions for which the school is preparing and must enable the student-engineer to mobilise the knowledge acquired during the first two years of training (just like the end-of-studies industrial project) and to continue acquiring skills,
- the project is carried out by the student when he or she is present at ENSIC: the work requested must therefore be achievable with the resources available at the school, for example bibliographical work, or computer-assisted work subject to the availability of the necessary software.

SPECIFIC OBJECTIVES

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

- compile a detailed and comprehensive bibliography on a given research topic,
- join a university or industrial Research and Development team,
- write a summary report of the work carried out,
- have an informed scientific opinion on its research topic,
- demonstrate autonomy in relation to the research topic assigned to them.

CONTENT AND TEACHING METHODS

The subject of the PRD is defined in advance with the industrial tutor (from the company) and must be approved by the Department of Studies. The work required of the trainee must correspond to the careers for which the school prepares and must enable the student-engineer to mobilise the knowledge acquired during the first two years of training and to continue acquiring skills. An industrial tutor (from the company) and an academic tutor (a teacher-researcher from the school) are appointed for each trainee.

The technical objectives of the project will be set at the beginning of the course and will describe the programme specifications.

TYPE OF ASSESSMENT

At the end of their training, student engineers must produce a written report setting out the purpose of their work and the results obtained. They must also make an oral presentation of their work to a jury made up of the industrial tutor, the university tutor and a teacher-researcher from the school who did not follow the work. The RDP is assessed by awarding a mark that takes into account the following points (each marked out of 3):

- the quality of the written report,
- the quality of the oral presentation,
- the work carried out during the project.

The oral presentation takes place on the same day as the engineering placement. The PRD report is separate from the placement report.

USEFUL INFORMATION

PREREQUISITES :

- Know the best practices for writing a report.
- Mastering all the concepts taught during training at the School.

LANGUAGE OF INSTRUCTION: French (English accepted)

CONTRIBUTION OF THE TEACHING UNIT TO THE ACQUISITION OF SKILLS

This unit contributes directly to the acquisition of skills 2, 3, 5, 6, 7, 8, 11 and 13.

Title of Curriculum Unit: *Batch Process Engineering*		Mandatory
	ECTS credits 4	S9 Procedis pathway

General objectives of the teaching unit

The courses in this module aim to:

- Learn to solve material and heat balances in a reactor using Matlab
- Introduce the basics needed to solve a dynamic optimisation problem; present the CVP solution method combined with the sensitivity method
- Explain the fundamental and technological aspects of industrial crystallisation and precipitation

Specific objectives

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

- Simulate batch chemical reactors with the aim of defining the operating conditions that lead to optimum management of the process
- Simulate a process described by ordinary differential equations, algebraic-differentials or partial algebraic-differentials
- Formulate a dynamic optimisation problem and use gPROMS software to solve dynamic optimisation problems with and without constraints
- Design, size and analyse the operation of crystallisation and precipitation equipment

Content and teaching methods

Simulation of batch reactions

Writing and solving material and heat balances in the presence of a chemical reaction in batch reactors; in transient conditions in piston reactors with or without axial dispersion. Population balances in batch mode. Simulation and optimisation of yield and selectivity.

Dynamic process simulation and optimisation

- Dynamic process models: models described by ordinary differential equations (ODEs), differential algebraic equations (DAEs) or partial differential algebraic equations (PDAEs) and their transformation into ODEs or DAEs
- Dynamic simulation: specification of initial conditions, simple and higher-order integration formulas (BDF combined with Newton's method, prediction-correction), notion of index and systems of high-index algebraic-differential equations, use of gPROMS software to simulate batch and fedbatch reactors.
- Dynamic optimisation: review of static optimisation (Karush-Kuhn-Tucker (KKT) optimality conditions and successive quadratic optimisation (SQP)); definition and mathematical formulation of a dynamic optimisation problem; calculation of gradients using the method of sensitivities; resolution using the "control variable parameterisation" (CVP) method; use of gPROMS software for batch reactor optimisation.
- Tutored project: description and modelling of a process (distillation columns, reactors, etc.); definition and formulation of dynamic optimisation problems; simulation and resolution using Gproms software.

