ESPCI PARIS | PSL

Syllabus

Semesters S5 and S6

Version 22.4

Table of contents

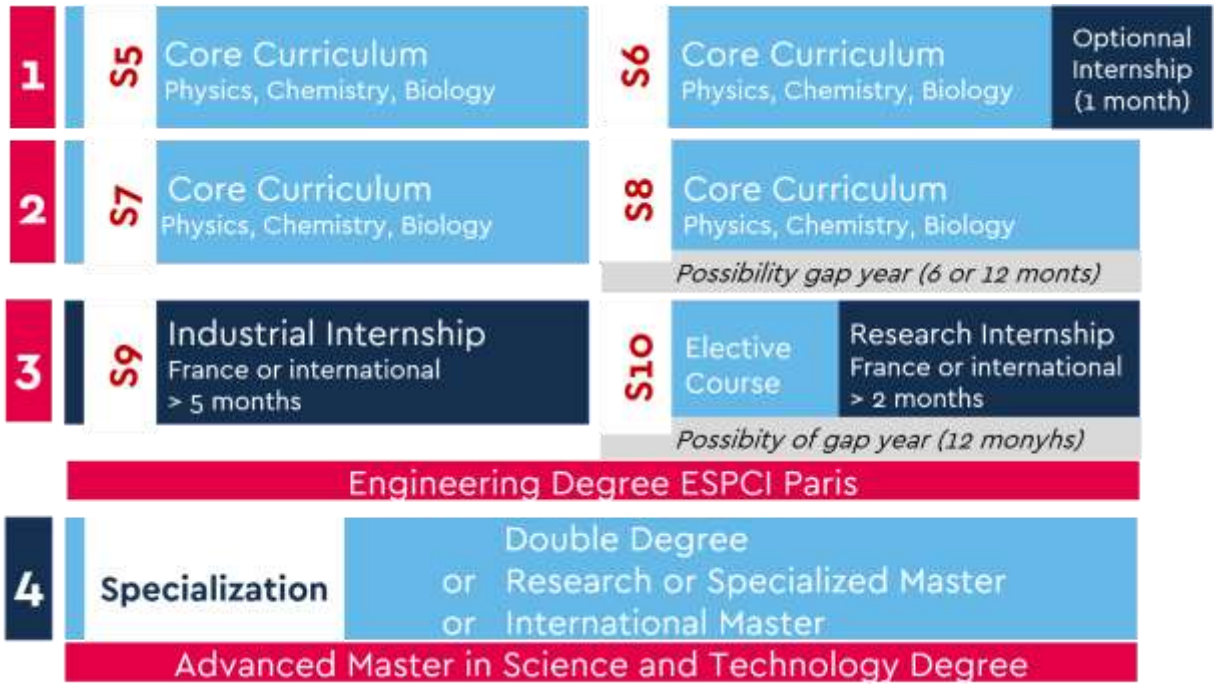
Introduction

The ESPCI Paris engineering program

ESPCI's central mission is to train innovation engineers capable of creating and guiding disruptive innovations in fields involving physics and chemistry and / or biology, while cultivating a solid foundation in relevant socio-economic fields.

The school's primary objective is to give student engineers the skills that will enable them to adapt to, anticipate, and respond to the demands of a constantly evolving society in an increasingly globalized context, throughout their careers as essential, responsible agents of change.
The goal of the educational training developed at ESPCI is to encourage learning through collective work and support students in developing an imaginative scientific approach.

ESPCI offers its students an original educational program (3 years + 1 optional year).



The first two years constitute a mandatory, shared core curriculum for all students, with foundational classes in physics, chemistry, biology, mathematics, and computer science, complemented by courses in foreign languages and socio-economics.

Learning through experimentation plays a very important role at ESPCI. Academic schedules include 15 hours of experimental work per week, through practical work in physics, chemistry, and biology, or group science projects. This time is intended to familiarize student engineers with a maximum of experimental techniques.

Lecture-based classes and tutorials are complemented by preceptorships that enable students to actively participate in their education by working in small groups of five or six, with a professor-researcher or a researcher.

In their second year, students have the opportunity to attend two weeks (one in November and the other in March) of a teaching module of their choice in another PSL establishment such as École des Mines ParisTech, Chimie ParisTech, ENSAD, or La Fémis.

Student engineers choose their specialty in their third year; they may choose four teaching units (known as *unités d'enseignement* or UE) in the following disciplines: physics, chemistry, physical chemistry, and biotechnology.

The ESPCI Paris engineering diploma, certified by the French commission of engineering titles, is awarded upon completion of three years' training, and the ESPCI diploma (Advanced Master in Sciences and Technology from ESPCI Paris) is granted following completion of an optional fourth year of study.

ESPCI Paris's objectives for its student engineers are articulated in a general skills base developed for the title of engineer and a skills base more specific to an ESPCI Paris engineer.

i) Skills base common to all engineer titles

C1. Ability to mobilize resources from a wide range of fundamental sciences.

C2. Mastery of engineering methods and tools: identification and resolution of problems, including those that are unfamiliar and incompletely defined; collection and interpretation of data; use of computer tools and modeling; analysis and conception of complex systems; experimentation.

C3. Awareness of industrial, economic, and professional challenges: competitiveness and productivity, innovation, and intellectual and industrial property. Respect for quality and security protocols; risk analysis and control.

C4. Capacity to integrate an organization, to drive it, to contribute to its evolution, and to manage it: engagement and leadership, project management and ownership, communication with specialists and non-specialists.

C5. Knowledge of and respect for societal values: knowledge of social relationships, environmental challenges, and engagement with society; to think and behave as a responsible, ethical citizen and professional.

C6. Ability to work in a multicultural and international environment, in English and in French. Capacity to suggest solutions adapted to this environment.

ii) Skills base specific to ESPCI Paris engineers

P1. Appropriation of a solid foundation in physics, chemistry, and biology.

P2. Mastery of a broad range of experimental techniques.

P3. Advanced expertise in one or more specialty fields including instrumentation, physics applied to health, materials, fine chemicals, biotechnology, etc.

P4. Ability to define a novel and innovative scientific project, and to manage a team to achieve its completion.

P5. Ability to work at the intersection of fields and lead a cross-disciplinary project.

P6. Ability to adapt to novel scientific and technical contexts.

P7. A culture of curiosity, creativity, innovation, and an openness to technology transfer and entrepreneurship.

P8. Unique, adaptive use of scientific knowledge, skill, and investigation that supports flexibility and reactivity to deliver innovative solutions to industrial challenges as well as important societal issues.

Core curriculum (S5 to S6)

The core curriculum is presented in chronological order by semester.

For each semester, teaching units (UE) are broken down into their constituent parts (*éléments constitutifs,* EC) in a table. This table includes the names of supervising teachers, the distribution of class hours (classes, tutorials or "TD", super TD, preceptorships, and lab work or "TP"), and the number of ECTS credits allocated to each UE. The volume of individual study is provided as a guide only.

The syllabus guides for each semester present the general and specific objectives of each UE, the EC that comprise it, the required prerequisites, any possible links with other UEs in the curriculum, the credits provided by each EC to complete the UE, and the skills covered in the UE (cross-reference matrix of skills / learning outcomes).

The syllabus guides for each EC specify teaching details (teaching staff, breakdown of hours, pedagogical content, materials provided, and test methods and credits). They also indicate the EC learning outcomes (LO) necessary to determining if ESPCI Paris training skills have been acquired at the targeted level (I: knowledge / understanding, II: application / analysis; III: synthesis / conception).

Semester 5

SEMESTER 5					426 h				30 ECTS
SEMESTER 5	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisor	Courses (h)	Tutorial (h)	Super Tutorial (h)	Preceptorships (h)	Lab (sessions
UE Mechanical Engineering I	56,5	5								
Mechanics of Solids ans Materials I	19	50%	SIM1	MSM1	P. Kurowski	14	5			
Applied Mechanics	37,5	50%		MAP	P. Kurowski					10
UE Electronics, Signals and Systems	99	7								
Electronics, Electrical Engineering, Robotics	29	40%	ES2	EEA	J. Lucas	17	5		7	
Linear Circuits and Signals, Noise	10	10%		SLS	F. Lemoult	8	2			
Electronics, Electrical Engineering, Robotics Lab Work	45	40%		TP EEA	J. Lucas					12
Linear Circuits and Signals, Noise Lab Work	15	10%		TP SLS	J. Lucas					4
UE Chemistry I	47,25	4								
Organic Chemistry I	12	30%	CH1	CO1	A. Guérinot, R. Nicolaÿ	10	2			
Polymer Chemistry	15,25	35%		CP	R. Nicolaÿ	4				3
Group Theory	20	35%		TDG	F. Volatron	10	8		2	
UE Mathematics and Numerical Methods I	56,75	5								
Mathematics I	38	60%	MMN1	MATH1	E. Raphaël	20	12		6	
PYTHON Development	18,75	40%		PYTHON	A. Allauzen					5
UE Life Sciences I	82,75	5								
Biochemistry / Cellular Biology	34	50%	SV1	BIO	P. Dupuis, A. Griffith	26			8	
Biochemistry / Cellular Biology Lab Work	48,75	50%		TP BIO	Y. Verdier					13
UE English I	30	2		ANGI	D. Moreau	30				
UE Engineer Skills	53,75	2								
Feedback, on Lab Immersion Experience	3	V	IM	IMM		3				
Risks and Prevention	4	V		RP		4				
Scientific Integrity	1	V		IS	M. Fermigier	1				
Climate Change Challenges	18	35%		ECC	G. Pakula	6				3
Intellectual Property Rights	10,5	15%		BRV	P. Brochard	3				2
Innovation Management	17,25	50%		GI	F. Vanhulle	6				3

One lab session is 3 h 45 min.
The volume of individual study is estimated to be 258 hours according to the following breakdown:
1 h class = 0.9 h individual study
1 h tutorial = 0.7 h individual study
1 h super tutorial / preceptorship = 1.5 h individual study
1 h lab = 0.3 h individual study

UE Mechanical Engineering I

Sciences de l'Ingénieur en Mécanique I

56.5 h - 5 ECTS

SEMESTER 5

UE SIM1

Description

The course Mechanics of Solids and Materials I (SIM1-MSM1) gives students the opportunity to acquire new skills in the mechanics of deformable bodies by introducing the concepts of stress and strain fields.

The first portion of the course introduces the basic concepts of material resistance through simple examples of the effect of forces like traction / compression, shear stress, flexion, and torsion, along with a more phenomenological approach to the Mechanics of Continuum Bodies. The second portion—theory of elasticity—generalizes these basic concepts by focusing on the tensorial quality of stress and strain.

The module Applied Mechanics (SIM1-MAP) includes tutorials that allow students to solve concrete problems a future engineer in mechanical engineer might be confronted with, as well as labs. These are structured around three main poles: the design office (conception, specifications, technical drawing), production tracking of mechanical parts on machine tools, and labs focused on stress analysis (characterization of materials using stress meters and optical methods). The goal of this module is to give students the necessary foundation in mechanical engineering to prepare them for effective communication with specialized participants (mechanics, technicians, and project engineers) with a view to creating experimental projects focused on research and development.

Semester	Program
S5	SIM1-MSM1 Mechanics of Solids and Materials I
	SIM1-MAP Applied Mechanics

Prerequisites

Mathematics: vector analysis, matrix calculus, vector calculus, linear differential equations, integral calculus. Classical mechanics.

Related classes

Mathematical methods (S5-MMN1-MATH1)
Optics (S8-OPT)

UE Validation

Weighted average: SIM1-MSM1 50%, SIM1-MAP 50%

Skills targeted

SIM1-MSM1	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	II	II				III		II					
LO2.	Ex.	III	III	II				III		II					
LO3.	Ex.	III	II	II				III		II					II
SIM1-MAP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report, Part.				III						III				
LO2.	Report, Part.		II					III	III						II
LO3.	Report, Part.	III	II					III	III	II					
LO4.	Report		III					III	III						
LO5.	Report	III	III					III	III						
LO6.	Mechanical components			II					II				II		

Ex.: written final exam, Part.: participation

S5 – SIM1 – MSM1	Mechanics of Solids and Materials I

Supervisor: Pascal Kurowski

| Course: 14h | Tutorial: 5h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. choose a material according to its mechanical, thermal, spatial, and temporal resistance;
LO2. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO3. analyze a data set to verify the weaknesses and advantages of a given material.

Contents	1. Extensometry The concept of continuum What is elasticity? Concepts of stress and strain (a bar under traction, the bulk modulus, shear stress, elastic energy, a material's experimental behavior—load curve, stress gauge) Several issues unique to elasticity (weak bending in beams, buckling, torsion of cylindrical beams) 2. Theory of elasticity Stress (external forces and mechanical equilibrium, internal forces and stress vector, normal and tangential stress, stress tensors, Mohr's circle, states of specific stress, dynamic equilibrium equation) Strain (strain tensors, translation, deformation, rotation, interpretation of tensor terms, strain from temperature change) Laws of behavior (Young's modulus, Lamé's modulus, effective modulus) Energy of elastic deformation, general relationship Hertzian contact theory

Bibliographic Resources	Handouts, corrected past exams

Evaluation	Written final exam (Part A applied exercises 40%, Part B complete problem 60%)

S5 – SIM1 – MAP | Applied Mechanics

Supervisor: Pascal Kurowski

Teaching staff: Amaury Fourgeaud, Alexandre Lantheaume, Erika Jean-Bart

| Lab: 37.5h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of lab work, students will be able to:

- LO1. work in a group;
- LO2. identify and independently carry out the various steps of an experimental approach;
- LO3. utilize various experimental techniques for material characterization in the laboratory;
- LO4. identify sources of error to calculate uncertainty and validate experiment results;
- LO5. synthesize and interpret experiment results from a critical perspective.

