ESPCI PARIS | PSL

Syllabus

Semesters S7 and S8

Version 22.4

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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, chemistry and / or biology, while cultivating a solid foundation in relevant socio-economic fields.

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

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

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

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

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

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

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

The ESPCI Paris engineering diploma, certified by the French commission of engineering titles, is awarded upon completion of three years' training, and the ESPCI diploma (Advanced Master in Sciences and Technology from ESPCI Paris) is granted following completion of an optional fourth year of study.
ESPCI Paris's objectives for its student engineers are articulated in a general skills base developed for the title of engineer and a skills base more specific to an ESPCI Paris engineer.

i) Skills base common to all engineer titles

C1. Ability to mobilize resources from a wide range of fundamental sciences.
C2. Mastery of engineering methods and tools: identification and resolution of problems, including those that are unfamiliar and incompletely defined; collection and interpretation of data; use of computer tools and modeling; analysis and conception of complex systems; experimentation.
C3. Awareness of industrial, economic, and professional challenges: competitiveness and productivity, innovation, and intellectual and industrial property. Respect for quality and security protocols; risk analysis and control.
C4. Capacity to integrate an organization, to drive it, to contribute to its evolution, and to manage it: engagement and leadership, project management and ownership, communication with specialists and non-specialists.
C5. Knowledge of and respect for societal values: knowledge of social relationships, environmental challenges, and engagement with society; to think and act as a responsible, ethical citizen and professional.
C6. Ability to work in a multicultural and international environment, in English and in French. Capacity to suggest solutions adapted to this environment.

ii) Skills base specific to ESPCI Paris engineers

P1. Appropriation of a solid foundation in physics, chemistry, and biology.
P2. Mastery of a broad range of experimental techniques.
P3. Advanced expertise in one or more specialty fields including instrumentation, physics applied to health, materials, fine chemicals, biotechnology, etc.
P4. Ability to define a novel and innovative scientific project, and to manage a team to achieve its completion.
P5. Ability to work at the intersection of fields and lead a cross-disciplinary project.
P6. Ability to adapt to novel scientific and technical contexts.
P7. A culture of curiosity, creativity, innovation, and an openness to technology transfer and entrepreneurship.
P8. Unique, adaptive use of scientific knowledge, skill, and investigation that supports flexibility and reactivity to deliver innovative solutions to industrial challenges as well as important societal issues.

Core curriculum (S7 to S8)

The core curriculum is presented in chronological order by semester.

For each semester, teaching units (UE) are broken down into their constituent parts (*éléments constitutifs*, EC) in a table. This table includes the names of supervising teachers, the distribution of class hours (classes, tutorials or "TD", super tutorials or "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 7

SEMESTER 7	432,75 h					30 ECTS				
SEMESTER 7	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisor	Courses (h)	Tutorial (h)	Super Tutorial (h)	Preceptorships (h)	Lab (sessions
UE Waves and Acoustics	71	5								
Waves and Acoustics	26	50%	OA	OA	A. Tourin	18	4		4	
Waves and Acoustics Lab Work	45	50%		TPOA	A. Tourin					12
UE Condensed Matter	90,5	6								
Crystallized Materials	23	27,5%	MATC	MC	N. Lequeux	15	8			
Solid-State Physics	20	27,5%		PS	D. Roditchev	20				
Preceptorships in Physics of Condensed Matter	10	15%		PSP	D. Roditchev N. Lequeux				10	
Material Engineering	37,5	30%		IM	S. Ithurria					10
UE Chemistry III	62	5								
Analytical Sciences	17	40%	CH3	SAN	J. Dugay, J. Vial	8	6	3		
Analytical Sciences Lab Work	45	60%		TP SAN	J. Dugay, J. Vial					12
UE Mathematics and Numerical Methods II	71,5	5								
Mathematics II	34	30%	MMN3	MATH2	V. Démery	14	14		6	
Numerical Simulations	18,75	25%		SIMUL	A. Allauzen					5
Numerical Methods	18,75	25%		MENU	D. Cassereau					5
UE Humanities & Social Sciences - General knowledge I	35,25	2								
PSL Week I	24	V	SHSCG1	PSL1	A. Bah	24				
Professional Project	11,25	30%		PP	B. Beaussart, E. Honikman					3
UE Project Management	76,5	5								
Financing Innovation	3	V	GP	FI	F. Kalb	3				
Project Management	13,5	15%		GP	F. Vanhulle	6				2
Group Science Project II	60	85%		PSE2	E. Fort, Y. Tran, M. Ardré					16
UE English III	26	2	ANG3	ANG3	D. Moreau		26			

One lab session is 3 h 45 min.
The volume of individual study is estimated to be 284 hours according to the following breakdown:
1 h class = 0.9 h individual study
1 h tutorial = 0.7 h individual study
1 h super tutorial / tutoring = 1.5 h individual study
1 h lab = 0.3 h individual study

UE Waves and Acoustics	SEMESTER 7
71h - 5 ECTS	UE OA

Description

The purpose of the course Waves and Acoustics (OA-OA) is to give students a very general conceptual framework for understanding propagation of different types of waves in a wide variety of media. This study framework is based on the concept that the evolution of a wave, regardless of its nature, is always governed by a differential equation with certain symmetrical properties: time translation invariance, spatial reciprocity, time reversal invariance.
To illustrate this, we will describe the propagation of acoustic waves in fluid media (homogenous, heterogeneous, with boundaries). Lab work (OA-TPOA) will provide the opportunity to explore subjects with industrial import (medical imaging, non-destructive ultrasonic control, sonar) and other more academic interests (for example, sonoluminescence).

Semester	Program	
S7	OA-OA	Waves and Acoustics
	OA-TPOA	Waves & Acoustics Lab work

Prerequisites

Mathematical tools: Fourier analysis; gradient, divergence, rotational and Laplacian operators; non-homogenous partial differential equations; complex notation of a periodic signal.
Electromagnetic waves: Maxwell's equations, wave equation, Helmholtz equation, plane and spherical waves, Poynting vector, Snell-Descartes laws, guided waves, optical cavity.

Related classes

Electromagnetic Waves (S6-PG-OEM)
Mathematics II (S7-MMN2-MATH2)
Optics (S8-OPT)
Waves in Complex Media(S10-OMC)

UE Validation

Weighted average: OA-OA 50%, OA-TPOA 50%

Targeted skills

OA-OA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.,prec., MCQ	II	II					II							
LO2.	Ex., QCM	II	II					II							
LO3.	Ex., QCM	II	II												
LO4.	Ex.	III	III					III							
LO5.	Ex., QCM	III	III					III							
LO6.	Ex.,prec., MCQ	II	II												
LO7.	Ex.,prec.	III	III					III					III		
OA-TPOA	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part., notebook		III	II									III	III	III
LO2.	Part.				III	II					III				
LO3.	Part., notebook		III												
LO4.	Part		II						III						
LO5.	Part., notebook	III	III												
LO6.	Part., notebook		III							III					
LO7.	Part., notebook	III	III							III			III		
LO8.	Notebook	III	III							III					

Ex.: Written exam, Prec.: Preceptorship, Part.: Participation

S7 – OA – OA	Waves and Acoustics

Supervisor: Arnaud Tourin

Teaching staff: Fabrice Lemoult, Charlie Demene

| Course: 18h | Tutorial: 4h | Preceptorship: 4h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. distinguish between a wave equation and a diffusion equation based on their respective properties;
LO2. construct an equation that governs the propagation of an acoustic wave using a constitutive equation and two continuity equations;
LO3. interpret phenomena that arise during the non-linear propagation of an acoustic wave in a homogenous fluid medium;
LO4. resolve a wave equation using Green's function;
LO5. apply the integral diffraction theorem to acoustics and optics for determining the radiation of any aperture of any shape;
LO6. Interpret diffraction as a filter for spatial frequencies;
LO7. utilize their knowledge to solve a complex wave propagation problem.

Contents	Course / Tutorial 1. Introduction • How do we "make" a wave? • Comparing the properties of the wave equation and the diffusion equation 2. Fluid acoustics • Generation of an acoustic wave in a fluid • Continuity equations and constitutive equation • Linear acoustics • Non-linear acoustics 3. Theory of diffraction • Unicity theorem • Temporal Green's function • Monochromatic Green's function • Reciprocity theorem • Integral theorem of diffraction in a monochromatic regime • Integral theorem of diffraction in the temporal domain • From Huygens's principal to Fermat's theorem 4. Wave propagation and signal theory • Diffraction as a filter for spatial frequencies; • Fresnel transform and Fourier transform • The lens as a spatial matched filter • Pulse compression radar and sonar Preceptorships • Coherence in wave physics • Manipulating spatial-temporal degrees of freedom of waves

Independent Study	Objectives: use concepts learned in the course to go beyond basic applications. Methods: preceptorship preparation

Bibliographic Resources	Course handouts and resources Tutorial and preceptorship instructions

Evaluation	Written final exam: part A (MCQ), part B (solve a problem)

S7 – OA – TPOA	Waves and Acoustic Lab Work

Supervisor: Arnaud Tourin

Teaching staff: Fabrice Lemoult, Charlie Demene

| Lab: 45h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. organize their laboratory work;
- LO2. work in a group;
- LO3. identify and independently lead the different steps of an experimental approach;
- LO4. interface and use measurement devices in the fields of electronics, acoustics, and optics;
- LO5. observe and interpret wave phenomena in real space (time, position) and in reciprocal space (temporal frequencies, spatial frequencies);
- LO6. take a critical approach to using data acquisition, signal processing, and image analysis programs;
- LO7. compare experiment results to simulation results;
- LO8. summarize, interpret, and present experimental results.

Contents	Four topics are addressed: • Acoustic focusing • Ultrasound imaging • Guided waves and dispersion • Sonoluminescence
Organization	Three half-days of lab work on each topic. Each student carries out all lab work exercises.
Bibliographic Resources	Lab work and course handouts, preceptorship subjects
Evaluation	Lab log (description, presentation, and interpretation of experimental results, summary) 50% Experiment work (organization, manipulation, observation, and interpretation) 50%

UE Condensed Matter	SEMESTER 7
90.5h - 6 ECTS	UE MATC

Description

This UE reveals the profound relationships between the structure of materials and their physical properties. Why are some materials, although composed of the same atoms, conductors and others insulators? What is behind the word "semi-conductor"? What microscopic processes are responsible for electronic, mechanical, optical, and other properties that we observe and use in various applications?

The course Crystalized Materials (MATC-MC) lays the foundation for understanding the organization of condensed matter at the atomic level: crystalline symmetries, classification, the structure of ionic and covalent crystals, deviation from perfect crystals, etc. The class introduces methods for investigating crystals and illustrates how crystalline symmetries influence the physical properties of materials.

The course Solid-State Physics (MATC-PS) enables students to discover the deeply quantic nature of materials. It creates the link between their atomic structure and their electronic, mechanical, and thermodynamic properties. It enables students to understand why certain materials are insulating, while others are metals, semi-conductors, or even superconductors.

The MC and PS courses are illustrated in the preceptorships "Structure-Properties" (MATC-PSP), which address several remarkable structural and electronic properties of materials. In each session, students lead a theoretical study, supported by a teacher-researcher.