Industrial crystallisation and precipitation

Basic knowledge of solutions and determination of solubility curves; characterisation of solids; crystallisation kinetics: nucleation, crystal growth, agglomeration, breaking, ripening and influence of impurities and solvent on crystallisation; design and overall analysis of crystallisation processes based on material and thermal balances; design, sizing and operational analysis of crystallisation equipment based on population balances: continuous and discontinuous processes; precipitation, chemical reaction engineering applied to the calculation of precipitators; industrial applications of crystallisation: processes and equipment, melt crystallisation; industrial approach to the quality control of divided solids and optimisation of the solid chain;

fundamental and applied aspects of the polymorphism of molecular and pharmaceutical compounds: thermodynamic and structural approaches, characterisation methods, examples and implications for industrial processes.

Type of assessment

Simulation of batch reactions: 3-hour examination in the form of a tutored project.
Dynamic process simulation and optimisation: 3-hour examination in the form of a tutored project.
Industrial crystallisation and precipitation: no assessment.

Useful information

Prerequisites: Transfer phenomena II, chemical kinetics, chemical thermodynamics, chemical reaction engineering, chemical engineering methods, numerical analysis and optimisation methods, computer science (programming).
Language of instruction: French
References:
Required: Handouts
Recommended:

1. Applied Optimal Control: Optimization, Estimation, and Control, Arthur E. Bryson and Yu-Chi Ho, Taylor & Francis Inc; Revised Edition, (1988)
2. Nonlinear Programming: Theory and Algorithms, Mokhtar S. Bazaraa, Hanif D. Sherali , C. M. Shetty, Wiley; 2nd edition, (1993)

Contribution of the teaching unit to the acquisition of skills

This course contributes directly to the acquisition of skills 3, 4 and 5.

TITLE OF CURRICULUM UNIT: *Design and operation of multi-product installations*		MANDATORY
	ECTS CREDITS 4	S9 PROCEDIS PATHWAY

GENERAL OBJECTIVES OF THE TEACHING UNIT

The courses in this module aim to:

- Give an introduction to batch planning.
- Explain the methodology used to design a batch unit based on laboratory data.
- Provide and reiterate the concepts required for sizing discontinuous installations.
- Provide a basic understanding of the operational management of a company.
- Develop the ability to integrate quickly and effectively as a scientific expert in a structured project group activity.

SPECIFIC OBJECTIVES

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

- Apply the methodology for designing a batch unit, which consists of building a batch plant on an industrial scale, based on a chemical synthesis protocol carried out on a laboratory scale.
- Optimise batch workshop production.
- Master the sizing techniques for batch, semi-continuous and continuous equipment forming part of a batch production workshop.
- Plan and manage a simple project to design an innovative chemical product.

CONTENT AND TEACHING METHODS

Design and operation of multi-product installations in a batch plant.
Definition of a batch unit. Differences with the continuous unit.
Block diagram, analysis and planning of process tasks, determining the duration of a batch. Methodology for designing a batch unit using laboratory data.
Material balance, process diagram, technology of equipment used in Batch units.
Structure and operation of batch plants. Sizing batch plants for one and/or more products based on the "minimum investment" criterion. Managing a fleet of equipment to make up a batch plant.

Introduction to the management of innovative projects.
Building a response to a call for tenders launched by the European Union.

TYPE OF ASSESSMENT

Design of multi-product installations and operation of a batch unit: Tutored project to set up a batch unit to manufacture a product: technology and sizing of the discontinuous equipment making up the unit and scheduling of tasks.
Introduction to the management of innovative projects: no exam.

USEFUL INFORMATION

PREREQUISITES: General basics of Process Engineering: Transport and Transfer Phenomena, Chemical Kinetics, Chemical Reaction Engineering. Separation Engineering, Mechanical Unit Operations.
LANGUAGE OF INSTRUCTION: French
REFERENCES:
Required: Handouts

CONTRIBUTION OF THE TEACHING UNIT TO THE SKILLS ACQUISITION

This course contributes directly to the acquisition of skills 3, 4 and 5.

The lessons in this course contribute indirectly (as resources) to Competency 11.

TITLE OF CURRICULUM UNIT: *PROCEDIS Engineering Internship*		MANDATORY
	ECTS CREDITS 30	S9 AND S10 PROCEDIS PATHWAY

GENERAL OBJECTIVES OF THE TEACHING UNIT

This is a compulsory work placement in a company or public industrial or commercial establishment, lasting a minimum of 33 weeks and a maximum of 43 weeks. The work placement takes place in France. This placement is the student's first significant experience of the professional world. Its aim is to bring the student engineer face to face with the reality of the engineering profession, both in its technical aspects and in its human, organisational and regulatory dimensions.