Contents	
	1. Design office Project design (conception, specifications, technical drawings) 2. Production Production of parts for the Design Office project 3. Strength of materials: stress analysis • Determination of elastic constants (Young's modulus, shear stress, Poisson's ratio) using extensometry applied to test tubes undergoing traction, flexion, and torsion • Definition of stress field using photoelasticity (networks of isoclines, isochromes, and isostatics) on birefringent materials • Determination of Young's modulus for a set of beams of varying geometry using the measurement of their deformation based on image processing • Measurement of stress and strain fields using cross-correlation of 2D images of elastomers undergoing elongation

Bibliographic Resources	Lab and tutorial instructions, course handouts.

Evaluation	Attendance 10% Report 50% Manufactured parts 40%

UE Electronics, Signals and Systems

Electronique, Signaux et Systèmes

99h - 7 ECTS

SEMESTER 5

UE E2S

Description

This module is intended to provide students with the necessary foundation to understand how modern electronic systems, from cell phones to everyday electronic devices, works. These omnipresent devices draw on the theory of signals and linear circuits. Noise, which is often the sticking point of these systems, is addressed through its mathematical description. These concepts are all important and appear across disciplines, in physics, chemistry, and biology, either directly as tools in a given field or simply when an electric or electronic measuring device must be used for taking measurements or controlling a system.

In the Electronics part of the course (ES2-EEA), the UE revisits and deepens the understanding of circuit theory. Operational amplifiers, the building blocks of low-frequency electronics, are studied with regards to their architecture and implementation. The fundamentals of digital electronic, as well as microcontrollers and programmable logic components, are addressed. Electronic systems are approached through applications in the field of regulations and of complex electronic function such as Phase Locked Loops. Finally, Non linear components, ie diodes, transistors are studied, starting with simple physical and behavioral models to their application in digital and analog systems.

In the Linear Circuits and Signals portion (ES2-SLS), time-invariant linear systems are characterized by their impulse response and their transfer function in the Fourier and Laplace spaces. Students are shown how to determine a system's stability using these tools. The Fourier Transform is then used to manipulate signals, then to determine the effect of sampling a signal on its spectrum (Nyquist-Shannon Sampling Theorem). Finally, noise is described as a random signal and characterized by its correlation function; its correspondence with power spectral density is then demonstrated (Wiener-Khinchin Theorem).

Semester	Program	
S5	E2S-EEA	Electronics, Electrical Engineering, Robotics
	E2S-TPEEA	EEA Lab
	E2S-SLS	Linear Circuits and Signals, Noise
	E2S-TPSLS	SLS Lab

Prerequisites

Basic knowledge of circuit theory is required. A certain number of basic concepts will be reviewed early in the course, as they are often lacking. Knowledge of complex numbers and the Fresnel diagram is helpful.
The decomposition of a rational fraction into simple expressions is used to manipulate transfer functions. Fourier and Laplace Transfers are defined; they are studied in more detail in the mathematics course.

UE Validation

Weighted average: E2S-EEA 40%, E2S-TPEEA 40%, E2S-SLS 10%, E2S-TPSLS 10%

Targeted skills

E2S-EEA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	II					III							
LO2.	Ex.	III	III					III							
LO3.	Ex.	III	III					III							
LO4.	Ex.	II	II					III							
LO5.	Ex.		III					III							
E2S-TPEEA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part., PO		III		II	II			III						
LO2.	Part.				II	II									
LO3.	Part., PO, notebook		III						III						
LO4.	Part., PO	II	III					II	III						
LO5.	Part., notebook	II	III					II	III						
LO6.	Part., PO		III						III						
LO7.	Part., PO		III	II					III						
E2S-SLS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	III												
LO2.	Ex.	III	III												
LO3.	Ex.	III	III												
LO4.	Ex.	II	II					II							
LO5.	Ex.	III	III												
LO6.	Ex.		III												
LO7.	Ex.		III												
LO8.	Ex.		III												
E2S-TPSLS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.		III						III						
LO2.	Part.		III	II					III						
LO3.	Part.		III						III						
LO4.	Part.		III	II					III						

Ex.: written final exam, Part.: participation, PO: oral exam

S5 – E2S – EEA | Electronics, Electrical Engineering, Robotics

Supervisor: Jérôme Lucas

Teaching staff: Jérôme Lucas, Yacine Oussar

| Course: 17h | Tutorial: 5h | Preceptorship: 7h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. identify and calculate impedances at work in a linear circuit, model the system, and solve problems of disadaptation;
- LO2. analyze an operational amplifier circuit and design a cirtuit that responds to their own needs;
- LO3. determine a system's stability by calculating or measuring its response to an open loop control system, model the system using its step response measurement, and stabilize or correct the system's response to meet a set of specifications;
- LO4. identify different types of non-linear components, carry out small-signal linearization on a non-linear model, analyze its functioning, and calculate the response to this type of model;
- LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course / Tutorial

1. Introduction
2. Prerequisites
   - Fundamental laws
   - Linear dipoles
   - Linear quadrupoles
   - Impedance matching
   - Basic elementary circuits
   - Elementary time-frequency duality
3. Operational amplifiers
   - Application and simple models
   - Elementary assemblies
   - Real operational amplifiers
4. Foundational digital electronics
   - Boolean algebra, Karnaugh Maps
   - Combinatory logic
   - Sequential and synchronous logic
   - Functions of digital electronics: registers, memories, counters, etc. EPLD FPGA configurable circuits.
5. Non-linear elements to semi-conductors
   - Semi-conductors, P-N junction
   - Diodes and interaction with light: photobatteries and photodiodes
   - Transistors: example of MOSFETs and BJTs
6. Introduction to power electronics

	Preceptorship • Superposition, conditioning, and impedance matching • Logic systems • Analog circuit design for MOSFET transistor • Proportional feedback and feedback with a reference model • Amplifier to Bipolar amplifier, Cascode Assembly

Independent study	Objective: Interpret and apply concepts learned in the course to go beyond simple elementary applications. Methods: Preparation for preceptorships

Bibliographic Resources	Course handouts Preceptorship and tutorial handouts Online resources at cours.espci.fr: corrected tutorial exams, application notes, etc.

Evaluation	Written final exam

S5 – E2S – TPEEA	Electronics, Electrical Engineering, Robotics Lab

Supervisor: Jérôme Lucas

Teaching staff: Jérôme Lucas, Emmanuel Géron

| Lab: 45h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of lab work, students will be able to:

LO1. identify and independently lead the different steps of an experimental approach;
LO2. organize their laboratory work;
LO3. use measurement tools and techniques in the laboratory in the field of electronics;
LO4. interpret experiment results with a view to modeling them;
LO5. validate a model by comparing predictions with experiment results and assess the limits of their validity;
LO6. take a critical approach to using data acquisition and analysis programs;
LO7. use their knowledge and draw on documentary resources to observe and interpret experimental phenomena.

Contents	• Generators, oscilloscope measurements, basic circuits: model and "reality" • Operational amplifiers • Microcontrollers • Logic systems • Automatic digital temperature control

Organization	Manipulations are divided into the five following themes. The first three themes are addressed respectively in two, three, and three sessions. Themes four and five are addressed in two sessions and alternatively by each half of the lab.

Independent Study	Objectives: Synthesize, interpret, and present experiment results. Methods: Solving practical problems.

Bibliographic Resources	Lab handouts

Evaluation	Manipulation, Organization, Comprehension, Involvement 80% The lab booklet will be evaluated by questions asked about the lab work on the final exam in January.

S5 – E2S – SLS | Linear Systems and Signals, Noise

Supervisor: Fabrice Lemoult

| Course: 8h | Tutorial: 2h | Course language: 🇫🇷 |

Objectives / Targeted Skills

Upon completion of the course, students will be able to:

LO1. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO2. take a critical approach to using data acquisition and analysis programs;
LO3. identify sources of error to calculate uncertainty in experiment results;
LO4. identify a linear circuit and calculate its impulse response and transfer function;
LO5. evaluate the stability of a linear circuit;
LO6. analyze a signal using the Fourier Transform;
LO7. calculate the error induced by a signal;
LO8. evaluate the effect of noise on signal transmission.

Contents	

1. Linear systems
   - Time-invariant linear systems, impulse response
   - Stability and causality: definitions and criteria
   - Fourier and Laplace series, stability and causality criteria
2. Signals
   - Signal representation and manipulation using the Fourier Transform
   - Sampling: Shannon-Nyquist Sampling Theorem, Fast Fourier Transform
3. Noise
   - Random signals
   - Characterization in the Fourier space, Wiener-Khinchin Theorem

Bibliographic Resources	Course handouts and tutorial handouts

Evaluation	Written final exam

S5 – E2S – TPSLS	Linear Systems and Signals, Noise Lab

Supervisor: Jérôme Lucas

Teaching staff: Jérôme Lucas, Emmanuel Géron

| Lab: 15h | Course language: |

Objectives / Targeted Skills

Upon completion of lab work, students will be able to:

LO1. use measurement tools and techniques in the laboratory in the field of frequency spectrum analysis;
LO2. use their knowledge and draw on documentary resources to observe and interpret experimental phenomena;
LO3. explain how a phase-locked loop works;
LO4. use a locked-in amplifier to measure a magnitude, a phase, or both.

Contents	1. Analog spectral analysis 2. FFT spectral analysis 3. Locked-in amplifier 4. Phase-locked loop

Bibliographic Resources	Lab handouts

Evaluation	Participation 100%

UE Chemistry I

Chimie I

47.25h - 4 ECTS

SEMESTER 5

UE CH1

Description

The Organic Chemistry course (CH1-CO1) aims to give students the fundamental tools to understand the chemical reaction between two organic species. The structure of molecules (VSEPR, hybridization), electron movements and the basis of reaction mechanisms (electrophilicity, nucleophilicity, frontier orbitals and orbital overlap), structure / reactivity correlation, concepts of kinetic and thermodynamic control, notions of transition states and Hammond's postulate will be covered in lectures or in the form of TDs / courses. The Organic Chemistry course (CH1-CO1) also presents the main chemical transformations of aromatic compounds. The reaction mechanisms are explained and applications in various fields (medicinal chemistry, materials chemistry, ...) are discussed. These bases, well assimilated, constitute an essential base of knowledge for the students whatever their future choice of orientation (chemistry, physical chemistry, biology or physics).

The teaching of Polymer Chemistry (CH1-CP) consists of a theoretical part (4 h) and an experimental part (11.25 h). The objective of this course is to present the main concepts and tools (structure / reactivity relationship, reaction mechanisms, kinetics, polymerization processes) used to design and synthesize custom polymers, taking into account the different structural parameters such as molar mass, dispersity, composition, topology and functionality. The experimental part aims at the acquisition of good laboratory practices, the learning of various techniques of implementation of a polymerization, of its analytical follow-up, then of the purification and the verification of the structure of the polymers obtained by NMR analysis, DSC, SEC, ATG, swelling tests. Emphasis is placed on learning autonomy, respecting safety rules and keeping a scientific laboratory notebook. Finally, students are made aware of a more environmentally friendly chemistry (eco-compatible or green chemistry).

The course Group Theory (MMN1-TDG) presents and uses concepts and nomenclature of group theory in molecular orbital calculus, UV / visible spectroscopy, and molecular vibration.

Semester	Program	
S5	CH1-CO1	Organic Chemistry I
	CH1-CP	Polymer Chemistry
	CH1-TDG	Group Theory

Prerequisites

Prerequisites and a number of basic concepts will be reviewed early in the course. A basic understanding of chemical reactions, including knowledge of fundamental reactions (substitution, elimination, addition) are recommended. If this is not the case, students are highly encouraged to take the organic chemistry review module (optional refresher course).

UE Validation

Weighted average: CH1-CO1 30%, CH1-CP 35%, CH1-TDG 35%

Targeted skills

CH1-CO1	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., prec.	II	II					II							
LO2.	Ex., prec., sTD	II	II					II							
LO3.	Ex., prec., sTD	II	II					III							
LO4.	Ex., prec., sTD	III	III							III			III		
LO5.	Ex., prec., sTD	III	III					III		III					
LO6.	Ex., prec., sTD		III												
LO7.	Prec.		II		II										
CH1-CP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	III					III		III					
LO2.	Ex.	II	II					III		III					
LO3.	Ex.	II						II							
LO4.	Ex.	III	III					III		III					
LO5.	Ex.	II	II					III		III					
LO6.	Ex.	III	III					III		III					
LO7.	Ex.	III	III					III		III					
CH1-TDG	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	II													
LO2.	Ex.														
LO3.	Ex.	II						II				III			
LO4.	Ex.	II						II							
LO5.	Ex.		III					II							
LO6.	Ex.		III					II							

Ex: written final exam, prec.: preceptorship, sTD: super tutorial, CL: lab log, TE: experimental work, AS: spectrum analysis, IS: structure identification, CR: report

S5 – CH1– CO1	Organic Chemistry I

Supervisors: Renaud Nicolaÿ, Amandine Guérinot

Teaching staff: Arthur Duprat, Domingo Gomez-Pardo

| Course: 10 h | Tutorial: 2 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. identify and use fundamental concepts to understand the reaction between two chemical entities.
- LO2. identify classical chemical transformations and the structure of the products formed.
- LO3. write a rational reaction mechanism for a chemical transformation.
- LO4. analyze a multi-step reaction sequence.
- LO5. construct a reasonable reaction sequence to access a target molecule.
- LO6. use their knowledge to solve a complex and / or transverse problem.