The MC and PC classes also include a practical portion, Materials Engineering (MATC-IM), which addresses several methods of synthesizing crystalline materials and of characterizing their physical properties (X-ray diffraction, electron microscopy, BET, and electrical, magnetic and optical characterization).

Semester	Program	
S7	MATC-MC	Crystallized Materials
	MATC-PS	Solid-State Physics
	MATC-PSP	"Structure-Properties" Preceptorships
	MATC-IM	Materials Engineering

Prerequisites

Group Theory (S5-MMN1-TDG). A basic understanding of the Fourier Transform and diffraction (S5-ES2-SLS). Basic notions of quantum mechanics (S6-PG-PQ).

UE Validation

Weighted average: MATC-MC 27.5%, MATC-PS 27.5%, MATC-PSP 15%, MATC-IM 30%

Targeted skills

MATC-MC	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., MCQ	III	I					II							
LO2.	Ex., MCQ	III	I					III							
LO3.	Ex.	III	II					III							
LO4.	Ex., MCQ	III						III							
LO5.	Ex.	II						II	III	II					
LO6.	Ex.	II								III					
MATC-PS	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Ex., Exp.	II	I	I				III						I	
LO2.	Ex., Exp.	III						II			II				
LO3.	Ex., Exp.	II						II							
LO4.	Ex.	II						II							
LO5.	Ex.	II						II							
LO6.	Ex.	III		II				III						I	
LO7.	Ex.	I	I	II				I		I				I	I
MATC-PSP	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Prep., Part.	I	I				I	II							
LO2.	Prep., Part.	II					I	III		II					
LO3.	Prep., Part.	III					I	III		II					
LO4.	Prep., Part.	I	I				I	I							
LO5.	Prep., Part.	II	II	I				II		III			I	I	I
LO6.	Prep., Part.	III					I	II		II		I	I	I	
MATC-IM	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	AE		II			I		II	III	III					
LO2.	AE, PO	II	III	I					III	III					I
LO3.	AE	II	II					III							
LO4.	AE	III	II							III			II	II	I
LO5.	AE, PO				I	II					III				
LO6.	AE				II	II									
LO7.	AE, PO				III					II	III				II

Ex.: written final exam, Exp.: end-of-term exam, Prep: written preparation, Part.: oral participation, AE: experimental aptitude, PO: oral exam

S7 – MATC – MC	Crystallized Materials

Supervisor: Nicolas Lequeux

Teaching staff: Sandrine Ithurria, Vanessa Pereira Pimenta

| Course: 15h | Tutorial: 8h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify lattice points, point symmetries, and orientation in crystals
LO2. interpret the notation of space groups; use International Tables for Crystallography;
LO3. define and defend conditions of diffraction and calculate diffraction intensities;
LO4. justify crystallographic models of simple ionic structures;
LO5. identify point defects and analyze their impacts on the ionic and electronic properties of materials;
LO6. connect symmetries between macroscopic and microscopic levels.

Contents	Course / Tutorial • Study of symmetries at the atomic and macroscopic scale and the classification of crystals (periodic networks, symmetry, point and space groups, International Tables for Crystallography. • Characterization of crystals using X-ray diffraction (reciprocal network, structure factor, structure resolution, diffuse diffusion, experimental methods). • Classification of crystals according to the type of bond and a thorough description of the ionic crystal model. • Intrinsic and extrinsic point defects and their consequences on transport properties (Kröger-Vink notation, ionic diffusion and conductivity, application to solid electrolytes and mixed conductors). • Relationship between crystalline symmetries and physical properties (Curie's principle, applications to ferrous materials).

Independent Study	Objectives: use concepts learned in the course to go beyond basic applications. Methods: prepare tutorial exercises during independent study.

Bibliographic Resources	Course handouts Tutorial instructions

Evaluation	MCQ without supporting documentation 40% Problem using course handouts 60%

S7 – MATC – PS	Solid-State Physics

Supervisor: Dimitri Roditchev

Teaching staff: Sergio Vlaic

| Course: 20h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify and classify materials according to their electronic properties;
LO2. calculate the band structure of a material according to its structure, predict its properties (metallic / insulating);
LO3. construct a material's Brillouin zones based on its crystal structure;
LO4. identify a crystal's vibrational modes;
LO5. evaluate the specific-heat behavior of a metal / semiconductor / insulator;
LO6. develop characterization experiments with a view towards identifying and classifying materials based on their primary properties;
LO7. identify a superconductor.

Contents	Course 1. Introduction (1h) • Solid-state physics as a science that investigates the properties and phenomena related to solid matter at every level. Related applications. • Example 1: computer processors. Moore's "Law", FET transistors • Example 2: computer memory HDD, SSD, and others • History of the physics of matter 2. The (classic) Drude model of metal (2h) • Phenomenon of electrical conduction: knowledge of the time, Drude's hypotheses • Drude formula; orders of magnitude • Temperature-induced conductivity variations • Specific heat • Applications for the Drude model • Drude gas high frequency response (20 min.): Drude AC conductivity; local equations, propagation 3. Hall Effect (1h) • Description of the phenomenon; movement equation • Hall constant • Applications 4. **Sommerfeld's Free Electron Model (2**h) • Limitations and insufficiencies of the Drude model • Schrödinger's equation; physical sense • Born von Karman periodic boundary conditions; quantification of a wave vector and energy spectrum • States in k-space; Fermi energy, Fermi sphere • Total energy of a system; density of electronic states • TD properties of Sommerfeld gas; strengths and weaknesses of the model: state occupation, specific heat of Sommerfeld quantum gas 5. Vibrations in the crystal lattice, Brillouin zones (2h) • Crystal potential • Harmonic approximation

	• 1D harmonic vibrations (a chain of atoms) • Harmonic vibrations of a 1D chain with two atoms per unit • Brillouin zones: Bravais network, Vigner-Seitz cell, constructing Brillouin zones 6. Specific heat of a crystal; phonons (1h30) • Case study, "classic" crystals: Dulong-Petit law (1812) • Quantum case study; phonons • Specific heat of the crystal lattice; the Einstein model; the Debye model 7. Nearly free electrons in a solid: band gaps (3h) • Introduction; historical context • Bloch's theorem • Electrons in a periodic potential; central equation • Opening of gaps on the edges of Brillouin zones; relation between gap energy and crystalline potential V(r) • Reduced zone: translation of branches E(k) in the first Brillouin zone • Band occupation; metal, insulators (semiconductors) 8. Modeling strong connections, law of dispersion (2h) • Introduction; general concepts • Construction of the wave function • Energy eigenvalues • Consequence of electronic gaps on the electronic properties of materials; group velocity, effective mass 9. Filling of bands, insulators, semi-conductors, metals (2h30) • Intrinsic semi-conductors; Fermi level; law of mass action; applications • Doped semiconductors; microscopic model of an insulated doping material • Applications 10. Introduction to superconductivity (2H) • A little background • Perfect diamagnetism • Consequences of the Meissner-Ochsenfeld effect (1933); thermodynamic considerations • Superconductor phase diagram; vortex • Applications 11. Conclusions: current issues and challenges in solid-state physics (1H) • New quantum materials and nano-materials (example: low-dimensional semiconductor heterostructures, graphene, topological insulators, new surface and interface properties). • Applications (example: photovoltaics) • Strongly correlated electron materials (example: HTSC cuprates) • Mott transition

Independent Study	Objectives: discover the deeply quantum nature of materials; acquire the skills to understand, describe, and anticipate the physical properties of materials according to their structure. Methods: Coursework

Bibliographic Resources	N.W. Ashcroft and N.D.Mermin. *Solid State Physics*. EDP Sciences, ISBN:2-86883-577-5 (Fr) and ISBN:0-03-083993-9 (En) C. Kittel. *Introduction to Solid State Physics*. Ed. Dunod,

	ISBN-10: 2100497103 ISBN-13: 978-2100497102 French versions: N.W.Ashcroft et N.D.Mermin. Physique des solides, EDP Sciences, ISBN:2-86883-577-5 (Fr) et ISBN:0-03-083993-9 (En) C. Kittel. Physique de l'état solide. Ed. Dunod, ISBN-10: 2100497103 ISBN-13: 978-2100497102

Evaluation	End-of-term exams; written final exam

S7 – MATC – PSP	Preceptorships in Physics of Condensed Matter

Supervisors: Dimitri Roditchev and Nicolas Lequeux

Teaching staff: S. Vlaic, C. Feuillet-Palma, S. Ithurria, V. Pereira Pimenta

| Preceptorship: 12h including 2 optional hours | Course language: 🇫🇷 🇬🇧

Objectives / Targeted Skills

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

LO1. calculate the vibration spectrum for a single crystal;
LO2. calculate electronic band structure in nearly free electron approximation;
LO3. calculate electronic band structure, effective mass, and the density of electronic states of real simple materials in approximation of strong bonds;
LO4. understand and simulate the function of a diode or a transistor;
LO5. analyze different types of materials and connect their properties to various applications;
LO6. identify the component parts of a complex problem and solve it.

Contents	Preceptorship (subjects may change) 1. Crystal lattice vibrations (2D phonons) 2. Nearly free electrons in a 2D square box 3. Electronic properties of graphene 4. Doped semiconductors (p-n junctions) 5. (1 topic per student) 5.1. Structure, properties, and synthesis of perovskite ceramics 5.2. Local atomic structure in oxide glass 5.3. Solid electrolytes 5.4. Characterization of disordered media using RX diffusion 6. Optional (students' choice): 6.1. Field-effect transistor 6.2. Magnetism 6.3. Quantum Hall Effect 6.4. Quantum corral
Independent Study	Objectives: discover the quantum nature of physical properties and phenomena of materials; acquire the skills necessary to understand, describe, and model the physical properties of materials according to their structure. Methods: homework; participation in preceptorships.
Bibliographic Resources	N.W. Ashcroft and N.D.Mermin. *Solid State Physics*. EDP Sciences, ISBN:2-86883-577-5 (Fr) and ISBN:0-03-083993-9 (En) C. Kittel. *Introduction to Solid State Physics*. Ed. Dunod, ISBN-10: 2100497103 ISBN-13: 978-2100497102
Evaluation	For each tutorial 1-4: a combined grade for preparatory work and participation

S7 – MATC – IM	Materials Engineering

Supervisor: Sandrine Ithurria

Teaching staff: Nicolas Lequeux, Vanessa Pereira Pimenta

| Lab: 37.5h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. prepare materials according to EHS norms and the engineering code of ethics (lab log, reliability of results);
LO2. justify methods of formatting and characterization adapted to synthesized materials;
LO3. calculate, simulate, and analyze diffraction patterns of powders and single crystals using dedicated software, if necessary;
LO4. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
LO5. discuss and develop a project in a group;
LO6. organize their laboratory work;
LO7. structure, interpret, and explain experiment results in an oral presentation.

