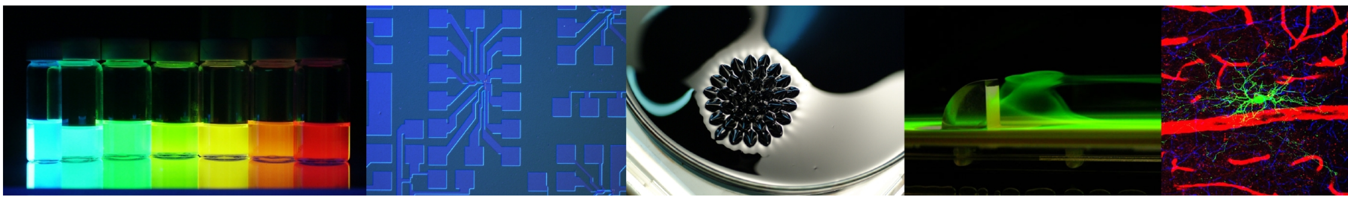
École Supérieure de Physique et de Chimie Industrielles

Ingénieur ESPCI
Undergraduate courses

2008-2009



ESPCI
ParisTech

The City of Paris Industrial Physics and Chemistry Higher Educational Institution, (ESPCI), is one of the most outstanding French institution that enhances the prestige and renown of our capital in the field of science. It has always been committed to maintaining the highest level of original and innovative research. At the same time it provides education and training in keeping with the expectations and requirements of the business world. Today, as industrialists are confronted with needs that span a wide range of disciplines, ESPCI is able to provide a variety of training and research options and cater to new sectors such as health, environment and imaging, thus proving that it can keep abreast with the changing demands of the business world.

Bertrand Delanoë, Maire de Paris

Taking a series of intelligent steps our former Director, the Nobel laureate Pierre-Gilles de Gennes has boosted the activity of ESPCI at the best world level. The very interdisciplinary education of the student engineers in Physics, Chemistry and Biology is deeply rooted in experimental practice balanced with a high theoretical level. Through intense work, we train genuine innovation professionals, with acute knowledge of our surrounding and able to irrigate industry or academic worlds in both traditional and emerging sectors of activity. The directions set by the Curies, Charpak and de Gennes are being actively followed.

Jacques Prost, Directeur Général de l'ESPCI

Contents

1 Strategy and education policy 6

2 Courses listed per year 8
2.1 Core curriculum: first and second year . . . 8
2.2 Third Year Courses . . . 11
2.3 Fourth year . . . 12

3 Biology Courses 13
3.1 Biology . . . 13
3.2 Biophysics . . . 14
3.3 Bioengineering . . . 15
3.4 Physiology . . . 15

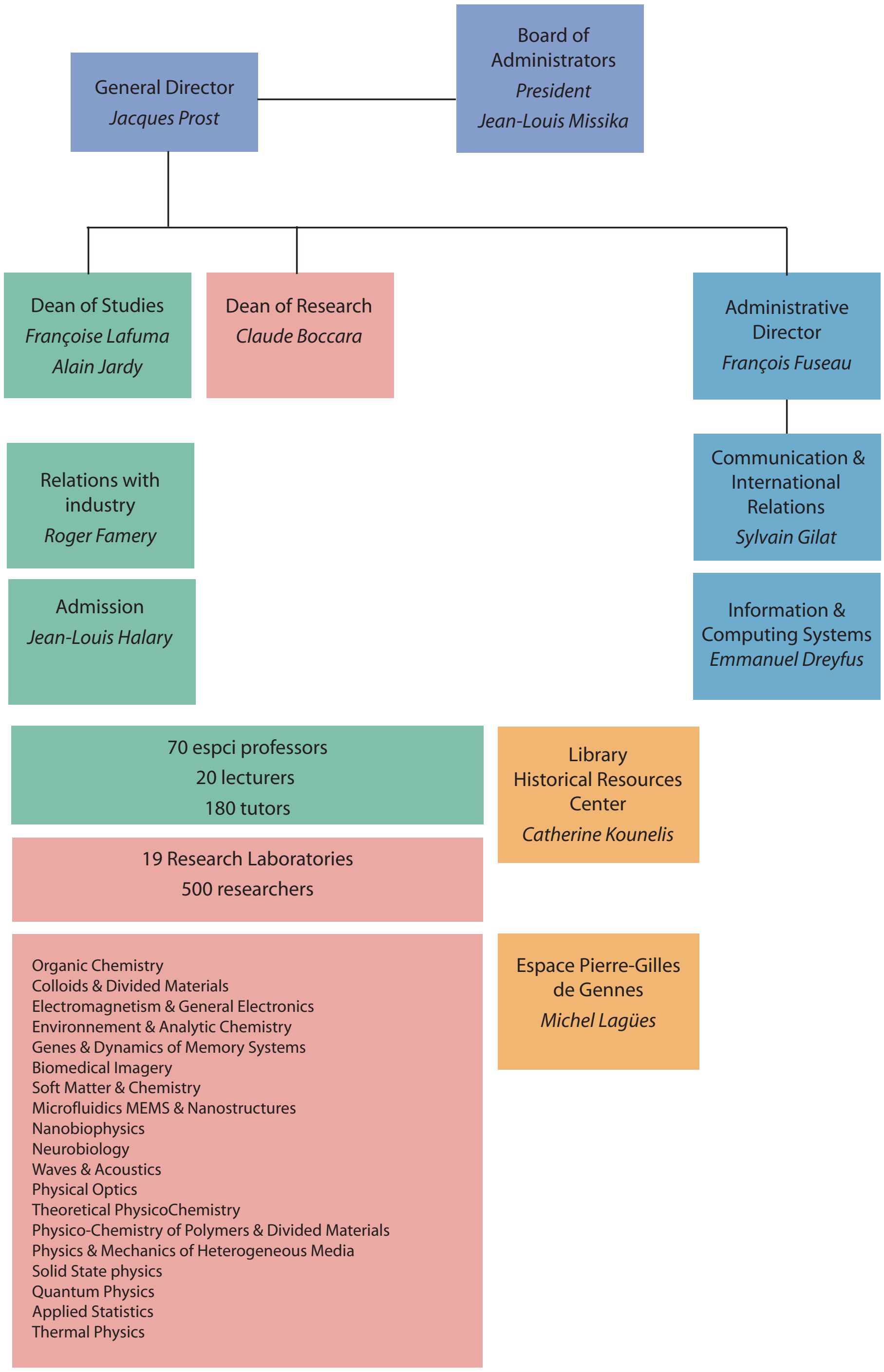
4 Chemistry courses 17
4.1 Fine Chemistry and Drugs . . . 17
4.2 Advanced Inorganic Chemistry . . . 17
4.3 Chemistry and Inorganic Materials . . . 19
4.4 Organic Chemistry . . . 20
4.5 Colloids, gels, suspensions . . . 21
4.6 Environment and Sustainable Growth . . . 22
4.7 Colloidal matter and biomolecules . . . 23
4.8 Identification of Organic Compounds . . . 24
4.9 Cristalline Materials . . . 24
4.10 Macromolecular Materials . . . 25
4.11 On-demand materials . . . 27
4.12 Soft Condensed Matter . . . 27
4.13 Reactivity . . . 29
4.14 Analytical et Bioanalytical Sciences . . . 29
4.15 Advanced Synthesis and Green Chemistry . . . 31
4.16 Organic Synthesis . . . 33
4.17 Polymer Synthesis . . . 34
4.18 Physico-Chemical Thermodynamics . . . 36
4.19 Molecular Characterisation Techniques . . . 37

