ESPCI PARIS | PSL

Syllabus

Semesters S9 and S10

Version 22.1

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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 (known in French as TD or *travaux dirigés*) 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 4 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; thinking and acting 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.

Internships and specialization (S9-S10)

Student engineers choose their specialties in their third year of study.

The ninth semester involves a minimum five-month internship in an industry setting. This timeline enables students to solidify and take stock of common core learning by tackling concrete industrial problems. It also gives them the opportunity to reflect upon their professional path and to make educated choices informed by true professional experience.

The tenth semester comprises sixteen weeks of specialization courses and an academic research project of at least eight weeks.

For their specialization, students choose four UE in the fields of physics, chemistry, physical chemistry, and biotechnology, two of which must be in the same field (the major). The large range of scientific courses enables students to personalize their curriculum. Three mandatory UE in English, personal development, finance, and economics round out the sixteen weeks of specialization in the tenth semester. During this same period, ESPCI students interested in Process Engineering may follow a specific course program offered at Chimie ParisTech.

A longer international experience is mandatory and must be carried out either in connection with the industry internship (S9) or the research project (S10).

Courses offered in the specialization year are presented in chronological order by semester: semester 9—industry internship (UE PRO); semester 10—core classes and elective classes by field, academic research project (UE ARP).

The UE are grouped in a table and broken down into their constitutive parts (EC). This table includes the names of supervising teachers, the distribution of class hours (classes, tutorials or "TD", super TD, mentoring sessions, 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 determine if ESPCI Paris training skills have been acquired at the targeted level (I: knowledge / understanding, II: application / analysis; III: synthesis / conception).

Semester 9
Minimum five-month internship – 30 ECTS

UE Industrial Internship	SEMESTER 9 UE IND
5 months - 30 ECTS	

Internship Duration
The industrial internship is at least five-months long (July to December—semester 9) and must take place in a corporate setting. Many industry sectors are represented and company size varies, from start-ups to large corporations.

Internship Objectives
The purpose of the industry internship is to acquaint students with the industrial environment while carrying out work for the host company. This internship enables students to take stock of the knowledge and skills acquired at ESPCI Paris and the professional expertise required by the company. Experiencing a corporate environment (organization, mode of operation, social relations, various engineering professions) enables students to refine their professional projects.

Finding internships
Internship research draws on several contact points with companies:
- ✓ partnerships developed between companies and ESPCI Paris—Industry Chairs, Class Sponsorship, Partnership Agreements with ESPCI Paris Laboratories;
- ✓ participation in the Forum Horizon Chimie, XForum, and the Forum TRIUM;
- ✓ the JobTeaser platform, accessible via the intranet and entirely customizable (selection according to scientific topics or activity sector).

Internship Supervision
Throughout the entire length of the industry internship, student engineers receive three levels of supervision.
1. In the company they are placed under the direct responsibility of an Internship Supervisor who supports them throughout the internship.
2. At ESPCI Paris, they are supervised by one of the school's teaching contacts, a teacher-researcher or a researcher (Internship Mentor).
3. They are also supervised by the school's Director of Industrial Relations.

The Internship Mentor is chosen ahead of time for his or her field of expertise, in line with the internship topic. An "Internship Supervisor-Student Engineer-Internship Mentor Liaison Sheet" is established at the beginning of the internship to help the student engineer dialog with their Supervisor in order to refine their understanding of company expectations.

Internship Evaluation
The industry internship is evaluated based on a technical report, a socio-economic report, an oral defense, and the Internship Supervisor's assessment sheet.

These four evaluations are carried out according to criteria-based grids that make it possible to evaluate the learning outcomes/skills targeted by the industry internship.

1. Technical report (IND-RAPTECH)
   Student-engineers must provide the school and the company with a detailed technical report highlighting their activity and the results of the study, which can later be used by the company. The Internship Supervisor evaluates the manner in which the study was conducted, the results obtained and the abilities of the student-engineer, the content, and writing of the technical report.
   The Internship Mentor evaluates the following learning outcomes:
   LO1. Situate the problem within a context, in relationship to the state of the art in that field
   LO2. Define and analyze the problem
   LO3. Utilize knowledge to solve the problem with rigor and logic
   LO4. Summarize the results concisely and clearly

2. Socio-economic report (IND-RAPSE)
   One of the most important goals of the internship is to gain knowledge of the industrial environment; student-engineers must therefore focus on gathering information that reflects their knowledge, perception, and personal analysis of the industrial environment in which they have carried out their internships. In this report, students must explain the company's business, organization, R&D funding, the roll of the engineer, management methods, interpersonal relationships within the company, the role of central management and unions, measures taken with regards to health, safety and security. Personal analysis of social relations is an important factor in judging students' understanding of human issues within a company.

   The Internship Mentor evaluates the following learning outcomes:
   LO1. Define, explain, and summarize the company's business activity, organization, R&D funding
   LO2. Define, explain, and evaluate the role of the engineer in the company
   LO3. Identify and evaluate management methods and social relations within the company
   LO4. Define and analyze the role of central management and unions
   LO5. Define and apply standard and specific rules of health and security

3. Oral defense (IND-SO)
   In order to encourage oral expression and communication, the technical component includes an oral defense before a jury of three teacher-researchers appointed by the Department of Studies. The Internship Mentor and Internship Supervisor may, if they wish, attend the presentation, but they do not participate in the jury's evaluation.

   The jury evaluates the following learning outcomes:
   LO1. Define and analyze technical or scientific content for a non-specialist audience
   LO2. Explain the scientific approach taken to solve the problem
   LO3. Provide materials and speak clearly and cogently
   LO4. Summarize the results to respect the time allotted for the presentation
   LO5. Defend and debate the results

4. Internship Supervisor Assessment (IND-ATS)
   The Internship Supervisor evaluates the following learning outcomes:
   LO1. Demonstrate initiative, independence, innovation, and relevance
   LO2. Formalize and solve interdisciplinary problems using critical thinking skills
   LO3. Accept critiques in order to question and improve the approach
   LO4. Adapt to one's environment, work in a team by understanding and respecting hierarchy and etiquette
   LO5. Communicate verbally and in writing about one's project, convince an audience

UE Validation

Weighted average: IND-RAPTECH 17%, IND-RAPSO 25%, IND-SO 25%, IND-ATS 33%

Targeted skills

IND-RAPTECH	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report		II	III									II	II	
LO2.	Report	III	III					III							
LO3.	Report	III	III	II				III					III		II
LO4.	Report				III		III *								
IND-RAPSE	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Report			III			III *								
LO2.	Report		II	III			III *								
LO3.	Report				II	III	III *				II				
LO4.	Report				II	II	III *								
LO5.	Report			III			III *								
IND-SO	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	PO		II		III										
LO2.	PO	III			III			III							II
LO3.	PO		III		III										
LO4.	PO		III		III										
LO5.	Questions	III			III			III							III
IND-ATS	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Internship			II		II	III *				III		II	II	III
LO2.	Internship	III	III					III	III			III	III		III
LO3.	Internship				III	III					II				II
LO4.	Internship			III	III	III	III *				III				
LO5.	Internship				III		III *								

*When the internship is carried out abroad, the LOs validate skill C6 (Ability to work in a multicultural and international environment) at level III

Semester 10

30 ECTS

Eight-week Research Project

+ 218h course

- ✓ 2 UE "SHS-SES"
- ✓ 1 UE English
- ✓ 4 UE chosen from the fields of physics, chemistry, physical-chemistry, and biotechnology

UE SHS / SES / English	86 +	8			
UE Personal Development	25	3			
Ethics	12	1 ECTS	DEV	ETH	M. Marcel
Preparation for Job Seeking	8			PRE	B. Beaussart
Overview of Professions	5			ALUMNI	S. Norvez
*Foreign Language II and III (1 ECTS / semester)**	13	2 ECTS		LV2	D. Moreau
*French as a Foreign Language (1 ECTS / semester)**	9			FLE	D. Moreau
*Stress Management (1 ECTS)**	9			SM	T. Gallopin
*ATHENS Week (2 ECTS)**	30			ATHENS	H. Ejja
*Student Engagement (1, 2 ECTS / year)**				EE	N. Lequeux
**: optional modules . A minimum of 2 ECTS for these modules is compulsory to validate the l'UE*					
UE Finance et Economics	40	3			
Economic Models	15	33%	FE	ET	T. Bros
Corporate Finance	15	33%		CF	V. Haan
Labor Law and Management	10	33%		DG	D. Bidoire
UE English V	21	2	ENG	ANG5	D. Moreau
4 UE Elective Science Courses	132	12			
UE1	33	3 / U	UE Sciences		
UE2	33				
UE3	33				
UE4	33				
UE Academic Research Project	> 8 weeks	10	ARP	ARP	J. Vial

The volume of individual study is estimated to be 278 hours according to the following breakdown:

UE DEV / FE: 1h course = 0.9h individual study

Student Participation, LV2 (foreign language 2): 30h

UE ENG: 1h = 1.5h individual study (TOIC / TOEFL preparation)

UE Sciences: 1h course = 1.5h individual study

UE Academic Research Project	SEMESTER 10 UE ARP
8 weeks - 10 ECTS	

Description

The year of specialization ends with a research project on an original topic lasting at least eight weeks and carried out in a research laboratory at ESPCI Paris or PSL or abroad.
The purpose of the internship is to acquaint students with the academic environment and take stock of the knowledge and skills acquired at ESPCI Paris, and in doing so, refine their professional projects.

Internship evaluation

The Academic Research Project is evaluated based on a written report, an oral defense, and the Internship Supervisor's assessment.
These three evaluations are carried out using criteria-based grids that make it possible to evaluate the learning outcomes/skills targeted by the academic internship.

1. Report (ARP-RAP)

   Student-engineers produce a detailed technical report highlighting their activity and the results of the study, which can later be used by the laboratory. The Internship Supervisor evaluates the way in which the study was carried out, the results obtained, and the student-engineer's capacity to present their research (content and writing).
   The Internship Supervisor evaluates the following learning outcomes:
   - LO1. Situate the problem within a context, in relationship to the state of the art in that field
   - LO2. Define and analyze the problem
   - LO3. Utilize knowledge to solve the problem with rigor and logic
   - LO4. Summarize the results concisely and clearly

2. Oral defense (ARP-SO)

   To encourage oral expression and communication, the project includes an oral defense before a jury of three teacher-researchers appointed by the Department of Studies.
   The jury evaluates the following learning outcomes:
   - LO1. Define and analyze technical or scientific content for a non-specialist audience
   - LO2. Explain the scientific approach taken to solve the problem
   - LO3. Provide materials and speak clearly and cogently
   - LO4. Summarize the results to respect the time allotted for the presentation
   - LO5. Defend and debate the results

3. Internship Supervisor Assessment (ARP-AMS)

The Internship Supervisor evaluates the following learning outcomes:
- LO1. Demonstrate initiative, independence, innovation, and relevance
- LO2. Formalize and solve interdisciplinary problems using critical thinking skills
- LO3. Accept critiques to question and improve the approach
- LO4. Adapt to one's environment, work in a team, understand and respect hierarchy and etiquette
- LO5. Communicate verbally and in writing about one's project, convince an audience

UE Validation

Weighted average: ARP-RAP 30%, ARP-SO 30%, ARP-AMS 40%

Targeted skills

ARP-RAP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report		III	III									III	III	
LO2.	Report	III	III					III							
LO3.	Report	III	III	III				III	III				III		III
LO4.	Report				III		III*								
ARP-SO	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	PO		III		III										
LO2.	PO	III			III			III	III						III
LO3.	PO		III		III										
LO4.	PO		III		III										
LO5.	Questions	III			III			III							III
ARP-AMS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Internship			III		III	III*				III		III	III	III
LO2.	Internship	III	III					III	III			III	III		III
LO3.	Internship				III	III					III				III
LO4.	Internship			III	III	III	III*				III				
LO5.	Internship				III		III*								

*When the internship is carried out abroad, the LOs validate skill C6 (Ability to work in a multicultural and international environment) at level III

UE SHS / SES / Languages

	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisors
UE SHS / SES / English	86 +	8			
UE Personal Development	25	3			
Ethics	12	1 ECTS	DEV	ETH	M. Marcel
Preparation for Job Seeking	8			PRE	B. Beaussart
Overview of Professions	5			ALUMNI	S. Norvez
*Foreign Language II and III (1 ECTS / semester)**	13	2 ECTS		LV2	D. Moreau
*French as a Foreign Language (1 ECTS / semester)**	9			FLE	D. Moreau
*Stress Management (1 ECTS)**	9			SM	T. Gallopin
*ATHENS Week (2 ECTS)**	30			ATHENS	H. Ejja
*Student Engagement (1, 2 ECTS / year)**				EE	N. Lequeux
**: optional modules . A minimum of 2 ECTS for these modules is compulsory to validate the l'UE*					
UE Finance et Economics	40	3			
Economic Models	15	33%	FE	ET	T. Bros
Corporate Finance	15	33%		CF	V. Haan
Labor Law and Management	10	33%		DG	D. Bidoire
UE English V	21	2	ENG	ANG5	D. Moreau

The volume of individual study is estimated to be 197 hours according to the following breakdown:
UE DEV / FE: 1h course = 0.9h individual study
UE ENG: 1h tutorial (TD) = 1.5h individual study (TOEIC / TOEFL preparation)

UE Personal Development

25h - 3 ECTS

SEMESTER 10

UE DEV

Description

The purpose of the module professional communication (DEV-PRE) is to prepare students to seek employment and assist them in appropriating the recruitment process (master, PhD, additional studies, employment, etc.).

Semester	Program	
S10	DEV-ETH	Ethics
	DEV-PRE	Preparation for Job Seeking
	DEV-ALUMNI	Overview of Professions
	DEV-SM*	Stress Management
	DEV-LV2*	Foreign Language II
	DEV-FLE*	French as a Foreign Language
	DEV-ATHENS*	ATHENS Week
	DEV-EE*	Student Engagement

UE Validation

The modules DEV-ETH, DEV-PRE, and DEV-ALUMNI are mandatory (1 ECTS).
Students will complete this UE by choosing EC from among DEV-SM (1 ECTS), DEV-LV2 (1 ECTS / semester), DEV-FLE (1 ECTS / semester), DEV-ATHENS (2 ECTS) and DEV-EE (maximum 2 per year of engineering studies) to obtain at least 2 ECTS.

Targeted skills

DEV-ETH	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.				II		II									
LO2.				II		II									
LO3.				II		II									
LO4.				II		II									
DEV-PRE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Interview													III	
LO2.	Interview			III											
LO3.	Interview					III									
LO4.	Interview			III											
LO5.	Interview					II									
DEV-ALUMNI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Attendance			II		II									
LO2.	Attendance			II		II									
LO3.	Attendance			II		II									
LO4.	Attendance			II		II									
DEV-SM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.	III													
LO2.	Part.	II												II	
LO3.	Part.	II										II	II		
LO4.	Part.	II											II		
LO5.	Part.	II			II								II		
LO6.	Part.				II										
LO7.	Part.				II							II	II		
DEV-LV2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.					II		III								
LO2.							III						II		
LO3.							III					II			
LO4.							III						III		
DEV-FLE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.					II		III								
LO2.							III					II			
LO3.							III						III		
DEV-ATHENS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Var.	III											II	II	
LO2.	Var.				III		III						II	II	
LO3.	Var.					III	III								

Part.: participation, Var.: varies according to program

S10 – DEV – ETH | Ethics

Supervisor: Mélanie Marcel

| Course: 12 h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. define criterias to discuss the responsibility and impact parts of a research project;
- LO2. identify the research and valorization structures and paradigms involved in their research / engineering projects;
- LO3. produce a critical analysis of the practices and players they will be working with;
- LO4. navigate the impact sector, both economical and in the research field.

Contents	What is the role of science in the upcoming social and environmental crisis? Can science collaborate with society to solve our most pressing social and environmental challenges, and if so, under which modalities? How can valorization of research no longer be only focused on economic return but also on social and environmental returns? Can a scientist engage as a citizen through research? Students will explore these questions and work on practical tools to assess their own responsibility and the impacts of the research project they are working on. A new vision of research and entrepreneurship rooted in specific philosophical principles, requiring new skills, tools and values, will be presented, as well as its current evolution on a local, national and international level.