Contents	Course / Tutorial 1. General • Hybridization • Acidity and basicity in Organic Chemistry • Chemical reactions • Kinetic and thermodynamic control of reactions • Structure / reactivity correlation • Major classes of reactions 2. Aromatic chemistry • Conjugation and aromaticity • Aromatic electrophilic substitutions • Aromatic nucleophilic substitutions • Synthesis strategy • Heteroaromatics

Bibliographic Resources	Course resources Tutorial instructions

Evaluation	Final written exam : course questions 50%, problem solving 50%

S5 – CH1 – CP | Polymer chemistry

Supervisor: Renaud Nicolaÿ

| Course: 4h | Lab: 11.25 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. identify and use the fundamental concepts governing polymer chain growth to analyze or predict the structure of polymers.
- LO2. write a reaction mechanism for a free radical polymerization, a controlled free radical polymerization, or a step polymerization.
- LO3. interpret and analyze experimental data to identify a type of polymerization and to identify spurious reactions.
- LO4. relate the composition of a reaction mixture to the structure of the polymers formed
- LO5. use knowledge to design a system for the synthesis of polymers of predetermined molar masses and compositions
- LO6. use their knowledge to solve a complex and / or transverse problem
- LO7. use classical techniques of polymer synthesis and purification (manipulation in inert atmosphere, kinetic follow-up, precipitation, freeze-drying)
- LO8. interpret experimental results and spectroscopic data to validate the structure of the polymers formed
- LO9. work in a group
- LO10. be autonomous and organize their work in the laboratory
- LO11. identify and carry out independently the different steps of an experimental approach
- LO12. carry out molecule syntheses in compliance with HSE standards and ethical rules of the engineer (laboratory notebook, reliability of results)
- LO13. identify specific regulations and implement the main preventive measures in terms of health and safety (e.g. chemical risks)
- LO14. observe and interpret experimental phenomena by mobilizing his / her knowledge and relying on documentary resources
- LO15. synthesize, interpret and report experimental results.

Contents	

1. Introduction
   - Thermoplastics / Thermosetting plastics
   - Chain-growth polymerization / Step-growth polymerization
   - Some properties of polymers
2. Free-radical polymerization
   - Structure / reactivity relationship
   - Initiation
   - Propagation
   - Termination
   - Transfer and telomerization
   - Degree of polymerization
   - Copolymerization
3. Controlled radical polymerization
   - Concepts and characteristics
   - Nitroxide-mediated radical polymerization (NMP)
   - Atom transfer radical polymerization (ATRP)

	• Reversible addition-fragmentation chain-transfer polymerization (RAFT) 4. Methods of radical polymerization • Bulk polymerization • Solution polymerization • Suspension polymerization • Emulsion polymerization 5. Step-growth polymerization • Degree of polymerization • Molar mass and molar mass distribution • Freezing point and networks • Kinetics of step-growth polymerizations • Major polymer families obtained by polycondensation and polyaddition • Design / synthesis of polymers

Bibliographic resources	Handouts and course materials Safety data sheets Examples of research articles

Evaluation	Experimental work (manipulation, organization, understanding) 45% Laboratory notebook 10% Report (writing of a publication-type procedure, analysis and discussion of results) 45%

S5 – CH1 – TDG	Group Theory

Supervisor: François Volatron

| Course: 10 h | Tutorial: 8 h | Preceptorships: 2 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. familiarize themselves with molecular geometries and elements of symmetry;
LO2. process experiment data within the group theory framework;
LO3. use these concepts to resolve / interpret experiment data;
LO4. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO5. interpret experiment results with a view to modeling them;
LO6. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes.

Contents	Course / Tutorial 1. The foundations of Group Theory • Example uses of symmetry • Symmetry operations group • Linear representation of a symmetric group • Elements of character theory 2. Applications • Calculus of molecular orbitals • Tensor product and applications • Molecular vibration • Electronic structure of transition-metal complexes) Preceptorships 1. Jahn-Teller effect 2. Carbocation stability

Prerequisites	Knowledge of atomic orbitals; interaction of two atomic orbitales over two centers

Related classes	Spectroscopic methods (S5-CH1-ICO); Inorganic Chemistry (S8-CH2-CMI)

Bibliographic Resources	A textbook on group theory and several articles

Evaluation	Written final exam

UE Mathematics and Numerical Methods I

Mathématiques et Méthodes Numeriques I

56.75 h - 5 ECTS

SEMESTER 5

UE MMN1

Description

The course of mathematics (MMN1-MATH1) presents students with a number of mathematical models necessary to developing solid training in physics and chemistry. These are not "formulas" to be applied blindly, but mathematical tools that must be mastered. The first portion of the course addresses the theory of holomorphic functions. Cauchy's method—which is based on the concept of a line integral in the complex plane—is a fertile one and leads to the residue theorem, in particular, and its many applications. The second portion of the course presents the basic notions of the Lebesque integration theory, then explores in detail the important concepts of convolution products, the Fourier Transform, and the Laplace Transform. The last portion of the course covers distribution theory. This theory, developed by Laurent Schwartz, has become an essential tool in many fields related to mathematics and physics.

The Python course (MMN1-PYTHON) introduces the essential knowledge to be able to program efficiently and to integrate this tool in the experimental practice. The course is organized around 5 practical sessions in order to learn by practice the good practices and the potential of this language (scientific calculation, analysis and visualization of results, apprehend the possibilities offered by all the existing scientific libraries and be able to use them.

Semester	Program	
S5	MMN1-MATH1	Mathematics
	MMN1-PYTHON	Programming with Python

Prerequisites

Study of functions; sequences and series; Fourier Series; first and second-order linear differential equations; complex number manipulation; polynomials and rational fractions; integrals (simple, double, and triple).

UE Validation

Weighted average: MMN1-MATH1 60%, MMN1-PYTHON 40%

Targeted skills

MMN1-MATH1	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., CC	III	III					III				II			
LO2.	Ex., CC	III	III					III							
LO3.	Ex., CC	III	III					III							
LO4.	Ex., CC	III	III					III							
LO5.	Ex., CC	II	II					II							

MMN1-PYTHON	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	CC, Report	II	II												
LO2.	CC, Report	II	II						II						
LO3.	CC, Report	II	II									II			
LO4.	CC, Report	II	III												
LO5.	CC, Report	II	III						II		II	II			

Ex.: final written exam, CC: coursework

S5 – MMN1– MATH1 Mathematics I

Supervisor: Elie Raphaël

| Course: 20 h | Tutorial: 12 h | Preceptorship: 6 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO2. manipulate the residue calculus of a holomorphic function to apply the residue theorem to integral calculus;
LO3. solve a linear problem using the Fourier Transform;
LO4. manipulate the convolution product;
LO5. solve a linear differential equation according to distributions by using Green's functions.

Contents	Course / Tutorial 1. Holomorphic functions • Derivatives of a function of a complex variable • Definition and properties • Integration in the complex plane • Residue theorem and applications 2. Supplement on integral integration and transformation • Supplement on integral integration and transformation • Lebesgue's concept of measure and integration • Convolution product • Fourier Transform • Laplace Transform 3. Distributions • Definitions and general properties • Derivation • Convolution product • Green's functions • Fourier Transform Preceptorships 1. Holomorphic functions (applied to the load-bearing capacity of an airplane wing) 2. Fourier and Laplace Transforms (applied to tomography) 3. Green's functions and distributions

Independent Study	Objectives: Use the concepts learned in the course to go beyond basic applications Methods: Preparation for preceptorships

Bibliographic Resources	Handouts and works provided as references

Evaluation	Ongoing assessment (1/3 of the final grade) and written exam (2/3) Final written exam: short exercises 40%, problem 60% <u>Methods of ongoing assessment</u> (out of 20) • Three 15-minute tests in the first portion of the tutorial (out of 10). Dates will be announced in advance. • Three tutorials (out of 10). Each tutorial is graded on a scale of three, with two points given for the assignment and one point given for participation. The assignment is awarded points in the following manner: ✓ 0: no assignment. ✓ 1: a rushed assignment—only the first questions are answered and the student stops at the first difficult question, although it is possible to provide results to continue. ✓ 2: a serious assignment—the entire test was addressed, even if some questions were not answered. To grade the test according to actual work performed, the student may redo the questions addressed on the test at the blackboard. A bonus point will be given to students who successfully solve the difficult questions.

S5– MMN1 – PYTHON	Programming with Python

Supervisor: Alexandre Allauzen

| Lab: 18.75h | Course language: 🇫🇷 |

Introduction

The goal of the course is to introduce students to the practice of this programming language, in order to be able to use it efficiently in future projects, with the necessary ease to evolve and find the right solutions. Each session is based on concrete examples in order to address the main themes of programming in Python.

Objectives / Targeted Skills

Upon completion of the lab, students will be able to:

LO1. solve real-world problems with the right approach and programming choices in Python;
LO2. exploit existing software resources in python to quickly develop effective solutions;
LO3. process, analyze and interpret results of scientific experiments using programming;
LO4. manipulate object programming in Python, its syntax and main principles;
LO5. develop a software solution in the context of a project carried out in pairs.

Contents	• The course is organized in 5 practical sessions to cover the basics of programming in Python. • The basics of the language, how it works and the programming tools • Scientific computing in Python, input / output and first scientific experiments (the logistic suite and fractals) • Numerical simulation and the Ising model • Object programming

Independent Study	The course ends with a project done in pairs that requires developing a complete solution in Python to a problem.

Bibliographic Resources	The course material is given in the form of slides and the practical exercises are notebooks.

Evaluation	Lab (30%) and project (70%)

UE Life Science I

Sciences du Vivant I

82.75 h - 5 ECTS

SEMESTER 5

UE SV1

Description

The main objective of the SV1 UE is to introduce students to basic concepts in biochemistry and molecular and cellular biology to support understanding of the current research challenges in these fields.

In biochemistry, students will be introduced to the main types of biomolecules (carbohydrates, lipids, nucleic acids, and proteins), biological catalysis, signal transduction, energy transformation, storage and replication of information by genes, as well as the way in which genes code for RNA (transcription), which in turn code for proteins (translation).

In cellular biology, students will learn general concepts of functional cell compartmentalization, intracellular transport, the basics of cell signaling, and the structure of cells and tissues, as well mecanotransduction. A portion of the course will then address the tools of cellular and tissue engineering and the challenges of biomedical research, which is highly interdisciplinary, in these fields.

Semester	Program	
S5	SV1-BIO	Biochemistry / Cellular Biology
	SV1-TPBIO	Biochemistry / Cellular Biology Lab

Prerequisites

None

UE Validation

Weighted average: SV1-BIO 50%, SV1-TPBIO 50%

Targeted skills

SV1-BIO	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., doc	II						I,III							
LO2.	Ex., doc	III		II				II	II			I			
LO3.	Ex., doc, POF	III	III					I	III	I		I	III		
LO4.	Doc, POF	III	III									I	I	III	
LO5.	Ex., doc		I	I				I	I			III	III	I	I
LO6.	Doc, POF		III						I			I	III	I	
LO7.	Ex., doc	III						III	I				III	I	
SV1-TPBIO	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.				II						III				
LO2.	Report		III						III		III		II		
LO3.	Report		II					III	III	II					
LO4.	Report, Part.	III								III					
LO5.	Report		III						III	II					
LO6.	Report		III					II	III				II		
LO7.	Part.			III					II						
LO8.	Report, Part.		II					II	II						
LO9.	Report, Part.	II	III							II					
LO10.	Report	II	III					III							II

Ex.: final written exam, doc: documents, POF: oral presentation in French, Part.: participation

S5 – SV1 – BIO	Biochemistry / Cellular Biology

Supervisors: Andrew Griffith, Pascale Dupuis-Williams

| Course: 26 h | Preceptorship: 8 h | Course languages: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. understand thematic fields of cellular biology (membranes and signaling, protein trafficking and secretion, cytoskeletons and mecanotransduction, cellular differentiation, and tissue organogenesis);
- LO2. identify the related fundamental principles and mechanisms;
- LO3. become familiar with biology methodologies, analyses, and processes (tracers and biosensors, photon and microscope microscopy, cell and animal models, etc.);
- LO4. grasp analysis of complex systems intrinsic to biology: multiple variables, multiple interactions, multi-level analyses;
- LO5. appropriate theoretical and methodological approaches through reading publications or examples in class;
- LO6. utilize their knowledge to analyze the results of a measurement;
- LO7. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course 1. Biochemistry • Main biomolecules (carbohydrates, lipids, nucleic acids, proteins) • Biological catalysis (enzymes) • Signal transduction • Energy transformation • DNA replication, RNA transcription and maturation, and protein translation • Introduction to recombinant DNA and DNA sequencing 2. Cellular biology • Cell evolution • Prokaryote vs. eukaryote • Cellular organization in eukaryotes • Properties of biological membranes • Cellular compartmentalization • Intracellular trafficking • Cytoskeletons and mechanotransduction • Stem cells and differentiation • Cellular and tissue engineering Preceptorships Publication analysis and thematic bibliographic research and summarization, organized in four sessions structured around the following themes: 1. the central dogma of molecular biology 2. membranes 3. the cell and its environment 4. biotechnology

Independent Study	Objectives: interpret and apply concepts learned in the course to go beyond simple elementary applications Methods: preparation for preceptorships

Bibliographic Resources	Course resources on the ESPCI site. Tutorial instructions

Evaluation	Homework (individual video 5 mn)

S5 – SV1 – TPBIO | Biochemistry / Cellular Biology Lab

Supervisor: Yann Verdier

Teaching staff: Yann Verdier - Alice Pavlowsky

| Lab: 48.75 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the lab, students will be able to:

- LO1. work in a group—lead an experiment in a pair, present a hypothesis to the lab group;
- LO2. organize their laboratory work—lead a procedure over eleven sessions, manage reagents and result traceability;
- LO3. synthesize a protein using molecular biology techniques;
- LO4. justify DNA and protein purification techniques;
- LO5. use laboratory equipment—electrophoresis, spectrophotometer, column chromatography, thermal cycler;
- LO6. use the image analysis program ImageJ to quantitatively interpret a western blot, analyze a DNA sequence and a protein sequence using bioinformatics;
- LO7. identify specific hygiene and safety regulations—CMR and biological waste management;
- LO8. identify sources of error to calculate output accuracy;
- LO9. use their knowledge to observe and interpret experimental phenomena;
- LO10. summarize, interpret, and present experiment results in a lab log.