5 Foreign languages , communication and economy 39
5.1 English . . . 39
5.2 Introduction to business finance . . . 39
5.3 Socio-economic lectures . . . 40
5.4 Communication & Social Relations. Module 1 . . . 41
5.5 Communication & Social Relations. Module 2 . . . 41
5.6 Preparation to job search . . . 42
5.7 Economic intelligence . . . 42

6 Mathematics and Numerical Methods Courses 44
6.1 Chemometrics . . . 44
6.2 Mathematical Methods I . . . 44
6.3 Mathematical Methods II . . . 45
6.4 Computer Programming . . . 46
6.5 Numerical Simulation . . . 47
6.6 Group Theory . . . 47
6.7 Applied Statistics . . . 48
6.8 Statistics and Learning . . . 49

6.9 Linear Systems and Signal Analysis . . . 50

7 Physics Courses **52**
7.1 Control of Processes . . . 52
7.2 Scales of Space and Time . . . 53
7.3 Electromagnetism and Telecommunications . . . 54
7.4 Electronics of Integrated Circuits . . . 55
7.5 Electrotechnics and Electrical Properties of Materials . . . 56
7.6 Nuclear Engineering . . . 57
7.7 Biomedical Instrumentation . . . 58
7.8 Light and Images . . . 58
7.9 Light and Matter . . . 59
7.10 Applied Mechanics . . . 61
7.11 Fluid Mechanics . . . 62
7.12 Mechanics of Solids . . . 63
7.13 Microfluidics . . . 64
7.14 Waves and Acoustics . . . 65
7.15 Physics of Microelectronics Circuits . . . 66
7.16 Quantum Physics . . . 67
7.17 Solid State Physics . . . 67
7.18 Rheology . . . 68
7.19 Signals and Images . . . 69
7.20 Energy Producing Systems . . . 70
7.21 Advanced Telecommunications . . . 70
7.22 Thermodynamics . . . 71
7.23 Statistical Thermodynamics . . . 72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Physics & Mechanics of Heterogeneous Media
Solid State physics
Quantum Physics
Applied Statistics
Thermal Physics
Espace Pierre-Gilles de Gennes
Michel Lagües