Bibliographic Resources	ARENDT (Hannah), Conditions de l'homme moderne. BENJAMIN (Ruha), Race after technology. BIHOUIX (Philippe), L'âge des low-tech. ELLUL (Jacques), Le bluff technologique. GRAS (Alain), Le choix du feu: Aux origines de la crise climatique. HORNBORG (Alf), La magie planétaire: technologies d'appropriation de la Rome Antique à Wall Street. JARRIGE (François), Technocritiques. JONAS (Hans), Le Principe responsabilité: une éthique pour la civilisation technologique. MARCEL (Mélanie), Science et impact social, vers une innovation responsable. MEADOWS (Dennis), Les limites à la croissance. ROSA (Hartmut), Résonance.

Evaluation	Attendance

S10 – DEV – PRE	Preparation for Job Seeking

Supervisors: Brigitte Beaussart, Esther Honikman

| Course: 8h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. consider different possible career paths;
LO2. explain and defend their professional projects;
LO3. write their "digital" profile and take into account their e-reputation;
LO4. plan a contact network;
LO5. distinguish between different selection processes.

Contents	Skills acquired: development of professional communication skills appropriate for the recruitment process, network, and socio-economic environment of companies. The module is carried out in two separate steps: 1. A course: • Assessment of the industry internship • "Co-Orientation" presentation • Network approach to the recruitment process • Passing a test 2. Individual professional situation: individual, 30-minute interview followed by a personalized debriefing with the group leader.

Bibliographic Resources	Socio-economic current affairs

Evaluation	No graded evaluation. Individualized accompaniment: individual, 30-minute interview about the professional project, followed by a personalized debriefing. Validation based on students' achieving their objectives.

S10 – DEV – ALUMNI | Overview of Professions

Supervisor: Sophie Norvez

| Course: 5h | Course language: 🇫🇷 |

Description

The course gives engineering students an overview of the career paths taken by former students to demonstrate possible outcomes and respond to their questions. It is prepared and presented voluntarily by members of the ESPCI Alumni Board of Directors and alumni with exemplary careers, who participate as "grands témoins" (highly-achieving alumni) and share their experience with students.

Objectives/Targeted Skills

Upon completion of the module, students will:

LO1. have heard about the experience of former students;
LO2. have reflected on the emblematic career paths of certain alumni;
LO3. be able to define a professional career outcome for themselves;
LO4. be able to identify the resources needed to refine their career choice.

Contents	The course consists of an overview module (1h30), followed by three one-hour modules about careers in academia, industry, and entrepreneurship (start-ups, industrial property, venture capital, etc.). Each module begins with a presentation of data, collected and analyzed by the alumni association (employment survey, etc.), followed by a presentation by a "grand témoin" alumnus/a, conceived as an interactive Q&A session.

Bibliographic Resources	Alumni directory at www.espci.org Document "Alumni in Academia," which aims to connect alumni in the academic field with student-engineers looking for master's programs, PhD opportunities, etc.: http://bit.ly/ESPCI-alumni-in-academia

Evaluation	Attendance

S10 – DEV – SM	Stress Management

Supervisor: Thierry Gallopin

| Course: 9h | Course language: 🇫🇷 |

Description

Knowing how to manage stress has become an essential skill for reaching personal and professional fulfillment. While stress can be motivating, it can also be an obstacle to achieving one's goals. There are many symptoms of stress: fatigue, trouble sleeping, trouble concentrating, decreased motivation, mood disorders, and health problems. Learning to manage stress has become necessary in modern society. The purpose of this workshop is to first understand what stress is, its purpose, and the factors that regulate it. Then students will learn to manage stress using meditation and self-hypnosis techniques.

Objectives / Targeted Skills

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

LO1. describe the different factors that create and regulate stress;
LO2. clearly define a goal and achieve it;
LO3. use subconscious communication;
LO4. simply and gradually use self-hypnosis;
LO5. simply and gradually use meditation;
LO6. quickly and sustainably manage their emotions and stress;
LO7. increase self-confidence and confidence in their performance;
LO8. identify and overcome their fears / resistance to change.

Contents	Workshop organization: 1. Introduction to the physiology of stress 2. Conscious and Subconscious: two sides of the same coin 3. How to define a goal 4. Introduction to self-hypnosis and meditation 5. Managing emotions through conditioning 6. Managing behavior 7. Better sleep management 8. Overcome resistance (fear, limits) 9. Identify and change beliefs
Organization	Three 3-hour sessions in small groups of ten students (workshop with role playing and exercises)
Bibliographic Resources	• Course handouts and resources • *Votre cerveau n'a pas fini de vous étonner*, Boris Cyrulnik, Christophe André, Jean-Michel Oughourlian, Patrice Van Eersel, Pierre Bustany and Thierry Janssen, Clés-Albin Michel, 2012 • *Psychobiologie – De la biologie du neurone aux neurosciences comportementales, cognitives et cliniques*, S. Marc Breedlove, Mark R. Rosenzweig, Neil Watson, Sylvain Bartolami, DE BOECK UNIVERSITE; Édition : 6th edition, 2015. • *Méditer, jour après jour*, Christophe André, L'Iconoclaste, 2011. • *Apprivoiser le changement avec l'auto-hypnose,* Kévin Finel, InterEditions
Evaluation	Behavior during the workshop: participation, motivation, attendance

S10 – DEV – LV2 | Foreign Languages II

Supervisor: Daria Moreau

| Course: 13h | Course language: Spanish, German, Chinese, Japanese, Portuguese, Italian, Russian, Arabic, etc.

Description

Students form level-based groups (A1-C2) that follow courses together, once a week, according to their chosen language and level.

Objectives / Targeted Skills

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

- LO1. communicate in writing and verbally about everyday subjects or a professional situation;
- LO2. examine the cultural, social, and historical particularity of a foreign country;
- LO3. understand everyday language through film and radio or television programs;
- LO4. analyze and summarize actual documents.

Contents	According to the level described in the CECR: • continuous and interactive verbal expression on a wide range of topics in daily and professional life, and on subjects related to the culture of the language studied; • acquisition of grammar and vocabulary; • regular practice in oral and written comprehension through various subjects; • writing various texts; • interaction with a native speaker; • verbal comprehension; • debate using current events and news, songs, and movie clips.

Organization	Students are divided by level into groups established at the beginning of the year based on a placement test and oral evaluations. Cultural outings will be proposed.

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

Evaluation	Ongoing assessment 75%, exam 25%

S10 – DEV – FLE French as a Foreign Language

Supervisors: Daria Moreau

| Course: 9h | Course language: 🇫🇷 |

Description

Students form level-based groups (A1-C2) that follow courses together, once a week, according to their level.

Objectives / Targeted Skills

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

LO1. communicate in French in writing and verbally about everyday subjects or a professional situation;
LO2. understand everyday language through film and radio or television programs;
LO3. analyze and summarize actual documents.

Contents	According to the level described in the CECR: • continuous and interactive verbal expression on a wide range of topics in daily and professional life, and on subjects related to the culture of the language studied; • acquisition of grammar and vocabulary; • regular practice in oral and written comprehension through various subjects; • writing various texts; • interaction with a native speaker; • verbal comprehension; • debate using current events and news, songs, and movie clips.
Organization	Students are divided by level into groups established at the beginning of the year based on a placement test and oral evaluations. Cultural outings will be proposed.
Bibliographic Resources	Course handouts, articles, journals, audio and video documents; examples of actual documents.
Evaluation	Ongoing assessment 75%, exam 25%

S10 – DEV – ATHENS	ATHENS Week

Supervisor: Hadil Ejja

| Course: 30h | Various activities: 10-15h | Course language: 🇬🇧 |

Description

The purpose of the ATHENS program is to organize intensive specialized courses in each member establishment over one or two defined periods ("sessions") during the academic year (November and March), giving students the opportunity to attend one of the courses offered by network members for seven days.

ATHENS Week allows participants from different institutions to take short, high-level science courses and to interact with students of different nationalities and origins. Approximately 60 courses are offered during each ATHENS session and cover a wide range of topics, from engineering to social sciences.
"European" activities are organized to complement courses students take. The purpose is to give ATHENS students a better understanding of the institution organizing the course, as well as the European city where the course is held. The opportunity to interact with students of different nationalities and origins during these activities is particularly important.

The host institution provides a detailed program for each participating site. Cultural activities are an integral component of an ATHENS session; therefore participation is mandatory.
Each session includes 30 hours of scientific courses and 10 to 15 hours of "European" activities.
http://athensnetwork.eu/index.html

This experience often gives students the desire to pursue longer-term studies (MSc and PhD levels) in an institution outside of their home country and thus facilitates exchanges between students from Europe's main technological institutions.

Objectives / Targeted Skills

At the end of this week, students will have:

- LO1. discovered or deepened knowledge of a scientific topic;
- LO2. discovered and experimented with working methods different from those practiced in their home countries;
- LO3. discovered and experienced other cultures through cultural exchanges and activities.

Contents	Varies according to program

Organization	Intensive, week-long courses (30 hours) and 10 to 15 "European" activities in a European university

Evaluation	Varies according to program

S10 – DEV – EE | Student Engagement

Supervisor: Nicolas Lequeux

Description

Supporting community engagement consists of recognizing the skills, knowledge, and capabilities required to conduct community work.
Decree no. 2017-962 of May 10, 2017, provides for the conditions of recognizing student engagement in community, social, or professional life, as of academic year 2017-2018: "Higher education institutions are, in this context, responsible for defining and implementing this system."

Implementation and validation

- Each year, the Department of Studies and students together establish a list of community activities for validation. The General Director of ESPCI Paris gives the final validation.
- ECTS awarded: a maximum of two per school year for a total maximum of six.
- Each community activity will be addressed in a summary document with a precise description for each position (president, treasurer, secretary, etc.) the role, the number of people concerned, time commitment, skills acquired, the number of ECTS credits to award (one or two ECTS), the year of validation, and the method of validation.
- The Head of the Department of Studies gives the final validation.
- All "recognized" student activities will be recorded in the diploma supplement with the corresponding skills.

Objectives / Targeted Skills

Varies according to activity

UE Finance and Economics

SEMESTER 10

40h - 3 ECTS

UE FE

Description

The purpose of the course Corporate Finance (FE-CF) is to give students a global understanding of the role of finance in business. The approach taken explains different financial concepts: accounting statements, cash flow, financial analysis, etc.
Students will understand a company's key financial information and examine it with a critical eye.

The purpose of the course Law and Management (FE-DG) is to provide students with a basic understanding of labor law and to introduce company accounts so they understand the issues at stake.

Semester	Program	
S10	FE-ET	Economic Models
	FE-CF	Corporate Finance
	FE-DG	Labor Law and Management

Prerequisites

None

UE Validation

Weighted average: FE-ET 1/3, FE-CF 1/3, FE-DG 1/3

Targeted skills

FE-ET	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Pitch/rapport	I		I											
LO2.	Pitch/rapport	II	II	II											
LO3.	Pitch/rapport	I		I											
LO4.	Pitch/rapport	II		II											
LO5.	Pitch/rapport						II								
FE-CF	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Materials + pitch	I		I		I									
LO2.	Materials + pitch	I													
LO3.	Materials + pitch	II		II			II								
LO4.	Materials						II								
FE-DG	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	MCQ	I		I		I									
LO2.	MCQ	I				I									
LO3.	MCQ	I													
LO4.	MCQ	I				I									
LO5.	MCQ	I		I											
LO6.	MCQ	I													
LO7.	MCQ	I		I											
LO8.	MCQ	I		I											

S10 – FE – ET | Energy, Climate & Economics

Supervisor: Thierry Bros

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. interpret the evolution of an industrial society;
- LO2. identify the different strategies used by energy groups;
- LO3. explain the intended goal;
- LO4. evaluate the potential risks involved in implementing these strategies;
- LO5. use technical English vocabulary.

Contents	With climate change becoming a major problem, this class provides students with an in-depth economic and strategic analysis of the main energy companies.
Organization	Course intended for the entire year group Case study: company presentations
Bibliographic Resources	Company annual reports and quarterly presentations available online
Evaluation	Short presentation in pairs for most students; written report for the others

S10 – FE – CF	Corporate Finance

Supervisor: Vincent Haan

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. describe a company's strategy and financial challenges;
LO2. interpret financial data;
LO3. calculate and analyze a company's key financial ratios;
LO4. use technical English vocabulary.

Contents	Corporate finance Balance sheet Profit loss Free movement of capital Key financial indicators for decision-making Projects / Decision making and management

Organization	Group work (see evaluation)

Bibliographic Resources	None

Evaluation	Homework carried out in groups of three to five students (materials and video pitch in English)

S10 – FE – DG	Labor Law and Management

Supervisor: Damien Bidoire

| Course: 10h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. define the main concepts of labor law in France;
LO2. identify risk zones in contracts and breaches of contract;
LO3. interpret current payroll documents, such as pay slips;
LO4. identify particular points of labor law as they apply to normal employer relations;
LO5. identify the important elements in company accounts;
LO6. define current aggregates;
LO7. interpret simple financial elements;
LO8. respond to classic financial questions.

Contents	
	Labor Law 1. Labor Law in France • Various sources of labor rights • Labor institutions • Social benefits taxes 2. Labor contract • Types of contracts (CDD, CDI) • Main clauses 3. Absences • Vacation • Sick leave • Unapproved absences 4. Professional expenses • Labor law • Social and fiscal tax rules • Fringe benefits 5. Rights and responsibilities • Employee responsibilities • Employee rights 6. End of contract • Dismissal • Mutually agreed severance • Resignation Management 1. Main accounting concepts • Description of the legal context of accounting • Description of the administrative system (internal monitoring) • Description of accounting organization (log, ledger) 2. Balance sheet and annex • Description of assets • Description of liabilities • Annex 3. Income statement and interim management balances • Analysis of products

	• Analysis of expenses • Calculated expenses • Different aggregates • Management tools 4. Company financing • Financial balances • Financing table • Preparing an estimated budget 5. Corporate taxation • VAT • Corporate tax • Local taxes

Organization	Labor law: Small-group classes with discussion (about 30 students) Management: Lecture courses

Bibliographic Resources	*Gestion de la PME*, éditions Francis Lefebvre

Evaluation	Two MCQ at the end of the course (15 questions)

UE English V

21h - 2 ECTS

SEMESTER 10

UE ENG

Supervisor: Daria Moreau

Tutorial: 21h | Course language: |

Description

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

Semester	Program	
S10	Ang5	21h, 2 ECTS

Prerequisites

Level B1 of the CEFRL reference chart

Evaluation

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

- an oral exam at the end of the third year (internship presentation) (EX; PO; R);
- a written task (R);
- international, external validation to meet CTI requirements for obtaining the engineering degree through the TOEIC (over 800 points) (EX);
- independent study (CC);
- 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.	EX, PO						III						II		
LO3.	Ex., CC						III					II			
LO4.	CC, PO						III						III		

Ex.: exam, CC: coursework, PO: oral exam

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

- LO1. perfectly apply their linguistic skills in written and verbal English in a professional situation within a multicultural company;
- LO2. give a presentation of at least 30 minutes about their international internship without notes (with a résumé), compare cultural similarities and differences, and evaluate their own ability to adapt to international contexts;
- LO3. analyze the TOEIC exam structure and develop a personal strategy to optimize their score;
- LO4. 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

- Verbal communication through internship presentations followed by questions, interview simulations, and debates;
- cultural knowledge of at least one English-speaking country and a good knowledge of the Anglo-Saxon context in order to grasp the psycholinguistic nuances of English (insinuations, cultural allusion);
- analysis of and practice for the international English exam (TOEIC);
- writing high-quality technical, professional, or scientific content in English.

Organization

English courses are mandatory for all students. Classroom work is accompanied by self-led learning in the language lab.