Contents	Experimental lab work to synthesize solid crystalline materials • BaTiO3 ceramics • Mesoporous silica by sol-gel process • Zeolites • Plasmonic gold nanoparticles and quantum dots Material characterization: • X-ray diffraction on single crystal and powder • Nitrate adsorption (BET) • Electrical, magnetic, and optical properties
Independent Study	Objectives: synthesize, interpret, and present experimental results. Methods: preparation and presentation of a lab subject
Bibliographic Resources	Course handouts
Evaluation	Oral exam on a subject addressed in class

# UE Chemistry III	SEMESTER 7
62h - 5 ECTS	UE CH3

Description

The purpose of the course Analytical Sciences (CH3-SAN) is to give student engineers the basic knowledge necessary to revolve an analytical problem, regardless of origin (food security, environment, fraud and counterfeit, doping, historical and archeological heritage, etc.). It also aims to provide students with the concepts needed to develop new, often miniaturized methodologies, a sector currently booming, that enables faster analyses and rapid diagnostics with fewer reagents and solvents (lab-on-a-chip, MEMS technology, and microfluidics).
The course is based on knowledge and understanding of the various types of interface interactions and transport modes, which make it possible to define an analytical strategy and implement a separation method. The basic aspects of separative methods are presented briefly and further explored in tutorial sessions, while their practical aspects are addressed during lab work (CH3-TPSAN).

Semester	Program	
S7	CH3-SAN	Analytical Sciences
	CH3-TPSAN	SAN Lab Work

Prerequisites

Fundamentals of analytical chemistry (chemistry of solutions, pH and complexes, redox), chemical synthesis, crystallography, spectroscopy techniques (S6-CH1-ICO)

UE Validation

Weighted average: CH3-SAN 40%, CH3-TPSAN 60%

Targeted skills

CH3-SAN	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1	Ex.	I						I							
LO2	Ex.							I							
LO3	Ex.							II							
LO4	Ex.							II							
LO5	Ex.							III		III					
LO6	Ex.		III					III		III					
LO7	Ex.		III												
LO8	Ex.		III										II		
CH3-TPSAN	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1	Notebook	I						I							
LO2	Part., notebook							II		II					
LO3	Part., notebook	III	III	II				III							
LO4	Notebook	III	II						III						II
LO5	Part	III													
LO6	Part				II	II									
LO7	Notebook							II	II	II					
LO8	Notebook			II	II	II	II								

Ex.: exam, prec.: preceptorships, Part.: participation, PubA: report delivered in the form of an English-language publication, doc.: use of documents provided

S7 – CH3 – SAN	Analytical Sciences

Supervisors: Jérôme Vial, José Dugay

Teaching staff: Audrey Combes

| Course: 8h | Tutorial: 6h | Super tutorial: 3h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. identify and describe the interactions involved in the various processes of analytical separation;
- LO2. list and describe the different analytical techniques commonly used in molecular analysis;
- LO3. assess the possibilities and limitations of various methods of separation and detection;
- LO4. apply theoretical concepts to calculate performance indicators related to different methods;
- LO5. use theoretical knowledge to justify the behaviors observed in experimental conditions;
- LO6. develop the most appropriate approach to analyzing desired molecule characteristics and the target matrix;
- LO7. utilize their knowledge to interpret the results of an analysis;
- LO8. utilize their analytical knowledge to solve a societal problem.

Contents	Course 1. Introduction: definition of the characteristics of current analytical chemistry in relation to needs 2. Fundamental quantities and kinetics of exchanges 3. Gas chromatography 4. Partition chromatography 5. Ion-exchange chromatography 6. Ion pair and steric exclusion chromatography 7. Instruments 8. Capillary electrophoresis Super tutorial 1. Supercritical fluid chromatography 2. Miniaturization and lab-on-a-chip 3. Two-dimensional chromatography

Bibliographic Resources	Course handouts Tutorial and Super tutorial instructions

Evaluation	Written final exam, 30% part A (course, tutorial, lab), 70% part B (course, tutorial, lab, super tutorial)

S7 – CH3 – TPSAN	Analytical Sciences Lab Work

Supervisors Jérôme Vial, José Dugay

Teaching staff: Audrey Combes

| Lab: 45h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. observe and interpret experimental behavior based on theoretical knowledge;
- LO2. apply an experimental protocol developed using equipment similar to that used in an industry context;
- LO3. evaluate the relevance of an approach based on the physical-chemical problem and available materials;
- LO4. choose the appropriate analytical strategy for solving a complex problem;
- LO5. develop an experimental setup capable of responding to given specifications;
- LO6. work in a group;
- LO7. take a critical approach to using data acquisition and analysis programs, and the validity of results;
- LO8. summarize, interpret, and present experimental results.

Contents	Twelve different experimental setups covering all separative approaches (gas phase and liquid phase chromatography, capillary electrophoresis) and fields of application (environment, food industry, pharmaceutical industry, oil industry): of these manipulations, three appeal to student engineers' creativity by asking them to design and carry out their own experiment protocol.
Organization	It is important to note that whenever possible, students work with the latest-generation material (for example, combining gas chromatography and liquid chromatography with mass spectrometry) to render them quickly operational in both industry and research.
Bibliographic Resources	Course and lab handouts
Evaluation	Work / attendance 25% Lab log 75%

UE Mathematics and Numerical Methods III

Mathématiques and Méthodes Numériques III

71.5h - 5 ECTS

SEMESTER 7

UE MMN3

Description

The course Mathematics II (MMN3-MATH2) addresses partial differential equations, variational calculus, and probability.

The course Numerical Methods (MMN3-MENU) offers a close analysis of the difficulties inherent in limited numerical precision used by current-day calculators.

The objective of the Numerical Simulation course (MMN3-SIMUL) is to develop in PYTHON the software tools necessary for molecular dynamics. This development will be done in team and will rely on PYTHON libraries and collaborative development tools (e.g. GIT). The aim of the course is to implement the software chain from simulation to generation and analysis of experimental results.

Semester	Program	
S7	MMN3-MATH2	Mathematics II
	MMN3-MENU	Numerical Methods
	MMN3-SIMUL	Numerical Simulation

Prerequisites

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

Related classes

Waves and Acoustic Lab (S7-OA-TPOA)

UE Validation

Weighted average: MMN3-MATH2 50%, MMN3-MENU 25%, MMN3-SIMUL 25%

Targeted skills

MMN3-MATH2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., CC	III	III					III				II			
LO2.	Ex., CC	III	III					III							
LO3.	Ex., CC	III	III					III							
LO4.	Ex., CC	III	III					III							
LO5.	Ex., CC	II	II					II							
MMN3-MENU	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	II	II												
LO2.	Ex.	II	II												
LO3.	Ex.	II	II					II							
LO4.	Ex.	II	II												
LO5.	Ex.	II	III					II				II			
LO6.	Ex.	II	III						II						
LO7.	Ex.	II	II						II			II			
MMN3-SIMUL	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part, R	II	II						II						
LO2.	Part, R	II	II								II				
LO3.	Part, R	II	II												
LO4.	Part, R	II	III								II				
LO5.	Part, R	II	III								II				
LO6.	Part, R	II	III						II						

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

S7 – MMN3 – MATH2 | Mathematics II

Supervisor: Vincent Démery

| Course: 14h | Tutorial: 14h | Preceptorships: 6h | 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. manipulate fundamental mechanisms at the microscopic level, model macroscopic phenomena, and connect a macroscopic phenomenon to microscopic processes;
- LO3. describe a partial differential equation (PDE) and its boundary conditions and solve it;
- LO4. solve a problem as a functional to be minimized;
- LO5. describe and analyze a random phenomenon.

Contents	1. Partial differential equations
	• Classification of partial differential equations (PDE)
	• Linear PDEs, Green's function
	• Constant-coefficient PDEs
	• First-order PDEs, characterization method
	• Second-order PDEs
	    o Classification of elliptic, parabolic, and hyperbolic PDEs
	    o Solving Poisson's equation, and heat and wave equations
	• Spectral analysis of PDEs
	2. Calculus of variations
	• Euler-Lagrange equation, boundary conditions
	• Constrained minimization
	• Invariants and integrals of motion
	3. Probability
	• Events and probability
	• Random variables
	• Continuation of random variables, central limit theorem

Independent Study	Objectives: use the concepts learned in the course to go beyond basic applications. Methods: Preceptorship preparation
Bibliographic Resources	Course notes
Evaluation	Ongoing assessment (1/3 of the final grade) and written exam (2/3) Methods of ongoing assessment (out of 20) • Three 15-minute tests in the first portion of the tutorial (out of 10); dates will be announced in advance. • Three tutorials (out of 10) Each tutorial is graded on a scale of one to three, with two points given for the assignment and one point given for participation. The assignment is awarded points in the following manner: ✓ 0: no assignment;

	✓ 1: a rushed assignment—only the first questions are answered and the student stops at the first difficult question, although it is possible to provide results to continue; ✓ 2: a serious assignment—the entire test was addressed, even if some questions were not answered. To grade the test according to the work actually provided, the student may redo the questions addressed on the test at the blackboard. A bonus point will be given to students who successfully solve the difficult questions.

S7 – MMN3 – MENU	Numerical methods

Supervisor: Didier Cassereau

| Lab: 18.75h | Course language: |

Objectives / Targeted Skills

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

LO1. analyze the problems that arise due to limited numerical accuracy;
LO2. Analyze and solve problems related to computational complexity;
LO3. Understand and implement standard algorithms applied to digital integration and matrix inversion;
LO4. Understand and implement spectral analysis tools for signal processing;
LO5. Use the digital tool to solve differential and partial differential equations;
LO6. Identify the interest and the possibility of parallelizing algorithms in order to reduce computation times;
LO7. Mobilize your knowledge to solve a complex and / or transversal problem.

Contents	Teaching consists of 5 practical sessions on a computer. During these sessions, the different themes of the course are organized in a practical way with a direct implementation on the machine. The Python language will be used during these practical sessions; However, students who can also implement all or part of it in C language. The objective of this course is to approach the problems in a concrete way and to see how the digital tools at our disposal get around the difficulties. The last session will take place at the introduction of a project subject to be carried out in pairs during the 2 weeks following the end of the practical work.

Related classes	The project part makes the link with physical phenomena, their equation and their numerical resolution.

Bibliographic Resources	Handouts

Evaluation	Project report by pairs

S7 – MMN3 – SIMUL | Numerical Simulation

Supervisor : Alexandre Allauzen

| Lab: 18,75h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. Design the algorithms necessary for the simulation of molecular dynamics ;
LO2. Develop with the PYTHON programming language the efficient software solution adapted to the targeted use;
LO3. Estimate the complexity (in time and memory) of its proposals, depending on the parameters of the problem modeled;
LO4. Write reusable and shareable code in PYTHON;
LO5. Build and share code using decentralized version control systems (e.g. git);
LO6. Generate, synthesize, interpret and report experimental results.

Contents	Molecular dynamics is a numerical simulation technique used to model the evolution of a particle system over time. This technique is applied in many fields of physics and chemistry. After an introduction of the scientific problems, the first part of the lab sessions will be dedicated to the development of the basic software tools in PYTHON, and to the formatting of the code so that it can be re-used and shared by others thanks to the GIT tool. During the last session, the students will work on a personal extension which will give rise to a report of experiments and a GIT deposit.