1 Strategy and education policy

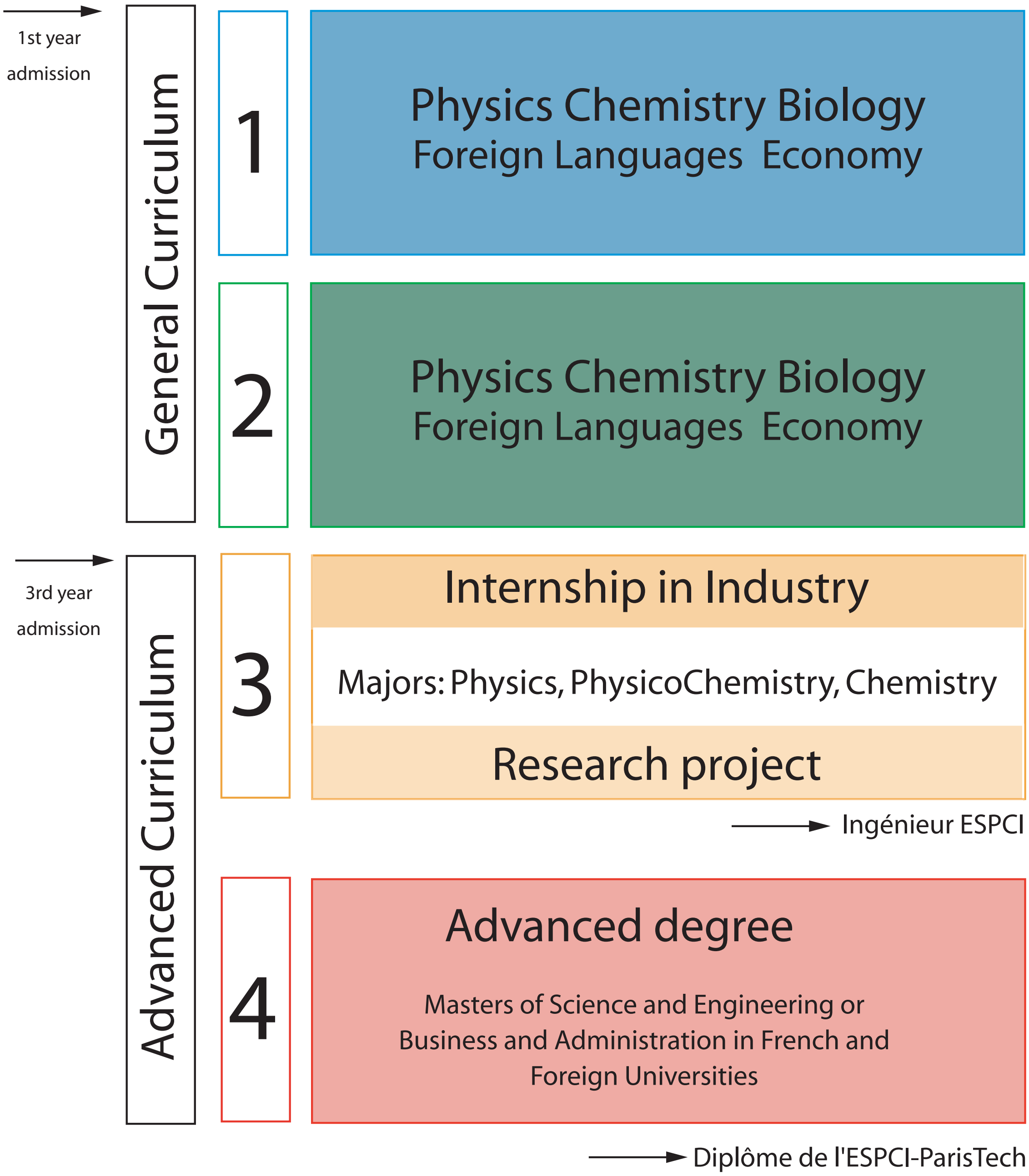
Education at ESPCI relies on a few basic principles that have been kept nearly unchanged since the 19th century, thanks to the long term insight and perspicacity of its founders. They understood that complex problems could no longer be solved from the point of view of a single academic discipline. They were convinced that coupling teaching with research and focusing the attention of students on real world problems, were the best ways to bring about and keep alive professional competence for engineers.

Thus the engineering graduate education at ESPCI has been developed around these ideas, taking into account the evolution of science and technology in order to be adapted to the requirements of the 21st century, i.e. :

- a very general training giving the students a strong scientific background with a deep knowledge of concepts and theoretical reasoning that confer them a significant capability of adaptation and help them develop creativity in defining problems and seeking solutions.
- a multidisciplinary formation including not only the traditional courses in scientific and engineering aspects of physics and chemistry, but including also an initiation in biology.
- a large amount of time allocated to experimental work: the students spend half of their training in laboratories, carrying out either supervised work or research projects.
- a 4 to 6 months internship in a company that open their mind to the industrial environment in order to prepare them for their future career.

Educational methods are designed to develop the ability for conceptual and practical problem solving. for each subject they contain main course, tutorial classes, laboratory work and tutorship. The latter allows a thorough understanding of the course through interactive further reflection, by groups of four students under the supervision of a tutor.

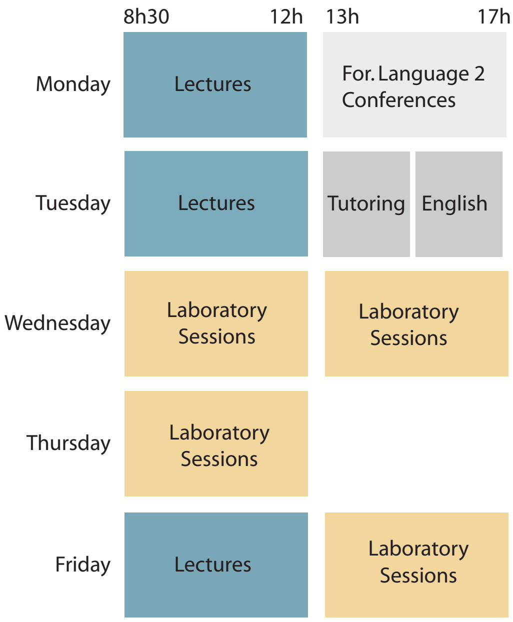
A four year curriculum.