Bibliographic Resources

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

Evaluation

Ongoing assessment 75%, exam 25%

Student progress will be evaluated using the following table:

ELEMENTS OF INTERCULTURAL COMPETENCE – EVALUATION GRID (adapted from Deardorf, 2006)

Deardorff, D. K. (2006) , The Identification and Assessment of Intercultural Competence as a Student Outcome of Internationalization at Institutions of Higher Education in the United States, Journal of Studies in International Education 10:241-266

KNOWLEDGE			
	REACHED	IN PROGRESS	NOT REACHED
Cultural self-awareness *the ability to articulate how one's own culture has shaped one's identity and world view*			
Culture-specific knowledge *the ability to analyse and explain basic information about other cultures (history, values, politics, economics, communication styles, values, beliefs and practices)*			
Sociolinguistic awareness *basic local language skills, the use of different verbal/non-verbal communication, and adjusting one's speech to accommodate nationals from other cultures*			
Grasp of global issues and trends *explaining the meanings and implications of globalisation, and relating local issues to global forces*			
Listening, observing, evaluating *using patience and perseverance to identify and minimise ethnocentrism, seek out cultural clues and meaning*			
SKILLS			
Analysing, interpreting and relating *seeking out linkages, causality and relationships using comparative techniques of analysis*			
Critical thinking			

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					

TOEIC blanc : date et résultat	
TOEIC exam : date et résultat	

Fait à :
Nom de l'enseignant :

Total points :

Specialization UEs in Physics

UE Sciences - Physics Specialization

SEMESTER 10	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisors
UE Quantum and Relativistic Engineering	33	3			
Electromagnetism and Special Relativity	18	50%	QRE	ESR	J. Lesueur
Quantum Engineering	15	50%		QE	N. Bergeal
UE Advanced Condensed Matter Physics	33	3			
Current Topics in Condensed Matter	10	30%	ACMP	MTCM	D. Roditchev
Numerical Approaches to Electronic States	23	70%		NAES	L. De Medici
UE Magnetism and Superconductivity	30	3			
Magnetism: From fundamentals to applications at nanoscale	15	50%	MS	MFN	S. Vlaic
Superconductivity: Properties, fundamentals, applications	15	50%		PFA	D. Roditchev
UE Waves and Light-Matter Interactions	30	3			
Waves in Complex Media	15	50%	WLMI	WCM	R. Carminati
Light-Matter Interactions	15	50%		QLM	A. Goetschy
UE Statistical Physics of Complex Systems	27	3			
Key Concepts in Statistical Physics	27	100%	SPCS	SPCS	O. Dauchot V. Démery
UE Physics of Signals	33	3			
Physics of Measurement	18	50%	PS	PM	V. Croquette
Physics of Telecommunication	15	50%		PT	E. Geron
UE Statistical Learning	30	3			
Statistics and Modeling	15	50%	SL	SM	I. Rivals
Modeling and Classifying using Machine Learning Techniques	15	50%		ML	Y. Oussar
UE Introduction to Deep Learning	30	3			
Introduction to Deep Learning	30	100%	IDL	IDL	A. Allauzen
UE Advanced Fluid Mechanics	30	3			
Microfluidics	8	30%	AFM	MIC	N. Brémond
Physics of Transport	12	40%		PT	M. Fermigier
Hydrodynamic Instabilities	10	30%		HI	L. Duchemin
UE Advanced Programming	30	3			
Advanced Programming	30	100	PrA	PrA	D.Cassereau

Given the evaluation methods (bibliographic report, independent study, case study, and oral presentation, etc.), the volume of personal work for an EU is estimated to be around 45h by applying the breakdown 1h = 1.5h individual study.

# UE Quantum and Relativistic Engineering	SEMESTER 10
33h - 3 ECTS	UE QRE

Description

Quantum mechanics and special relativity are two pillars of modern physics. But they also lie at the heart of today's Information and Communication Technologies (ICTs), from micro-processors to GPS systems. They will be even more present in the future, with the rise of quantum information. A true engineering field is developing that uses the fundamental concepts of quantum mechanics and relativity to invent and build new ways of conveying and processing information. This is the idea behind the UE Quantum and Relativistic Engineering.

Newtonian mechanics reveals its limits in situations involving electromagnetism. Einstein's restricted relativity was a new framework introduced in the early twentieth century to properly describe these mechanics. The course Electromagnetism and Special Relativity (QRE-ESR) provides an overview of the foundations of relativistic mechanics, with a particular focus on Minkowski spacetime and its consequences for kinematics and system dynamics. It then addresses mass-energy equivalence and its consequences for nuclear reactions, before offering a relativistic formulation of the electromagnetic field. The course concludes with a relativistic and quantic study of the electron, which leads to the Dirac equation. The course is illustrated with examples from nuclear physics and solid-state physics.

Quantum engineering is a rapidly growing field that uses the laws of quantum physics to develop new technology with no classical equivalents. The QRE-QE course will build on the basic concepts of quantum mechanics discussed in the first year and gradually introduce important concepts for quantum engineering, including quantum bits and quantum entanglement. In the second part of the course, students will learn how to use these new concepts to build complex quantum systems that are useful for applications in quantum computing and quantum communications.

Semester	Program
S10	QRE-ESR Electromagnetism and Special Relativity QRE-QE Quantum Engineering

Prerequisites

Classical mechanics (S5-SIM1, S8-SIM2), electromagnetism (S6-PG-OEM), foundations of quantum physics (S6-PG-PQ)

UE Validation

Weighted average: QRE-ESR 50%, QRE-QE 50%

Targeted skills

QRE-ESR	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	RB	II						II		II			II		
LO2.	Exam	III						III							
LO3.	RB	III	III					III		III			III		
LO4.	RB	III	II							III			III		
LO5.	Exam	III	III					III							
LO6.	RB	III	III					III		III			III		
LO7.	RB						II								
QRE-QE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	III	II					III							
LO2.	Exam	III	II					III							
LO3.	LO, Exam	II						III		III					
LO4.	Exam	II						III		III					
LO5.	LO	III	II	I				III		III			III		II
LO6.	LO	III	III					III		III			III		
LO7.	LO						II								

RB: bibliographic report, LO: article analysis

S10 – QRE – ESR	Electromagnetism and Special Relativity

Supervisor: Jérôme Lesueur

| Course: 18h | Course language: English |

Objectives / Targeted Skills

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

LO1. identify situations in physics that pertain to relativistic mechanics;
LO2. calculate relativistic corrections in mechanics and electromagnetism;
LO3. argue the relevance of considering relativistic corrections in physics, chemistry, or engineering problems;
LO4. write a summary on the practical applications of special relativity;
LO5. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
LO6. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO7. use scientific and technical English vocabulary.

Contents	• Limits of Newtonian-Galilean mechanics • Special relativity • Minkowski spacetime (four-vectors, causality) • Relativistic kinematics • Relativistic dynamics • Electromagnetism • Dirac equation (electron spin, antimatter)

Bibliographic Resources	• *Feynman Lectures on Physics: Mechanics 2*, Feynman / Leighton / Sands – InterEditions • *Feynman Lectures on Physics: Electromagnetism 2*, Feynman / Leighton Sands – InterEditions. • *Special Relativity*, A. P. French – CRC Press

Evaluation	Bibliographic report (50%) Written exam (50%)

S10 – QRE – QE	Quantum Engineering

Supervisor: Nicolas Bergeal

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. apply quantum mechanics to processing a quantum bit and to processing two coupled quantum bits;
- LO2. apply quantum mechanics to the interaction between a two-level system and an optical cavity mode;
- LO3. explain how a circuit with several qubits works to perform a logical computing function;
- LO4. explain how a quantum communication system works;
- LO5. offer practical solutions to create the building blocks of a quantum computer and a quantum communication system;
- LO6. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
- LO7. use scientific and technical English vocabulary.

Foundational	1. Contents • Quantum coherence and superposition • Quantum bits, Bloch sphere • Entanglement of two quantum bits and Bell inequality • Jaynes–Cummings model 2. Introduction to quantum computing • Different implementation of quantum bits • Superconductive foundations of quantum bits • Controlling quantum bits • Multiquantum logic gates • Quantum algorithms • Current technology 3. Introduction to quantum communication • Theory of information (classic and quantum) • No-cloning theorem • Quantum cryptography • Quantum teleportation • Current technology

Bibliographic Resources	• Cohen-Tannoudji, Claude, Diu, Bernardet and Laloë, Franck. *Mécanique quantique tome I et II*, EDP Sciences. • *Quantum computation and quantum information* de M. Nielsen et I. Chuang.

Evaluation	Analysis of scientific articles (50%) Written exam (50%)

UE Advanced Condensed Matter Physics

33h - 3 ECTS

SEMESTER 10

UE ACMP

Description

When attempting to describe the electrical, magnetic, optical, or thermal behavior of solids, it is not possible, given the large number of atoms per unit of volume, to carry out a precise analysis based on the behavior of individual atoms.
Solid-state physics allows for the construction of models that may be considered representative if they are verified with experiments.
Formalism, developed to this end, has many applications. Examples will be given in various fields, some of them seemingly far removed from solid-state physics.

Semester	Program	
S10	ACMP-MTCM	Current Topics in Condensed Matter
	ACMP-NAES	Numerical Approaches to Electronic States

Prerequisites

Level M1 (first year of master's) in physics

UE Validation

Weighted average: ACMP-MTCM 50%, ACMP-NAES 50%

Targeted skills

ACMP-MTCM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Examen	III	III					III		II			II		II
LO2.	Examen	III						III	III	II					
LO3.	Examen	III						III		II					
LO4.	Examen	III	III					III	III	II			II		
LO6.	Examen						II								
ACMP-NAES	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Examen	III	III					III		II					
LO2.	Examen	III						III							
LO3.	Examen	III	II					III		II					
LO4.	Examen	III						III		III					
LO5.	Examen	III	II					III	II						
LO6.	Examen	III	III					III	III	III					
LO7.	Examen						II								

S10 – ACMP – MTCM | Current Topics in Condensed Matter

Supervisor: Dimitri Roditchev

| Course: 16 h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. use their knowledge to solve a complex and / or cross-disciplinary problem;
- LO2. justify using a diverse range of advanced methods in Quantum Physics of Condensed Matter;
- LO3. connect a macroscopic phenomenon to microscopic processes;
- LO4. validate a model by comparing predictions to experiment results and evaluate the limits of validity;
- LO5. use scientific and technical English vocabulary.

Contents	This EC presents recent trends in Quantum Physics of Condensed Matter and illustrates the related experimental challenges. The course is divided into 8 blocks of 2 hours each. 1. Introduction to "Trends in Condensed Matter" (first hour) Mesoscopic phenomena in superconductivity (second hour) Proximity effect, Josephson effect 2. Nanoscale superconductivity The Ginzburg-Landau approach to phase transitions, magnetic flux quantification, vortex, Cooper pairs 3. Electrical conductivity of low-dimensional systems Electron transport: ballistic vs. diffusive transport, charge transport and 1D spin, quantum resistance, non-local phenomena 4. Photons and semiconductors Quantum optical properties of materials, Fermi's golden rule, excitons, quantum confinement, quantum optics to quantum calculus 5. Low-dimensional collective quantic phenomena Charge density waves, superconductivity, vortex matter Optical properties of hetero structures 6. Thermoelectric effects Models, phenomena, applications 7. Magnetism Phenomenological and microscopic description, ferromagnetism, paramagnetism, magnetism and dimensions: from super-para to nanoparticle ferromagnetism, spintronics 8. Atomic nanostructures: The structure of matter at the atomic scale, surface phenomena, spectroscopy of electronic states, ARPES, STS

Bibliographic Resources	• N.W. Ashcroft et N. D. Mermin *Physique des Solides*, EDP Sciences • Ch. Kittel *Introduction to Solid State Physics* • P.G. de Gennes *Superconductivity of Metals and Alloys* • A.V. Narlikar *Small Superconductors,* in The Oxford books series, OUP

Evaluation	Final exam with ACMP-NAES (oral or written, 2 to 3 hours, according to the number of students enrolled)

S10 – ACMP – NAES	Numerical Approaches to Electronic States: from molecules to solids

Supervisor: Luca De Medici

| Course: 17 h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. Model macroscopic phenomena, such as properties of solids like metallicity or a material's magnetism, by connecting them to the microscopic processes of the quantum particles (specifically electrons) that comprise them;
LO2. evaluate the complexity of modeling a quantum system with several particles;
LO3. test theoretical analytical models to solving Schroedinger's equation for a multi-electron system and identify the limits in problems with increasing complexity;
LO4. justify so-called "mean field" approximations that reduce a multi-body problem to a single-body problem;
LO5. use state-of-the-art software to calculate realistic electron structures for simple materials;
LO6. validate a model by comparing predictions to experimental results and evalute the limits of its validity;
LO7. use scientific and technical vocabulary in English.

Contents	This course lays the foundations to realistically model the properties of molecules and solids based on their chemical composition. Particular attention will be given to the digital techniques and approximations necessary to quantitatively solve quantum mechanics equations for multi-electron systems, from polyelectronic atoms and molecules to solids. This is necessary to understand most of the electronic properties of solids (and to predict them for new materials), such as their magnetic tendency, their capacity to carry electric current or heat, and for example, what makes diamond an insulator, silicium a semiconductor, and aluminum a metal. • Systems of identical particles, multiparticle wave function, Slater determinant • Helium atom and multi-electron atoms in mean-field; Thomas-Fermi method; exchange energy and Hund rules; Hartree-Fock (HF) method • Density functional theory (DFT) • Numerical methods for solving HF and DFT equations • "Beyond-Hartree-Fock" techniques

Bibliographic Resources	• Bransden, B.H. and Joachain, C. J. *Physics of Atoms and Molecules* • N.W. Ashcroft and N. D. Mermin *Physique des Solides*, EDP Sciences • Martin, R. M. *Electronic Structure*

Evaluation	Final eam with ACMP-MTCM (oral or written, 2 to 3 hours, depending on the number of students enrolled)

UE Waves and Light-Matter Interactions

SEMESTER 10

UE WLMI

30h - 3 ECTS

Description

The course Waves in Complex Media (WLMI-WCM) addresses the physical foundations of wave propagation in disordered media (ex: soft matter, biological tissues) and introduces imaging techniques using measurements of mean intensity (diffusive transport) or speckle imaging (interferences). Although the main theme of the course is light propagation and scattering, the generalized nature of the concepts and methods make them applicable to acoustics and electronic transport.

The course Light-Matter Interactions (WLMI-QLM) provides students with an introduction to the basic principles of and contemporary applications for quantum optics. Relying on a microscopic description of the light-matter interaction, the course will present the different semi-classical or quantum states of radiation, the interaction processes necessary for their emergence, as well as their applications in metrology, imaging, and quantum simulation.

Semester	Program	
S10	WLMI-WCM	Waves in Complex Media
	WLMI-QLM	Light-Matter Interactions

Prerequisites

Wave propagation and light-matter interaction (courses S6-PG-OEM, S7-OA, S8-OPT)

Related classes

The course WLMI-WCM is interdisciplinary by its very nature. Although the course is structured around propagation and optical imaging through scattering media (S8-OPT), the link with electromagnetic propagation is continuously established in other frequency fields (S6-PG-OEM), acoustic propagation (S7-OA), and electronic transport (S7-PS). The statistical approach used to model waves in random media is related to the course applied statistical physics (S6-PSA). The course naturally follows on to applications for soft matter characterization (dynamic light scattering) and biomedical imaging.

The course WLMI-QLM complements other courses given in S10. In particular, we will make connections with topics covered in courses on quantum engineering (S10-QRE) and statistical physics of complex systems (S10-SPCS).

UE Validation

Weighted average: WLMI-WCM 50%, WLMI-QLM 50%

Targeted skills

WLMI-WCM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	III						III							
LO2.	Exam	III						III							
LO3.	Exam	III	III					III							
LO4.	Exam	III	III					III							
LO5.	Exam	III										III			
LO6.	Exam	III								III		III	III		
LO7.	Exam						II								
WLMI-QLM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	III						III							
LO2.	Exam	III						III							
LO3.	Exam	III						III							
LO4.	Exam	III						III							
LO5.	Exam	III						III							
LO6.	Exam	III	III									III	III		
LO7.	Exam	III	III									III	III		
LO8.	Exam						II								

Required / Recommended for the following masters programs

Recommended UE for M2 LM (Laser, Optics, Matter), LUMI (Light, Matter, Interactions), and ICFP (Condensed Matter or Quantum Physics specialization)

S10 – WLMI – WCM | Waves in Complex Media

Supervisor: Rémi Carminati

| Course: 15h | Course language: |

Objectives / Targeted Skills

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

LO1. analyze scattering regimes and identify the appropriate model to describe a given problem;
LO2. describe and predict the behavior of waves in complex media described statistically;
LO3. apply technical calculus methods to solve simple problems and calculate orders of magnitude;
LO4. interpret an observation and quantitatively analyze a measurement in a real case;
LO5. analyze a complex problem connecting wave physics to other topics;
LO6. broadly design an optical detection or imaging system through (or in) a highly scattering medium;
LO7. use scientific and technical English vocabulary.