Contents	Labs are designed as a series of experiments in molecular biology. Each lab pair carries out the complete process of gene cloning that gives bacteria a green color through overexpression of the fluorescent protein GFP. ▪ Preparation of the vector (linearization, dephosphorylation, purification) ▪ Preparation of the insert (PCR, purification, enzymatic digestion) ▪ Ligation ▪ Transformation ▪ Screening for recombinant clones using PCR ▪ Protein expression induction ▪ Protein extraction and western blot analysis During the bioinformatics lab, students will analyze a DNA sequence and identify relevant information (gene structure, sequence structure, and protein function) using databases and prediction tools. Finally, students must design an experiment to clone a gene with the goal of expressing the protein coded by the gene, thereby making the connection with work carried out during lab sessions.

Organization	A procedure carried out over eleven sessions. Two bioinformatics sessions.

Bibliographic resources	Lab and tutorial handouts

Evaluation	60% results and interpretation 15% lab log 25% involvement in lab (participation, etc.)

UE Engineer Skills

Métier de l'Ingénieur

53.75 h - 2 ECTS

SEMESTER 5

UE MI

Description

The objective of the immersion module (MI-IMM) is to give students an opportunity to discover life in a laboratory, accompanied by one of the school's researchers.

The aim of the MI-IS conference is to increase the awareness of students for questions regarding scientific integrity and open data.
Through examples of scientific misconduct, we will show their implication on the quality of scientific production and the perception of science by the general public.
The students will be encouraged to use good research practices in their activities at ESPCI and in particular during laboratory sessions and research projects.

The Climate Change Challenges module (MI-ECC) is intended to give students a basic understanding of three growing societal problems that will impact their future activities, whatever they may be (R&D, teaching, patents, marketing, etc.):

1) sustainable development and circular economy
2) environmental impacts : mechanicms, mitigation and adaptation
3) Life Cycle Assessment and eco-design: methods for innovation towards environmentally & socially responsible products & services

Consideration for these aspects is now essential, as much for regulatory compliance as for the economic, social, and environmental longevity of organizations. The module provides context, regulatory frameworks, theory and best practices in these three areas. Furthermore, it provides several methodological elements, particularly for carrying out a life cycle analysis, a study that precedes any eco-design project. The theoretical aspects of environmental impacts, life cycle assessment and ecodesign are presented briefly during the class; practical aspects are addressed in more depth during tutorials.

The module Innovation Management (MI-GI) is intended to foster awareness about innovation and enable students to understand the internal and external obstacles to developing new concepts. The many definitions of innovation are provided to illustrate the difference between incremental change and disruptive change, and to help students understand why, contrary to incremental change, innovation fails. The profile of the innovator, whether industrial, collective, or individual, will be described in order to identify the roles of each. Innovation centers will be used as an example. By understanding the drivers of innovation based on an expanded version of Porter's model and exploring its evolution over time from a quantitative and sociological angle, each student will be able to recognize and appreciate the importance of innovation management.

The course Intellectual Property Rights (MI-BREV) aims to give students tangible understanding of intellectual property rights, with an emphasis on patents.

Semester	Program	
S5	MI-IMM	Feedback on Laboratory Immersion Experience
	MI-RP	Risks and Prevention
	MI-IS	Scientific Integrity
	MI-ECC	Climate Change Challenges
	MI-GI	Innovation Management
	MI-BREV	Intellectual Property Rights

UE Validation

AMI-ANG1 100%, AMI-IMM, AMI-RP & AMI-IS attendance

Targeted skills

MI-IMM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Attendance				I	I							I		
LO2.	Attendance				II										
LO3.	Attendance				II	II							I		
MI-RP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Attendance					II									
LO2.	Attendance					II									
MI-IS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Attendance			I	I	I							I		
LO2.	Attendance				I	II									II
MI-ECC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex		II	II		II								II	III
LO2.	Ex	II	III	II	I	III			II	II	II	III	II	II	II
LO3.	Ex	II	III	II	I						I	III	II	III	III
LO4.	Ex	II		II		II						II	I		II
LO5.	Ex	I	II	I						II			II		III
LO6.	Ex				II	II							II		II
LO7.	Ex				II							II			
LO8.	Ex		III	II						II			II	III	III
MI-GI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Final project	I		I										I	
LO2.	Final project	I		I										I	
LO3.	Final project	I		I										I	
LO4.	Final project	I		I										I	
LO5.	Final project	II		II	II	II					II			II	
LO6.	Final project	I		I	I	I								I	
LO7.	Final project	I		I							I			I	
LO8.	Final project	II		II	II	II					II			II	
MI-BREV	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.			I											
LO2.	Ex.			I										II	
LO3.	Ex.			II										II	
LO4.	Ex.			I										II	

S5 –MI – IMM | Feedback on Laboratory Immersion Experience

Supervisors: Nicolas Lequeux, Pascal Kurowski, Corinne Soulié-Ziakovic

| Presentation: 3 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

After spending two days in a laboratory and completing a summary of the experience, students will be able to:

LO1. understand and value an academic research working environment;
LO2. work in a group;
LO3. communicate appropriately both verbally and in writing to a given audience.

Contents	Differs according to the themes suggested by school researchers.
Organization	In pairs, students complete a two-day observational internship accompanied by a researcher from one of the school's laboratories. They then summarize their experience in a 15-minute presentation and respond to their classmates' questions.
Evaluation	Mandatory presence during the two-day immersion and at the presentation session.

S5 –MI– RP	Risk and Prevention

Supervisor: ESPCI Paris Prevention Department

| Course: 4 h | Course language: |

Contents	Risk management awareness Presentation of general safety rules established at ESPCI Presentation of the procedures to follow to protect one's health (obligation to wear personal protective equipment at all times and to use collective protective equipment when carrying out experiments—extractors, fume hoods, etc.) Awareness of preserving environmental quality and minimizing risks (waste management—storing chemicals and solvents) These laboratory rules and best practices are reviewed, explained, and applied during experiment work during the course of the two-year core curriculum.

Evaluation	Attendance mandatory

S5 –MI – IS	Scientific Integrity

Supervisor : Marc Fermigier

| conference : 1h | language : |

Objectives / Targeted Learning Outcomes

After the presentation, the student will be able to:

LO1. know the principles of scientific integrity.

LO2. observe these principles in his own activity, in particular laboratory sessions and research projects.

Contents	The principles of scientific integrity as defined by the national and European codes of conduct. Discussion of a few examples of scientific misconduct in fundamental an d applied research and their consequences.

Evaluation	Mandatory attendance.

S5– MI – ECC	Climate Change Challenges

Supervisor: Guillaume Pakula

| Course: 6h | Lab: 9h + 3h (fresco) | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. explain and justify the issues surrounding climate change, its scientific basis, and its social, societal, human and environmental consequences and ramifications
- LO2. identify the role and importance of energy and its close links to climate change
- LO3. evaluate the orders of magnitude associated with climate change: GHG emissions, energy, scientific trajectories (IPCC, TEN report, SNBC...).
- LO4. put into perspective their role as an engineer and / or scientist in a world in transition, understand and measure its impact.
- LO5. quantify the impacts of individuals, companies and products: discover the carbon footprint and the LCA.
- LO6. perform a carbon footprint at least on simple cases.
- LO7. conduct an LCA (life cycle assessment) using appropriate software.
- LO8. use their knowledge to solve a complex and / or cross-cutting problem, reduce the complexity of a problem to draw the main conclusions.
- LO9. work in a group.

Contents	Course 1. The stakes of climate change • The foundations, origin, causes, consequences: what science says • Impacts of human origin: GHG emissions • Trajectories up to 2100, consequences and possible solutions 2. Energy & the magnitude of climate change • Role and dependence on energy in our modern societies • The orders of magnitude of energy, producing and consuming it • The energy of the future: between sobriety and electrification 3. Measuring the impact: carbon balance and LCA • Tools for quantifying GHG and other environmental indicators • Applications of the carbon footprint: the need to quantify to reduce • Case studies and uses Throughout this course, we will try to create the closest possible link with current societal considerations. From the theoretical foundations to the use of operational quantification tools, we will scan the complex and intertwined landscape of climate change and its different facets. Tutorials 1. Energy-climate issues: manipulate the tools, orders of magnitude and compare them with the physical realities of climate change. 2. LCA / carbon balance: understand during a practical case the joint use of carbon balance and LCA. Practical studies on semi-real cases related to the daily life of an engineering student.

Organization	6 hours of lecture (3x2 hours) 3x3h of practical work / demonstration related to the course themes to practice and illustrate the subject matter based on concrete (and real, as much as possible) cases + Mural (mandatory) : Climate or Digital or Plastics

Bibliographic Resources	Electronic course resources 3 sets of tutorial instructions

Evaluation	Written final exam (open-ended questions on the course and TDs) + mural attendance

S5 – MI – GI	Innovation Management

Supervisor: Faustine Vanhulle

| Course: 6 h | Lab: 11.25 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. define the primary terms related to innovation management (innovation, creativity, discovery, etc.);
- LO2. explain diffusion and the innovation lifecycle;
- LO3. describe the main challenges of innovation, the primary types of innovation, and the sources of and participants in innovation;
- LO4. explain the steps involved in an innovation management process;
- LO5. describe the structure of a creativity session, establish a plan for leading one, and analyze the viability of ideas expressed during such a session;
- LO6. list several different creativity techniques, and identify related obstacles and conditions for success;
- LO7. describe the Business Model Canvas;
- LO8. carry out a SWOT analysis.

Contents	Definitions of innovation The need to innovate: diffusion, lifecycle, the challenges of innovation for companies and society Types of innovation Who innovates? Sources of and participants in innovation, collaboration with suppliers, clients, the public at large; obstacles to and drivers of innovation Innovation management: definition and parameters of innovation management, process Monitoring and forecasting: definitions and utility Axes of innovation: definition, identification of potential axes, SWOT Creativity: definitions, obstacles to and drivers of creativity; process, structure, and organization of a creativity session Presentation of the Business Model Canvas Definition and utility of managing an innovation portfolio Introduction to design thinking Group work: Practical application Select a field of activity Identify an innovation in this field Identify axes of innovation Choose an axis Generate ideas for new products, services, etc. using this axis Choose an idea; development; illustration; construction of the Business Model Canvas Pitch the idea to the group

Organization	Course + practical application in tutorials in smaller groups

Bibliographic Resources	Course-related bibliographic resources: see sources in course resources + lectures, TED talks, and recommended MOOCs

Evaluation	Grade based on a final project to be handed in at the end of tutorials

S5 – MI – BREV	Intellectual Property Rights

Supervisor: Pascale Brochard

| Course: 3 h | Lab: 7.5 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. define which IP rights protect innovations;
LO2. identify innovations that may be patented;
LO3. analyze a patent, understand the key information, form an idea of the legal implications;
LO4. interpret a discussion with an IP expert in a decision-making context.

Contents	• Definition of intellectual property rights (brands, patents, drawings and model, copyright) that entrepreneurs can use to protect their innovations • The choice between keeping an innovation secret, publishing it, or registering a patent • What is an exclusive right (and what isn't)? • How can respect of intellectual property rights be ensured (licenses or litigation)? • What innovations can be patented (the concept of patentability will be addressed mainly through examples)? • Who has the right to obtain patents (employee inventions)? • The patent document and the different types of patents

Independent Study	Practical work based on research using open-access patent databases and a role-playing game that will render the concepts addressed in class more concrete.

Evaluation	A 45-minute written exam

UE English I

Anglais I

30h – 2 ECTS

SEMESTRE 5

UE ANG1

Supervisor : Daria Moreau

| Tutorail : 30h | Course language : |

Description

The purpose of English courses is to improve students' English skills and teach them linguistic independence to prepare them to use technical and scientific English in an international, intercultural, and professional context. These courses are also intended to assist students in preparing for the TOEIC exam, required by the CTI to obtain the ESPCI engineering degree.

Semester	Program
S5	Ang1 30h, 2 ECTS

Prerequisites

Level B1 of the CEFRL reference chart

Evaluation

Validation of the five linguistic skills listed in the CEFRL reference chart at level B2 minimum through:

- end-of-semester TOEIC mock exams and ongoing assessment (EX; CC; PO);
- independent study (P);
- understanding of intercultural communication and culture, and mediation (CC);
- motivation (Part.);
- class participation (Part.);
- attendance (Part.).

Targeted skills

	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	CC				II		III								
LO2.	CC				II		III								
LO3.	Ex., CC						III								
LO4.	CC						III					III	III		
LO5.	CC, PO						III						III		

Ex.: exam, CC : ongoing assessment, Part.: participation, PO: oral exam

Upon completion of the course, students will be able to:

LO1. quickly identify resources for internships and employment, analyze and summarize employer's expectations, and respond in English to internship opportunities by writing a cover letter and/or creating a video cv taking into account the cultural specificities of English-speaking countries;

LO2. apply in-depth knowledge of thematic and scientific grammar and vocabulary to communicate both in writing and verbally in a professional situation within a multicultural company;

LO3. analyze the structure of the TOEIC exam and develop their personal strategy to maximize their score;

LO4. summarize a scientific text or audio document, identify key information, and present it to an audience;

LO5. defend their point of view in a debate, a discussion about a technical or scientific subject, or one drawn from everyday life, and respond to factual questions about the subject.