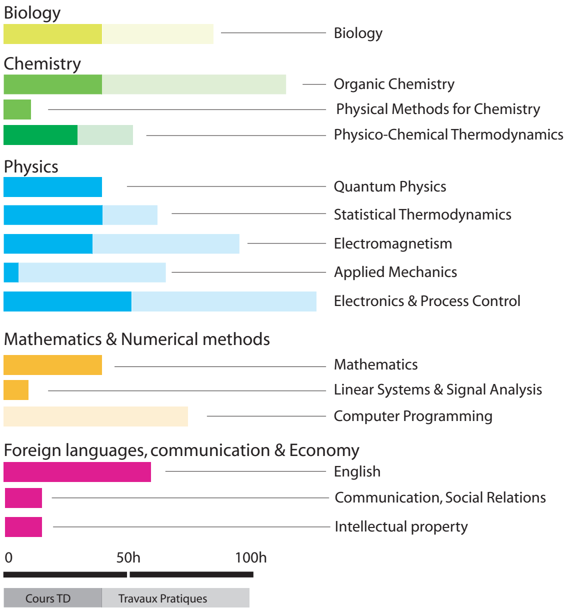
2 Courses listed per year

2.1 Core curriculum: first and second year

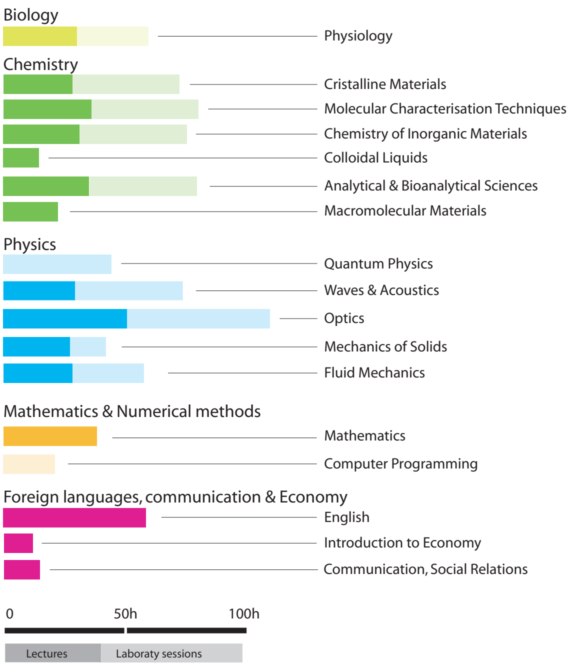
The teaching of the two first years is intended to provide the scientific and technological background on which the whole formation is based.



A typical week: three mornings are devoted to lectures. A total of two days is reserved for laboratory sessions. One afternoon for tutorship and english. Thursday afternoon can be used for sports and other extra-curricular activities. Monday afternoon there is time to prepare the tutorship sessions, learn a second foreign language or attend lectures given by researchers or representatives from the industry.



Synoptic view of first year courses



Synoptic view of second year courses

First Year

Biology

Biology

Chemistry

Organic Chemistry
Identification of Organic Compounds
Physico-Chemical Thermodynamics

Physics

Control of Processes
Electromagnetism and Telecommunications
Electronics of Integrated Circuits
Applied Mechanics
Quantum Physics
Thermodynamics
Statistical Thermodynamics
Electrotechnics and Electrical Properties of Materials

Mathematics and Numerical Methods

Mathematical Methods
Linear Systems and Signal Analysis
Computer Programming

Foreign languages, Communication, Economy

English
Socio-economic lectures
Communication, Social Relations

Second year

Biology

Physiology

Chemistry

Chemistry and Inorganic Materials
Cristalline Materials
Macromolecular materials
Molecular Characterisation Techniques
Analytical et Bioanalytical Sciences

Physics

Fluid Mechanics
Mechanics of Solids
Light and Images
Light and Matter
Waves and Acoustics

Mathematics and Numerical Methods

Mathematical Methods
Group Theory

Foreign languages, Communication, Economy

English
Communication, Social Relations

2.2 Third Year Courses

The third year is devoted to a first orientation of the students and an initiation to research. It begins with the 4 to 6 months industrial internship followed by a common scientific training; afterwards they can choose between 3 programs: Physics, Chemistry and Physical Chemistry (courses of the latter curriculum being chosen in the two former ones). Finally, students conduct a research project, 3 or 4 month long, in academic laboratories.

Common Curriculum

Soft Condensed Matter
Applied Statistics
Economic intelligence
Introduction to business finance
Preparation to job search
English

Physics major

Signals and Images
Solid State Physics
Biophysics
Waves in Complex Media
Scales of Space and Time
Statistics and Learning

Optional Course 1

1 course within the following list :
Microfluidics
Advanced Telecommuncia-tions
Physics of Microsystems
Nuclear Engineering

Physico-Chemistry Major

Signals and Images
Solid State Physics
Colloids, gels, suspensions
Advanced Inorganic Chemistry
Rheology

Optional Course 1

Microfluidics

Chemistry Major

Colloids, gels, suspensions
Advanced Inorganic Chemistry
Chemometrics
Rheology
Organic Synthesis
Bioengineering
Reactivity
Polymer Synthesis

Optional Course 1

1 course within the following list :
Colloidal matter and biomolecules
Environment and Sustainable Growth
Advanced Synthesis and Green Chemistry