Related classes	Programming with PYTHON (S5-MMN1-PYTHON)

Bibliographic Ressources	Course material and python-notebooks for the lab

Evaluation	Lab (1/3) and project (2/3) reports

UE Humanities & Social Sciences – General Knowledge I *Sciences Humaines et Sociales – Culture Générale I*	SEMESTER 7
32.25h - 2 ECTS	UE SHSCG1

Description

The purpose of the module Professional Project (PP) is to help students develop their professional project through mastering recruitment techniques / processes, gaining a better understanding of what motivates individual collaborators in an organization, understanding certain mechanisms to rally and train a team around a shared goal, awareness of working with different personalities and cultures, taking a step back, and reflecting on how they fit within a team.

During the PSL Weeks, several PSL establishments come together to suggest shared courses. These weeks give students the opportunity to acquire new scientific knowledge and to discover new fields related to the humanities and social sciences, entrepreneurship, and economics.

Semester	Program	
S7	SHSCG1-PP	Professional Project
	SHSCG1-PSL1	PSL Week

UE Validation

Weighted average: SHSCG1-PP 100%, SHSCG1-PSL Validated / No validated

Targeted skills

SHSCG1-PP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Participation, evaluation				II	II			II						II
LO2.	Interview, evaluation			II	II							II		II	
LO3.	Cover letter, interview, evaluation				II	II							II		
LO4.	Resume, cover letter, interview				III	II				II					II
LO5.	Interview			II	II								II		

S7 – SHSCG1 – PP	Professional Project

Supervisor: Brigitte Beaussart, Esther Honikman

| Workshops: 11.25h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. interpret their personal evaluation;
LO2. define and develop their approach to a professional project;
LO3. evaluate their future work environment;
LO4. communicate appropriately both verbally and in writing to a given audience;
LO5. defend their application in an interview.

Contents	• Recruitment process: tools and strategies to find internships; writing application and cover letters and resumes; online job applications, etc. • Personal evaluation, development of a professional project and the skills necessary to pursing a chosen direction (knowledge, skills, interpersonal skills, professional development).
Organization	Prerequisites S5 – COMMI1 – CRS Sessions include scenarios and active student participation. These are interactive workshops with role-playing games and scenarios.
Bibliographic Resources	Self-evaluations
Evaluation	Mandatory workshop attendance Attendance at professional conferences is highly recommended. Participation in the workshop 50% Internship research efforts and the quality of follow-up with companies and ESPCI supervisors 50%

S7 – SHSCG1 – PSL1	PSL Week I

Coordinating supervisor: Assiatou BAH, Corinne Souilé-Ziakovic

| Course: 24h | Course language: 🇫🇷 🇬🇧 |

Objectives / Targeted Skills

This week gives students the opportunity to acquire new scientific knowledge, and to discover new fields related to the humanities and social sciences, entrepreneurship, and economics.

Catalog	www.pslweek.fr • Soft and Living Matter (ISAI Graduate Program) • Ethics and Artificial Intelligence (ENS) • Prospective Anthropology: thinking about the future of humanity (MINES) • Echo-design (MINES) • Production and Logistics Systems (MINES) • Energy Efficiency of Systems (MINES) • Control Theory (MINES) • Image Analysis: From Theory to Practice (MINES) • Material Design for New Challenges (MINES) • Fluids (MINES) • Finite Elements (MINES) • Atomic Engineering (MINES) • The care of water (MINES) • Energy and order of magnitude or will renewable energies be enough to meet our energy needs? (ESPCI) • Biology, a beautiful playground for engineers (ESPCI) • Biomimetic - Bio-inspired materials (ESPCI) • -...

Organization	Mandatory enrolment in a module

Bibliographic Resources	Varies according to module

Evaluation	Varies according to module

# UE Project Management	SEMESTER 7
76.5h - 5 ECTS	UE GP

Description

Projets Scientifiques en Equipe (Group Science Projects / PSEs) form an interdisciplinary teaching model developed for semesters 6, 7, and 8. The goal of this module is to carry out experiment projects and it is modeled after a "hacklab." Projects embrace all disciplines taught at ESPCI Paris—physics, chemistry, and biology—and some are interdisciplinary. They are all different and change each year. Thirty projects are carried out each year by the entire year group.
These projects teach students to lead team-based projects and to communicate about them in several formats (presentation, poster, video), which forms an essential part of the module. For this reason, the module is linked to the semester 6 module Verbal Communication (S6-COMMI2-COMOR).

The module Project Management (GP) aims to show students the importance of project management. Vocabulary, key factors for project management success, and basic tools are presented and applied during lab work. Reflection based on projects carried out in TPEs is proposed.

Semester	Program	
S7	GP-PSE2	Group Science Projects II
	GP-GP	Project Management
	GP-FI	Financing Innovation

UE Validation

Weighted average: GP-PSE2 85%, GP-GP 15%

Targeted skills

GP-PSE2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.	III	III						III		II	II		II	I
LO2.	Part.				II		II				II				I
LO3.	Part.				II				III	III			II		I
LO4.	Part.	III	III					II			II	II	II		
LO5.	Part.	III	III												
LO6.	Part.	III	III						II				II		
LO7.	Part.	III	III												
LO8.	Part.	III	III						III						
LO9.	Part.	III	III								II	II			
LO10.	Aff.	II	II								II				I
GP-GP	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Project		I	I	I										
LO2.	Project		I	I	I										
LO3.	Project		I	I	I										
LO4.	Project		I	I	I	I									
LO5.	Project		I	I	I										
LO6.	Project		II		II						II				
LO7.	Project		II		II						II				
GP-FI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.															
LO2.															
LO3.															
LO4.															

Part.: participation, Aff.: poster

S7 – PG – PSE1	Group Science Project II

Supervisors: Emmanuel Fort, Maxime Ardré, Yvette Tran

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

| Lab: 60h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

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

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

Independent Study	Objectives: training through experimental research, experiment and original protocol design, critical analysis of results, project development skills, communicating about progress and results. Methods: experiments and development of experiment protocols and methods; creation of a presentation, posters, and a video.

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

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

S7 – PG – GP	Project Management

Supervisors: Faustine Vanhulle

| Course: 6h | Lab: 7.5h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. define a project and basic project management terminology (project, specifications, team, etc.);
LO2. explain what defines a project compared with other company activities;
LO3. describe different types of projects, list essential project elements, explain the Q-C-D triangle, describe different project management methodologies;
LO4. identify the main causes of failure and key success factors, project stakeholders, and the different tasks and groups of tasks within a project;
LO5. describe project monitoring tools;
LO6. frame a project;
LO7. carry out risk analysis and develop a simple project plan.

Contents	• Definition of a project based on student examples • Introduction to different types of projects • Introduction to key elements: Project framing Project planning Project team and team leader Project monitoring and risk management Communication • Group work Reflection on and analysis of practices and possible improvements for TPE projects Choice of concrete actions for each group and each student to implement in the continuation of TPEs

Bibliographic Resources	Course resources Resources: See sources in course resources + lectures, TED talks, and recommended MOOCs

Evaluation	Grade based on a report to be handed in at the end of lab

S7 – PG – FI	Financing Innovation

Supervisors: Frédérique Kalb

| Course: 3h | Course language: 🇫🇷 |

Objectives / Targeted Skills

Contents	

Independent Study	

Bibliographic Resources	

Evaluation	Attendance mandatory

UE English III

26h - 2 ECTS

SEMESTER 7

UE ANG3

Supervisor: Daria Moreau

| Tutorial: 26h | Course language: |

Description

The purpose of English courses is to improve students' English skills and teach them linguistic independence to prepare them to use technical and scientific English in an international, intercultural and professional context. These are theme-based classes which aim at teaching students working in English on a selected topic and to deepen their intercultural knowledge and skills. They are also intended to assist students in preparing for the TOEIC exam, required by the CTI to obtain the ESPCI engineering degree.

Semester	Program	
S7	Ang3	26h, 2 ECTS

Prerequisites

Level B2 of the CEFRL reference chart

Evaluation

Validation of the five skills listed in the CEFRL reference chart at level B2 / C1 minimum through:

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

Targeted skills

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

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

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

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

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

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

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

LO5. defend their point of view in a debate on a subject studied this year and respond to factual questions about the subject.

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

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

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

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

RAPPORT PEDAGOGIQUE

Nom et prénom de l'étudiant(e) :

L'année d'études :

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

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

Attitude pendant la formation et connaissance de la culture

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

Fait à :
Nom de l'enseignant :

Total points :

SEMESTER 8

SEMESTER 8					453 h		30 ECTS				
SEMESTER 8	Presential study (h)	ECTS weighting	Code UE	Code EC	Supervisor	Courses (h)	Tutorial (h)	Super Tutorial (h)	Preceptorships (h)	Lab (sessions
UE Optics	77.25	5								
Optics and Images - Optics and Matter	36	50%	OPT	OPT	E. Fort	21	9		6	
Optics Lab Work	41.25	50%		TP OPT	F. Ramaz					11
UE Mechanical Engineering II	84.5	5								
Mechanics of Solids and Materials II	25	33%	SIM2	MSM2	M. Ciccotti	17	6		2	
Fluid Mechnanics	22	33%		MF	M. Reyssat, J. Bico			22		
Hydrodynamics and Physical Mechanics Lab Work	37.5	33%		HMP	M. Reyssat					10
UE Soft Matter Physics	41	3								
Colloids	17	50%	PMM	COL	J. Bibette	17				
Introduction to Polymer Physics	24	50%		IPP	K. Dalnoki-Veress	18			6	
UE Life Sciences	50	4								
Physiology	20	50%	SV2	PHYS	G. Vetere, T. Gallopin	14			6	
Physiology Lab Work	30	50%		TP PHYS	T. Gallopin					8
UE Chemistry IV	76.25	5								
Inorganic Chemistry and Materials	35	50%		CMI	S. Norvez C. Soulié-Ziakovic	23	4		8	
Inorganic Chemistry and Materials Lab Work	41.25	50%		TP CMI	S. Norvez C. Soulié-Ziakovic					11
UE Deep Learning	19.5	1	DL	DL	A. Allauzen	12				2
UE Humanities & Social Sciences - General knowledge II	51	3								
History of Science and Technology in Society	27	100%	SHSCG2	HSTS	E. Bertrand	27				
PSL Week II	24	V		PSL2	A. Bah	30				
UE Communication II	25.5	2								
Group Science Project III	22.5	100%	COMM2	PSE3	E. Fort, Y. Tran, M. André					6
Oral Communication	3	V		COMOR	C. Probst		3			
UE English IV	28	2	ANG4	ANG4	D. Moreau	28				

One lab session is 3 h 45 min.

The volume of individual study is estimated to be 284 hours according to the following breakdown:

1 h class = 0.9 h individual study

1 h tutorial = 0.7 h individual study

1 h super tutorial / tutoring = 1.5 h individual study

1 h lab = 0.3 h individual study

# UE Optics	SEMESTER 8
77.25h - 5 ECTS	UE OPT

Description

This purpose of this optics teaching model is to give students understanding and mastery of phenomena involving optics. It addresses very diverse aspects of optics both in terms of fundamental concepts and through many fields of application. This module includes a tutorial class and preceptorships, as well as a strong experimental component through lab work.