Contents	Light scattering by particles
	    Scattering, cross-sections, optical theorem
	    Specific cases (Rayleigh scattering, Mie scattering)
	
	Multiple scattering
	    Statistical approach, mean field and fluctuating field
	    Ballistic and scattered intensity, length scales
	    Homogenization (finely divided media)
	
	Intensity transport
	    Radiative transfer equation
	    Scattering approximation
	    Scattering behaviors (example applications)
	
	Speckle
	    Intensity statistics (Rayleigh)
	    Dynamic light scattering: simple scattering and multiple scattering
	    Example applications in imaging (soft matter, living organisms)
	    Second order statistics; spatial and angular correlations

Bibliographic Resources	• Course handouts (in English) • C.F. Bohren and D.R. Huffman, *Absorption and Scattering of Light by Small Particles* (Wiley, 1983) • E. Akkermans and G. Montambaux, *Mesoscopic Physics of Electrons and Photons* (Cambridge University Press, 2007)

Evaluation	Individual work on an excerpt from a scientific article (addressing a topic in the course) accompanied by questions intended to assess comprehension and calculations of orders of magnitude. Individual paper written within three weeks of submitting the topic.

S10 – WLMI – QLM	Light-Matter Interactions

Supervisor: Arthur Goetschy

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. identify physics situations that require a quantum description of radiation;
LO2. analyze sources of decoherence in light-matter interaction and identify factors to modify to solve it;
LO3. identify sources of non-linearity in light-matter interaction and explain their usefulness in quantum optics;
LO4. manipulate fundamental concepts involved in generating compressed states, Fock states, and entangled states;
LO5. justify the usefulness of quantum states of radiation in metrology, imaging, and quantum simulation;
LO6. use their knowledge to analyze the operation and particularities of quantum optical devices;
LO7. use their knowledge to solve a complex and / or cross-disciplinary problem;
LO8. use scientific and technical English vocabulary.

Contents	
	The course contains three sections: 1) Light-atom interactions • Polarizability and cross-section • Atoms in cavities • Environment and decoherence • Microscopic theory of lasers 2) Quantum optics and applications • Foundational experiments • Quantification of the electromagnetic field • Fluctuations in vacuum, spontaneous emission, Casimir force • Squeezing and entanglement • Quantum simulators 3) Quantum optics and condensed matter • Coherent photon-phonon interaction • Photon-photon interaction, superfluid light

Bibliographic Resources	
	• V. Wogel and D. G. Welsch, *Quantum Optics*, Wiley (2006) • S. Haroche and J.-M. Raimond, *Exploring the quantum*, Oxford University Press (2006)

Evaluation	Analysis of scientific articles

UE Statistical Physics of Complex Systems

27h - 3 ECTS

SEMESTER 10

UE SPCS

Description

This module introduces the basic concepts of equilibrium and out-of-equilibrium statistical physics.

Semester	Program	
S10	SPCS-SPCS	Statistical Physics of Complex Systems

Prerequisites

Undergraduate physics and mathematics

UE Validation

SPCS-SPCS average

Targeted skills

SPCS-SPCS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III	III					III		III		II			III
LO2.	Ex.	III	III					III		III		II			II
LO3.	Ex.	III	III					III		III		II			II
LO4.	Ex.	III	III					III		III		II			II
LO5.	Ex.	II	II					III		III		II			II
LO6.	Ex.						II								

S10 – SPCS – SPCS	Key Concepts in Statistical Physics

Supervisors: Olivier Dauchot, Vincent Démery

| Course: 30h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. use their knowledge to solve a complex and / or cross-disciplinary problem;
- LO2. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO3. formulate a statistical physics model and propose methods of resolution, specifying the underlying approximations;
- LO4. analyze the phenomenology of an equilibrium phase transition, identify the type of transition, and deduce the necessary approaches to a more quantitative description;
- LO5. describe and analyze an out-of-equilibrium stochastic process using a master equation or a Langevin equation;
- LO6. use scientific and technical English vocabulary.

Contents	• Equilibrium Physical Statistics • Foundations, microcanonical, and canonical ensembles, Legendre Transform • Large deviation function of a quantity conserved or not • Phase Transition: Landau / Widom / Introduction to RG • Out-of-Equilibrium Statistical Physics • Master equation • Langevin equation • Fokker-Planck equation • Fluids in and out of equilibrium • Fluids in equilibrium • Introduction to glass • Introduction to active fluids

Bibliographic Resources	Course notes

Evaluation	In-class exam without supporting materials, evaluation of student comprehension

# UE Physics of Signals	SEMESTER 10
33h - 3 ECTS	UE PS

Description

The objectives of the course Physics of Measurement (PS-PM) are to provide students with the basics of signal filtering techniques, to demonstrate the importance of FFT in linear problems, and to present nonlinear effects and their characteristics.

The main purpose of the course Physical Coding (PS-PE) is to present the basic elements necessary for the transmission of information by electromagnetic waves, in particular by Hertzian waves. The concepts of physical coding, modulation and demodulation, as well as the notion of noise in the transmission channel and its influence on the transport of information, are presented. An initial approach to the structure of transmission and reception systems is also discussed.

Semester	Program	
S10	PS-PM	Physics of Measurement
	PS-PE	Physics of Telecommunication

Prerequisites

Classical mechanics (S5-SIM1 and S8-SIM2), electromagnetism (S6-PG-OEM), signal processing (S5-E2S-SLS)

UE Validation

Weighted average: PS-PM 50%, PS-PE 50%

Targeted skills

PS-PM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	exam	III	III					III		III			II		III
LO2.	exam	III	III					III		III					
LO3.	exam	III	III					III	III	III					
LO4.	exam	III	III	III				III		III					
LO5.	exam	III	III					III	III	III			II		III
LO6.	exam	III	III	III				III	III	III			II		III
LO7.	exam						II								
PS-PT	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	exam	III	II	II				III		III					III
LO2.	exam	III	II	II				III		III					III
LO3.	exam	III	II	II				III		III			II		III
LO4.	exam	III	II	II				III		III			II		III
LO5.	exam	III	II	III				III		III	II	I	II	II	III
LO6.	exam						II								

S10 – PS – PM | Physics of Measurement

Supervisor: Vincent Croquette

| Course: 18h | Course language: |

Objectives / Targeted Skills

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

LO1. predict a non-linear system's ability to become chaotic and therefore unpredictable by analyzing the conditions that lead to this state;
LO2. justify the idea that the Fourier basis is ideal for linear systems, Fourier modes being the solutions to the differential equations that govern them;
LO3. use the FFT tool and identify the importance of phase and possible operations in Fourier space;
LO4. choose the conditions for good digitization and identify the artifacts that characterize aliasing;
LO5. evaluate the optical resolution limits of a microscope and choose the conditions to overcome them;
LO6. Identify different visible noise in a system, predict the system's thermodynamic noise, and suggest ways to minimize it;
LO7. use scientific and technical English vocabulary.

Contents

1. Non-linear systems and introduction to chaos
    - Definition of regular and chaotic systems
    - Integrability conditions for non-linear systems
    - Characterization of regular and chaotic trajectories
    - Chaotic behavior of dissipative systems
    - Transition to chaos
2. 1D Fourier Transform
    - Fourier: the ideal foundation for linear equations
    - Discrete transform; the 2N FFT algorithm
    - FFT artifacts
    - Filtering, correlation, convolution, applications
    - Necessity of filtering before digitalization, aliasing (example of a camera)
3. 2D Fourier Transform
    - Convolution and deconvolution; example: sharpening a blurry photo
    - Reconstructing an image using the Fourier space; image of an X-ray; tomography
4. New super-resolution optical microscopy
    - Understanding the resolution of a microscope
    - Techniques: STED, PALM / STORM and structured illumination
5. Physics of noise
    - The different kinds of noise and their physical origins
    - Resistance noise, shot noise, effects of temperature
    - Discussion on the fluctuation-dissipation theorem
    - Adaptation of an amplifier in a measurement chain
    - Spectral characteristics of physical noises; spectral density of noise; noise in 1 / f
    - Variation of these noises according to temperature
    - Adaptation of an amplifier in a measurement chain

Bibliographic Resources	The course will draw on a self-contained handout (in French and English)

Evaluation	Two-hour written exam

S10 – PS – PE Physics of Telecommunication

Supervisor: Emmanuel Géron

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. move from analog information to its digital counterpart, and characterize it in a relevant way;
LO2. clearly identify the role of logical coding and physical coding in the transportation of digital information;
LO3. adapt the physical coding of information to the transport medium used to optimize flow performance in the presence of noise;
LO4. appropriate the specificities of any communication system based on the concepts presented in class;
LO5. analyze the functional block diagram of any data transmission system and give a reasoned choice for its use or acquisition for professional purposes in the context of engineering work;
LO6. use scientific and technical English vocabulary.

Contents	• Physical coding of data with some refreshers about digital processing of an initially analog signal • From classic analogous modulations to digital modulations • Advanced digital modulation with spread spectrum and high speed • Factors limiting data output in a propagation channel • The vital role of signal filtering in emission and reception • Multiplexing techniques to effectively share the transport medium between multiple simultaneous communications • Architecture of radiofrequency emission and reception systems

Bibliographic Resources	The course is based on a complete, self-contained handout (in French and English)

Evaluation	Two-hour written exam

UE Statistical Learning

30h - 3 ECTS

SEMESTER 10

UE SL

Description

The objective of the course Statistics and Modeling (SL-SM) is to provide students with methods for adjusting and validating a linear model according to its parameters, as well as those adapted to nonlinear models, whether physical or behavioral models (such as neural networks), frequently used by engineers and researchers.

The purpose of the course Machine Learning (SL-ML) is to introduce students to theoretical and algorithmic notions to help them understand the current enthusiasm for statistical learning relying on big data. The course will refer to concepts from the course Applied Statistical Physics (S6-PSA) and will present applications in different fields, including biology; no prerequisite knowledge is required.

Semester	Program	
S10	SL-SM	Statistics and Modeling
	SL-ML	Machine Learning

Prerequisites

Statistics (S7-MMN2-STAP), linear algebra

UE Validation

Weighted average: SL-SM 50%, SL-ML 50%

Targeted skills

SL-SM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., report	III	III						III			III			
LO2.	Ex., report	III	III	III					III			III			
LO3.	Ex., report	III	III						II			II			
LO4.	Ex., report	III	III						III			III			
LO5.	Ex., report	III	III						III			III			
LO6.	Report						II								
SL-ML	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	SL-ML	III	III						III						III
LO2.	Ex., report	III	III	II		II			III						III
LO3.	Ex., report	III	III						III			II	II		III
LO4.	Ex., report	III	III						III			III	II		III
LO5.	Ex., report	II	II					I	II			II	II	II	III
LO6.	Report						II								

S10 – SL – SM	Statistics and Modeling

Supervisor: Isabelle Rivals

| Course: 15h | Course language: |

Objectives / Targeted Skills

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

LO1. build and statistically characterize simple and multiple linear regression models, especially for concrete problems that engineers face, such as sensor calibration;
LO2. develop and analyze an experiment design using a simple spreadsheet if the plan is complete, or using statistical software if it is complex, so as to combine model parsimony and quality;
LO3. analyze results concerning models nonlinear with respect to their parameters such as non-linear physical models with a limited number of parameters and neural networks with a layer of hidden neurons;
LO4. summarize, model and interpret experimental results;
LO5. take a critical approach to using data modeling and analysis programs.
LO6. use scientific and technical English vocabulary.

Contents	1. Linear modeling • Linear regression and least squares estimation • Interval estimation and hypothesis testing • Confidence intervals for regression and prediction intervals • Concepts related to the design of experiments • Model construction and validation: stepwise regression, residual and leverage-based diagnostics, test for lack of fit, cross-validation 2. Nonlinear modeling • Non-linear regression and algorithms for non-linear least-squares problems • Linearization of the least-squares estimator • Non-linear generalization of interval estimation, hypothesis testing, and model construction and validation

Bibliographic Resources	Handouts

Evaluation	Written exam (1 hour, 75%), practical session report (25%)

S10 – SL – ML	Modeling and Classifying using Machine Learning Techniques

Supervisor: Yacine Oussar

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. Master the fundamentals and terminology of machine learning techniques for dynamic modeling and classification
LO2. Determine the relevance of the implementation of machine learning methods for a given problem
LO3. Distinguish between regression-based and classification-based solutions
LO4. Take advantage of existing knowledge-based modeling to design a semi-physical model from data
LO5. Design and configure a support vector machine to maximize the generalization capabilities
LO6. Master the implementation of classification methods for multiclass problems

Contents	1-Dynamic modeling from data • Introduction to dynamic modeling from data: hypothesis models, state-space representation, input-output representation. • Feedforward Neural Nets and Recurrent Neural Nets for dynamic modeling • Training algorithms for recurrent Neural Nets • Application in the automotive field • Introduction to semi-physical modeling (also known as gray-box modeling) • Application in physical chemistry 2-Classification with Neural Nets and SVM • Neural Nets for classification • Support Vector Machines for classification (SVM) • Application to indoor localization • Support Vector Machines for regression (SVR) • LS-SVM and their properties for validating models • Application to Electrical Capacitive Tomography (ECT)

Bibliographic Resources	Handouts

Evaluation	Written exam 1 hour.

UE Introduction to Deep Learning

SEMESTER 10

30h - 3 ECTS

UE IDL

Description

In recent years, deep learning has renewed perspectives and practices in the field of data sciences. The objective of this course is to provide engineering students with theoretical and practical tools so they can integrate this type of approach into their practice.

Semester	Program	
S10	IDL-IDL	Introduction to Deep Learning

Prerequisites

Mathematical Methods I (S5-MMN1-MATH1)

Related classes

This UE complements courses in the UE Statistical Learning (S10-SL)

UE Validation

IDL-IDL average

Targeted skills

IDL-IDL	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	R, POF	I								I					
LO2.	R, POF	I								I					
LO3.	R, POF		II									II			
LO4.	R, POF		II									II			
LO5.	R, POF		III	I									I		III
LO6.	R, POF		III	I											III
LO7.	R						II								

R: report ; POF: oral presentation in French

S10 – IDL – IDL	Introduction to Deep Learning

Supervisor: Alexandre Allauzen

| Course: 30h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. identify the steps essential to learning and inference with artificial neural networks;
- LO2. identify the major types of network architecture and define the types of problems to which they apply;
- LO3. identify difficulties related to deep learning and identify methods for resolving them;
- LO4. apply major types of network architecture and build the appropriate software framework;
- LO5. design a deep neural network suitable for data and a prediction task;
- LO6. evaluate the results;
- LO7. use scientific and technical English vocabulary.

Contents	Classes will address the following themes: • concepts related to artificial neural networks (from logistic regression to multi-layer networks); • network-supervised learning methods (objective functions and stochastic gradient descent optimization); • architectures for modeling complex data such as sequences and images (convolutional and recurrent networks, transformers); • practice with real data and tasks using PyTorch.

Bibliographic Resources	*Deep Learning* by Ian Goodfellow, Yoshua Bengio and LOron Courville, MIT Press, 2016.

Evaluation	Report and oral presentation in French

UE Advanced Programming
Programmation Avancée

UE Advanced Programming *Programmation Avancée*	SEMESTER 10
30h - 3 ECTS	UE PrA

Description
The objective of this course is to study several aspects of advanced programming with the C / C++ language in a unix environment.
The whole course will be based on lab experimentation on computers, with a direct application of the concepts.

Semestre	Programme	
S10	PrA-PrA	Advanced Programming

Pre-requisite
A good knowledge of programming techniques in Unix environments, knowledge of the C language or at least a low level language will be a plus.