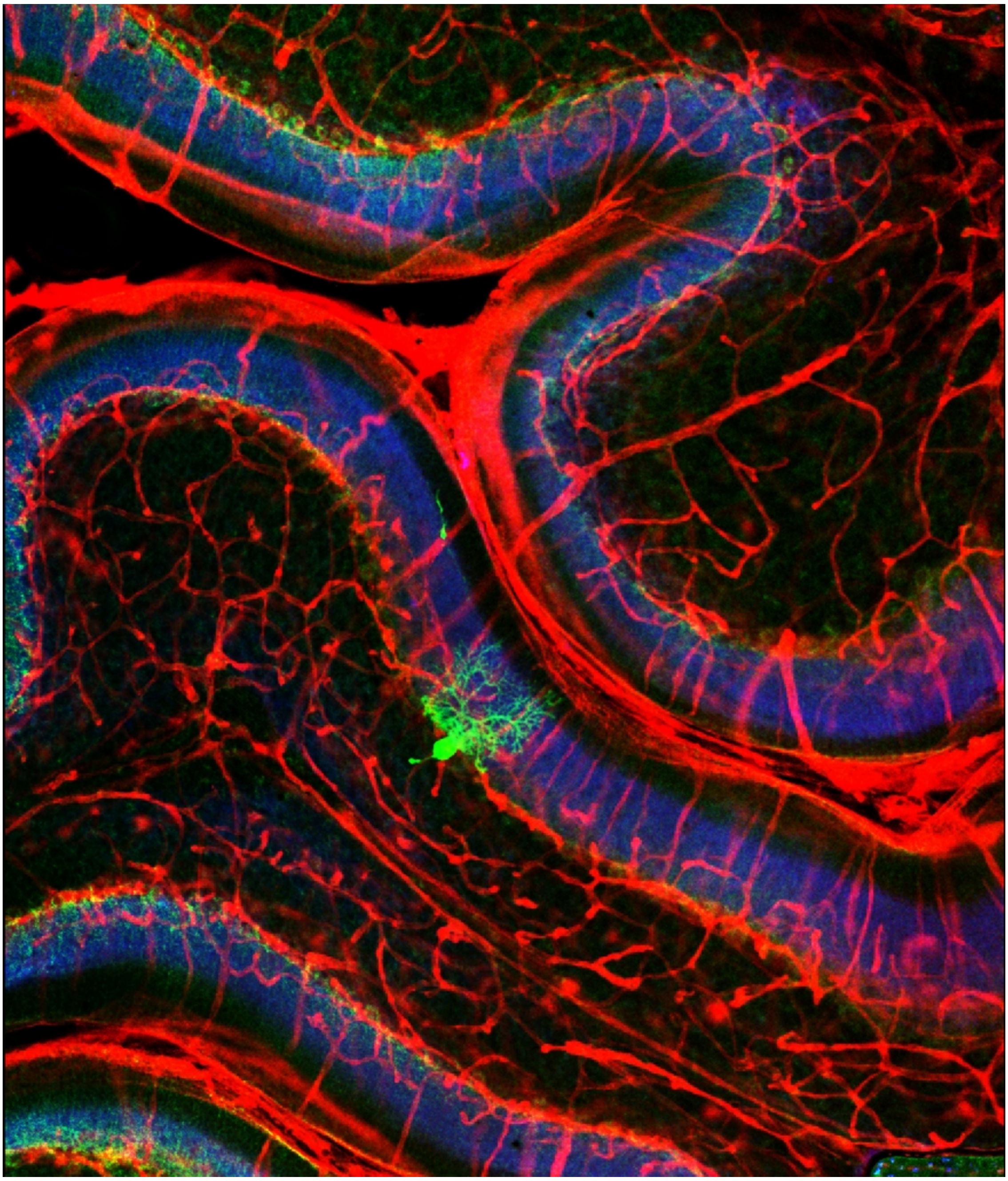
Optional Course 2 for all majors

1 course within the following list :
- On-demand materials
- Biology
- Numerical Simulation
- Biomedical Instrumentation
- Energy Producing Systems
- Fine Chemistry and Drugs

2.3 Fourth year

In addition to their high level general training, the students acquire a specialization during year 4 by following a joint degree program in another French or Foreign Institution. A very large panel is offered to them in scientific, technological, engineering or economical domains.

3 Biology Courses



3.1 Biology

Core Curriculum 1st year

Lectures : 32 h - Supervisions : 8 h - Laboratory sessions : 45 h.

Objectives

The first year biology teaching is organised to provide the students with a general biology culture that will allow them at the end of the year to read biology articles in general English language scientific journals such as ÏScienceÓ and ÏNatureÓ. Through his/her participation in the lectures, conferences, tutorials and laboratory course, the student will become familiar with general concepts of the living world. The course insists on the importance of life sciences on the earth comparing the Earth to other planets. Simple observation shows that the appearance of life on earth with the production of oxygen via the photolysis of water shaped the world in which we live today. Phenomena that at first sight seem merely chemical or physical, such as metal corrosion or the production of the H2S by hydrothermal sources, are in fact due to microorganisms.

The course describes the general principles of biology with the description of chemistry of the living, template replication, cell cycle, the origin and evolution of life on earth. Apart from these general chapters, several lectures given by external lecturers from academia or industry, offer varied points of view on subjects such as the catalytic function of enzymes, cancer, genome analysis by bioinformatics, and biotechnologies (DNA chips, gene therapy).

The lecture course insists on the epistemological aspect of basic biology experiments. The laboratory course allows the student to become familiar with all the molecular biology tools as practised today in research laboratories.

Syllabus

Introduction to Life Sciences

- The chemistry of life
- DNA and Molecular Biology
- Cell Biology (Organelles, cytoskeleton, membranes and secondary messagers)
- Basic principles of immunology (self and non-self)
- Cell Cycle and Cancer
- The origins of life, the theory of evolution
- Genome analysis and bioinformatics
- Biotechnologies, DNA chips and gene therapy
- Proteins:
- low energy bonds and the construction of macromolecular edifices.
- haemoglobin and the beginning of structural biology
- three-dimensional structure
- catalytic function of enzymes
- cell regulation by allosteric enzymes
- cell communication: allosteric receptors

Laboratory Sessions

The laboratory course is designed as a series of molecular biology experiments. Each pair performs all the steps for cloning a gene that gives bacteria a green colour by the overexpression of a fluorescent molecule: GFP.

- Preparation of the insert (PCR, purification, enzymatic digestion)
- Ligation
- Transformation

Screening of recombinant clones by PCR
Induced protein expression
Protein extraction and electrophoresis analysis

Supervisions

The tutorials provide students with a study of current research in the different subjects treated in the course by analysis of recent articles published in scientific journals. At the end of the tutorials, the students should be capable of writing a research project from the original articles.

The subjects treated in the tutorials are the following:
Regulation of gene expression
Genome structure
Cell cycle and cancer
Biological membranes
Evolution and Darwin's Theory
Functional genomics

Lecturers

Jean Rossier, Pascale Dupuis-Williams, Yann Verdier.