Optical waves are first addressed in terms of light speed. This provides historical perspective on the fundamental role of optics in the evolution of scientific theories (relativity, quantum mechanics), and also enables students to understand phenomena like the Doppler effect or phase invariance. Optics is then addressed using a variational approach to approximation in geometric optics (Fermat's principal, eikonal equation, etc.). Concepts of spatial and temporal coherence are then studied, including applications like spectroscopy and correlative imaging. Propagation of optical waves is discussed through the formation of images and Fourier optics. Knowledge of applications in the field of microscopy and astrophysics is essential. A portion of the course is also dedicated to photometry and discusses properties of sources and detectors. A chapter on the polarization of light aims to help students understand how this phenomenon can be controlled and modified during propagation in naturally birefringent materials or through external control. Light-matter interaction is also studied from a classical perspective. The final chapter addresses the function and use of LASERs and includes many example applications.

Semester	Program	
S8	OPT-OPT	Optics and Images – Optics and Matter
	OPT-TPOPT	Optics Lab Work

Prerequisites

Familiarity with Maxwell's equations (in a void and in homogenous media), Poynting vectors, Alembert's equation, geometric optics, notions of waves (wave length, number of waves, frequency, etc.), light speed, refractive index, Fourier Transform, wave planes.

UE Validation

Weighted average: OPT-OPT 50%, OPT-TPOPT 50%

Targeted skills

OPT-OPT	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	III						III							
LO2.	Ex.	III						III							
LO3.	Ex.	III						III							
LO4.	Ex.	III						III							
LO5.	Ex.	III						III							
LO6.	Ex.	III						III							
LO7.	Ex.		III												
LO8.	Ex.		III												
OPT-TPOPT	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	AE, CL	III	III												
LO2.	AE, PO						II								
LO3.	AE, CL								III	III			II		
LO4.	AE, CL	III	III										II		
LO5.	AE	III	III												
LO6.	AE, CL	III	III						II				II		
LO7.	AE	III	III												
LO8.	AE, CL	III	III						III						
LO9.	AE, PO	III	III												

Ex.: Written final exam, AE: Experimental skills, CL: lab log, PO: oral presentation

S8 – OPT – OPT	Optics and Images — Optics and Matter

Supervisors Emanuel Fort, François Ramaz

Teaching staff: Arthur Goetschy, Igancio Izeddin, François Ramaz, Olivier Thouvenin

| Course: 21h | Tutorial: 9h | Preceptorships: 6h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify and apply basic concepts involving light propagation and image creation;
LO2. identify and apply basic concepts involved in developing a LASER;
LO3. identify and apply basic concepts that allow for control of the polarization of light in birefringent materials;
LO4. develop a system of optical detection and imaging that responds to a set of specifications;
LO5. develop an optical spectrometer using characteristics provided;
LO6. connect macroscopic properties to the structure of transition metal complexes and inorganic materials;
LO7. utilize their knowledge to analyze how optical systems work;
LO8. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course / Tutorial The course is divided into eight chapters: 1. Speed of light 2. Variational optics 3. Coherence — Interferences 4. Propagation — Fourier optics 5. Photometry — Detectors 6. Polarization — Natural and induced anisotropy 7. Light-matter interaction 8. Lasers Preceptorships 1. Microscopy 2. Multi-wave imaging 3. Lasers

Independent Study	Objectives: use concepts learned in the course to go beyond basic applications. Methods: Preceptorship preparation

Bibliographic Resources	Online course notes, course handouts

Evaluation	Written final exam

S8 – OPT – TPOPT	Optics Lab Work

Supervisors Emanuel Fort, François Ramaz

Teaching staff: Arthur Goetschy, Igancio Izeddin, François Ramaz, Olivier Thouvenin

| Lab: 41.25h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

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

Contents	Four topics will be suggested: 1. Interferential spectroscopies - Fourier transform spectroscopy (x2) - Study of a hyperfine structure; Fabry–Pérot interferometer - Spectroscopy of polarized light; measuring birefringence - Heterodyne interferometric detection - Fiber-optic interferometer 2. Lasers - HeNe Laser Study of Gaussian beams of an optical cavity (x3) - Laser Nd:YAG; Intracavity frequency doubling - Wavelength-tuneable dye laser 3. Spatial frequency diffraction and filtering - Laser granularity (speckle) - Numerical holography - Ultrasonic diffraction - Wave front manipulation / control with an SLM (x2) - Photorefractive effect—Mixing two waves 4. Light modulation and signal detection - Detection using the mirage effect - Differential profilometer - Measurement of a magnetic rotary polarization (x2) - Infrared imaging

Independent Study	Objectives: manipulate, synthesize, interpret, and present experimental results Methods: lab log, preparation for a 15-presentation of a manipulation using lab instructions and lab log (final session)

Organization	4 manipulations / pair (1 per topic), one manipulation = 3 sessions 22 experimental assemblies, including 17 unique versions

Bibliographic Resources	Lab instructions

Evaluation	Experimental Skills (AE) 1 / 3 Lab log (CL) 1 / 3 Oral presentation (PO) 1 / 3

UE Mechanical Engineering II

SEMESTER 8

84.5h - 6 ECTS

UE SIM2

Description

The course Mechanics of Solids and Materials II (SIM2-MSM2) addresses the mechanical properties of materials. It explores the main types of behavior by explaining their physical origin. The viscoelastic, plastic, and fracture characteristics of the main classes of materials are discussed in relation to the study of corresponding behavioral laws. A study of simple forces explains the ideas that guide the choice of a material according to an intended application (structure and load). A methodology light on formalism will be used to address physical modeling of the more complex situations encountered in daily life or in modern applications.

The course Fluid Mechanics (SIM2-MF) provides a general overview of fluid mechanics for physicians, chemists, and biologists. It aims to teach students the fundamental concepts necessary to understanding flow dynamics. Emphasis is placed on determining relevant orders of magnitude, on the wise use of dimensionless physical parameters, and reasoning using scaling law.
This course is complemented by a third-year class on mass and heat transfer (S10-HT).

Semester	Program	
S8	SIM1-MSM1	Mechanics of Solids and Materials II
	SIM2-MF	Fluid Mechanics
	SIM2-HMP	Hydrodynamics and Physical Mechanics

Prerequisites

A basic understanding of continuum mechanics and linear elasticity (S5-SIM1-MSM1); ability to solve ordinary differential equations, scaling laws.
Recommended: Fundamentals of fluid mechanics (viscous fluids, perfect fluids, Reynolds number).

UE Validation

Weighted average: SIM2-MSM2 33%, SIM2-MF 33%, SIM2-HMP 33%

Targeted skills

SIM2-MSM2	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.,prec.	III	II					III					II		
LO2.	Ex.,prec.	II	II					II							
LO3.	Ex.,prec.		II					III					II		
LO4.	Ex.,prec.	III	III					III							
LO5.	Ex.,prec.	III	III					III							
LO6.	Ex.,prec.	III	III					III							
LO7.	Ex.,prec.	III	III					III					II		II
LO8.	Ex.,prec.		III					III					II		II
LO9.	Ex.,prec.	III	III					III					II		II
SIM2-MF	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Ex.,prec.	III	III					III							
LO2.	Ex.,prec.	III	II					III							
LO3.	Ex.,prec.		II					II							
LO4.	Ex.,prec.		II					II							
LO5.	Ex.,prec.	III						II							
LO6.	Ex.		II										II		II
LO7.	Prec., POF		III												
LO8.	Prec., POF	III	III					III					II		II
SIM2-HMP	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Part.		III						III						
LO2.	Part., notebook		III						III						
LO3.	Part., Notebook, Report		III						III						
LO4.	Part.		III						III						
LO5.	Part., Notebook, Report		III						II				II		II
LO6.	Notebook, Report		III						III				II		II
LO7.	Notebook, Report		III						II						
LO8.	Notebook, Report		III						III				II		II

Ex.: exam, prec.: preceptorships, POF: oral presentation in French, Part.: participation

S8 – SIM2 – MSM2	Mechanics of Solids and Materials II

Supervisor: Matteo Ciccotti

Teaching staff: Zorana Zeravzic, José Bico, Benoit Roman

| Course: 17h | Tutorial: 6h | Preceptorship: 2h + 2h (optional) | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. analyze a general problem in solid mechanics such as "How an object responds to a load" (concepts of material, structure and load bearing);
- LO2. estimate orders of magnitude by resolving the general equation of dynamics using scaling law coupled with the appropriate behavioral laws: elasticity, dynamics, viscoelasticity, elastoplasticity, or failure;
- LO3. identify physical scales, express results in a dimensionless form, preserve and interpret tensorial quality when necessary;
- LO4. represent viscoelastic behavior in time or frequency fields, evaluate elastic or dissipative response regimes in terms of loading speed and temperature for the intended application;
- LO5. calculate the critical load at which plastic behavior appears in a structure, identify the regions affected by plastification, and evaluate the response mechanism of a plastified structure;
- LO6. identify the critical load that will initiate or propagate a crack, evaluate the equilibrium of its propagation, and consider the effect of material behavior law on crack propagation;
- LO7. evaluate the limits of application for hypotheses of linearity, semi-static states and isothermal states for the system being studied, and interpret the consequences of violating these hypotheses;
- LO8. choose the appropriate material and optimal dimensions to obtain the necessary response, while taking into consideration typical loading scales for an application;
- LO9. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course / Tutorial • An overview of strength of materials • Classes of materials and behavioral families • Review of continuum mechanics (deformation and strain tensors, fundamental equation of equilibrium) • Review of 3D linear elasticity (Young and Lamé laws, elastic modules, elastic energy) • Further exploration of linear elastic behavior (energy theorems, stability analysis, problem solving using scaling law) • Waves and vibrations • Viscoelastic behavior: rheological models, modeling time and frequency, time-temperature superposition • Elastoplastic behavior: plasticity criteria, flow laws, rheological models (perfect plasticity, strain hardening, viscoplasticity) • The paradox of theoretical resistance to failure • Linear Elastic Fracture Mechanics (LEFM): Local criterion: the stress intensity factor (Irwin). Energy criterion (Griffith): energy restitution rate

	• Fragility and ductility: physical dissipation mechanisms and scales • Slow and fast fractures • Heterogenous media: inclusions, composites • Contact, adhesion, and friction Preceptorships Annually renewed topics enable students to understand calculation using scaling law, as well as to explore applications beyond the course in more depth.

Bibliographic Resources	Course handouts and resources Tutorial and preceptorship instructions Resources available at http: / / cours.espci.fr

Evaluation	Written final exam MCQ 25%, scaling law problem 75%

S8 – SIM2 – MF	Fluid Mechanics

Supervisor: Mathilde Reyssat, José Bico

| Course: 2 hours | Tutorial: 20 hours | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify the different terms in the Navier-Stokes equation and identify different flow regimes according to Reynolds number;
LO2. evaluate approximations of the Navier-Stokes equation according to the geometry of a problem and its flow regime;
LO3. estimate orders of magnitude by solving the Navier-Stokes equation using scaling law;
LO4. estimate the stresses induced by a flow on a solid;
LO5. analytically solve flow profiles in simplified situations;
LO6. develop and size a hydro or aerodynamic device (ex.: size a foil);
LO7. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO8. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena.