Contents	• Analysis of internship offers in English-speaking countries and simulating job interviews; • writing cover letters; • exercises to prepare for the TOEIC exam(a practice TOEIC exam will be given at the end of each semester); • familiarity with technical and scientific vocabulary; • written work in the form of reports, summaries, instructions, product descriptions, procedures, chart analyses, etc. on a wide range of subjects; • summary and comparison of actual technical documents; • debates on any subject (cultural, economic, technical, scientific, etc.) without prior training or special training, in order to participate in group exchanges; • practice with oral and written comprehension.

Organization	English courses are mandatory for all students. Students are divided into level groups established at the beginning of the year based on a placement test and oral evaluations. Classroom work is complemented by appropriate and varied e-learning modules (the applications are intended to facilitate reading in English; various linguistic activities; self-led learning in the language lab).

Bibliographic Resources	Course handouts, articles, journals, audio and video documents; examples of actual documents.

Evaluation	Progression, skills and results will be summarized in a personalized pedagogical report.

RAPPORT PEDAGOGIQUE

Nom et prénom de l'étudiant(e) :

L'année d'études :

L'étudiant(e) se situe à ces niveaux (voir définition au verso)

	A1	A2	B1	B2	C1	C2
Compréhension orale						
Compréhension écrite						
Production orale						
Production écrite						
Niveau global						
Médiation						
Note globale						

Attitude pendant la formation et connaissance de la culture

	excellent	bon	satisfaisant	insuffisant	médiocre
Motivation					
Participation					
Travail personnel					
Assiduité					
Connaissance de la culture et communication interculturelle					
Note globale					

Fait à :
Nom de l'enseignant :

Total points :

Semester 6

SEMESTER 6					461.25 h			30 ECTS		
SEMESTER 6	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisor	Courses (h)	Tutorial (h)	Super Tutorial (h)	Preceptorships (h)	Lab (sessions
UE Applied Statistical Physics	76	5								
Applied Statistical Physics	31	50%	PSA	PSA	A. Colin	24		7		
Applied Statistical Physics Lab Work	45	50%		TP PSA	H. Montès					12
UE General Physics	128.75	8								
Electromagnetic Waves	26	30%	PG	OEM	R. Carminati	15	5		6	
Quantum Physics	39	30%		PQ	N. Bergeal	26	5		8	
Electromagnetic Waves Lab Work	33.75	20%		TP OEM	C. Feuillet-Palma					9
Quantum Physics Lab Work	30	20%		TP PQ	N. Bergeal					8
UE Chimie II	96.25	7								
Organic Chemistry II	22	40%	CH2	CO2	A. Guérinot, R. Nicolaÿ	11	4	1	6	
Identification of Organic Compounds	18	20%		ICO	D. Gomes-Pardo	9	9			
Organic Chemistry Lab Work	56.25	40%		TP CO	A. Duprat					15
UE Mathematical and Numerical Methods	38.25	2								
Applied Statistics	19.5	50%	MMN2	STAP	I. Rivals	12				2
Numerical Analysis with Matlab	18.75	50%		ANUM	I. Rivals					5
UE Communication I	45	3								
Written Communication Pratices and Analysis	18	50%	COMM1	PACE	I. Garron	1	17			
Verbal Communication	12	25%		COMOR	C. Probst		12			
Communication and Social Relations	15	25%		CRS	B. Beaussart, E. Honikman					4
UE Initiation in Scientific Research	45	3								
Group Science Project I	45		INREC	PSE1	E. Fort, Y. Tran, M. Ardré					12
UE English II	32	2	ANG2	ANG2	D. Moreau		32			

One lab session is 3 h 45 min.
The volume of individual study is estimated to be 275 hours according to the following breakdown:
1 h course = 0.9 h individual study
1 h tutorial = 0.7 h individual study
1 h super tutorial / preceptorship = 1.5 h individual study
1 h lab = 0.3 h individual study

UE Applied Statistical Physics

Physique Statistique Appliquée

76 h - 5 ECTS

SEMESTER 6

UE PSA

Description

The Applied Statistical Physics UE introduces students to the general ideas and methods involved in statistical physics. Particular emphasis is given to fundamental concepts (entropy, temperature) and the relevance of the methods used. Several classic examples will be discussed (ideal gas, paramagnetism, polymer elasticity), as well as the physics of phase transitions, collective phenomena, and quantum statistics. An effort will be made to maintain a (difficult) balance between an intuitive approach to phenomena and more rigorous calculus.

Semester	Program	
S6	PSA-PSA	Applied Physical Statistics
	PSA-TPPSA	PSA Lab

Prerequisites

Thermodynamics and basic mathematics

UE Validation

Weighted average: PSA-PSA 50%, PSA-TPPSA 50%

Targeted skills

PSA-PSA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	III					II							
LO2.	Ex.		II							II					
LO3.	Ex., Super Tutorial	III	III					II							
LO4.	Ex., Super Tutorial		III												
LO5.	Ex., Super Tutorial		III										II		II
PSA-TPPSA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	CR + oral				II	II									
LO2.	Report + oral				II										
LO3.	Report + oral				II										
LO4.	Report + oral			II	II	II	II								
LO5.	Report + oral		III			II		II	II						
LO6.	Report + oral		III					II							
LO7.	Report + oral	I	II	I				I	II						
LO8.	Report + oral		II						II						
LO9.	Report + oral	II	II					II							
LO10.	Report + oral	II	II					II	II						

Ex.: written exam

S6 – PSA – PSA	Applied Statistical Physics

Supervisor: Annie Colin

| Course: 24 h | Super Tutorial: 7 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. identify and apply the fundamental concepts that govern the systems of many elements;

LO2. connect the microscopic properties of particles to their macroscopic behavior;

LO3. analyze and justify the connection between classic thermodynamics and statistical physics;

LO4. utilize their knowledge to analyze the result of a measurement;

LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Introduction to and review of thermodynamics Statistical physics of an isolated system: "microcanonical" ensemble Statistical physics with temperature constant: free energy, canonical ensemble Statistical physics with constant chemical potential: grand canonical ensemble Ensemble equivalence Statistical physics of classic systems without interactions: ideal gas, measurement of a chemical reaction's constant. Ideal quantum gas Phase transitions, average field

Bibliographic Resources	Coursework and handouts

Evaluation	Written final exam 70% Super tutorial 30%

S6 –PSA – TPPSA	Applied Statistical Physics Lab

Supervisor: Hélène Montes

| Lab: 45 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the lab, students will be able to:

- LO1. work in a group;
- LO2. operate independently and organize their laboratory work;
- LO3. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
- LO4. summarize and present experiment results in a report written in French;
- LO5. make and characterize an emulsion according to EHS norms and the engineering code of ethics (lab log, reliability of results);
- LO6. apply teachings from the statistical physics course to describe a phase transition;
- LO7. use measurement tools and techniques in the laboratory to observe and characterize phase transitions (DSC, microscopy, dynamic light scattering, granulometry);
- LO8. take a critical approach to using data acquisition and analysis programs (DSC, Python);
- LO9. interpret experiment results with a view to modeling them (thermoporometry, kinetic monitoring);
- LO10. calculate and interpret the properties of a microscopic model using digital simulations.

Contents	

1. Emulsion
   Through four distinct experiments, this thematic module illustrates emulsion interface phenomena and metastability explored during lab sessions:
   - Solid-gas phase diagram, categorization by depletion
   - Metastable system, drainage, coalescence, Ostwald ripening
   - Study of the absorption of a soluble surfactant into a liquid-air interface
   - Measurement of the chemical activity of a saltwater solution
2. Modeling: simulation and study of the thermodynamics of spheres and hard disks
   Students use digital simulations and analyze the results with Python to explore the consequences of the atomist hypothesis by studying, within a hard sphere system, the state equation and gas-crystal transition phase, the Brownian motion of a macromolecule, and the depletion interaction between two macromolecules.
3. Phase transitions using Differential Scanning Calorimetry (DSC)
   - The polymer Glass Transition experiment
   - Phase transition in confined systems: fusion and crystallization of a simple liquid

Bibliographic Resources	Lab working documents: instructions, articles, classwork.

Evaluation	Participation 50% Report 50%

UE General Physics

Physique Générale

128.75 h – 8 ECTS

SEMESTER 6

UE PG

Description

The course Electromagnetic Waves (PG-OEM) introduces students to the physics concepts necessary to understanding the phenomena of electromagnetic wave propagation. Understanding the methods of modeling elementary systems (ex: waveguides, antennas) enables students to grasp connections with other subjects in the basic and engineering sciences (optics, solid-state physics, signal processing, telecommunications).

The Electromagnetic Waves lab (PG-TPOEM) demonstrates the concepts presented in class, in particular guided propagation and propagation in free space of high-frequency waves in multiple media. Emphasis is placed on the measurement and identification of phase and group velocities, the dispersion curve, and characteristic impedance.

The purpose of the course Quantum Physics (PG-PQ) is to introduce students to the basic principles necessary to understanding modern science and technology (materials science, electronics, molecular chemistry, quantum engineering, nanotechnologies, phototonics, etc.). The course emphasizes an understanding of concepts in physics, while building on a degree of mathematical formalism necessary to mastering quantum mechanics. Many examples of practical uses of quantum mechanics are presented during the course and are explored in more depth during tutorials and preceptorships.

The Quantum Physics lab (PG-TPPQ) illustrates concepts presented during the course. Students carry out various experiments (atomic spectroscopy, Zeeman Effect, electron spin resonance, etc.) with instruments that are useful both in basic science and engineering science.

Semester	Program	
S6	PG-OEM	Electromagnetic Waves
	PG-TPOEM	Electromagnetic Waves Lab
	PG-PQ	Quantum Physics
	PG-TPPQ	Quantum Physics Lab

Prerequisites

Classic physics and mathematics as taught in Physics-Chemistry preparatory classes in France.

UE Validation

Weighted average: PG-OEM 30%, PG-TPOEM 20%, PG-PQ 30%, PG-TPPQ 20%

Targeted skills

PG-OEM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III						III		III					
LO2.	Ex.	III						III		III					
LO3.	Ex., prec.	III	II					III							
LO4.	Ex.	II	II					III							
LO5.	Ex., prec.	II						III							
LO6.	Prec.	II	II							II			II		
PG-TPOEM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report, Part.	III	III		II			III	III	II			I		
LO2.	Part.	III	III		II			III	III	II			I		
LO3.	Part.	III	III		II			II	III				I		
LO4.	Part.	III	III		II			III	III	II			I	II	
LO5.	Part.		III		II				III	II			I	II	
LO6.	Report, Part.		III		II			III	III	II			I	II	
LO7.	Report, Part.		III		II			III	III	II			I	II	
LO8.	Part.		III		II			III	III	II			I	II	
LO9.	Report				III	II									
PG-PQ	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	II					III							
LO2.	Ex.	II						III							
LO3.	Ex.	III	III					III							
LO4.	Ex.	II						III							
LO5.	Ex.,prec.	II	II					III		II					
LO6.	Ex.	III	III					III		II					
LO7.	Prec.		II					II					II		
PG-TPPQ	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report,Part.	III	III					III	III				I	I	
LO2.	Report,Part.	III	III					III	III	III			II	I	
LO3.	Report,Part.	III	III					III	III	II			I		
LO4.	Report,Part.	III	III					III	III				I		
LO5.	Report,Part.	III	III					III	III				I		
LO6.	Report,Part.				II	I									
LO7.	Report				II										

Ex: written exam, Prec.: preceptorship, Part.: participation

S6 – PG – OEM	Electromagnetic Waves

Supervisors: Rémi Carminati, Cheryl Feuillet-Palma

Teaching staff: Fabrice Lemoult, Ricardo Lobo, Bastien Guigue

| Course: 15 h | Tutorial: 5 h | Preceptorship: 6 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. explain and justify the emission phenomena and propagation of electromagnetic waves;
LO2. describe and predict the behavior of electromagnetic waves in free and confined spaces;
LO3. identify and choose the physics concepts necessary to modeling simple electromagnetic systems;
LO4. apply technical calculus methods to solve simple problems;
LO5. analyze a problem using an order-of-magnitude estimate;
LO6. identify and illustrate links with other concepts in the basic and engineering sciences using concrete examples.

Contents	Course / Tutorial 1. Maxwell's equations in empty space and closed surfaces 2. Waves in various media and at interfaces 3. Guided propagation, transmission lines, and impedance matching 4. Electromagnetic cavities 5. Radiation and antennae Preceptorships • Telecommunications • Metamaterials • Antenna

Related classes	Quantum Physics (S6-PG-PQ), Optics (S8-OPT), Solid-State Physics (S7-MATC-PS), Signal Processing and Telecommunications (S5-E2S-SLS)

Bibliographic Resources	Course handouts Lab instructions and corrected assignments J.D. Jackson, *Electrodynamique Classique* (Paris: Dunod, 2001) A. Zangwill, *Modern Electrodynamics* (Cambridge: Cambridge University Press, 2013)

Evaluation	Final written exam: course questions 40%, problem solving 60%

S6 – PG – TPOEM | Electromagnetic Waves Lab

Supervisor: Cheryl Feuillet-Palma

| Lab: 33.75 h. | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the lab, students will be able to:

LO1. utilize their understanding to interpret electronic wave propagation phenomena;
LO2. work with their lab partners to optimize available time and use of various instruments of measure;
LO3. organize their work to confidently and independently carry out measurements and interpretations in order to test only those manipulations necessary to illustrate a given theoretical concept;
LO4. go beyond the framework of a lab subject to conduct manipulations optimally and explore in more depth the concepts presented;
LO5. independently manipulate measurement tools unique to microwave frequencies;
LO6. make hypotheses and compare them to experiment results to validate a model;
LO7. evaluate the limits of validity of the model used;
LO8. identify sources of measurement error (noise, non-ideal assembly, uncertainty about elements) and evaluate the uncertainty of an experiment result;
LO9. use their knowledge and draw on course and lab handouts to observe and interpret experiment phenomena;
LO10. synthesize, interpret, and present experiment results.