Research Laboratory

Laboratoire de Neurobiologie et Diversité Cellulaire

3.2 Biophysics

Physics major 3rd year
Lectures : 12 h - Supervisions : 4,5 h -

Objectives

The course covers the physical bases and physical investigation methods of life at a biological cell scale. A selection of experimental techniques and theoretical concepts is examined to illustrate the contribution of physics to the study of biological objects, assemblies and processes and the corresponding applications, which range from technology to medical diagnosis. The biophysics course is also an introduction to an important field of research in full expansion. The teaching will use previously acquired knowledge, in particular in molecular biology, experimental physics and statistical physics.

Syllabus

Components and physical principles of biological cells.
Measurement techniques on a single cell.
Biochips, biosensors and DNA-based nanotechnology.
Molecular motors.
Regulation network.

Supervisions

DNA denaturation
Bacterial movement
Evolution of genomes and major biological networks.

Lecturers

Ulrich Bockelmann, Herve Isambert, Tony Maggs, Virgile Viasnoff.

Research Laboratory

Laboratoire de Nanobiophysique

3.3 Bioengineering

Chemistry major 3rd year

Lectures : 12 h - Supervisions : 5 h -

Objectives

A rational approach of the transformations in biological matter will be presented based on process engineering foundations. This course reviews the main theoretical principles that preside to the understanding of Bioprocedures. Examples of industrial processes will be chosen in the agricultural industry sector leading to food, energy, chemical or even pharmaceutical applications. More originally, the course opens up the interest of process engineering concepts to the understanding of the function of the human body with the concept of unit operations of living organisms.

This course uses knowledge in physics, physical and reactional kinetics, fluid mechanics, thermodynamics, organic chemistry and computer science.

Syllabus

Introduction to process engineering (bases and concepts applied to biotransformations)

Microbiological engineering: tools for biotransformations

Separation: unit operations for new functionalities

Stabilisation of bioproducts

An example of industrial process

Living organisms operations: mouth perception by the customer

Supervisions

Use of simulation tools: performance of a biotransformation (production of antibiotics) and/or control of the release of compounds in food matrices.

Lecturer

Michèle Marin

Research Laboratory

AgroParisTech

3.4 Physiology

Core Curriculum 2nd year

Lectures : 24 h - Problem classes : 6 h - Supervisions : 6 h - Laboratory sessions : 45 h.

Objectives

Physiology is a discipline based on the systematic analysis of the regulation of major body functions. It is a field in total renewal which is developing thanks to the contribution of new techniques from both molecular biology (applications to studies of the genome, transcriptome and proteome) as well as physics (use of optics, acoustics and nuclear magnetic resonance in the development of real time imaging analytical techniques, for example). The objective of this course is to allow starting the study of the physiology of regulations by treating the world of complex systems using a grid: that of cybernetics. To describe and understand the function of a complex physiological system it is essential to go through a representation and simplification step, the elaboration of a model. The language of cybernetics is particularly suited to the formalisation of physiological models. This course will allow the discovery that most physiological functions concur to make the body function as a constant regulator ("homeostat"), with the purpose of enabling the survival of the body when sudden or prolonged variations of its environment occur.

Syllabus

Cybernetic representation of living systems
Internal milieu
Hormone communication system
Short term glycaemia regulation: glucostat
Nervous communication system
Short-term blood pressure regulation: barostat
The endocrine brain
The role of the kidney in the regulation of the internal milieu

Laboratory Sessions

The objective of the laboratory course is to provide an insight into the study of the regulation of parameters involved in the adaptation of the human body to a physical effort through its various components: cardiac activity (electrocardiogram), blood pressure, respiratory rate.

This study will be completed by computer simulation experiments using software that allows the study of the effects of the in vivo administration of medicinal products on blood pressure and heart rate.

Supervisions

Hormones
Nervous information
Vegetative nervous system
Rennin/angiotensin system
The kidney