Contents	Course / Tutorial
	Course / Tutorial 1. Introduction: fluid mechanics equations • Flow at different scales: Reynolds number • Fundamental principle of dynamics applied to a continuous medium • Viscous stresses, analogy with Hook's law in mechanics • Navier-Stokes equation 2. Viscous flows • Measuring the viscosity of a fluid • Poiseuille flows • Elongational flows 3. Interfaces • Surface energy • Laplace law • Menisci • Capillary action • Impregnation dynamics 4. Low Reynolds number locomotion • Sedimentation in a viscous liquid • Propeller fall • "Corkscrew" propulsion 5. Lubrification approximation • Crushing a layer of liquid • Viscous fingering • Leveling of a viscous film, Rayleigh-Taylor instability 6. Boundary layers • Plate set in motion in a fluid • Diffusion of vorticity

	• Boundary on the leading edge of a plate • Friction drag • Oscillating boundary layer 7. Bernoulli's Equation • Venturi effect, Pitot tube Unsteady Bernoulli Equation • Cavitation 8. Vortices • Vortices and vorticity • Interactions between vortices • Lamb-Oseen model • Stretched vortices 9. Load-bearing capacity and drag • Load-bearing capacity of a rotating cylinder • Form drag 10. Wings and sails • Boundary-layer-induced circulation • Marginal vortices • Sizing a foil and adjusting a sail 11. Surface waves • Dispersion relation • Phase velocity / group velocity • Circles in water • Breaking waves • Wind on the sea: Kelvin-Helmholtz instability

Organization	This course is taught using exercises that, ideally, enable active student participation. Following an introduction to fundamental equations in fluid mechanics, we will use exercises to gradually illustrate different flow regimes.

Bibliographic Resources	Various course resources are available on the following blog: https://blog.espci.fr/mecaflu/

Evaluation	Written final exam

S8 – SIM2 – HMP	Hydrodynamics and Physical Mechanics Lab Work

Supervisors: Mathilde Reyssat

Teaching staff: Nicolas Brémond, Zorana Zervavcic, Matteo Ciccotti

| Lab: 37.5h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify and independently lead the different steps of an experimental approach;
LO2. carry out mechanical measurements in compliance with EHS norms and the engineering code of ethics (lab log, reliability of results);
LO3. use measurement tools and techniques in the laboratory in the field of solid and fluid mechanics;
LO4. take a critical approach to using data acquisition and analysis programs;
LO5. interpret experiment results with a view to modeling them;
LO6. validate a model by comparing predictions with experiment results and assess the limits of their validity;
LO7. identify sources of error to calculate uncertainty in experiment results;
LO8. summarize, interpret, and present experimental results.

Contents	Five experiments randomly selected from the following topics: 1. Sedimentation / Fluidization • Fluidized bed: upward-flow-induced fluidization of a particle bed followed by sedimentation (small Reynolds number) • Marbles and bubbles: rising bubbles in a bath in free or confined medium, toric bubbles; comparison with particle fall (large Reynolds number) 2. Velocity fields • Thermal plume: measuring velocity field using Particle Image Velocimetry (PIV) in a convective flow • Waves: studying wave propagation in a tank, visualizing the velocity field • Leaves in the wind: measuring the velocity field behind an obstacle using hot wire anemometry; measuring the drag coefficient of an object deformed by flow • Wake behind an obstacle (experiment): measuring a velocity field using Laser Doppler Anemometry (LDA); measuring the stability threshold of flow and frequency of oscillations • Wake behind an obstacle (digital): digital simulation, using finished elements (FreeFem++ software), of the instability of a flow's wake behind an obstacle; growth rate, magnitude, and oscillation frequency 3. Wetting, tensiometry, physical chemistry • Capillarity: capillary impregnation / saturation, film deposit • Impacts: study of the impact of drops on surfaces of varying wettability using rapid video

	• Diffusion and viscosity: study of dispersion of a colorant in a flow using microfluidics techniques; measurement of an unknown viscosity 4. Granular materials Avalanches: study of the flow of a dry granular medium on an inclined plane; flow of grain in a silo 5. Solid mechanics • Duct tape: demonstration of the elastoviscoplastic behavior of a polymer film (Duct tape) using a traction machine • Cracks: photoelastic study of stresses at the tip of a crack • Vibrations: vibration modes of a recessed beam, resonance frequency at the buckling threshold, viscoelastic attenuation • Bubble rafts: study of crystalline defects in model bubble rafts

Bibliographic Resources	Instructions and teaching materials available at: https://blog.espci.fr/mecaflu/travaux-pratiques/

Evaluation	Lab log (1/3) and two reports on randomly chosen topics per pair (2/3)

# UE Soft Matter Physics	SEMESTER 8
41h - 3 ECTS	UE PMM

Description

The purpose of the course Colloids (PMM-COL) is to present students with the main classes of colloids, discuss the different interactions that structure these systems, and study the primary strategies for stabilizing and / or destabilizing these "colloidal phases." Colloids correspond to a highly divided state of matter (objects of intermediate size (mesoscopic) between 10^{-8} m and 10^{-6} m) where interfaces play a predominant role. Such systems are commonly found in everyday life (liquid or solid aerosols, foams, mayonnaise, cosmetic creams, paint, drilling muds, precursor catalyzers and ceramics). Industrial applications for the systems are extremely diverse and are characterized by close connections between product synthesis, formulation, and functionalization. In general, colloidal systems are relatively unstable or a precarious balance between antagonistic forces can be observed.

The course Introduction to Polymer Physics (PMM-IPP) addresses the study of the physical properties of polymers through a statistical physics approach that relies largely on an intuitive understanding of phenomena. The objective is to give students a good intuition regarding the physical properties of these systems by emphasizing the large length scales and time scales involved in polymeric materials.

Semester	Program	
S8	PMM-COL	Colloids
	PMM-IPP	Introduction to Polymer Physics

Prerequisites

Stress-strain relationship of viscoelastic solids; definition of entropy, internal energy; statistical description of a random walk; short-range interactions: VdW, H, etc .; conformation and configuration of a polymer chain; thermodynamics of binary mixtures.

UE Validation

Weighted average: PMM-COL 50%, PMM-IPP 50%

Targeted skills

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

S8 – PMM – COL	Colloids

Supervisor: Jérôme Bibette

| Course: 17h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. identify and describe the main types of colloids;
LO2. explain and justify interactions involved in structuring colloids;
LO3. develop one or more strategies for stabilization and / or destabilization;
LO4. select a strategy adapted to a given application.

Contents	1. Systems in equilibrium • General overview of the condensed liquid state • Molecular interactions • Pure liquids and phase diagram • Amphiphilic molecule solution • Surface and interfacial tension of solutions • Wetting and detergency 2. Metastable states • Dispersions • Emulsions • Gels

Related classes	This course draws on and applies skills learned in other classes at the school, and provides example applications of these skills. It introduces certain problems encountered in the fields of materials, specialty chemistry, pharmaceuticals, cosmetics, paint and coatings, and hydraulic binders.

Evaluation	Written final exam

S8 – PMM – IPP | Introduction to Polymer Physics

Supervisors: Kari Dalnoki-Veress, Hélène Montes

| Course: 18h | Preceptorships: 6h | Course language: |

Objectives / Targeted Skills

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

- LO1. use basic concepts that explain the structural and dynamic properties of polymers in solution and in the solid state;
- LO2. connect the macroscopic mechanical properties of polymer materials to structural parameters (length and conformation of polymer chains) and physical-chemical parameters (solvent, temperature);
- LO3. connect basic dynamic mechanisms at the microscopic scale to the macroscopic rheological properties of polymer materials;
- LO4. analyze the mechanical behavior of a polymer in an experimental situation in relation to the time scales involved;
- LO5. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents

Course

1. Entropy of polymer chains (in connection with UE PSA, S6)
   - Intrinsic dimensions of a polymer chain (ideal, real, stretched chain / confined chain, size measurement using radiation scattering)
   - Polymer mixes and solutions (free energy of a binary mix)
   - Rubber elasticity (refined network model and its limits, swelling properties)
2. Dynamics of conformational changes
   - Thermal energy vs. weak interactions (Van der WLOls, H-bonds, etc.)
   - Observation time vs. time of conformational changes
   - Length scales: i) chain diffusion; ii) glass transition; iii) typical chain rearrangement times and mechanical stress (mechanical modulus E (T, t), viscoelasticity and time-temperature equivalence (WLF equation))

Preceptorships

- Chain dimensions: conformations and properties in solution
- Glass transition
- Rubber elasticity

Related classes

Applied physical statistics (S5-PSA-PSA), Mechanics of Solids and Materials II (S8-SIM2-MSM2), and Crystalized Materials (S7-MATC-MC)

Bibliographic Resources

Polymer Physics (R.Colby. M. Rubinstein)

Evaluation

Final exam in English:
Course questions (10) 50%
Short problems (5) 50%

UE Life Science II

SEMESTER 8

UE SV2

50h - 4 ECTS

Description

The courses Physiology (SV2-TPPHY) and Lab Work (SV2-TPPHY) introduce students to the fundamental concepts of physiology with a particular focus on neurophysiology by drawing on concepts of molecular and cellular biology introduced in the first year of study (S6-SV1). Different physiological systems will be addressed with the aim of introducing current and emerging innovative applications in the bioengineering field.

Semester	Program	
S8	SV2-PHYS	Physiology
	SV2-TPPHYS	Physiology Lab Work

Prerequisites

Basic knowledge of biology

UE Validation

Weighted average: SV2-PHYS 50%, SV2-TPPHYS 50%

Targeted skills

SV2-PHYS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex.	I	I					I							
LO2.	Ex.	II						II							
LO3.	Ex.	III	I						I				I		I
LO4.	Ex., prec.	III											III		
LO5.	Ex.,prec.	III	III												
LO6.	Ex., prec.	II													
LO7.	Ex., prec.	III											II		
SV2-TPPHYS	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1.	Report, Part.	III	III												
LO2.	Report, Part.	III	III												
LO3.	Report, Part.					I									
LO4.	Report, Part.	III	III	I		I			III				I	I	
LO5.	Report, Part.		II										II		
LO6.	Report, Part.	II	II												
LO7.	Report, Part.		II												
LO8.	Report, Part.	III	III												
LO9.	Report, Part.	III	III							I			II		

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

S8 – SV2 – PHYS	Physiology

Supervisors: Gisella Vetere, Thierry Gallopin

| Course: 14h | Preceptorship: 6h | Course language: 🇬🇧 🇫🇷 |

Objectives / Targeted Skills

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

LO1. outline the physiological systems studied (including the neural, cardiovascular and digestive systems) and their integration within the body;

LO2. understand, recognize, and apply the principle of different levels of organization of the human body (from cellular to the organismal level);

LO3. Apply basic concepts of physiology to engineered products for medical and scientific purposes (through concrete examples); How to develop new bioengineering applications using physiological variables taught in the course;

LO4. take a critical approach to analyzing a biology article in English;

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 their knowledge and draw on documentary resources to observe and interpret experiment phenomena;

Contents	Course / Tutorial At the level of the organism, we will focus in greater detail on four major systems or functions: the nervous system functions and the sensory systems (and their interactions), the cardiovascular system, digestive and respiratory system. Course overview: 1. Physiology: from the molecule to the organism in its environment 2. Introduction to intercellular communication 3. Introduction to the cardiovascular system 4. Introduction to the nervous system and its cognitive functions 5. Different states of consciousness: sleep and wakefulness 6. Memory and neuroplasticity 7. Development of bioengineering applications based on neurophysiology (brain-machine interphase) Preceptorships Analysis of scientific articles on the following topics: 1. Use of innovative techniques in the study of neurosciences (optogenetics, potential-sensitive imaging, rapid ultrasound imaging); each tutor chooses one of these articles. 2. Study of optogenetic mechanisms responsible for wake / sleep alternations 3. Neuroscience article (about brain damage associated with neurodegenerative disease) in connection with NMR

Independent Study	Objectives: use the concepts learned in the course to go beyond basic applications. Methods: preparation for preceptorships

Bibliographic Resources	• Course handouts and resources • Gerard Tortora and Bryan Derrickson. *Principles of Anatomy and Physiology,* 14th edition. 2014: Wiley. Chapters 1, 3, 12, 14, 17,19, 20, 23 • Dale Purves and coll. *Neuroscience,* 5th edition. 2011: Sinauer Associates. French translation of the 4th edition (2007): *Neurosciences.* D. Purves and coll. 2011: Editions De Boeck. • Mark Bear, Barry Connors et al. Neuroscience (Exploring the Brain).