Contents	• Manipulating microwaves (9 GHz metallic waveguide) • Propagation of waves along continuous lines, photonic crystals, 1D metamaterials (right line, left line at 1 MHz) • Microwave simulation and impedance matching in the context of 2 GHz microribbon lines • Propagation in free space and antenna radiation patterns
Organization	Each manipulation is carried out over two half-days in the lab. A rotation ensures that all students participate in each manipulation. The first half day includes a two-hour review of the concept of the reflection coefficient, its polar representation in the complex plane, and the Smith chart, which allows for its rapid manipulation.
Bibliographic Resources	Lab handouts are available for download. Each handout provides reminders and / or additional theoretical information that may help to fully understand each experiment.
Evaluation	The evaluation comprises two non-equivalent parts: a dominant portion (80%) carried out by a jury of teachers through evaluation of students' work during lab sessions, and a second portion comprising a very brief summary of the one of the four experiments (20%).

S6 – PG – PQ	Quantum Physics

Supervisor: Nicolas Bergeal

Teaching staff: Cheryl Feuillet-Palma, Sergio Vlaic, Stéphane Pons & Nicolas Bergeal

| Course: 26 h | Tutorial: 5 h | Preceptorship: 8 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. identify and justify situations that necessitate the use of quantum theory;
LO2. explain the fundamental premises of quantum mechanics and apply them;
LO3. solve Schrödinger's equation and calculate the time evolution of a quantum state;
LO4. explain the theory of angular momentum (orbital and spin) and apply it;
LO5. apply quantum mechanics to process different simple systems (harmonic oscillator, two-level system, hydrogen atoms);
LO6. apply the quantum mechanics theories of stationary and time-dependent perturbations to suggest an approximate solution to a problem when no exact simple solution exists;
LO7. choose concrete examples to illustrate the main concepts of quantum mechanics.

Contents	Course • Introduction to quantum physics • Wave mechanics • Formalities of quantum mechanics • The premises of quantum mechanics • Theories of stationary and time-dependent perturbations • Quantum harmonic oscillator • Orbital angular momentums and spins • Hydrogen atom • Addition of two angular momenta • Quantum statistics Preceptorships Preceptorships will enable students to explore many fields of contemporary physics (fundamental or applied) in which quantum mechanics plays a major role. • "Wave-particle" duality and its applications in material probes and atom optics • Color centers in ionic crystals (F-centers) • W.K.B. method and its applications to the tunnel effect and Gamow's Theory of Alpha Decay • Formation of interstellar molecular hydrogen • Neutron interferometery and its applications to spin rotation and gravitational effect • Pure quantum states and quantum entanglement and their applications to the principles of teleportation of a qubit and quantum cryptography • MASER NH3 • Zeeman effect and Stark effect on the hydrogen atom • Superconducting quantum bits

Bibliographic Resources	Cohen-Tannoudji, Claude, Diu, Bernardet and Laloë, Franck. *Mécanique quantique tome I et II*, EDP Sciences. Aslangul, Claude. *Mécanique quantique, Tome 1,2&3.* De Boeck University.

Evaluation	Final written exam: course exercises without supporting materials 40%, problem with supporting course materials 60%.

S6 – PG – TPPQ	Quantum Physics Lab

Supervisors: Nicolas Bergeal

Teaching staff: Luca De Medici, Jérôme Lesueur, Sergio Vlaic & Nicolas Bergeal

| Lab: 30 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the lab, students will be able to:

LO1. Use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
LO2. Independently operate measurement tools and techniques in the laboratory in the fields of electronics, electromagnetism, optics, and quantum physics;
LO3. Take a critical approach to using data acquisition and analysis programs;
LO4. Validate a model by comparing predictions with experiment results and assess the limits of their validity;
LO5. Identify sources of error to calculate uncertainty in experiment results;
LO6. Discuss and develop a project in a group;
LO7. Summarize, interpret, and present experimental results.

Contents	• Optical pumping of Rubidium atoms • The Zeeman effect • Scanning tunneling microscopy and spectroscopy • Radioactivity • Nuclear resonance principle • Electron paramagnetic resonance

Bibliographic Resources	Lab instructions, course handouts, scientific articles Cohen-Tannoudji, Claude, Diu, Bernardet and Laloë, Franck. *Mécanique quantique tome I et II*, EDP Sciences

Evaluation	Experiment work (manipulation, organization, comprehension) 20% Report (summary article) 80%

UE Chemistry II

Chimie II

96,25h - 7 ECTS

SEMESTRE 6

UE CH2

Description

Building on the fundamental tools taught in CH1-CO1, the Organic Chemistry (CH2-CO2) course aims to introduce students to a selection of essential chemical transformations covering the reactivity of carbonyl derivatives and acid derivatives, the reactivity of alkenes and homogeneous organometallic catalysis. Reaction mechanisms are explained and applications in various fields (medicinal chemistry, materials chemistry, chemistry-biology...) are discussed. These bases, well assimilated, constitute an essential base of knowledge for the students whatever their future choice of orientation (chemical, physicochemical, biological or physical).

The experimental module of Organic Chemistry (CH2-TPCO) aims at the acquisition of good laboratory practices, the learning of the different techniques of implementation of a reaction, of its analytical follow-up, then of the purification and the verification of the structure of the compounds obtained by analysis of the IR, NMR and mass GC spectra. The students become familiar with the use of chemoinformatics databases (Reaxys, Scifinder...), ^{1}H and ^{13}C NMR spectra simulation software (ChemDraw), and consult online scientific publications. This part of analysis and simulation of spectra allows to apply the concepts put forward in the course of identification of organic compounds (CH2-ICO). Emphasis is also placed on learning autonomy, respecting safety rules and keeping a scientific laboratory notebook. Finally, students are made aware of a more environmentally friendly chemistry (eco-compatible or green chemistry).

The course Identification of Organic Compounds (CH2-ICO) presents the basic concepts of characterization techniques: Infrared, Mass Spectrometry, Nuclear Magnetic Resonance, UV-visible and Fluorescence. The detailed analysis of spectra allows to understand the applications and limitations of these techniques for the chemical characterization of organic compounds.

Semester	Program	
S6	CH2-CO2	Organic Chemistry II
	CH2-ICO	Identification of Organic Compounds
	CH2-TPCO	Organic Chemistry Lab Work

Prerequisites

Prerequisites and a number of basic concepts will be reviewed early in the course. A basic understanding of chemical reactions, including knowledge of fundamental reactions (substitution, elimination, addition) are recommended. If this is not the case, students are highly encouraged to take the organic chemistry review module (optional refresher course).

UE Validation

Weighted average: CH2-CO2 40%, CH2-ICO 20%, CH2-TPCO 40%

Targeted skills

CH2-CO2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., prec.	II	II					II							
LO2.	Ex., prec., sTD	II	II					II							
LO3.	Ex., prec., sTD	II	II					III							
LO4.	Ex., prec., sTD	III	III							III			III		
LO5.	Ex., prec., sTD	III	III					III		III					
LO6.	Ex., prec., sTD		III												
LO7.	Prec.		II		II										
CH2-TPCO	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	CL, TE		II						III						
LO2.	CL, TE		II						II	II					
LO3.	AS		III												
LO4.	CL, TE		III						III						
LO5.	IS		II						II				II		II
LO6.	CL,TE, AS, IS, CR	III	III					III	III						
LO7.	CL, AS				I	II					III				
LO8.	CL, TE		III			II			III						
LO9.	CL, TE, AS		III						III						II
LO10.	CL, TE		III	II											
LO11.	TE		III												
LO12.	CL			II											
LO13.	CL, CR	II							II						
LO14.	CL, CR, AS	II													
CH1-ICO	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	II						II							
LO2.	Ex.	III	III					III							
LO3.	Ex.	III						III							
LO4.	Ex.	II						II							
LO5.	Ex.	III	III					III							II

Ex : Final written exam, prec : preceptorship, sTD : super Tutorail, CL : lab notebook, TE : experimental work, AS : spectra analysis, IS : structure identification, CR : report

S6 – CH2– CO2	Organic Chemistry II

Supervisors: Renaud Nicolaÿ, Amandine Guérinot

Teaching staff: Arthur Duprat, Domingo Gomez-Pardo

| Course: 11 h | Tutorial: 4 h | Super Tutorial : 1 h | Preceptorship : 6 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

- LO1. identify and use fundamental concepts to understand the reaction between two chemical entities.
- LO2. identify classical chemical transformations and the structure of the products formed.
- LO3. write a rational reaction mechanism for a chemical transformation.
- LO4. analyze a multi-step reaction sequence.
- LO5. construct a reasonable reaction sequence to access a target molecule.
- LO6. mobilize their knowledge to solve a complex and / or transverse problem
- LO7. work in a group to analyze a complex problem or synthesis (preceptorships).

Contents	Course 1. Reactivation of carbonyl compounds and acid derivatives • Nucleophilic additions to aldehydes and ketones • Formation and reactivity of enols and enolates • Formation and reactivity of acid derivatives • Reactivity of α,β-unsaturated carbonyl derivatives 2. Reactivity of alkenes • Epoxidation and reactivity of epoxides • Dihydroxylation and ozonolysis 3. Homogeneous organometallic catalysis • Elementary steps • Coupling reactions catalyzed by Pd complexes • Olefin metathesis Preceptoships • Reactivity of carbonyl derivatives • Organometallic catalysis • Multi-step synthesis analysis of functionalized molecules

Bibliographic Resources	Course resources Tutorial and preceptorship instructions

Evaluation	Final written exam : course questions 50%, problem solving 50%

S5 – CH1 – TPCO | Organic Chemistry Lab

Supervisor: Arthur Duprat

Teaching staff: D. Gomez-Pardo, A. Guérinot, R. Nicolaÿ, B. Laroche

| Lab: 56.25 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of lab work, students will be able to:

- LO1. use classic and advanced synthesis techniques (working in an inert atmosphere, microwave activation, hydrogenation using continuous flow processes);
- LO2. use purification techniques (recrystallization, vacuum distillation, column chromatography);
- LO3. interpret spectroscopic data to validate the structures of synthesized compounds;
- LO4. use characterization techniques adapted to synthesized molecules;
- LO5. interpret spectra (IR, mass, NMR proton and 1D and 2D carbon) to identify an unknown compound;
- LO6. use NMR spectrum modeling programs and consult chemical databases;
- LO7. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
- LO8. work in a group;
- LO9. organize their laboratory work;
- LO10. identify and independently lead the different steps of an experimental approach;
- LO11. synthesize molecules according to EHS norms and the engineering code of ethics (lab log, reliability of results);
- LO12. use measurement tools and techniques in the laboratory in the field of organic chemistry (scale, melting point, rotational power, etc.);
- LO13. identify specific regulations and apply primary preventative measures in terms of hygiene and security (for example, chemical risks);
- LO14. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
- LO15. synthesize, interpret, and present experiment results.

Contents	
	• Eight experiments to take students deeper into Organic Chemistry (CO) and enable them to become familiar with new general techniques (vacuum fractional distillation, experimentation in an inert atmosphere, column chromatography separation, multi-step synthesis, enzymatic, and microwave) • Analyzing the chosen experimental conditions and the mechanism of the reactions studied • Using characterization methods on synthesized entities (measurement of melting, boiling, and rotational temperatures, thin-layer chromatography) and spectroscopic analysis methods (NMR ^{1}H and ^{13}C, IR, CPG-mass chromatography and in super-critical phase) • Identifying the structure of an unknown compound using different spectra (NMR 1D and 2D, mass, IR) in connection with the course Identification of Organic Compounds (ICO). Computerized bibliographic research and NMR spectra modelling

Organization	49 hours dedicated to entity / molecule synthesis 7 hours dedicated to identifying an unknown molecule

Bibliographic Resources	Lab handouts and course resources Safety guidelines Examples of research articles

Evaluation	Experiment work (TE, results and purities) 70% Lab log (CL) 10% Report (CR, creation of a process document such as a publication) 5% Structure identification (IS) 10% Spectrum analysis (AS) 5%

S5 – CH1 – ICO Identification of Organic Compounds

Supervisor: Domingo Gomes-Pardo

Teaching staff: Hélène Montès, Corinne Soulié-Ziakovic, Yvette Tran
| Course: 9 h | Tutorial: 9 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. apply basic concepts of common characterization techniques—infrared, mass spectrometer, nuclear magnetic resonance, visible UV rays, and fluorescence;
LO2. analyze spectra in detail to identify / solve the chemical structure of organic compounds;
LO3. analyze and justify the effects of experimental parameters on the appearance of spectra (solvent, concentration, temperature, etc.);
LO4. choose the appropriate technique or techniques based on the particular chemical or physical characteristics of the analyzed sample and cross-reference them to confirm / reinforce the analysis;
LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course • Infrared basics (2h) • Mass spectrometer basics (3h) • NMR basics (2h) • Visible-UV and fluorescence basics (3h) Tutorials • Reading NMR ^{1}H spectra • Parameters that influence spectrum appearance • NMR ^{13}C: Impulse NMR, decoupling • Reading NMR ^{13}C spectra • 2D NMR • Infrared • Visible UV rays, fluorescence • Practice: use all spectroscopic techniques to determine a chemical structure.