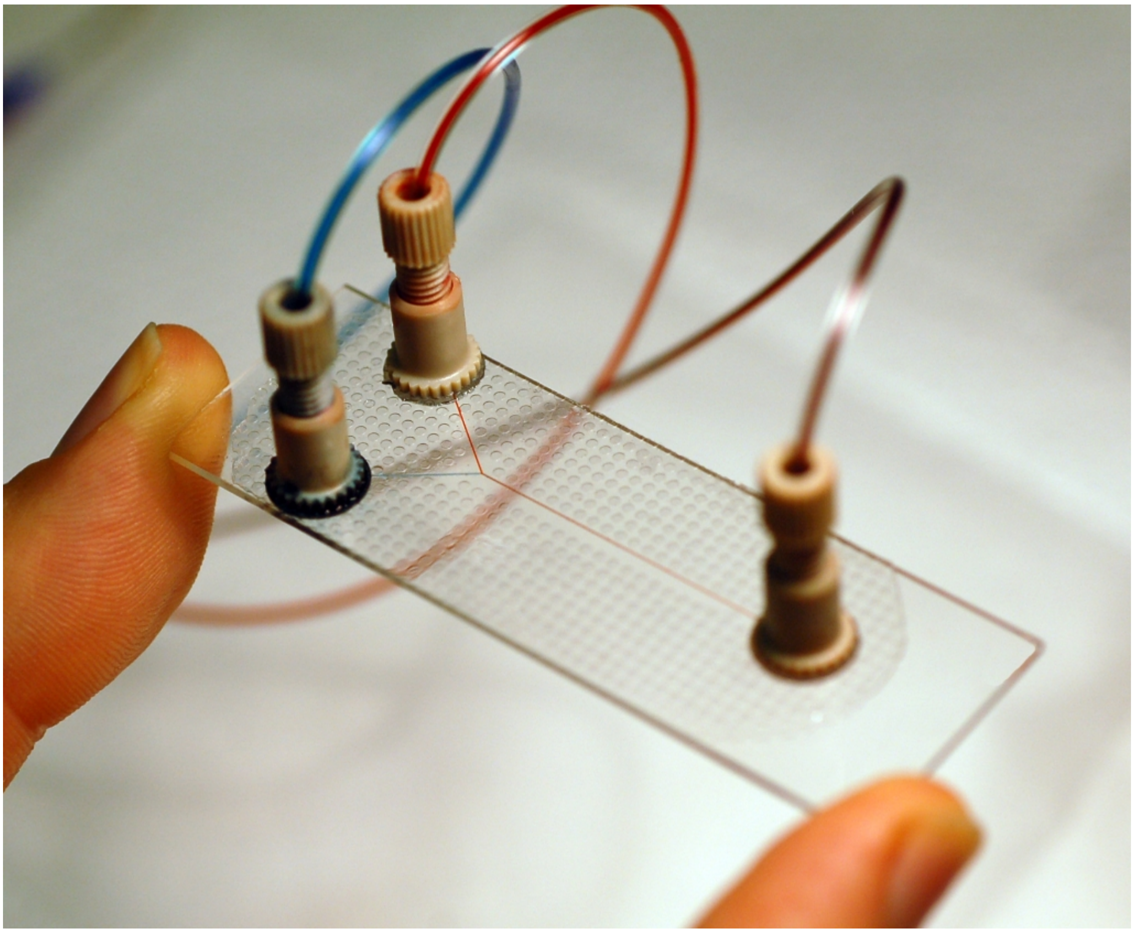
Lecturers

Bernard Calvino,Thierry Gallopin, Brigitte Quenet.

Research Laboratory

Laboratoire de Neurobiologie et Diversité Cellulaire

4 Chemistry courses



4.1 Fine Chemistry and Drugs

Optional course 3rd year

Lectures : 30 h -

Objectives

The search for new medicinal drugs is a constant challenge. The objective of the Fine Chemistry and Drugs option is to illustrate using examples the principles and tools used in the research and development of new drugs. Different steps of the processes leading to the marketing authorisation for a new drug will be approached by the some of the lecturers.

Syllabus

Professeur Jean-Marc PARIS (ENSCP, Paris) (9h)

Discovery and development of new drugs processes (research and discovery of the first "hit", optimisation of a "hit", preclinical development, etc.)

Antibacterial agents.

Anti-inflammatory drugs.

Diabetes: obesity

Professeur Sylviane GIORGI-RENAULT (Faculte de Pharmacie, Paris V) (9h)

Mechanism of action of drugs: application to cytotoxic anti-tumour agents. **Docteur Vincent MIKOL (Sanofi-Aventis) (6h)**

Molecular modelling applied to the discovery and optimisation of new drugs.

Docteur Michel BAUER (Sanofi-Aventis) (6h)

Crystallisation of molecules of pharmaceutical interest.

Pharmaceutical consequences of crystal polymorphism and crystal morphology.

Regulatory aspects related to the registration of drugs.

Lecturers

Veronique Bellosta, Michel Bauer, Sylviane Giorgi-Renault, Vincent Mikol, Jean-Marc Paris.

Research Laboratory

Laboratoire de Chimie Organique

4.2 Advanced Inorganic Chemistry

Chemistry and Physico-Chemistry majors 3rd year

Lectures : 12 h -

Objectives

More than 80% of manufacturing processes include at least one catalysed reaction. Catalysis generally allows decreasing costs (energy, separation, reprocessing, etc.) and limits the use of toxic or dangerous materials. The economic and ecological stakes are therefore obvious. In order to thoroughly understand the phenomena involved, the course presents the different types of catalysis through the study of major industrial processes and basic living cycles. The problems related to the performance and optimisation of a catalytic system, its cost and ecological impact are highlighted and explained via a mechanistic kinetic approach. The course is based on the knowledge acquired in the second year in Chemistry and Inorganic materials.

Syllabus

Industrial catalysis

1. Catalysis: fondamental concepts
   (a) Principles of catalysis
   (b) Homogeneous vs heterogeneous catalysis
   (c) Criteria for a good catalyst: activity, selectivity, stability, quotient environnemental, atomic efficiency
   (d) Developments of catalysis
2. Catalysis and industrial processes
   (a) Homogeneous catalysis: processes, mecanisms and kinetics, problems and solutions
   (b) Heterogeneous catalysis: processes, catalyst fabrication, mecanisms
3. Mecanisms and kinetics of heterogeneous catalysis
   (a) Reaction steps: physisorption vs chimisorption
   (b) Adsorbtion: Langmuir models, BET, measurements of specific surfaces
   (c) Kinetic equations: solid-gas and solid-liquid systems, Langmuir-Hinshelwood mecanisms, Eley-Rideal
4. Performances of an heterogeneous catalytic system
   (a) Characteristics of a good catalyst
   (b) Stability: deactivation of the catalyst
   (c) Selectivity
   (d) Types of chemical reactors

Biocatalysis

1. Elements of the biosphere
   (a) Biological role of metallic ions
   (b) Calcium in biological systems
   (c) Transport and storage of oxygen
2. Acidic catalysis, zinc enzyme
   (a) Metalloenzymes
   (b) Carbonic anhydrase
   (c) Carboxypeptidases
3. Redox catalysis
   (a) Importance in respiration and photosynthesis processes
   (b) Proteins iron-Sulphur
   (c) Cytochromes of the electron transport chain
   (d) Blue copper proteins
   (e) Cytochrome P-450
   (f) Coenzyme B12, an organometallic biomolecule

   (g) Nitrogen fixation
   (h) Photosynthesis

4. Industrials processes using biocatalysts.
   (a) Kinetics of enzyme-catalysed reactions
   (b) Acrylamide from acrylonitrile
   (c) Aspartame through peptidic enzymatic synthesis
   (d) L-aminoacids through amylocylase process

Lecturers

Sophie Norvez, Corinne Soulié-Ziakovic.