UE Validation
Travaux Pratiques

Targeted skills

AP-AP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	TP	III	III					III	III	III					
LO2.	TP	III	III					III	III	III					
LO3.	TP	III	III					III	II	II					
LO4.	TP	III	III					III	II	II					
LO5.	TP	III	III					III	II	II					

S10 – AP – AP	Advanced Programming

Supervisor : Didier Cassereau

| Lab work : 30h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. design a software architecture adapted to a specific problem
LO2. implement the corresponding software, test it and make it behave as defined in the initial specifications
LO3. use basic and system tools that are required for the practical implementation of the software architecture
LO4. use the multiple processors or processing cores of the machines and manage parallel tasks
LO5. assemble these different elements to develop a numerical simulation software

Contents	The main key points will be : • multithreading (based on POSIX threads) • system programming, particularly the communication sockets between processes • some elements of the C++ language: classes, constructors and destructor, operator overloading, inheritance… • practical implementation of a client / server architecture to crypt / decrypt data • practical implementation of simulation codes bases these different tools, particularly the parallel computing

Evaluation	Programming

UE Advanced Fluid Mechanics

30h - 3 ECTS

SEMESTER 10

UE AFM

Description

The course Microfluidics (AFM-MIC) focuses on the mechanics of fluids with low Reynolds number in confined systems where interfaces play a major role. The properties of mono-phasic and bi-phasic flows, and dispersions, colloidal or otherwise, are presented. The possibility of modifying these flows by controlling pressure, temperature, or electromagnetic fields is also discussed. One of the objectives of this course is to bridge the gap between microfabrication capabilities and the basic and applied sciences, which, together, lead to innovations in areas such as biotechnology or chemistry.

The course Transport Physics (AFM-PT) gives students an introduction to the physics of mass and heat transport. It will answer a variety of questions such as: Why does my coffee cool much faster than the sugar dissolves in the cup? How long can I stay at the summit of Everest without gloves? How can I design a microfluidic chip to efficiently capture biomolecules? How many showers can I take each day with a 10-square-meter solar water heater? What do cetaceans and heat exchangers have in common? Why is mixing within turbulent flows so effective?

The course Hydrodynamic Instabilities (AFM-HI) introduces students to the study of the stability of certain flows. After an introduction to the general concepts of stability studies, students will focus on instabilities arising in a fluid initially at rest: in particular, they will address the so-called Rayleigh-Taylor instabilities related to gravity and the Rayleigh-Bénard instability, observed in a fluid heated from below. Then, they will describe the instabilities of parallel flows, from which large structures can emerge (Kelvin-Helmholtz). Finally, they will take a brief look at homogeneous isotropic turbulence (Kolmogorov Theory) from a phenomenological standpoint.

Semester	Program	
S10	AFM-MIC	Microfluidics
	AFM-PT	Physics of Transport
	AFM-HI	Hydrodynamic Instabilities

Prerequisites

A basic understanding of fluid mechanics (S8-SMS2-MF) and thermodynamics (S6-PSA)

UE Validation

Weighted average: AFM-MIC 30%, AFM-PT 40%, AFM-HI 30%

Targeted skills

AFM-MIC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	III	III							III					
LO2.	Exam	II						II							

LO3.	Exam	II						II							
LO4.	Exam	II						II							
LO5.	Exam						II								
AFM-PT	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	II	II					II							
LO2.	Exam	II	II					II							
LO3.	Exam	III						III							
LO4.	Exam	III						III							
LO5.	Exam	III						III							
LO6.	Exam						II								
AFM-HI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	II						II							
LO2.	Exam	III						III							
LO3.	Exam	II						II							
LO4.	Exam	III						III							
LO5.	Exam						II								

S10 – AFM – MIC	Microfluidics

Supervisor: Nicolas Brémond

| Course: 8h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. identify different microfabrication techniques and determine the most relevant for the intended application;
LO2. solve problems with a low Reynolds number;
LO3. solve problems with a low Reynolds number presenting interface fluids;
LO4. solve electrohydrodynamic problems;
LO5. use scientific and technical English vocabulary.

Contents	• Microfabrication techniques • Monophasic flows • Multiphasic flows • Electrohydrodynamics • Microfluidics and physical chemistry • Microfluidics in biology

Bibliographic Resources	• Petit, L., Hulin, J. P., & Guyon, É. *Hydrodynamique physique*. EDP Sciences. • Tabeling, P. *Introduction à la microfluidique*. Belin. • Bruus, H. *Theoretical microfluidics*. Oxford University Press.

Evaluation	Written exam

S10 – AFM – PT | Physics of Transport

Supervisor: Marc Fermigier

| Course: 12h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. identify heat and mass exchange mechanisms in natural and industrial physical systems and in biological systems;
LO2. compare different modes of transport using dimensionless numbers;
LO3. model a diffusion-transport problem;
LO4. model a radiation-transport problem;
LO5. model a convection-transport problem;
LO6. use scientific and technical English vocabulary.

Contents	• Local transport equations and global evaluations • Radiative heat transfer • Heat transfer through molecular diffusion • Laminar flow transfer; coupling of diffusion and advection; transport boundary layers • Thermal convection
Independent Study	The course is designed as an inverted class: course materials are given to students in advance. Time spent with students is used solely for solving problems.
Bibliographic Resources	Course notes and descriptions of problems solved in class are available online. Bibliographic references: • Bird, Stewart, Lightfoot, *Transport Phenomena*, Wiley (1960). • F. Incropera, D. Dewitt, T. Bergman & A. Lavine, *Principles of heat and mass transfer*. Wiley (2013). • H.S. Carslaw, J.C. Jaeger, *Conduction of heat in solids*, Oxford Clarendon Press (1959). • B. Levich, *Physico-chemical hydrodynamics*, Prentice Hall (1962).
Evaluation	Written exam

S10 – AFM – HI | Hydrodynamic Instabilities

Supervisor: Laurent Duchemin

| Course: 10h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. identify instability mechanisms in a fluid at rest and in motion;
LO2. formulate a linear stability problem;
LO3. establish the dispersion relationship in a linear stability problem;
LO4. formulate a free-surface linear stability problem;
LO5. use scientific and technical English vocabulary.

Contents	• Phenomenological description of instabilities, scaling laws • Instabilities of fluids at rest • Dispersion relation • Non-viscous instability of parallel flows • Viscous instability of parallel flows • Scaling laws in turbulence

Bibliographic Resources	• Petit, L., Hulin, J. P., & Guyon, É. *Hydrodynamique physique*. EDP Sciences. • Charru, F. *Instabilités hydrodynamiques*, EDP Sciences.

Evaluation	Written exam

UE Magnetism and Superconductivity

30h - 3 ECTS

SEMESTER 10

UE MS

Description

Magnetism and superconductivity are two most famous macroscopic quantum phenomena. Boosted by the hope of applications in spintronics and quantum computing, the corresponding research fields are currently strongly expanding. The knowledge of the quantum mechanical forces that operate in the Matter on microscopic scale is crucial to understand and control macroscopic magnetic and superconducting properties of materials. The purpose of this UE is to provide the students with the necessary tools to understand the microscopic origins of these ordered phases, to expand this knowledge to nano- and macro-scale, and to bring them an overview of state-of-the art research and applications.

Semester	Program	
S10	MS-MFN	Magnetism: From fundamentals to applications at nanoscale
	MS-PFA	Superconductivity: Properties, fundamentals, applications

Prerequisites

Level M1 (first year of master's) in physics

UE Validation

Weighted average: MS-MFN 50%, MS-PFA 50%

Targeted skills

MS-HFA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Examen	III	III					III		II			II		II
LO2.	Examen	III						III	III	II					
LO3.	Examen	III						III		II					
LO4.	Examen	III	III					III	III	II			II		
LO5.	Examen						II								
MS-MFN	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Examen	III	III					III		II					
LO2.	Examen	III	III					III		II			II		
LO3.	Examen	III	III					III	III	II			II		
LO4.	Examen	III	III					III	III	III			II		II
LO5.	Examen	III	III					III		II			II		II
LO6.	Examen						II								

S10 – MS – MFN	Magnetism: From fundamental to applications at nanoscale

Supervisor: Sergio Vlaic

| Course: 15 h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO8. Model magnetic phenomena by connecting it to the microscopic processes of the quantum particles that comprise it;
LO9. Transfer the physical properties of macroscopic systems to low dimensional materials;
LO10. Validate a model by comparing predictions to experimental results and evaluate the limits of validity;
LO11. Identify the most suited experimental approach to address a specific technological challenge;
LO12. Use their knowledge to solve a complex and / or cross-disciplinary problem;
LO13. Use scientific and technical vocabulary in English.

Contents	This course addresses the quantum mechanical description of magnetic materials, from macroscopic solid systems to magnetic nanostructures. It starts with a fundamental description of magnetic interactions in simple systems, followed by the application of such interaction at the micro and nanoscale. Finally, this course presents an overview of some of the most technologically relevant contemporary research topics in magnetism. • Origin of magnetic moment, from classical to quantum description • Magnetic order of matter • Exchange interaction in simple systems • Itinerant and localized magnetism • Magnetic anisotropies • Experimental techniques for magnetic measurements • Superparamagnetism • Giant and tunneling magnetoresistance • Spin transfer torque • Magnetic impurities in supercondcutors for quantum computing

Bibliographic Resources	• Bransden, B.H. and Joachain, C. J. *Physics of Atoms and Molecules* • N.W. Ashcroft and N. D. Mermin *Physique des Solides*, EDP Sciences • Sthör, J. and Siegmann, H. C. *Magnetism, From Fundamentals to Nanoscale Dynamics*, Springer series in Solid-State Sciences

Evaluation	Final joint exam MS-MFN / PFA (oral or written, 2 to 3 hours, depending on the number of students enrolled)

S10 – MS – PFA	Superconductivity: Properties, fundamentals, applications

Supervisor: Dimitri Roditchev

| Course: 15 h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO6. use their knowledge to solve a complex and / or cross-disciplinary problem;
LO7. justify using a diverse range of advanced methods in Quantum Physics of Condensed Matter;
LO8. connect a macroscopic phenomenon to microscopic processes;
LO9. validate a model by comparing predictions to experiment results and evaluate the limits of validity;
LO10. use scientific and technical English vocabulary.

Contents	This course overviews the essential phenomena related to superconductivity, brings macroscopic and microscopic insights to them. In the final part, recent trends and challenges in superconductivity are discussed. • Discovery of superconductivity. Zero-resistivity, Meissner-Ochsenfeld effect. First experimental realizations, ideas, applications. TD considerations (entropy, specific heat). • London's local electrodynamics of superconductors. Penetration depth. Quantum generalization of London's theory. Flux quantization. • Ginzburg-Landau (GL) theory of phase transitions: general considerations, two GL equations. • Coherence length and penetration depth of superconductivity. Proximity effect at S-N interface. Two kinds of superconductors. • Vortex lattice. Vortex matter in nano-structured superconductors. • Weak Superconductivity: stationary and RF Josephson effect (SIS, SNS), Josephson effect-based devices (DC-SQUID). • Microscopic picture of superconductivity. Instability of the Fermi sea. Electron-phonon interaction. Ground state and elementary excitations. Superconducting gap, tunneling phenomena. • Non-conventional, multi-gap and magnetic superconductors.

Bibliographic Resources	• V.V. Schmidt: *The Physics of Superconductors (Introduction to Fundamentals and Applications)* • P.G. de Gennes: *Superconductivity of Metals and Alloys* • James F. Annett : *Superconductivity, superfluids, and condensates* • Ph. Mangin, R. Kahn: *Superconductivity, An introduction* • Ch. Kittel: *Introduction to Solid State Physics* • A.V. Narlikar: *Small Superconductors*

Evaluation	Final joint exam MS-MFN / PFA (oral or written, 2 to 3 hours, depending on the number of students enrolled)

Specialization UEs in Chemistry

	Presential study	ECTS		Code	Supervisor
UE Analytical Chemistry	30	3			
Chemometrics	12		ANC	CHE	J. Vial
Bioanalytics, Miniaturization and LC / MS Coupling	18			BMMS	V. Pichon
UE Chimie Inorganique pour la Catalyse et l'Energie	30	3			
Electrochimie	15		ICCE	EC	F. Kanoufi
Chimie Inorganique et Catalyses	15			ICC	S. Norvez, C. Soulié-Ziakovic
UE Advanced Chemistry	30	3			
Synthesis of Inorganic and Hybrid Materials	14		AC	SIHM	V. Pimenta, S. Ithurria
Synthetic Tools for Materials Science	6			STMS	A. Guérinot, C. Meyer
Synthesis of Functional Materials*	8			FMS	V. Pimenta, S. Ithurria
Advanced Selective Organic Synthesis*	12			ASOS	A. Guérinot, C. Meyer
** one module of your choice*					
UE Synthetic Chemistry and Applications	33	3			
Polymer Chemistry and Applications	15		SCA	PCA	R. Nicolaÿ
Synthetic Methods in Molecular Chemistry	18			SMMC	A. Guérinot, C. Meyer

UE Analytical Chemistry

30h - 3 ECTS

SEMESTER 10

UE ANC

Description

This purpose of this UE is to provide students with advanced concepts in analytical chemistry, particularly in the field of liquid chromatography and its use with mass spectrometry, alternative or complementary methods using biological or biomimetic tools, miniaturization of analytical tools, and chemometrics.

Bioanalysis can be defined as the analysis of compounds (drugs, doping agents, pollutants, etc.) in biological samples (biological fluids, tissues, etc.), or a field in which the coupling of liquid chromatography with mass spectrometry (LC/MS) is now essential. Bioanalysis can also be used to describe any analytical method based on the use of biological tools (antibodies, DNA strands, etc.) to improve the potential of conventional analytical approaches.

The course Bioanalytics and Miniaturization (ANC-BMMS) presents recent developments in chromatography and related techniques to improve their separation power and evolve towards ultra-fast analyses with high separation power. High-pressure and multidimensional chromatography, LC/MS coupling, selective biological and biomimetic tools for sample processing, and bioassays applied to the analysis of trace compounds in complex samples will be addressed. Emphasis will also be placed on the miniaturization of these analytical devices for lab-on-a-chip development.

The course Chemometrics (ANC-CHE) aims to give students the mathematical and statistical tools necessary to rationally construct experiments and achieve optimal use of the results. Students will also be exposed to the notion of uncertainty and trained in the tools used to identify and quantify the sources of variability in a process or method. Calibration issues will also be addressed from the user's point of view. Particular attention is paid to the relationships between statistical findings, their physico-chemical interpretation, and the practical consequences that arise from them.

Semester	Program	
S10	ANC-BMMS	Bioanalytics, Miniaturization and LC/MS Coupling
	ANC-CHE	Chemometrics

Prerequisites

Applied Statistics (S7-MMN2-STAP), Analytical Sciences (S8-CH2-SAN)

UE Validation

Weighted average: ANC-BMMS 50%, ANC-CHE 50%

Targeted skills

ANC-BMMS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam	I						I							
LO2.	Exam	I						I							
LO3.	Exam	II	II					III		III					
LO4.	Exam	III	III												
LO5.	Exam	III	III												
LO6.	Exam	III						III		III					
LO7.	Exam	III	III					III		III					
LO8.	Exam						II								

ANC-CHE	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exam		I					I							
LO2.	Exam		II					II							
LO3.	Exam		I					I							
LO4.	Exam	III	III					III		III					
LO5.	Exam	II	II					II							
LO6.	Exam	II	II					II							
LO7.	Exam	II	II	II				II							
LO8.	Exam		II					II							
LO9.	Exam	II													
LO10.	Exam		III												
LO11.	Exam		II												
LO12.	Exam		II												
LO13.	Exam						II								

S10 – ANC – BMMS	Bioanalytics, Miniaturization, and LC / MS Coupling

Supervisor: Valérie Pichon

Teaching staff: Valérie Pichon and Christophe Chendo

| Course: 18h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. list and describe the different analytical techniques and sample preparation techniques commonly used in bioanalysis;
LO2. cite the constituent elements of a mass spectrometer and their main characteristics, limitations, and applications;
LO3. discuss the advantages and constraints related to miniaturization of analytical systems and sample processing, and their integration in chips;
LO4. use theoretical knowledge to justify behaviors observed in experimental conditions;
LO5. develop the most appropriate bioanalytical approach to analyzing desired molecule characteristics and / or the target matrix;
LO6. use their knowledge to deliver a critical analysis of results presented in a publication;
LO7. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
LO8. use scientific and technical English vocabulary.