Related classes	Through Organic Chemistry lab work (CH1-TPCO), students analyze and interpret NMR ^{1}H, ^{13}C NMR, and 2D NMR spectra, as well as infrared and mass spectra on products they synthesize or use in the lab course. In this way, they receive concrete feedback about the purity of their own experimental work in organic chemistry.

Bibliographic Resources	Course handouts and resources Tutorial instructions Corrected tutorials

Evaluation	Written exam: 1) solving chemical structures through NMR, IR, and mass spectrum analysis (16 / 20); 2) visible-UV and fluorescence problems (4 / 20).

UE Mathematics and Numerical Methods II

Mathématiques et Méthodes Numériques II

38,25h - 2 ECTS

SEMESTER 6

UE MMN2

Description

The purpose of the course Applied Statistics (MMN2-STAP) is to teach students the statistical concepts necessary to rational application of numerical experiment results, especially to support decision making. It should also enable them to correctly present a specific problem to a statistician.

The Numerical Analysis with Matlab course (MMN2-ANUM) proposes to program with Matlab, not as with a black box, but on the one hand by exploiting its specificities (vectorization of calculations), and on the other hand by knowing how to analyze the results and evaluate the confidence to be given to them (importance of the concept of conditioning of a linear system).

Semester	Program	
S6	MMN2-STAP	Applied Statistics
	MMN2-ANUM	Numerical Analysis with Matlab

Prerequisites

Mathematics I (S5-MMN1-MATH1)
Programming Basics (S6-MI-PYTHON)
Basic understanding of: proof and random events, algebra of events, the probability of a random event; conditional probability and independent events, Bayes' Formula; random variables.

UE Validation

Weighted average: MMN2-ANUM 50%, MMN2-STAP 50%

Targeted skills

MMN2-STAP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex	II	II												
LO2.	Ex	II	II												
LO3.	Ex	II	III	II											
LO4.	Ex	II	III									II			
LO5.	Ex	II	II									II			
LO6.	Ex	II	III									II			
MMN2-ANUM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part, R	II	II												
LO2.	Part, R	II	II												
LO3.	Part, R	II	II												
LO4.	Part, R	II	III					II							
LO5.	Part, R	II	III					II				II			
LO6.	Part, R	II	III						II						
LO7.	Part, R	II	II						II			II			

Ex : exam, CC : ongoing evaluation, Part : participation, R : report

S6 – MMN2 – STAP	Applied Statistics

Supervisor: Isabelle Rivals

Teaching staff : Alexandre Allauzen, Brigitte Quenet, Yacine Oussar

| Course: 12h | Lab : 7.5h | Course language: |

Objectives / Targeted Skills

Upon completion of the course, students will be able to:

LO1. characterize random variables and pairs of said variables;
LO2. estimate parameters (expectancy, variance, probability) using numerical data, as well as the confidence these estimates should be given;
LO3. make decisions regarding the real value of parameters using hypothesis testing and evaluating the risks of error associated with these decisions;
LO4. estimate the relation between a quantitative response and one or more explanatory variables using linear regression
LO5. estimate the probability of a binary result for classification problems using logistic regression
LO6. take a critical look at the way numerical results and statistical interpretation are presented in scientific literature, including analysis of unquestioned hypotheses;
LO7. summarize, interpret, and present experimental results;
LO8. take a critical approach to using data analysis programs.

Contents	

1. Random variables
   - Definitions, concepts of descriptive statistics
   - Useful probability densities
   - Fisher-Cochran theorem
2. Point and interval estimation
   - Of variance
   - Of mathematical expectancy
   - Of probability
3. Hypothesis testing
   - Comparison of two samples
   - Comparison with a reference
   - Elimination of abnormal values
   - X2 test for distribution conformity and independence
   - P value
4. Linear regression
   - Least squares estimation
   - Simple and multiple linear regression
5. Logistic regression
   - Binary classification and logistic regression
   - Cross-entropy cost function
   - Gradient descent optimisation

Related classes	Mathematics I (S5-MMN1-MATH1)

Bibliographic Resources	Handouts

Evaluation	Written final exam (2/3) and lab session report (1/3)

S6 – MMN2 – ANUM	Numerical Analysis with Matlab

Supervisor: Isabelle Rivals

Teaching staff: Yacine Oussar, Maxime André, Brigitte Quenet

| Lab: 18.75h | Course language: |

Objectives / Targeted Skills

Upon completion of the lab, students will be able to:

LO1. analyze the problems that arise due to limited numerical accuracy;
LO2. program with MATLAB using vectorization;
LO3. use MATLAB to solve classic numerical problems (solving systems, numerical integration, finding zeros) using standard algorithms;
LO4. apply the preceding tools to complex numerical problems (solving differential equations, principal component analysis);
LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO6. take a critical approach to using data analysis programs.
LO7. interpret experiment results for modeling purposes.

Contents	• Introduction • Development environment • Handling data • Handling graphs • MATLAB types and numerical accuracy • Programs and functions • Reading and writing files • Linear system solution and least squares • Matrix factorizations and conditioning • Principal component analysis

Organization	Teaching is delivered as a lab course during which concepts and associated tools are introduced in brief presentations, followed immediately by practical application.

Bibliographic Resources	Handouts MMN2-MENU handouts

Evaluation	A report on one of the suggested topics (report + related Matlab programs)

UE Communication I

Communication I

45 h - 3 ECTS

SEMESTER 6

UE COMM1

Description

The module Written Communication Practices and Analysis (COMM1-PACE) addresses issues related to writing and research by having students write a document about a subject of their choice. The class follows a project mode and provides students with notions from information and communication science, the sociology of science, and sciences of art. Concretely, the project is built around several steps, each one validated by the teacher.

At the end of the module, students present a written document summarizing their completed research projects, outlining an intention regarding information processing and consideration for a specific readership.

The module is led by a team of teachers who actively practice writing in their professional activity.

In the professional sphere and research, students will be constantly asked to work in a team, to present their projects and their results, to assert their opinions, either to the people they manage, to their superiors, or even to people from very different fields (legal experts, engineers, salespeople, IT specialists, etc.). It isn't always easy to clearly communicate a message within these relationships and to be heard, much less to be convincing. Public speaking doesn't come naturally; it requires captivating an audience who is already burdened with information overload and capturing their attention to transmit a clear, strong message that will be remembered. The art of inspiring one's audience is one that is learned; it is a discipline with its own very technical and concrete tools, which we will teach throughout this training. Verbally communicating a message, an argument, or a conviction, whether to one's classmates, teachers, team, superiors, or clients, is not an inherent skill.
While not a theater course, the Verbal Communication module (COMM1-COMOR) draws on the actor's skills to work concretely on the various aspects of public speaking: occupying space, gestures, gaze, silence, posture, speed, articulation, stress management, vocal placement, managing interaction, consideration of others, etc.

The main objectives of the module Communication and Social Relations (COMM1-CRS) are to introduce students to the primary functions of any company, establish their professional projects, better anticipate their responsibilities as future managers (rights and responsibilities), and to understand the role of human resources in a company

Semester	Program	
S6	COMM1-PACE	Written Communication Practices and Analysis
	COMM1-COMOR	Verbal Communication
	COMM1-CRS	Communication and Social Relations

UE Validation

Weighted average: COMM1-PACE 50%, COMM1-COMOR 25%, COMM1-CRS 25%

Targeted skills

COMM1-PACE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part, PMC, Ent				III										
LO2.	PMC, CR	III			III									III	
LO3.	CR	II			II										
LO4.	Part, PMC, Ent				II									II	
LO5.	CR	II			II										
LO6.	CR	III			III										
LO7.	Part, PMC				II										
LO8.	Pres				III										
LO9.	Pres				III										
LO10.	CR, Pres				III										
LO11.	Part, Ent				III										
COMM1-COMOR	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part., POF				III							II		III	
LO2.	Part., POF				II							II		II	
LO3.	Part., POF				III							II		III	
LO4.	Part., POF				II							II		II	
COMM1-CRS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Attendance, Part.			I		I								I	
LO2.	Attendance, Part.			I							I	I			
LO3.	Part., CV, C. letter	II							II		I				
LO4.	Part., pitch				III										II

Ex.: written final exam, POF: oral exam in French, PMC: mid-year presentation, Part.: Participation, Ent: final interview

S6 – COMM1 – PACE	Written Communication Practices and Analysis

Coordinating supervisor: Isabelle Garron (Telecom ParisTech)

| Workshops: 18 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completing the module, students will be able to:

- LO1. plan and complete a project;
- LO2. establish a bibliography: define a research problem, organize targeted documentary research, consult information and cite without plagiarizing;
- LO3. organize relevant annexes;
- LO4. argue their ideas;
- LO5. write for an intended audience;
- LO6. develop editorial guidelines adapted to the project;
- LO7. work on an alternating schedule: presence / distance;
- LO8. communicate in a digital environment outside of an informal context;
- LO9. verbally present written work and participate in circulating knowledge;
- LO10. present themselves in writing and verbally;
- LO11. develop listening and critical thinking skills.

Contents	Step 1 : choice of subject and communication contract Step 2 : define a problem and implement documentary research Step 3 : research strategies : literature review and field inquiry Step 4 : plan the doument and editorial guidelines Step 5 : iconography and writing Step 6 : proofs

Organization	Each session of this module introduces students to a concept and gives them time to work individually, in pairs, or in a group (excercises and / or writing), which enables them to advance design, development, and writing work. 1 hour discussion of concepts, tools, and methods 1 hour of individual or small-group work

Bibliographic Resources	Works that inspired this module but that students do not necessarily have to have read in their entirety for the class. • *Dictionnaire d'analyse du discours*, sous la direction de Patrick Charaudeau et Dominique Maingeneau, Paris, Seuil, 2002 • Barthes, Roland, *Le plaisir du texte*, Paris, Seuil, 1973 • Barthes Roland, *Mythologies*, Paris Seuil, coll° essais, 1957, 2014 • Compagnon, Antoine, *La seconde main ou le travail de la citation*, Paris, Seuil, 1979 • Glevarec, Hervé, Macé, Eric,Maigret, Eric, *Cultural Studies, Anthologie*, Paris, Armand Colin, 2008

	• Goldsmith, Kenneth, *L'écriture sans écriture, du langage à l'ère numérique*, Paris, Jean Boite Editions, 2018 • Goody, Jack, *La raison graphique*, Paris, Editions de Minuit, 2002 • Jauss, H.R, *Pour une esthétique de la réception*, Paris, Gallimard, 1978, coll° Tel Winkin, Yves, 1996. *Anthropologie de la communication : de la théorie au terrain*, Bruxelles, Éditions De Boeck Université. Nouvelle édition entièrement refondue aux Éditions du Seuil, collection "Points", 2001	

Evaluation	Participation and summaries: 25% Mid-term presentation: 25% Document submitted + final interview: 50%

S6 – COMM1 – COMOR	Verbal Communication

Coordinating supervisor: Clément Probst

Teaching staff: C. Probst, A. Robinet, A. Maquiné-Denecker, A. Balme, B. Guillemain

| Workshops: 12 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the workshops, students will be able to:

LO1. establish a direct connection with each person to capture their attention and captivate an audience;
LO2. be comfortable on stage and develop a large range of clear, precise body language to illustrate their words;
LO3. express themselves without verbal tics and without saying "um";
LO4. slow down their speech and make impactful silences;
LO5. articulate and speak loudly enough for their audience;
LO6. summarize by eliminating unnecessary details during a verbal presentation and deliver a clear, structured, and impactful argument.

Contents	The techniques presented enable students to feel more at ease and less stressed, to capture attention, to be clear and concise in their speech, and to convey the strength of their conviction in a situation that we have too few opportunities to experience—they will learn to be effective and even enjoy it! Objectives : • Feel more at ease and reduce feelings of stress • Capture and retain an audience's attention • Deliver a clear message • Develop power of conviction • Built a structured, impactful argument, adapted to a given time, context, and target audience We will move forward in stages through shared diagnostic exercises, then by reading texts, and finally in public speaking situations without notes.

Organization	We will work on students' physical and verbal expression, and on structuring their message for verbal presentations. For greater efficiency, it would be beneficial for students to prepare a speech, a three-to-five minute professional presentation, ahead of time. They will work from a professional situation (for example, speaking at a meeting) that they have experienced or might experience. They should come with material intended to be convincing about an idea, the benefits of a projects, etc. If they have no ideas, they can choose a current events topic in their professional field and prepare a three-to-five minute speech presenting their opinion on the subject. The more familiar students are with their material ahead of time, the better they will be able to concentrate on speaking with impact.

Bibliographic Resources	Review sheet distributed at the end of the training.

Evaluation	Evaluation is carried out by the teacher throughout the course based on students' attention, participation, and application of tools presented during the verbal presentation. As this course focuses on soft skills, we will evaluate the final level, but also take into consideration students' effort and progress throughout the training.

S6 – COMM1 – CRS Communication and Social Relations

Supervisors: Brigitte Beaussart, Esther Honikman

| Workshops: 15 h | Course language: 🇫🇷 |

Objectives / Targeted Learning Outcomes

Upon completion of the course, students will be able to:

LO1. identify different types of company organization;
LO2. distinguish between different professions related to the engineering degree;
LO3. write a resume and cover letter for internships;
LO4. present and defend their academic background verbally.