SPECIFIC OBJECTIVES

At the end of the engineering placement, students should be able to:

- Fulfil an engineering mission by solving complex technical problems (with objectives set in terms of deadlines, costs and quality)
- Demonstrate imagination and creativity; be proactive and show autonomy in relation to the mission entrusted to them
- Present concrete conclusions and proposals; provide technical expertise and decision-making support; convey a message with force and conviction
- Write a report that meets academic and industrial expectations

CONTENT AND TEACHING METHODS

The subject of the internship is defined in advance and must be approved by the Dean of Studies. The work required of the trainee must correspond to the professions for which the school is preparing and must enable the student-engineer to mobilise the knowledge acquired during the first two years of training and to continue acquiring skills. An industrial tutor (from the company) and an academic tutor (a teacher-researcher from the school) are appointed for each trainee.

TYPE OF ASSESSMENT

At the end of the work placement, the student engineer must produce a written report setting out the purpose of the work and the results obtained. They must also make an oral presentation of their work to a panel made up of the industrial tutor, the university tutor and a teacher-researcher from the school who did not supervise the work.
The engineering placement is assessed by awarding a mark based on the following points (each marked out of 4):

- the quality of the written report,
- the quality of the oral presentation,
- the work carried out during the placement,
- assessment by the industrial tutor.

The oral presentation takes place on the same day as the research and development project (PRD). The placement report is separate from the RDP report.

USEFUL INFORMATION

PREREQUISITES :

- Have defined a career plan.
- How to write a Curriculum Vitae and covering letter.
- Mastering the keys to a successful job interview.

- Know the best practices for writing a report.
- Mastering all the concepts taught during training at the School.

Language of instruction: French

References: Engineering internship guide available on JobTeaser

Contribution of the teaching unit to the acquisition of skills

This unit contributes directly to the acquisition of skills 2, 3, 4, 6, 7, 8, 9, 10, 11, 13 and 14.

REVIEW OF SEMESTERS 9 & 10

I2C FISE Semestres 9 & 10		CONNAISSANCES SCIENTIFIQUES ET TECHNIQUES ET MAITRISE DE LEUR MISE EN ŒUVRE																													
		COMPETENCE 1					COMPETENCE 2					COMPETENCE 3					COMPETENCE 4					COMPETENCE 5					COMPETENCE 6				
Libellé UE	ECTS	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Projet de recherche et développement	10									x					x										x					x	
Management et économie V	2																														
Langues V	3																														
Options	3									x					x					x											
Parcours de spécialisation	12									x				i	x					x					x					x	
Journée métiers et carrières																															
Forum Entreprises																															
Mentorat																															
Stage en entreprise	30									x					x					x										x	

I2C FISE Semestres 9 & 10	L'ADAPTATION AUX EXIGENCES PROPRES DE L'ENTREPRISE ET DE LA SOCIÉTÉ																			
	COMPETENCE 7					COMPETENCE 8					COMPETENCE 9					COMPETENCE 10				
Libellé UE	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Projet de recherche et développement				x					x										x	
Management et économie V																				
Langues V																				
Options														x						
Parcours de spécialisation				x					x					x						
Journée métiers et carrières				x																
Forum Entreprises				x																
Mentorat																				
Stage en entreprise				x					x					x					x	

I2C FISE Semestres 9 & 10	LA PRISE EN COMPTE DE LA DIMENSION ORGANISATIONNELLE, PERSONNELLE ET CULTURELLE																			
	COMPETENCE 11					COMPETENCE 12					COMPETENCE 13					COMPETENCE 14				
Libellé UE	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Projet de recherche et développement				x										x						
Management et économie V									x											
Langues V														x						
Options																				
Parcours de spécialisation			x	x					i					x						
Journée métiers et carrières									x										x	
Forum Entreprises									x										x	
Mentorat																			x	
Stage en entreprise				x										x					x	

For options and specialisation pathways, the contribution to skills acquisition depends on the choice (the table shows the contributions of all options and pathways). The specific contributions of each option and each specialisation pathway UE are indicated in the files (see above).