<table>
<tr><td>Contents</td><td>The following topics will be addressed:
(i) Analytical approaches leading to increases in resolution, such as multi-dimensional chromatographic techniques that combine several separation systems that must be made compatible, or the coupling of liquid chromatography with mass spectrometry.
(ii) Highly selective approaches using biological tools or biomimetic molecular recognition used in both sample processing and separation techniques, but also in developing bioassays applicable to analyzing traces in complex samples.
(iii) The miniaturization of these analytical devices, particularly by presenting different systems on chips, ultimately resulting in the concept of a lab-on-a-chip (a concept known as μ TAS, micro Total Analytical System).

Course
1. Choosing the biological matrix
2. Analytical methods
• Review of liquid and gas chromatography
• New trends: fast or multidimensional chromatographic analyses
3. Coupling liquid chromatography with mass spectrometry (LC / MS)
• Source types (EI, ESI, APCI, APPI) and their uses
• Types of analyzers (high and low resolution and their applications)
• Constraints related to the implementation of coupling
4. Preparing a sample for analyzing trace compounds
• Liquid samples: solvent extraction, solid phase extraction, selective approaches to eliminating macromolecules, adsorbents based on</td></tr>
</table>

	molecular recognition mechanisms (immuno-, oligo-adsorbents, molecular fingerprint polymers) • Solid samples: extraction by pressurized liquid, in microwave fields • Methods of trapping volatile compounds 5. Bioassays • Based on structural recognition • Based on the action mode involving molecular receptors or enzymes 6. Miniaturization • Objectives and basic concepts • Miniaturized separation methods: nanoLC, CE, and GC on a chip • Miniaturized tools for preparing samples, coupling with separation devices • Chip-based bioassays

Bibliographic Resources	Course handouts

Evaluation	Written exam (2 hours): questions about articles handed out one to two weeks prior to the exam

S10 – ANC – CHE	Chemometrics

Supervisor: Jérôme Vial

| Course: 12h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. identify the factors responsible for a significant dispersion in results;
- LO2. calculate this contribution;
- LO3. interpret the results of a design of experiments;
- LO4. design the best tests to be carried out in the framework of experimental investigations;
- LO5. establish the appropriate calibration model for a given problem and list its possibilities and limitations;
- LO6. carry out estimation by interval of a content based on a calibration;
- LO7. apply the concepts of repeatability and reproducibility adequately;
- LO8. build a strategy to reduce the impact of influent factors on the quality of the results;
- LO9. use their knowledge to evaluate a method's performance and validate it;
- LO10. identify and autonomously carry out the different steps of a method with a view to optimization;
- LO11. take a critical approach to using data analysis programs;
- LO12. identify sources of error to calculate uncertainty in experiment results;
- LO13. use scientific and technical English vocabulary.

Contents	1. One-way ANOVA (Analysis of Variance) • Principle and usefulness • Statistical tests • ANOVA table and interpretation • Case studies 2. Linear regression • Principle and usefulness • Regression statistics • Confidence and prediction hyperboles • Lack of fit • Case studies 3. Experiment plans • Principle and usefulness • 2^n factorial designs • Significance of effects • 2^{n-p} fractional factorial designs and screening designs • Response surface designs

Bibliographic Resources	Course handouts

Evaluation	One hour and a half written exam

UE Inorganic Chemistry of Catalysis and Energy

30h - 3 ECTS

SEMESTER 10

UE ICCE

Description

Electrochemistry lies at the heart of societal issues, such as new energies (for the production and storage of electrical energy from chemical reactions), nanosciences, catalysis, and biology. It makes it possible to measure and govern charge transfer reactions using a wide variety of concepts including thermodynamics, kinetics, transport processes, electricity, etc.
In the Electrochemistry module (ICCE-EC), students will work with current research applications and problems to acquire the theoretical bases and know-how that will allow them to understand any question related to electrochemistry.

More than 80% of manufacturing processes include at least one catalyzed reaction. In general catalysis leads to cost reduction (energy, separation, reprocessing, etc.) and limited use of toxic or dangerous materials. The economic and ecological stakes are obvious. To help students understand the phenomena involved, the course Inorganic Chemistry and Catalysis (ICCE-ICC) presents different types of catalysis through the study of major industrial processes and fundamental life cycles.
Problems related to the performance and optimization of a catalytic system, its cost, and its ecological impact, are highlighted and explained through a mechanistic kinetic approach.

Semester	Program	
S10	ICCE-EC	Electrochemistry
	ICCE-ICC	Inorganic Chemistry and Catalyses

Prerequisites

Nernst equation for redox systems; chemical kinetics; general concepts of analytical chemistry (S8-CH2-SAN), physical chemistry; mathematics (S5-MMN1-MATH1 and S7-MMN2-MATH2) and physics of matter transport (diffusion, differential equations); reactivity of inorganic and organometallic complexes (S8-CH2-CMI)

UE Validation

Weighted average: ICCE-EC 50%, ICCE-ICC 50%

Targeted skills

ICCE-EC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	TD, Exam	II						II		II					
LO2.	TD, Exam	II						II		II					
LO3.	TD, Exam	III						III		III					
LO4.	TD, Exam	III						III		III					
LO5.	TD, Exam	II						II		II					
LO6.	TD, Exam	II						II		II					
LO7.	TD, Exam						II								
ICCE-ICC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	LO	III						III		III					
LO2.	LO	III						III		III					
LO3.	LO	III						III		II					
LO4.	LO	III						III		II					
LO5.	LO	III		II		II		III		III					
LO7.	LO						II								

TD: tutorial; LO: Article analysis

S10 – ICCE – EC	Electrochemistry

Supervisor: Frédéric Kanoufi

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. apply the Nernst equation to electrochemical systems and describe the difference between a system in equilibrium and a system subjected to an electric current;
- LO2. define the concepts of overvoltage and exchange current; read and understand a Tafel plot;
- LO3. predict the shape of the intensity-potential curve in the case of electrochemical processes controlled by the kinetics of charge transfer or by matter transport; describe the i-E curve in different examples of matter transport;
- LO4. analyze i-E curve shape changes for simple reaction mechanisms, particularly heterogeneous or homogeneous catalysis reactions;
- LO5. explain the importance of microelectrodes in analytical electrochemistry or for electrochemical imaging;
- LO6. explain the operation and operating properties (charge, f.e.m., power, energy) of batteries and fuel cells;
- LO7. use scientific and technical English vocabulary.

Contents	• Review of redox and the simplified approach to the intensity-potential curve • Energy storage: charge (Faraday's law); electromotive force (Nernst equation); power versus energy (Ragone plot); application for the study of batteries, their composition and predicted operation • Conversion of chemical energy into electrical energy: electrochemical kinetics (Butler-Volmer, Marcus) and the shape of i-E curves; exchange current (Tafel representation); application to (bio)fuel cells and electrocatalysis; application to corrosion; electrochemical supercapacitors (electrochemical double layer) • Molecular electrochemistry and reaction mechanisms; transport versus reaction (diffusion), formalism and i-E curve shapes; reaction mechanisms (how to estimate the kinetics of electron transfer, chemical reactions, and catalytic reactions using i-E curves) • Current trends in analytical electrochemistry; contribution of micro / nanoelectrodes; amperometric sensors based on catalytic reactions; local probes and electrochemical imagery • Electrical analogy: electrochemical impedance Tutorials Operation of a lead battery; corrosion; electrochemical catalysis for CO2 reduction Reactivity of a living cell by electrochemical microscopy

Bibliographic Resources	Course handouts

Evaluation	1 tutorial of choice 40% Written exam (1h to 1h30) 60%

S10 – ICCE – ICC	Inorganic Chemistry and Catalyses

Supervisors: Sophie Norvez, Corinne Soulié-Ziakovic

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. analyze catalytic and biocatalytic cycles with a critical eye;
LO2. propose a catalytic cycle by detailing the elementary actions of reaction mechanisms in organometallic complexes;
LO3. determine, analyze, and justify the kinetic quantities of catalytic and biocatalytic cycles (homogeneous and heterogeneous catalysis);
LO4. propose methods to determine the kinetic quantities of catalytic and biocatalytic cycles;
LO5. critically analyze an industrial process from an economic and environmental standpoint;
LO6. use scientific and technical English vocabulary.

Contents	1. Industrial catalyzes • Catalysis: basic concepts • Catalysis and main industrial processes • Mechanisms and kinetics of heterogeneous catalysis • Performance of a heterogeneous catalytic system 2. Biocatalyzes • Elements of the biosphere • Acid catalysis, zinc enzyme • Redox catalysis • Industrial processes using biocatalyzers

Bibliographic Resources	Course handouts, slides

Evaluation	Analysis of articles about homogenous / heterogenous catalysis (50%) and biocatalysis (50%)

UE Advanced Chemistry

SEMESTER 10

30h - 3 ECTS

UE AC

Description

The UE Advanced Chemistry includes a mandatory core curriculum (20h):

- The course Synthesis of Inorganic and Hybrid Materials (AC-SIHM, 14h) is designed for chemists who wish to develop a broader vision of the synthesis and characterization of functional inorganic and hybrid materials.
  The course is comprised of two parts: Crystallized Inorganic Materials and Crystallized Porous Materials (7 hours each). For both classes of materials, the synthesis methods and the challenges related to their characterization will be addressed, as well as their potential applications in various fields (health, energy, environment, optoelectronics).
- The course Synthetic Tools for the Science of Materials (AC-STMS, 6h), included in molecular chemistry training, aims to provide students with in-depth knowledge about certain classes of essential transformations in materials chemistry such as click reactions, reversible reactions for dynamic covalent chemistry, and some applications of cross-coupling catalyzed by transition metals.

Students may then choose one of the following modules:

- The course Synthesis of Functional Materials (AC-FMS, 8h, two blocks of 4-hour lab sessions) will deepen their knowledge of synthesis in functional materials and their properties, in particular the synthesis of semiconducting nano-crystals and porous hybrid networks.
- The course Advanced Selective Organic Synthesis (AC-ASOS, 12h) will deepen, more specifically, their knowledge of selective organic synthesis while introducing them to asymmetric synthesis (diastereoselective and enantioselective reactions) - two areas of crucial importance, especially in medicinal chemistry.

Semester	Program	
S10	AC-SIHM	Synthesis of Inorganic and Hybrid Materials
	AC-STMS	Synthetic Tools for Materials Science
	AC-FMS*	Synthesis of Functional Materials
	AC-ASOS*	Advanced Selective Organic Synthesis

* one module of your choice

Prerequisites

AC-SIHM: notions of structural order and solid-state chemistry (S7-MATC), notions of coordination chemistry (S8-CH2-CMI)

AC-STMS: basic understanding of organic chemistry (S5-CH1-CO)

AC-ASOS: reactivity profiles of major functional groups, classic transformations in organic synthesis (oxidation reactions, reduction and interconversion of functional groups), writing reaction mechanisms (S5-CH1-CO)

UE Validation

Weighted average: AC-SIHM 40% (20% porous + 20% inorganic crystallines), AC-STMS 20% and, according to student's choice, AC-FMS 40% ou AC-ASOS 40%

Targeted skills

AC-SIHM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	POF, MCQ	I	I			II		I		I			I		II
LO2.	POF, MCQ	II	II							II			I		
LO3.	POF, MCQ	III	II							III					
LO4.	POF, MCQ	III	III			I		I		III					
LO5.	POF, MCQ	II	III	II		II		I	I	II					I
LO6.	POF, MCQ	II	II		I	I	II	II	II	II	II	I	II		II
LO7.	POF, MCQ	II						II	I	I	III	III	II	I	I
LO8.	POF materials						II								
AC-STMS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	AD	II	II					II							
LO2.	AD	II	II					II		II					
LO3.	AD									III		III			III
LO4.	AD		III									III			III
LO5.	AD		III									III			III
LO6.	AD		III									III			III
LO7.	AD						II								
AC-FMS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	R	III	II			I		II	III	II	II	II	I		
LO2.	R	III	II					II	II	I	II	II	II	I	II
LO3.	R	III	III					III	III	III	II	II	III		
LO4.	R	III	III					III	II	III	II	II	III		
LO5.	R	III	III					III	II	III	II	II	III	I	II
LO6.	R	III	II			I		II	III	II	II	II	I		
LO7.	R						II								
AC-ASOS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	AD	III	III					III							
LO2.	AD	III	III					III		III					
LO3.	AD	III	III					III		III					
LO4.	AD	III	III					III		III				III	
LO5.	AD	III	III							III			III		
LO6.	AD		III									III			III
LO7.	AD		III									III			III
LO8.	AD						II								

POF: oral presentation in French, AD: document analysis, R: report

Required / Recommended for the Following Masters Programs

Master in Molecular Chemistry, Paris Centre, Materials Chemistry major (STMS)
Master in Molecular Chemistry, Paris Centre, Molecular Chemistry major (STMS, ASOS)

S10 – AC – SIHM | Inorganic and Hybrid Material Synthesis

Supervisors: Sandrine Ithurria, Vanessa Pereira Pimenta

Teaching staff: Sandrine Ithurria, Thomas Pons, Vanessa Pimenta, Christian Serre

| Course: 14h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. identify different classes of inorganic materials and crystalline hybrids;
LO2. describe the different synthesis modes of functional materials;
LO3. connect structural characteristics to the properties of materials;
LO4. discuss the characterization methods addressed;
LO5. consider the potential applications for crystalline functional materials;
LO6. analyze and identify key results from a collection of scientific publications;
LO7. explain concepts and ideas during a short presentation;
LO8. use scientific and technical English vocabulary.

Contents	1. Introduction to porous crystalline solids (zeolites, clays, LDH, MOFs, hybrid cages) 2. Synthesis and porosity modulation methods (exfoliation, composites, etc.) 3. The challenges of characterizing porous networks (BET, in-situ IR, solid-state NMR, MET, modeling) 4. Potential applications of porous solids (environment, energy, health) 5. Outlook: scaling, shaping, and industrialization (marketing, proven applications) 6. Introduction to advanced inorganic materials 7. Synthesis methods for inorganic materials 8. Characterization methods 9. Applications for advanced inorganic materials

Bibliographic Resources	Course slides Further study: F. Schüth, K. S. W. Sing, J. Weitkamp, *Handbook of Porous Solids*, Wiley Print ISBN:9783527302468 |Online ISBN:9783527618286 |DOI:10.1002/9783527618286

Evaluation	Crystalline inorganic materials: presentation (included in the 7h of class time, 50%) Inorganic and porous hybrid materials: MCQ (1h outside of class, 20%)

S10 – AC – STMS | Synthetic Tools for Materials Science

Supervisors: Amandine Guérinot, Christophe Meyer

| Course: 6h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. identify the different reactions involved in a synthesis process;
- LO2. analyze the multi-step synthesis process of a complex molecular structure;
- LO3. use and apply knowledge of molecular chemistry to materials science applications;
- LO4. identify the connection between properties at the macroscopic level and mechanisms at the molecular level;
- LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem
- LO6. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO7. use scientific and technical English vocabulary.

Contents	1. "Click" reactions (Diels-Alder and hetero Diels-Alder reactions, cycloaddition (3+2), thiol-ene reaction, Michael reaction) 2. Reactions used in dynamic covalent chemistry 3. Applications for transition-metal-catalyzed cross-coupling

Bibliographic Resources	Course handouts, cours.espci.fr

Evaluation	Exam with questions closed to the course

S10 – AC – FMS	Synthesis of Functional Materials

Supervisors Sandrine Ithurria, Vanessa Pereira Pimenta

Teaching staff: Sandrine Ithurria, Thomas Pons, Vanessa Pimenta, Christian Serre

| Lab: 8h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. prepare functional inorganic and hybrid materials;
LO2. discuss the synthesis methods used;
LO3. determine structural characteristics using analysis techniques;
LO4. interpret data sets and justify the results;
LO5. explain the relationship between the structure of materials and their properties;
LO6. use scientific and technical English vocabulary.

Contents	1. Semiconductor nanocrystal synthesis 2. Nanocrystal surface chemistry control 3. Study of optical properties (UV-Vis) 4. Synthesis of MOF-type porous hybrid networks 5. Adsorption properties 6. Structural characterization (DRX, IR)

Bibliographic Resources	Course handouts

Evaluation	Two written summaries (50 / 50)

S10 – AC – ASOS	Advanced Selective Organic Synthesis

Supervisors: Amandine Guérinot, Christophe Meyer

| Course: 12h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. identify the different reactions involved in a synthesis process;
- LO2. analyze the multi-step synthesis process of a complex molecular architecture;
- LO3. explain the stereoselective control involved in the different steps of a synthesis process;
- LO4. develop a synthesis design for a targeted molecule;
- LO5. analyze a publication describing the synthesis of a complex molecule and justify the strategies used;
- LO6. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
- LO7. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO8. use scientific and technical English vocabulary.