Evaluation	Written exam comprising course questions (50%) and analysis of data taken from a scientific article (50%) Preceptorships: evaluation of the quality of work submitted and participation during sessions

S8 – SV2 –TPPHYS	Physiology Lab Work

Supervisors: Thierry Gallopin

Teaching staff: Sophie Pezet, Thierry Gallopin, Gisella Vetere

| Lab: 30h | Course language: 🇫🇷 🇬🇧 |

Objectives / Targeted Skills

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

LO1. record and analyze a biological signal (ECG, EEG, OEA, PEA);
LO2. understand the variability of biological data, identify normal variants and detect anomalies / distortions, optimize the signal-to-noise ratio;
LO3. reflect on experimentation on animals;
LO4. utilize their knowledge to solve a complex and / or cross-disciplinary problem;
LO5. work in a group;
LO6. use measurement tools and techniques in the laboratory in the field of...;
LO7. take a critical approach to using data acquisition and analysis programs;
LO8. use their knowledge and draw on documentary resources to observe and interpret experiment phenomena;
LO9. summarize, interpret, and present experiment results.

Contents	Proposed topics: 1. Study of human cardiac activity using an electrocardiogram (ECG) 2. Study of blood glucose regulation 3. Study of the human auditory system 4. Modeling electrical activity in a nerve cell 5. Analysis of EEG signals in waking / sleeping mice and humans 6. Analysis of behavioral changes induced by optogenetics manipulation
Organization	One half-day per topic, for a total of eight sessions
Bibliographic Resources	• Neurosciences (D. Purves et al., éditions De bock) • Maitriser l'ECG : De la théorie à la clinique (A. Houghton. Editions Elsevier, Masson). • Imaging Brain Function With EEG. Advanced Temporal and Spatial Analysis of Electroencephalographic Signals. 2013. Springer New York Heidelberg Dordrecht London • John N. Demos - Getting Started with EEG Neurofeedback-Norton Professional Books (2019)
Evaluation	Report written at home (one per pair)

UE Chemistry IV

SEMESTER 8

UE CH4

76.25h - 5 ECTS

Description

The course Chemistry and Inorganic Materials (CH4-CMI) explores applications using materials with specific optical, magnetic, electronic, or catalytic properties. Fundamental concepts of inorganic chemistry are explained through these examples. The molecular and collective aspects are addressed simultaneously. Advances in synthetic chemistry and in our understanding of properties allows for the development of new materials and new applications. CMI Lab Work (CH4-TPCMI) enables students to gain a deeper understanding of fundamental concepts while demonstrating the usefulness of chemistry and inorganic materials in modern, and sometimes every day, applications.

Semester	Program	
S8	CH4-CMI	Inorganic Chemistry and Materials
	CH2-TPCMI	CMI Lab Work

Prerequisites

Fundamentals of analytical chemistry (chemistry of solutions, pH and complexes, redox), chemical synthesis, crystallography, spectroscopy techniques (S6-CH2-ICO)

UE Validation

Weighted average: CH4-CMI 50%, CH4-TPCMI 50%

Targeted skills

CH4-CMI	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1	Ex., prec., MCQ	II	II					II							
LO2	Ex.,prec.	II	II					II							
LO3	Ex.		II							II					
LO4	Ex., prec., MCQ	II						II							
LO5	Ex.	II	II					II							
LO6	Ex., prec., MCQ		III												
LO7	Ex.,prec.		III										II		II
CH4-TPCMI	**Eval**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
LO1	Part., PubA, Notebook		III			II			III						
LO2	Part., PubA		III						III						II
LO3	Part., PubA		III												II
LO4	Part., PubA, doc.	III	III						III				II		II
LO5	Part., PubA				II	II									
LO6	Part.				II										
LO7	PubA, doc.	II		II	II	II	II								

Ex.: exam, prec.: preceptorships, Part.: participation, PubA: report delivered in the form of an English-language publication, doc.: use of documents provided

S8 – CH4 – CMI	Inorganic Chemistry and Materials

Supervisors: Sophie Norvez, Corinne Soulié-Ziakovic

| Course: 23h | Tutorial: 4h | Preceptorships: 8h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

- LO1. identify and use fundamental concepts that explain reactivity and complex properties of transition metals (molecular scale) and inorganic materials (crystal lattice scale);
- LO2. analyze the fundamental actions of reactional mechanisms in transition metal complexes and organometallic complexes;
- LO3. construct a catalytic cycle;
- LO4. connect macroscopic properties to the structure of transition metal complexes and inorganic materials;
- LO5. analyze and justify the limiting parameters of inorganic materials, suggest solutions;
- LO6. utilize their knowledge to analyze measurement results;
- LO7. utilize their knowledge to solve a complex and / or cross-disciplinary problem.

Contents	Course / Tutorial 1. Optical properties • Crystalline field and precious stones • Luminescence and lasers 2. Electronic properties • Charge transfer complex and light-emitting diode • Crystal defects and film photography • Semiconductors and p-n junctions 3. Magnetic properties • Molecular magnetism and Prussian blue • Lanthanides 4. Synthesis and reactivity • Soft chemistry and inorganic polymerization • Substitution chemistry vs. electronic transfer chemistry • Isomerisms and characterizations • Organometallic chemistry and catalytic cycles Preceptorships 1. Tanabe-Sugano diagrams 2. Lanthanides and luminescence 3. Organometallic chemistry and catalysis 4. Identification of inorganic compounds
Independent Study	Objectives: using the concepts learned in the course to go beyond basic applications. Methods: Preceptorship preparation
Bibliographic Resources	Course handouts and resources Tutorial and preceptorship instructions
Evaluation	Written final exam (part B, resolution of a complex problem) 60% Lab post-requisites (part A, MCQ) 40%

S8 – CH4 – TPCMI	Inorganic Chemistry and Materials Lab Work

Supervisors: Sophie Norvez, Corinne Soulié-Ziakovic

| Lab: 41.25h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

LO1. adapt experimental techniques for synthesizing transition metal complexes and inorganic materials in compliance with EHS standards and the engineering code of ethics (lab log, reliability of results);
LO2. choose characterization techniques adapted to synthesized products (molecules or materials) or the products to be highlighted;
LO3. adapt formatting methods to the material used and the intended application;
LO4. use their knowledge and draw on documentary resources to observe and interpret experimental phenomena;
LO5. work in a group;
LO6. operate independently and organize their laboratory work;
LO7. summarize and present experiment results as an English-language publication.

Contents	Four topics directly related to the course will be suggested. 1. Ligand field theory: cobalt rainbow; alcohol test complex; mordançage 2. V_2O_5 gel: soft chemistry; electrochromic cell; semiconductor plate 3. Photography: cyanotype, Prussian blue, electrochromic glass 4. Luminescence: construction of a light-emitting diode with $[Ru(bpy)_3]^{2+}$ (OLED) and synthesis of a Y_2O_3:Eu luminophore

Bibliographic Resources	Lab instructions, course handouts, tutorial and preceptorships A selection of research articles on each topic

Evaluation	Experiment work (manipulation, organization, comprehension) 40% Lab log 10% Report (article about a manipulation written in English) Pre-requisite (MCQ) 20%

UE Deep Learning

SEMESTRE 8

UE DL

19.5h - 1 ECTS

Supervisors: Alexandre Allauzen

| Courses: 12h | lab: 7.5h | Course language: |

Description

This course is an introduction to Deep Learning or more precisely to supervised machine learning using artificial neural networks. Supervised machine learning consists in "learning" a function that associates knowledge to a complex input (e.g. an image, a set of signals from different sensors, a sound or a text) (e.g. categorizing the content of the image, identifying a person or type of object, predicting a physical quantity or characteristics of the object). The particularity of machine learning is that this function is "learned" from the input / output examples and not built from expert knowledge.

Machine learning is now ubiquitous in the engineering profession and in our daily lives. Artificial neural networks are one of the most widely used and effective approaches to machine learning today. The objective of this course is to acquire the basic knowledge and know-how to integrate this type of approach in one's future job and to master the theoretical bases in order to be able to follow the rapid evolution of the field.

Semester	Program	
S8	DL	Deep Learning

Prerequisites

Basics of programming (S5-MMN1-PYTHON) and the Applied Statistics course (MMN2-STAP)

Links to other courses

Applied Statistics (MMN2-STAP), Statistical Leaning (3A-S10)

UE Validation

DL 100%

Targeted skills

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

Report : Lab Report

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

- LO1. Identify the steps essential for deep neural network learning and inference ;
- LO2. Design a processing chain from data to deep neural network learning;
- LO3. Build the software framework to enable the implementation of an experimental framework;
- LO4. Distinguish the difficulties associated with machine learning;
- LO5. Evaluate the results obtained, identify the limits of the approach.

Contents	Starting from the limitations of logistic regression, the course introduces non-linear data modeling through artificial neural networks. The course covers the following points: Feed-forward architecture Data-driven learning algorithms Best practices in machine learning The necessary software tools The practical sessions will be done in PYTHON using the pytorch library.

Bibliographic Resources	Course material and practical exercises

Evaluation	Lab report (60%) and experiment report (40%)

UE Humanities & Social Sciences – General Knowledge II

51h - 3 ECTS

SEMESTER 8

UE SHSCG2

Description

The purpose of the module History of Sciences and Technology in Society (SHSCG2-HSTS), at the intersection of natural sciences (known as the "hard" sciences) and human and social sciences, is to encourage student engineers to reflect on the co-construction of science (and technology) and society.
The educational objective is to help train future graduates who, rather than a naive vision of science and technology, are equipped with a professional (and personal) conscience, open to the causes and consequences of scientific practices and technological innovations. Over the course of this week, teachers help students gain perspective on science and technology. Upon completion of this teaching module, we expect student-engineers to have acquired the understanding necessary to a clearer, richer view of the role of science and technology in past and contemporary societies.

During the PSL Weeks (SHSCG2-PSL2), several PSL institutions come together to suggest shared courses. These weeks give students the opportunity to acquire new scientific knowledge, and to discover new fields related to the humanities and social sciences, entrepreneurship, and economics.