Contents	• Positioning of companies on the French market • Company organization • Engineering professions • The role of HR in a company and its connection to engineers • Recruitment process • Resume and cover letter writing • Public speaking (pitches, etc.)
Organization	The course is held in the form of interactive workshops. Each student must do an oral presentation.
Bibliographic Resources	INSEE, socio-economic studies, society and economics newspapers, company annual reports.
Evaluation	Active participation in the module 25% Attendance at company conferences is highly recommended Questionnaire about the concepts reviewed in the module 75%

UE Initiation in Scientific Research

Initiation à la Recherche

45 h - 3 ECTS

SEMESTER 6

UE INREC

Description

Projets Scientifiques en Equipe (Group Science Projects / PSEs) form an interdisciplinary teaching model developed for semesters 6, 7, and 8. The goal of this module is to carry out experiment projects. It is modeled after a "hacklab." Projects embrace all disciplines taught at ESPCI Paris: physics, chemistry, and biology. Some projects are interdisciplinary. The projects are all different and change each year. Thirty projects are carried out each year by the entire year group.

These projects teach students to lead team-based projects and to communicate about them in several formats (presentation, poster, video). This is an essential part of the module. For this reason, the module is linked to the semester 6 module Verbal Communication (S6-COMMI2-COMOR).

Semester	Program	
S6	INREC-PSE1	Group Science Project I

Prerequisites

There are no specific skills required, as the subjects are varied and drawn from many different fields. This is training through research. A critical scientific approach rooted in observation investigation and analysis form the core of this module, along with communication.

UE Validation

INREC-PSE1 average

Targeted skills

INITREC-PSE1	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.	III	III						III		II	II		II	I
LO2.	Part.				II		II				II				I
LO3.	Part.				II				III	III			II		I
LO4.	Part.	III	III					II			II	II	II		
LO5.	Part.	III	III												
LO6.	Part.	III	III						II				II		
LO7.	Part.	III	III												
LO8.	Part.	III	III						III						
LO9.	Part.	III	III								II	II			
LO10.	Pres.	II	II								II				I

Part. participation, Pres.: attendance

S6 – INREC – PSE1 | Group Science Project I

Supervisor: Emmanuel Fort, Maxime Ardré, Yvette Tran

Teaching staff: Philippe Nghe, Pascale Dupuis-Williams, Antonin Eddi, André Klarsfeld, Lea-Laetitia Pontani, Emilie Verneuil, Raymond Even, Suzie Protière, Jean-Baptiste d'Espinose, Amandine Guérinot, Thomas Aubineau, Justine Laurent, Matthew Deyell

| Lab: 45 h | Course language: |

Objectives / Targeted Learning Outcomes

Upon completion of the module, students will be able to:

LO1. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO2. work in a group;
LO3. organize their work to reach a target goal;
LO4. identify and independently carry out the various steps of an experimental approach;
LO5. use effective measurement tools and techniques in the project area of study;
LO6. interpret experiment results with a view to modeling them;
LO7. take a critical approach to using data acquisition and analysis programs;
LO8. identify sources of error to calculate uncertainty and validate experiment results;
LO9. manipulate scientific concepts in an experimental context;
LO10. communicate with an audience of non-specialists.

Contents	The general structure of the PSE module is described as follows: • This experiment module takes a cross-disciplinary approach to different fields in physics, chemistry, biology, and interdisciplinary projects. • Training takes place in thirty-some half-day sessions spread over a year (1 / 3 in S6, S7, and S8, respectively). • Topics are suggested by teachers or by students themselves. Students form groups of three and choose one of the suggested topics. Each group commits to its topic for the duration of the module. • PSEs are held in specific facilities in order to maintain the experiments underway. Students have access to scientific equipment as well as a machine shop to help them carry out their projects. Budget is allocated for the purchase of specific tools. • Projects (subjects?) change each year and all projects are different. • At the end of the semester, students must present their projects to the entire class year. They must also create an online video (Experimental MOOC) to communicate with an external audience.

Independent Study	Objectives: Training through experimental research, development of an experiment plan and original protocols, critical analysis of results, project development skills, communicating about progress and results. Methods: Experiments and development of experiment protocols and methods. Creation of presentation, posters, and a video.

Bibliographic Resources	Documents provided at the beginning of the PSE (articles, websites, etc.), self-led bibliographic research, discussions with researchers and teachers.

Evaluation	Oral presentation 30% (Pres.) Participation and personal involvement in sessions 70% (Part.)

UE English II

Anglais II

32h – 2 ECTS

SEMESTRE 6

UE ANG2

Supervisor : Daria Moreau

| Tutorial : 30h | Course language : |

Description

The purpose of English courses is to improve students' English skills and teach them linguistic independence to prepare them to use technical and scientific English in an international, intercultural, and professional context. These courses are also intended to assist students in preparing for the TOEIC exam, required by the CTI to obtain the ESPCI engineering degree.

Semester	Program
S6	Ang2 32h, 2 ECTS

Prerequisites

Level B1 of the CEFRL reference chart

Evaluation

Validation of the five linguistic skills listed in the CEFRL reference chart at level B2 minimum through:

- end-of-semester TOEIC mock exams and ongoing assessment (EX; CC; PO);
- independent study (P);
- understanding of intercultural communication and culture, and mediation (CC);
- motivation (Part.);
- class participation (Part.);
- attendance (Part.).

Targeted skills

	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	CC				II		III								
LO2.	CC				II		III								
LO3.	Ex., CC						III								
LO4.	CC						III					III	III		
LO5.	CC, PO						III						III		

Ex.: exam, CC : ongoing assessment, Part.: participation, PO: oral exam

Upon completion of the course, students will be able to:

LO1. quickly identify resources for internships and employment, analyze and summarize employer's expectations, and respond in English to internship opportunities by writing a cover letter and/or creating a video cv taking into account the cultural specificities of English-speaking countries;

LO2. apply in-depth knowledge of thematic and scientific grammar and vocabulary to communicate both in writing and verbally in a professional situation within a multicultural company;

LO3. analyze the structure of the TOEIC exam and develop their personal strategy to maximize their score;

LO4. summarize a scientific text or audio document, identify key information, and present it to an audience;

LO5. defend their point of view in a debate, a discussion about a technical or scientific subject, or one drawn from everyday life, and respond to factual questions about the subject.

Contents	• Analysis of internship offers in English-speaking countries and simulating job interviews; • writing cover letters; • exercises to prepare for the TOEIC exam(a practice TOEIC exam will be given at the end of each semester); • familiarity with technical and scientific vocabulary; • written work in the form of reports, summaries, instructions, product descriptions, procedures, chart analyses, etc. on a wide range of subjects; • summary and comparison of actual technical documents; • debates on any subject (cultural, economic, technical, scientific, etc.) without prior training or special training, in order to participate in group exchanges; • practice with oral and written comprehension.

Organization	English courses are mandatory for all students. Students are divided into level groups established at the beginning of the year based on a placement test and oral evaluations. Classroom work is complemented by appropriate and varied e-learning modules (the applications are intended to facilitate reading in English; various linguistic activities; self-led learning in the language lab).

Bibliographic Resources	Course handouts, articles, journals, audio and video documents; examples of actual documents.

Evaluation	Progression, skills and results will be summarized in a personalized pedagogical report.

RAPPORT PEDAGOGIQUE

Nom et prénom de l'étudiant(e) :

L'année d'études :

L'étudiant(e) se situe à ces niveaux (voir définition au verso)

	A1	A2	B1	B2	C1	C2
Compréhension orale						
Compréhension écrite						
Production orale						
Production écrite						
Niveau global						
Médiation						
Note globale						

Attitude pendant la formation et connaissance de la culture

	excellent	bon	satisfaisant	insuffisant	médiocre
Motivation					
Participation					
Travail personnel					
Assiduité					
Connaissance de la culture et communication interculturelle					
Note globale					

Fait à :
Nom de l'enseignant :

Total points :

Foreign Language II - French as a Foreign Language

LV2	Foreign Language II

Supervisor : Daria Moreau

| Tutorial : 13h | Language : German, Chinese, Japanese, Portuguese, Italian, Russian, Arabic... |

Description

Linguistic and cultural training form an integral part of the curriculum of ESPCI students. These classes aim to prepare them for internships or exchange studies in foreign countries and for a possible international professional career as well as to familiarize them with other cultures.

The foreign language teachers organize also a preparation that allows students to take internationally recognized language exams.

Foreign language courses are optional at ESPCI.
This course gives 1 ECTS / semester and allows to validate the UE S10-DEV at the end of the formation.

Students choose on Moodle the languages they wish to study.
Placement tests are compulsory for German and Spanish classes.

Students can choose from the list of the following foreign languages:

- German (4 level groups A1-C1),
- Spanish (4 level groups A1-C1),
- Chinese (2 level groups A1-A2),
- Japanese (2 level groups A1-A2),
- Italian (2 level groups A1-A2),
- Swedish (1 level group A1).

Students can also attend Arabic, Portuguese or Russian classes proposed by PSL.

Objectives / Targeted Learning Outcomes

At the end of the course students will:

LO1. develop linguistic and cross-cultural skills,
LO2. be able to integrate into a foreign professional, academic and social environment,
LO3. be ready to work in a foreign language speaking team,
LO4. be able to discuss in a foreign language both topics of everyday life and the technical or scientific ones,
LO5. reply in a foreign language to factual questions and defend their points of view,
LO6. hold a conversation and express themselves with ease on a wide range of subjects,
LO7. synthesize a scientific or a general text or an audio document by extracting the relevant information and presenting it to an audience,
LO8. respond to the cultural, social, and historical particularities of a foreign country,

LO9. understand everyday foreign language through movies, radio, and television programs.confronter les particularités culturelles, sociales et historiques d'un pays étranger,

LO10. understand everyday language through movies, radio and television programs.

Contents	According to the level as described in the CEFRL: • communicating on a wide range of topics from everyday, professional, and cultural life, • mastering the foreign language grammar and vocabulary, • practicing oral and written comprehension on a variety of topics, • writing various texts, • interacting with a native speaker, • discussing current events, news, songs, and film extracts.

Organization	Classes are held in level groups established at the beginning of the year based on placement tests and oral evaluations. Cultural outings will be offered.

Bibliographic Resources	Audio and video documents; examples of authentic, factual documents.

Evaluation	At the end of each semester, validation of the 5 skills of the CEFR grid and of personal work, knowledge of culture and intercultural communication, motivation, participation in classes, and attendance.

Targeted Skills

DEV-LV2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.							III								
LO2.					II		III								
LO3.					II		III					II	III		
LO4.					II		III						III		
LO5.					II		III					II			
LO6.					II		III								
LO7.					II		III						III		
LO8.						II	III							II	
LO9.							III								

FLE	French as Foreign Language

Supervisor : Daria Moreau

| Tutorials : 9h | langue du cours : |

Description

The objective of these courses is to help all students get at least the B2 level in FLE.

During the classes, the focus will be put on helping students:

1. fully follow and participate in science courses: comprehension, production, interaction, mediation
2. communicate with French students and integrate into the social life at School and in France.

This course gives 1 ECTS / semester and allows to validate the UE S10-DEV at the end of the formation.

Course Prerequisites:

B1

Objectives / Targeted Learning Outcomes

At the end of the course students will:

LO1. develop linguistic and cross-cultural skills,
LO2. be able to integrate into a professional, academic, and social French-speaking environment,
LO3. be able to work in a French-speaking team,
LO4. answer in French factual questions and discuss a given topic,
LO5. hold a conversation and express themselves with ease on a wide range of subjects,
LO6. synthesize a scientific or general text or an audio document by extracting relevant information and presenting it to an audience,
LO7. communicate in writing and orally on a subject of everyday life, a technical or a scientific one,
LO8. give a clear presentation on a subject with cultural, civilizational, technical or scientific content, prepared in advance.

Contenu	

<u>Before arriving in France</u>

Before arriving at ESPCI, international students take an online placement test and oral interviews are organised to assess their oral and written skills in French. This evaluation allows us to accompany the students beforehand by offering remote linguistic tools for self-studying while they are still in their countries of origin.

<u>Before the beginning of studies</u>

- FLE summer classes

Before the beginning of their studies, intensive summer courses (3 hours per day / 3 weeks) are offered to those who have an inferior to C1 level in French,

	in order to better integrate them into the professional, administrative and daily French-speaking environment. • Conferences on Studying in France Then all international students participate in conferences on preparing for engineering studies in France. At ESPCI • FLE classes During the academic year, students must attend weekly FLE classes in groups corresponding to their levels according to the Common European Framework of Reference for Languages (CEFRL). • Additional resources Cultural and gastronomic outings are proposed by PSL Welcome Desk. Students have also access to numerous linguistic and cultural resources available on school's Moodle platform. • French Speaking Workshops In addition to the courses given by qualified teachers in FLE, some French-speaking students organise conversation workshops (1hx1/ week). These optional workshops, composed of 3 international students and one French-speaking student, create a space for a daily language practice and are also a means of integration. In order to acquire more fluency in speaking and to develop the ability to work in a group, international students can also participate in a theatrical group led by their French-speaking classmates. Exam At the end of the 3rd year of studies the level in FLE is verified by an external TCF (Test des Competences du Français) test and by an internal evaluation. The level B2 at the TCF test is required by the CTI in order to validate the engineering diploma.

Supports Bibliographie	Course documents: Handouts, articles, newspapers, audio, and video documents; examples of authentic, factual documents.

Évaluation	At the end of each semester each student with the inferior to B2 level in FLE must validate 5 skills of the CEFRL grid (CC) and personal work (CC), cultural knowledge and cross-cultural communication skills (CC), motivation (CC), course participation (CC), attendance (P). Test de Connaissance du Français (TCF) is compulsory for all international students at the end of the 3rd year of studies (EX) and B2 level in French is required by the CTI from all international students.

Targeted Skills

DEV-FLE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.							III								
LO2.					II	II	III								
LO3.					II		III						III		
LO4.					II		III					II			

LO5.					II		III								
LO6.					II		III						III		
LO7.					II		III						III		
LO8.					II		III						III		