Contents	1. Principles of asymmetric synthesis 2. α-alkylation of carbonyl compounds 3. Asymmetric aldolization and allylation reactions 4. Enantioselective oxidation 5. Enantioselective reductions 6. Pericyclic reactions

Bibliographic Resources	Course handouts, cours.espci.fr

Evaluation	Homework including problems

UE Synthetic Chemistry and Applications

33h - 3 ECTS

SEMESTER 10

UE SCA

Description

The purpose of the course Chemistry of Polymers and Applications (SCA-PCA) is to introduce students to polymer applications by addressing both fundamental and application aspects. Particular emphasis is placed on the structure / property relationship and on designing complex macromolecular systems with a view to final targeted properties.
A wide range of fields are presented: porous polymer materials and their applications, molecular and macromolecular materials in organic electronics, dynamic covalent chemistry and its application for the design of polymer materials and formulations, the design and use of polymer nanoparticles in biomedical applications, olefin polymerization and catalysis, photopolymerization, and biopolymers.

The course Molecular Chemistry Synthesis Methods (SCA-SMMC) intends to show students that understanding the reactivity of organic compounds at the molecular level is essential to developing molecular architectures of diverse complexity, which can be applied to various fields (medicinal chemistry, agricultural chemistry, biology, materials science). The course will focus on the study of important chemoselective synthetic tools in organic chemistry and on fundamental transformations such as oxidation reactions, reduction reactions, functional group interconversion reactions, and reactions allowing the formation of carbon-carbon or carbon-heteroatom bonds. Applications in polymer chemistry, medicinal chemistry, and chemical biology will be presented.

Semester	Program	
S10	SCA-PCA	Polymer Chemistry and Applications
	SCA-SMMC	Synthetic Methods in Molecular Chemistry

Prerequisites

Basic knowledge of polymer chemistry and physical chemistry (S5-CH1-CP), organic chemistry (S5-CH1-CO), and inorganic chemistry (S8-CH2-CMI)
Students will need to know the reactivity profiles of the most important functional groups (alkenes, alkynes, carbonyl compounds, acid derivatives) and be able to write reasonable reaction mechanisms.

UE Validation

Weighted average: SCA-PCA 50%, SCA-SMMC 50%

Targeted skills

SCA-PCA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	P.R.	III	III					III		III					
LO2.	P.R.	III	III					III		III					
LO3.	P.R.	III	III					III		III		III			
LO4.	P.R.	III	III					III		III		III	III		III
LO5.	P.R.	III		III								III	III		III
LO6.	P.R.	III		III				III		III		III			III
LO7.	P.R.	III		III				III		III	III	III			III
LO8.	P.R.						II								
SCA-SMMC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	II	II					II							
LO2.	Ex.	II	II					II							
LO3.	Ex.	III	III					III		III				III	
LO4.	Ex.	III	III					III		III			III		
LO5.	Ex.									III		III			III
LO6.	Ex.		III									III			III
LO7.	Ex.		III									III			III
LO8.	Ex.						II								

P.R.: group research project; Ex.: exam

Required / Recommended for the Following Masters Programs

Master in Molecular Chemistry, Paris Centre, Molecular Chemistry major (SCA-SMMC)
Master in Chemistry, Paris Sorbonne University, Materials major (SCA-PCA)

S10 – SCA – PCA | Polymer Chemistry and Applications

Supervisor: Renaud Nicolaÿ

| Course: 15h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. use macromolecular synthesis tools to design complex functional polymers;
LO2. mobilize and apply knowledge acquired in molecular and macromolecular chemistry and physical chemistry to identify the relevant characterization techniques needed to solve the structure and physicochemical properties of polymers and polymeric materials;
LO3. mobilize and apply knowledge acquired in polymer chemistry and materials chemistry to connect the structure of a complex polymer or polymer system with its physicochemical and thermomechanical properties;
LO4. mobilize and apply knowledge acquired in polymer chemistry and polymerization processes to design polymer systems or materials with a set of predefined physicochemical and mechanical properties;
LO5. mobilize and apply knowledge acquired in macromolecular chemistry to various applications in organic electronics, structured porous materials, bio-sourced and / or recyclable materials, medicine and pharmacology, and smart coatings;
LO6. utilize their knowledge to solve a complex and / or cross-disciplinary problem in polymer physical chemistry;
LO7. work in a group to develop a research project in chemistry and polymer physical chemistry;
LO8. use scientific and technical English vocabulary.

Contents	• Porous polymer materials • Molecular and macromolecular materials for organic electronics • Dynamic covalent chemistry • Polymer nanoparticles for biomedical applications • Olefin polymerization and catalysis • Photopolymerization • Biopolymers

Bibliographic Resources	Handouts

Evaluation	Group research project

S10 – SCA – SMMC | Synthetic Methods in Molecular Chemistry

Supervisors: Amandine Guérinot, Christophe Meyer

| Course: 18h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. identify classic chemical transformations and the structure of the resulting products;
- LO2. write a rational reaction mechanism of a chemical transformation;
- LO3. use chemoselective synthetic tools to design the synthesis of a target molecule;
- LO4. analyze a multi-step synthesis of a complex molecule;
- LO5. mobilize and apply knowledge from molecular chemistry to various applications in medical chemistry, chemical biology, and materials synthesis;
- LO6. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
- LO7. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO8. use scientific and technical English vocabulary.

Contents	1. Introduction 2. Oxidation reactions • Alcohol oxidation • Epoxidation • Dihydroxylation, oxidative cleavage • Beckmann rearrangement and Baeyer-Villiger oxidation 3. Functional group interconversion • Converting alcohols to sulfonates and halogenides • Nucleophilic substitutions • Mitsunobu reaction • Acid derivative interconversion (esterification, amidation) 4. Reduction reactions • Reducing agents • Reduction of acid derivatives • Reduction of aldehydes and ketones • Reduction of alpha and beta-unsaturated carbonyl compounds • Reductive amination • Reduction of halogenated derivatives • Deoxygenation and radical decarboxylation • Reduction of alkenes and alkynes 5. Organometallic chemistry • Synthesis and reactivity of Grignard and organolithium reagents • Organometallic compounds derived from copper, zinc, tin, and boron • Cross-couplings catalyzed by palladium complexes

Bibliographic Resources	Course handouts, cours.espci.fr

Evaluation	Written exam including course questions and reflection problems

Specialization UEs in Physical Chemistry

	Presential Study	ECTS		Code	Supervisor
UE Soft Matter	36	3			
Soft Matter and Development	26		SoM	SMD	M. Cloitre
Colloids and Biomolecules	10			CB	J. Bibette
UE Advanced Materials	30	3	AM	AM	S. Ithurria

# UE Soft Matter	SEMESTER 10
36h - 3 ECTS	UE SoM

Description

Soft Matter refers to a set of materials that ranges from plastics to liquid crystals and includes gels, colloid pastes, surfactant solutions, biopolymers, foams, and more. These materials have the ability to easily deform and react to low physical or chemical stresses. This property derives from interaction forces whose amplitude is generally comparable to that of Brownian forces. Entropy also plays a key role. Competition between enthalpic forces and entropic forces is responsible for self-assembly phenomena that lead to fascinating structures involving a whole hierarchy of scales of length and time.
These materials form the basis of a multitude of technical industrial products and commodities. Polymer blends and block copolymers are the basis of high-performance plastics, recyclable elastomers, barrier films for packaging, adhesives, and more. Our screens and display devices contain liquid crystals that can be directed through the simple application of an electric field. Formulas for paints, printing inks, and cosmetics use combinations of surfactant molecules, colloids, and polymers that achieve the required physicochemical properties in low concentrations.

The course Soft Matter and Development (SoM-SMD), intended for physicists, chemists, and physical chemists, illustrates how a good knowledge of the basic concepts in soft matter, a firmly interdisciplinary approach, as well as a lot of imagination, support the design and development of innovative materials and processes.

The course Colloids and Biomolecules (SoM-CB) addresses the dynamics and microscopic behavior of colloids and, more particularly, bioactive colloids such as proteins, enzymes, and antibodies. The first three sections are theoretical and provide methods to rationalize and model the systems in interaction, taking into account specificity and catalysis. The last section describes how the evolution of colloid science has been used to design a range of innovations, from 20th-century diagnostic health devices to the latest discoveries and strategies currently being developed by start-ups.

Semester	Program	
S10	SoM-SMD	Soft Matter and Development
	SoM-CB	Colloids and Biomolecules

Prerequisites
Diffusion, chemical kinetics

UE Validation
Weighted average: SoM-SMD 70%, SoM-CB 30%

Targeted skills

SoM-SMD	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.		III						III		III					III
LO2.		III	III					III		III			III		
LO3.		III	III					III		III					
LO4.		III						III		III					III
LO5.		III						III		III					III
LO6.							II								
SoM-CB	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.		III						III		III					
LO2.		III	III					III		III			III		
LO3.		III						III	III	III					
LO4.		III						III		III			III		III
LO5.							II								

S10 – SoM – SMD	Soft Matter and Development

Supervisor: Michel Cloître

Teaching staff: Sophie Norvez

| Course: 26h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. use their knowledge to solve a complex problem;
- LO2. use critical thinking skills to analyze a scientific article;
- LO3. interpret and model experimental data;
- LO4. connect a macroscopic behavior to microscopic phenomena;
- LO5. establish analogies between different issues;
- LO6. use scientific and technical English vocabulary.

Contents	
	1. Macromolecular engineering o Polymer blends and alloys o Block copolymers o Microphase separation in block copolymers o Thermoplastic elastomers o Nanostructured materials o Nanostructure control o Analogy with surfactant phases 2. Molecular engineering o Nematics, smectics, chiral phases o Defects and textures o Liquid crystal displays and other flat panel displays 3. Colloid engineering o Hard sphere suspensions o Glasses and colloid crystals o Attractive interactions o Directional interactions o Applications for the creation of photonic materials o Deformable colloids: emulsions, microgels, micelles, etc. o Jamming transition 4. Formulation in solution o Polymers in diluted and semi-diluted solutions o Physical and chemical gels o Intelligent gels o Gel swelling: equilibrium and kinetics o Gels and biomaterials o Polyelectrolytes o Poisson-Boltzmann equation, Manning condensation, etc. o Hydrophobic skeleton polyelectrolyte

Bibliographic Resources	
	• Course material available online at.espci.fr • Richard A.L. Jones, *Soft Condensed Matter*, Oxford University Press • Masao Doi, *Soft Matter Physics*, Oxford University Press

Evaluation	Article analysis

S10 – SoM – CB | Colloids and Biomolecules

Supervisors: Jérôme Bibette

| Course: 10h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. explain and predict the diffusion of colloids in complex media;
- LO2. explain and model interactions between colloids and biomolecules;
- LO3. explain and predict association / dissociation dynamics;
- LO4. connect associations and their dynamics to the properties of macroscopic structures;
- LO5. propose a strategy appropriate for the application of medical diagnostics;
- LO6. use scientific and technical English vocabulary.

Contents	The main questions addressed in this course are: • How do colloids diffuse in their environment via Brownian motion? • How do biomolecules and colloids react and interact in a complex environment? How can we model the interactions between a ligand and a receptor on cell membranes? • What are the dissociation dynamics of bio-complexes and how can we study the properties of these interactions? • How can colloid science be applied to medical diagnostics?
Bibliographic Resources	Handouts
Evaluation	Written exam

UE Advanced Materials

30h - 3 ECTS

SEMESTER 10

UE AM

Description

The UE Advanced Materials is offered through the Saint-Gobain chair and is intended for students who wish to develop a broad vision of materials and their applications. This class will included eight to nine conferences, three hours in length, presented by speakers outside of ESPCI, from industry (Saint-Gobain) or academia on materials for contruction, optics, energy, biology, and more. Manufacturing methods, characterization techniques, and the properties of these materials will be presented.

In 2019, students heard conferences on ceramics (Eric Lintingre from CREE), porous materials (Christian Serre), perovskites (Maksym Kovalenko), superconductors (Patric Simon), cements (Jean-Michel Torrenti), peptide assembly (Alvaro Mata), and biopolymers (Joris Spräkel).

In 2020, conferences are planned on topics including ceramics, glass, diods, materials for energy storage, transition metal dichalcogenides, metamaterials, metals, and biomaterials. (To be confirmed)

The conference series will end with a visit to one or two Saint-Gobain sites. In 2019, students visited the Domolab at Saint-Gobain Recherche in Paris, as well as the Placoplatre factory in Vaujours. In 2018, students visited the blast furnaces in Pont-à-Mousson.

Semester	Program	
S10	AM-AM	Advanced Materials

UE Validation

Average

Targeted skills

AM-AM	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Report	III		III		III		III		II					II
LO2.	Report	III		III		III		III		II					II
LO3.	Report	III	III					III	III						
LO4.	Report	III	III	III				III	III				II		II
LO5.	Report	III	III					III		II					
LO6.	Report						II								

S10 – AM-AM	Advanced Materials

Coordinating supervisor: Sandrine Ithurria

| Course: 30h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. choose materials for a sustainable world;
LO2. take a critical approach to analyzing issues related to different materials;
LO3. select relevant characterization techniques depending on the material in question;
LO4. summarize a material's properties and suggest an industrial application;
LO5. summarize two articles relevant to a material;
LO6. use scientific and technical English vocabulary.

Contents	Eight or nine conference and a factory visit

Bibliographic Resources	Conference materials

Evaluation	Two-part written report: • summary of one of the conferences • a 2 to 3-page bibliographic report based on two recent articles related to the material addressed in the selected conference

Specialization UEs in Biotechnology

	Presential study	ECTS		Code	Supervisor
UE Systems Biology et Neurobiology	33	3	SBN	SBN	P. Nghe, G. Vetere
UE Interface Physics Biology	33	3			
Biophysics	22		IPB	BP	U. Bockelman, D. Lacoste
Medical Imaging	11			MI	C. Demene
UE Biologie Chimique et Biotechnologie Moléculaire	33	3	CBMB	CBMB	A. Griffiths, R. Rodriguez

UE Systems Biology and Neurobiology

33h - 3 ECTS

SEMESTER 10

UE SBN

Description

Understanding biological systems requires integrating an increasing amount of data between different organizational levels in a quantitative way. The purpose of the module Biology and Neurobiology of Systems (SBN) is to help students understand the current state of the art of research and implement tools for analysis and modeling across disciplines in the following areas:

- approaches drawing on statistical physics for analysis of biological complexity, including self-organization of molecular and cellular systems;
- population-level interactions, including cooperative systems, for example, the emergence of multi-cellularity;
- understanding brain function at a systemic level by linking behavior and neuronal activity.

These topics will enable students to address techniques ranging from DNA sequencing to *in situ* visualization of individual neuron activity, and mobilize advanced techniques for analyzing biological data. This knowledge will be applied in practical sessions through bibliographic projects and analysis of data extracted from the systems presented.

Semester	Program	
S10	SBN	Biology and System Neurobiology
	TPSBN	Lab Work

Prerequisites

The following elements are recommended but will be reintroduced at the beginning of the course:

- basic concepts of cellular and molecular biology (eg, replication, transcription, translation) (S5-SV1);
- brain anatomy and neuron function (S6-SV2);
- Matlab programming basics (S7-MMN2-ANUM);
- basic statistical concepts: mean, error, correlations (S7-MMN2-STAP).

UE Validation

Average 10 / 20

Targeted skills

SBN	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	POA	III													
LO2.	POA						II				III				
LO3.	POA		II											III	
LO4.	POA												III		
LO5.	POA											II	III		I
LO6.	POA						II								

POA: oral presentation in English

S10 – SNB	Systems Biology and Neurobiology

Supervisors: Philippe Nghe, Gisella Vetere

| Course: 18h | Lab: 15h | 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. work in a group;
- LO3. take a critical approach to using data acquisition and analysis programs;
- LO4. interpret experiment results with a view to modeling them;
- LO5. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO6. use scientific and technical English vocabulary.

Contents	Lab Work Lab work will familiarize students with advanced techniques of biological data analysis. It will also help guide projects based on a literature review, data analysis, and modeling data extracted from the systems presented in the course or from articles in scientific literature.