Semester	Program	
S8	SHSCG2-HSTS	History of Science and Technology in Society
	SHSCG2-PSL2	PSL Week II

UE Validation

Weighted average: SHSCG2-HSTS 50%, SHSCG2-validated / non validated

Targeted skills

SHSCG2-HSTS	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Ex., Part.			II		II						II		II	II
LO2.	Ex., Part.	II										II		II	II
LO3.	Ex.	III		II		II						II		II	II
LO4.	Ex., Part.	II		II		II						II		II	II
LO5.	Ex.	III		II								II		II	III
LO6.	Ex.	II		II								II		II	II

Ex.: exam, Part.: participation

S8 – SHSCG2 – HSTS	History of Science and Technology in Society

Supervisor: Emanuel Bertrand

| Course: 27h | Course language: 🇫🇷 |

Objectives / Targeted Skills

By the end of the week, students will be able to:

- LO1. identify and analyze social, societal, and political challenges related to technological innovation;
- LO2. argue the influence of social and historical context on scientific discoveries and technological innovations;
- LO3. distinguish between scientific challenges and social / political challenges in the context of a sociotechnical controversy;
- LO4. evaluate the role of scientific and sociotechnical controversies in past and contemporary societies;
- LO5. utilize their knowledge to analyze a complex situation;
- LO6. utilize their knowledge to write a summary.

Contents	A non-exhaustive list of topics addressed: • What is "science"? What is "scientific evidence"? What is "scientific truth"? Illustration: Hertz's experiment and the propagation of electromagnetic waves (Emanuel Bertrand, ESPCI Paris) • What is the impact of the social and political context on the validation of a scientific statement? An example of a scientific controversy in society: Pasteur versus Pouchet (Emanuel Bertrand, ESPCI Paris) • A history of anatomy: scholarly constructions of the body (from the Renaissance to the nineteenth century) (Rafael Mandressi, CNRS) • Science and knowledge in early modernity: world scales (Antonella Romano, EHESS) • The history of biodiversity and championing of biological resources (Valérie Boisvert, University of Lausanne) • Sciences versus the humanities: *L'inconscient d'école* (Wolf Feuerhahn, CNRS) • Scientific publishing, peer reviewing and academic fraud (Charlotte Bigg, CNRS) • The French civil nuclear industry and its governance (Sezin Topçu, CNRS)
Organization	This module takes place over a dedicated week and is structured around three-hour presentations. Each presentation addresses a fundamental topic of importance in current research into the history and sociology of science and technology. The speakers are researchers and teacher-researchers recognized in their field.
Bibliographic Resources	Bibliography for informational purposes: Dominique Pestre, *Introduction aux Science Studies*, 2006, Paris, La Découverte. Dominique Pestre (dir.), *Histoire des sciences et des savoirs* (3 volumes), 2015, Paris, Le Seuil.
Evaluation	Written final exam (1h30)

S8 – SHSCG2 – PSL2	PSL Week II

Coordinating supervisor: Assiatou BAH, Corinne Soulié-Ziakovic

| Course: 24h | Course language: 🇫🇷 🇬🇧

Objectives / Targeted Skills

This week gives students the opportunity to acquire new scientific knowledge, and to discover new fields related to the humanities and social sciences, entrepreneurship, and economics.

Catalog	www.pslweek.fr • Time (ESPCI Paris) • New perspectives for the environmental transition (ESPCI Paris) • Introduction to Quantum Materials (ESPCI Paris) - ...

Organization	Mandatory enrolment in a module

Bibliographic Resources	Varies according to module

Evaluation	Varies according to module

UE Communication

SEMESTER 8

UE COMM

25.5h - 2 ECTS

Description

Projets Scientifiques en Equipe (Group Science Projects / PSEs) form an interdisciplinary teaching model developed for semesters 6, 7, and 8. The goal of this module is to carry out experiment projects and it is modeled after a "hacklab." Projects embrace all disciplines taught at ESPCI Paris—physics, chemistry, and biology—and some are interdisciplinary. They are all different and change each year. Thirty projects are carried out each year by the entire year group.
These projects teach students to lead team-based projects and to communicate about them in several formats (presentation, poster, video, the latter forming an essential part of the module). For this reason, the module is linked to the semester 6 module Verbal Communication (S6-COMMI2-COMOR).

The module Project Management (GP) aims to show students the importance of project management. Vocabulary, key factors for project management success, and basic tools are presented and applied during lab work. Reflection based on projects carried out in TPEs is proposed.

Semester	Program
S8	COMM-PSE3 Group Science Projects III COMM2-COMOR Oral Communication

Prerequisites

Presentation of studies carried out in modules S6-INREC-PSE1 and S7-GP-PSE2

Validation

COMM-PSE3 100% - COMM2-COMOR validation

Targeted skills

COMM-PSE3	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Part.	III	III						III		II	II		II	I
LO2.	Part.				II		II				II				I
LO3.	Part.				II				III	III			II		I
LO4.	Part.	III	III					II			II	II	II		
LO5.	Part.	III	III												
LO6.	Part.	III	III						II				II		
LO7.	Part.	III	III												
LO8.	Part.	III	III						III						
LO9.	Part.	III	III								II	II			
LO10.	MOOC, Pres.	II	II								II				I
COMM-COMOR	Eval	C1	C2	C3	C4	C5	C6	P1	P2	P3	P4	P5	P6	P7	P8
LO1.	Oral				III	II									III

Part.: participation, Pres.: presentation, MOOC: filmed presentation of results

S8 – COMM – PSE3	Group Science Project II

Supervisors: Emmanuel Fort, Maxime Ardré, Yvette Tran

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

| Lab: 22.5h | Course language: 🇫🇷 |

Objectives / Targeted Skills

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

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

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

Independent Study	Objectives: training through experimental research, experiment and original protocol design, critical analysis of results, project development skills, communicating about progress and results Methods: experiments and development of experiment protocols and methods; creation of presentation, posters, and a video

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

Evaluation	Video + Methods and Protocols + Data to upload online (MOOC) 35% Presentation (Pres.) 15% Participation and personal involvement in sessions 50% (Part.)

S8 – COMM2 – COMOR | Oral Communication

Supervisors : Clément Probst

| Preceptorship:: 3h | langue du cours : |

Objectives / Targeted Skills

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

LO1. communicate to a non-specialist audience its work and the results of Group Science Project.

UE English IV

28h - 2 ECTS

SEMESTER 8

UE ANG4

Supervisor: Daria Moreau

| Tutorial: 28h | Course language: 🇬🇧 |

Description

The purpose of English courses is to improve students' English skills and teach them linguistic independence to prepare them to use technical and scientific English in an international, intercultural and professional context. These are theme-based classes which aim at teaching students working in English on a selected topic and to deepen their intercultural knowledge and skills. They are also intended to assist students in preparing for the TOEIC exam, required by the CTI to obtain the ESPCI engineering degree.

Semester	Program	
S8	Ang4	28h, 2 ECTS

Prerequisites

Level B2 of the CEFRL reference chart

Evaluation

Validation of the five skills listed in the CEFRL reference chart at level B2 / C1 minimum through:

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

Targeted skills

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

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

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

- LO6. quickly identify resources for internships and employment, analyze and summarize employer expectations, and respond in English to internship opportunities by writing a cover letter and/or creating a video resume, with the cultural specificities of English-speaking countries in mind;
- LO7. apply in-depth knowledge of thematic and scientific grammar and vocabulary to communicate both in writing and verbally in a professional situation within a multicultural company;
- LO8. analyze the structure of the TOEIC exam and develop their personal strategy to maximize their score;
- LO9. summarize a scientific text or audio document, identify key information, and present it to an audience;
- LO10. defend their point of view in a debate on a subject studied this year and respond to factual questions about the subject.

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

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

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

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

RAPPORT PEDAGOGIQUE

Nom et prénom de l'étudiant(e) :

L'année d'études :

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

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

Attitude pendant la formation et connaissance de la culture

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

Fait à :
Nom de l'enseignant :

Total points :

Foreign Language II - French as a Foreign Language

LV2	Foreign Language II

Supervisor : Daria Moreau

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

Description

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

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

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

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

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

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

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

Objectives / Targeted Learning Outcomes

At the end of the course students will:

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

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

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

Contents	According to the level as described in the CEFRL: • communicating on a wide range of topics from everyday, professional, and cultural life, • mastering the foreign language grammar and vocabulary, • practicing oral and written comprehension on a variety of topics, • writing various texts, • interacting with a native speaker, • discussing current events, news, songs, and film extracts.
Organization	Classes are held in level groups established at the beginning of the year based on placement tests and oral evaluations. Cultural outings will be offered.
Bibliographic Resources	Audio and video documents; examples of authentic, factual documents.
Evaluation	At the end of each semester, validation of the 5 skills of the CEFR grid and of personal work, knowledge of culture and intercultural communication, motivation, participation in classes, and attendance.

Targeted Skills

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

FLE	French as Foreign Language

Supervisor : Daria Moreau

| Tutorials : 9h | langue du cours : 🇫🇷 |

Description

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

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

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

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

Course Prerequisites:

B1

Objectives / Targeted Learning Outcomes

At the end of the course students will:

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

Contenu	<u>Before arriving in France</u> Before arriving at ESPCI, international students take an online placement test and oral interviews are organised to assess their oral and written skills in French. This evaluation allows us to accompany the students beforehand by offering remote linguistic tools for self-studying while they are still in their countries of origin. <u>Before the beginning of studies</u> • FLE summer classes Before the beginning of their studies, intensive summer courses (3 hours per day / 3 weeks) are offered to those who have an inferior to C1 level in French, in order to better integrate them into the professional, administrative and daily French-speaking environment. • Conferences on Studying in France

Then all international students participate in conferences on preparing for engineering studies in France.

At ESPCI

- FLE classes

During the academic year, students must attend weekly FLE classes in groups corresponding to their levels according to the Common European Framework of Reference for Languages (CEFRL).

- Additional resources

Cultural and gastronomic outings are proposed by PSL Welcome Desk. Students have also access to numerous linguistic and cultural resources available on school's Moodle platform.

- French Speaking Workshops

In addition to the courses given by qualified teachers in FLE, some French-speaking students organise conversation workshops (1hx1 / week). These optional workshops, composed of 3 international students and one French-speaking student, create a space for a daily language practice and are also a means of integration.

In order to acquire more fluency in speaking and to develop the ability to work in a group, international students can also participate in a theatrical group led by their French-speaking classmates.

Exam

At the end of the 3rd year of studies the level in FLE is verified by an external TCF (Test des Competences du Français) test and by an internal evaluation. The level B2 at the TCF test is required by the CTI in order to validate the engineering diploma.

Supports Bibliographie

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

Évaluation

At the end of each semester each student with the inferior to B2 level in FLE must validate 5 skills of the CEFRL grid (CC) and personal work (CC), cultural knowledge and cross-cultural communication skills (CC), motivation (CC), course participation (CC), attendance (P).

Test de Connaissance du Français (TCF) is compulsory for all international students at the end of the 3rd year of studies (EX) and B2 level in French is required by the CTI from all international students.

Targeted Skills

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