Bibliographic Resources	Course presentations will be made available to students online, as well as scientific articles related to the proposed projects.

Evaluation	Group-led oral defense of a project chosen in advance and developed during lab work sessions.

UE Interface Physics Biology	SEMESTER 10
33h - 3 ECTS	UE IPB

Description

The course Biophysics (IPB-BP) addresses the physical bases and methods of physical investigation of living organisms at the level of the biological cell. A selection of experimental techniques and theoretical concepts is presented to illustrate the contribution of physics to the study of biological objects, assemblies, and processes, and associated applications, which range from technology to medical diagnosis.
This course also provides an introduction to an important research field undergoing rapid growth. It draws on students' acquired knowledge, particularly in molecular biology, experimental physics, and statistical physics.

The course Medical Imaging (IPB-BP) offers student-engineers tools to understand the issues and challenges of current research in medical imaging. More specifically, it enables them to gain an understanding of the physical mechanisms involved in the main clinical imaging methods; to define a general theory (direct problem-opposite problem) common to these methods that formalizes the notion of image reconstruction; to apply some of these image reconstructions to experimental data by themselves; and to identify the most prominent research topics currently being studied in imaging.

Semester	Program	
S10	IPB-BP	Biophysics
	IPB-MI	Medical Imaging

Prerequisites

Molecular Biology (S6-SV1), Statistical Physics (S6-PSA, S10-SPCS), Experimental Physics
Fourier Transform (S5-E2S-SLS), fundamentals of waves and acoustics (S7-OA), optics (S8-OPT), NMR (S5-CH1-ICO), and programming (S6-COMMI2-PROG)

UE Validation

Weighted average IPB-BP 2/3, IPB-MI 1/3

Targeted skills

IPB-BP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.															
LO2.															
LO3.															
LO4.															
LO5.															
IPB-MI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Exmat.	II													
LO2.	Pres.				III		III								
LO3.	Exmat.		III												
LO4.	MCQ, Pres.	III	III										III		
LO5.	MCQ, Pres.	I						I							
LO6.	MCQ, Exmat.	I													
LO7.	MCQ	I		I	I	I				I					
LO8.	MCQ, Pres.	I			I					I					
LO9.	MCQ, Exmat.		I		II					I					
LO10.	Exmat.		II							II				II	
LO11.	Pres.	III	III	III	III								III	III	
LO12.	Pres.						II								

Exmat: Matlab exercise, Pres.: video presentation

S10 – IPB - BP	Biophysics

Supervisors: Manuel Théry, David Lacoste

| Course: 22h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. mobilize;
LO2. work;
LO3. use;
LO4. interpret;
LO5. model;
LO6. use scientific and technical English vocabulary.

Contents	• Cellular migration • Molecular motors, biofilaments of cytoskeleton (actin and microtubules) • Stochastic processes and applications to gene expression • Chirality in living systems • Regulation of cell size • Research on the Origin of life and towards building an artificial cell

Bibliographic Resources	• Physical biology of the cell, R. Philipps, J. Kondev, J. Thériot and H. Garcia • Physics in Molecular Biology, K. Sneppen and G. Zocchi • Biological Physics, energy, information, life, P. Nelson • The origins of order, S. A. Kauffman • The origin and nature of life on earth, E. Smith and H. J. Morowitz

Evaluation	Written exam based on a paper.

S10 – IPB - MI	Medical Imaging

Supervisor: Charlie Demene

| Course: 11h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

- LO1. mobilize knowledge to solve an image reconstruction problem using raw data (physical measurements) (II);
- LO2. work in a group to produce an educational video (III);
- LO3. identify and independently carry out the different steps of image reconstruction using experimental data (III);
- LO4. justify the imaging techniques appropriate for the tissues and organs being studied (III);
- LO5. connect observations of macroscopic imaging to the process of microscopic interactions (I);
- LO6. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
- LO7. identify the main methods of medical imaging and their applications (I);
- LO8. describe the physical mechanisms involved in each method and their implications for resolution, sensitivity, and contrast (I);
- LO9. define a direct problem for a given imaging situation and identify a possible inversion technique (I);
- LO10. apply several inversion techniques in Matlab code and reconstruct images from raw data (II);
- LO11. summarize a scientific article about imaging, argue the relevance of the innovation described, and create an original video to present it (III);
- LO12. use scientific and technical English vocabulary.

Contents	The first part of the course introduces the notions of image reconstruction from measurements in physical space, in particular direct and inverse problem formalism, which is widely used in research. The course then presents the major existing clinical imaging methods (X-ray radiography, CT), (SPECT, PET) (MRI) (Ultrasound), emphasizing three aspects: 1. identification of implemented physical phenomena and their implications in terms of resolution, sensitivity, the nature of contrast agents and safety; 2. description of image reconstruction methods based on these physical measurements and their applications to concrete cases, 3. integration of these methods within the hospital context: for which cases, at what costs, etc. Each imaging method will be used to explore current research topics and key players (academic or otherwise) will be identified at the global level. The purpose of this course is to familiarize students with the main imaging methods and associated research fields; and to master the physical and algorithmic mechanisms and applications behind these methods in order to communicate with specialists in the field.

Bibliographic Resources	Course slides and notes are available on OASIS. Further study:

	Medical Imaging de Paul Suetens, available at the library (online)

Evaluation	1. Five-minute online MCQ (5 questions) to be taken at the beginning of the class on topics addressed in the previous course; instant correction will evaluate students' understanding (25% of grade) 2. Matlab exercises to apply simple image reconstruction algorithms and solidify theoretical concepts addressed in class (20 minutes per exercise) (25 % of grade) 3. Creation of an 8-minute video explaining a scientific article about a major advance in imaging (50% of grade)

UE Chemical Biology and Molecular Biotechnology

33h - 3 ECTS

SEMESTER 10

UE CBMB

Description

Chemical biology and molecular biology form a powerful collection of techniques to study biological systems at the organism's molecular and cellular levels. They are also powerful tools for discovering new targets for medications, developing new medications (small chemical molecules and large biopharmaceutical molecules), creating organisms and individual biomolecules (proteins and nucleic acids), processing information, and developing chemical circuits for industrial, diagnostic, and therapeutic applications. The unit's goal is to help students grasp the state of the art of research and technology in the field and its applications. Another goal is to illustrate how paradigm-changing technology development is often complex and interdiscplinary, combining, for example, next-generation sequencing, optics, nanomanufacturing, microfluidics, organic chemistry, molecular biology, and biocomputing. This knowledge will be applied to bibliographic projects during lab sessions.

Semester	Program	
S10	CBMB-CBMB	Chemical Biology and Molecular Biotechnology

Prerequisites

The following concepts are recommended, but will be briefly reviewed early in the course: molecular biology (S5-SV1) and organic chemistry (S5-CH1-CO)

UE Validation

Written exam (70% of the final grade); oral presentation of group projects (30% of the final grade)

Targeted skills

CBMB-CBMB	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	POA	III													
LO2.	POA						II				III				
LO3.	POA												III		
LO4.	POA											II	III		I
LO5.	POA						II								

POA: oral presentation in English

Recommended / required for the following masters programs

UE recommended for M2 AIV, IMALYS, BME

S10 – CBMB	Chemical Biology and Molecular Biotechnology

Supervisors: Andrew Griffiths, Raphaël Rodriguez

| Course: 26h | Course language: 🇬🇧 |

Objectives / Targeted Skills

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

LO1. use their knowledge to solve a complex and / or interdisciplinary problem;
LO2. work in a group;
LO3. interpret experiment data with a view to modeling them;
LO4. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, connect a macroscopic phenomenon to microscopic processes;
LO5. use scientific and technical English vocabulary.

Contents	Course This unit aims to provide insights into advanced techniques in chemical and molecular biology, as well as their applications, to study biological systems and develop new diagnostic, therapeutic, and industrial applications. The main objectives of the Chemical Biology course will be to familiarize students with the complexity of eukaryotic cells, including major biological processes (for example endocytosis, signaling, transcription, translation, chromatin biology and epigenetics, epithelial–mesenchymal transition, cell aging and cancer), and using small synthetic molecules or natural products that allow for the regulation / adjustment of these processes. Several concrete cases will serve as examples to illustrate the identification of new biological targets with therapeutic interest and to use these molecules as a starting point to develop unique medications. The molecular biology course explains techniques such as amplification, cloning, gene editing, and transcription regulation (including use of CRISPR-Cas9), DNA sequencing and synthesis (including next-generation sequencing), mutagenesis and recombination, and screening strategies (including microfluic systems), selection and directed evolution. Applications in metabolic engineering (reengineering strategies of microbial metabolisms to reconfigure the microbial metabolism for bioproduction), constructing synthetic biochemisty and biocomputing (using biomolecules to process information and chemical circuit engineering) and protein engineering (for example, therapeutic antibodies) will be explored. The unit also aims to illustrate how the development of paradigm-changing technology is often complex and multidisciplinary, combining, for example, next-generation sequencing, optics, nanomanfacturing, microfluidics, organic chemistry, biology, and biocomputing. Tutorials Tutorials will familiarize students with advanced techniques in chemical synthesis and molecular biology and their applications. They will also guide bibliographic projects to identify the most important advances. Students will work in small groups to prepare an oral presentation on recent developments in the field.

Bibliographic Resources	Class presentations will be available online for students, as well as scientific articles relevant to suggested projects.

Evaluation	Oral presentation of group projects (100%)

Specialization UEs in Process Engineering

	Presential study	ECTS		Code	Supervisor
UE Process Engineering	99	6			
Flow Chemistry	21		MH24OP	FLC	S. Ognier
Experimental Training	30			PRO	C. Guyon
Process Optimization and Control	24			OPC	J. Pulpytel
Process Simulation	24			SP	C. Guyon

This option implies following a complete curriculum at Chimie ParisTech (2A, Semester 4, 30 ECTS).

Syllabus 2A : https://www.chimieparistech.psl.eu/wp-content/uploads/2019/05/chimie-paristech-formations-syllabus-2019-2a-fr.pdf

Online : https://www.chimieparistech.psl.eu/formations/syllabus/annee/2e-annee/?_sfm_syllabus_semestre=4

Core curriculum (6 ECTS)
Process Option (6 ECTS)
Management, Human Resources (6 ECTS)
Internship (12 ECTS)

Core Curriculum UE
- Corrosion
- Inorganic chemistry: from molecules to materials
- Modeling
- Energy Conferences
- Digital engineer

UE Process Option
- Process simulation
- Process optimization and control
- Flow chemistry
- Experimental training, process option

UE Management
- Human Resources Management
- English

UE Process Engineering

Chimie ParisTech

99h - 6 ECTS

SEMESTER 10

UE MH24OP

Semester	Program	
S10	MH24OP.FLC	Flow Chemistry
	MH24OP.PRO	Experimental Training
	MH24OP.OCP	Process Optimization and Control
	MH24OP.SP	Process Simulation

UE Validation

Weighted average: MH24OP.FLC 25%, MH24OP.PRO 25%, MH24OP.OCP 25%, MH24OP.SP 25%

Targeted skills

MH24OP.FLC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.		II							II					
LO2.	Ex., TP (lab)	III	II					III		II					
LO3.	Ex., TP			II						II			II		
LO4.	Ex., TP		II							II			II		
LO5.	Ex.		III							III					
MH24OP.PRO	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	TP		III						III	II					
LO2.	TP		III						III	II					
LO3.	TP		III						III	II					
LO4.	TP			III					III	III					
LO5.	TP								III	III					
LO6.	TP		III	III					III	III					
MH24OP.OCP	**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						III					
LO4.	Ex.		III	III						III					
MH24OP.SP	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Ex., TP, Oral		III							III					
LO2.	Ex., TP, Oral		III	III						III					
LO3.	Ex., TP, Oral		III	III						III					

S10 – MH24OP- FLC	Flow Chemistry

Supervisor: S. Ognier

| Course: 15h | Tutorial: 3h | Lab: 3h | Course language: 🇫🇷 |

Description

Process intensification supports an effort to improve the productivity and selectivity of chemical reactions, in particular through the use of milli- and micro-structured reactors, *in-situ* coupling of reaction and separation, and the use of alternative energy sources (photochemistry, ultrasound, etc.). The course begins with a theoretical component intended to show students how the intensification of transfers within a chemical reactor influences its performance. In this first section, concrete examples will be analyzed in class, in tutorials, and in lab work. The second section will be more descriptive, and involve teachers and researchers from disciplines other than process engineering (materials, molecular chemistry). They will share their experiences as users of new, intensified technologies.

Objectives / Targeted Skills

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

- LO1. analyze the context of intensification;
- LO2. describe the fundamentals of matter, heat, and momentum transfers, particularly in small channels;
- LO3. analyze referenced industrial cases and developments in chemical engineering;
- LO4. analyze academic examples of flow chemistry in the fields of molecular synthesis and material synthesis;
- LO5. propose relevant intensification solutions for a given process.

Bibliographic Resources	Course slides, and tutorial and lab work instructions

Evaluation	Written exam (70%) and lab work evaluation (30%)

S10 – MH24OP- PRO	Experimental Training, Process Option

Supervisors: C. Guyon

| Lab: 30h | Course language: 🇫🇷 |

Description

This experimental training is offered as part of the Flow Chemistry option in Process Engineering. It was developed as lab work carried out in the laboratory.
The teacher will first present various miniaturized reactors and the control system (flow control, temperature control, etc.). Then students must build a reaction setup with glass micro-reactors to create a parallel reaction system. The notions of "residence time" and "mixing time" will be presented during the lab, and the advantages and disadvantages of the miniaturized reactor will also be discussed during this lab.

Objectives / Targeted Skills

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

- LO1. build a flow chemistry setup;
- LO2. characterize the mixing / reaction time in a miniaturized reactor;
- LO3. establish material / energy balances in a reactive system;
- LO4. compare different reactors (miniaturized reactor and batch reactor) for a system of parallel reactions;
- LO5. cite advantages and / or disadvantages of the continuous flow chemistry system over traditional reactors;
- LO6. choose a reactor suitable for a given process.

Bibliographic Resources	Handouts

Evaluation	Lab work

S10 – MH24OP- OCP | Process Optimization and Control

Supervisor: J. Pulpytel

| Course: 6h | Tutorial: 18h | Course language: 🇫🇷 |

Description

This course is divided into two main sections. The first addresses experiment design. This statistical and mathematical approach aims to minimize the number of trials needed to study and optimize multifactor systems. Students will learn about "classic" designs such as full factorial, fractional, and composite designs, as well as the necessary statistical tools.
Process regulation will be taught in the second section, which covers all the material and technical resources used to measure and maintain a physical quantity and, therefore, production of constant quality. During disturbances or setpoint changes, regulation provokes a corrective action in process actuators (valves, etc.). Different types of regulation and the methods of adjustment will be taught in this course.
Tutorials are completed using Matlab and Nemrod.

Objectives / Targeted Skills

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

- LO1. implement experiment designs and define an optimal experiment strategy;
- LO2. calculate multilinear regression models and use software to interpret the results statistically;
- LO3. identify and configure the operation of a regulator to control process operation and stability;
- LO4. explain the operating principle of different sensors used in industry to determine the fundamental quantities of a chemical process (flow, temperature, etc.).

Bibliographic Resources	Handouts

Evaluation	Written exam

S10 – MH24OP-SP	Process Simulation

Supervisor: C. Guyon

| Course: 3h | Lab: 21h | Course language: |

Description

The objective of this training is to simulate a real industrial process using commercial process simulation software (Aspen Hysys). It will consist in choosing certain units (reactions, separation), optimizing operating parameters, and evaluating unit performance (production, selectivity, efficiency, etc.) according to defined specifications. Once these parameters are established, students will have to evaluate the economic potential of the studied process (Aspen Icarus and bibliographical data).

Objectives / Targeted Skills

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

- LO1. perform a material assessment for a global process;
- LO2. simulate an industrial process on large software under static conditions (Aspen Plus, Aspen Hysys) in order to optimize process operating parameters;
- LO3. carry out an economic assessment of the process (energy costs, CO_2 emissions, revenue, expenses, wages, installation costs, taxes, etc.).

Bibliographic Resources	PDF in English https://coursenligne.chimie-paristech.fr/course/view.php?id=299

Evaluation	Written 30% Lab work 10% Oral 60%