Research Laboratory

Laboratoire de Matière Molle et Chimie

4.3 Chemistry and Inorganic Materials

Core Curriculum 2nd year

Lectures : 21 h - Problem classes : 4 h - Supervisions : 6 h - Laboratory sessions : 45 h.

Objectives

The basic concepts of inorganic chemistry are exposed by the study of applications that use materials with specific optic, magnetic, electronic or catalytic properties. The molecular and collective aspects are treated in parallel. The progress made in synthetic chemistry and in the understanding of properties allow the development of new materials and new applications.

Syllabus

Optical Properties
Crystalline field and precious stones
Luminescence and lasers
Electronic Properties
Charge transfer and diode electroluminescence
Crystalline defects and silver halide photography
Semiconductors and p-n junctions
Magnetic Properties
Molecular magnetism and Prussian blue
Lanthanides, actinides and MRI
Reactivity and Synthesis
High temperature chemistry and micro-electronics
Soft chemistry and nanocrystals
Substitution chemistry vs electronic transfer chemistry
Isomerisms and characterisations

Laboratory Sessions

Four subjects directly related to the course are proposed. They allow an in-depth study of the basic notions while demonstrating the usefulness of chemistry and inorganic materials in modern and sometimes daily applications.

- Fabrication of a LED with $[Ru(bpy)_3]^{2+}$ (OLED) and synthesis of a luminophore
- making of a cyanotype and a silver-based photography without chemical developer
- Fabrication of a semiconducting SnO_2 wafer and an electrochromic cell with vanadium pentoxyde gel
- Use of a coordination complex in alcohol dosimetry

Supervisions

- Color phenomena in minerals and gem stones
- Lanthanides, actinides and Magnetic Resonance Imaging (MRI)
- Organometallic chemistry and homogeneous catalysis

Lecturers

Sophie Norvez, Corinne Soulié-Ziakovic, Marcel Bouvet.

Research Laboratory

Laboratoire de Matière Molle et Chimie

4.4 Organic Chemistry

Core Curriculum 1st year

Lectures : 26 h - Problem classes : 7 h - Supervisions : 9 h - Laboratory sessions : 75 h.

Objectives

The objective of the Organic Chemistry course is to provide all the students with the essential bases of this discipline. Well assimilated, these bases will provide them with essential conceptual tools irrespective of their future orientations (chemical or biological and even physical).

Syllabus

Stereochemistry

Conformational analysis of linear and cyclic molecules
Chirality of organic molecules.
Absolute configurations (CIP Convention). Relative configurations specifically applied to amino acids and sugars. D/L Convention.
Principle of enantioselective and diastereoselective reactions.

Reaction Mechanisms

Inductive effect, mesomeric effect
Acidity and alkalinity in Organic Chemistry
Kinetic and thermodynamic control of reactions
Substitution, elimination and addition reactions
Aromatic electrophilic substitution reaction
Electrocyclic reactions

Fonctional groups
Amines and alcohols
Alcenes
Aldehydes and ketones
Acids and derivatives

Laboratory Sessions

The Laboratory Work emphasises the preparative aspect of Organic Chemistry as well as on structural analysis (IR, NMR, MS).

Supervisions

Review of preparatory classes, nomenclature
Electronic effects, acids and bases, protective groups
Aldehydes and ketones, part one
Aldehydes and ketones, end.
Enols, enolates and enones
Carboxylic acids and acid derivatives, reviews

Lecturers

Janine Cossy, Véronique Bellosta, Arthur Duprat, Domingo Gomez Pardo, Sébastien Reymond.

Research Laboratory

Laboratoire de Chimie Organique

4.5 Colloids, gels, suspensions

Chemistry and Physico-Chemistry majors 3rd year
Lectures : 15 h - Supervisions : 4,5 h -

Objectives

Industry uses a wide range of formulation methods. This step often leads to a use value in the cosmetic, pharmaceutical and food industry. Formulation is the "art" of combining in the right order and with the proper protocols manufactured products or active substances to obtain a finished product with new properties. The encapsulated active molecules in pharmacy, emulsion paints, creams, pastes and gels are often formulated materials that modern industry seeks to optimise. The objective of the course is to provide the bases and tools required to approach these specific materials: diagnosis and solutions to some practical problems.

Syllabus

Weak interactions and steady-state phase transitions
Strong interactions and gel transitions
Elasticity and compressibility of emulsions and foams.
Emulsification
Metastability

Supervisions

Use of colloids for immunological diagnosis
Colloids for drug vectoring
Colloids and nanostructures for DNA sorting

Lecturers

Jérome Bibette, Pierre Levitz.

Research Laboratory

Laboratoire Colloïdes et Matériaux Divisés

4.6 Environment and Sustainable Growth

Optional course 3rd year

Lectures : 24 h -

Objectives

All industries, and more specifically in the fields of petrochemistry, metallurgy, chemistry, automotive construction, pharmacy, food, paper manufacture or recycling and textiles, are faced with environmental problems. They all currently carry out specific actions, such as risk prevention inside and outside production sites, studies on the environmental impact of the goods produced, product life cycle analyses, waste management, waste treatment, increasing the possibility of recycling and waste recovery-revalorisation in materials and energy or the development of clean technologies.

This course is part of a "better knowledge for better assessment of the various contexts related to environmental problems" context, with the following main objectives: the notion of sustainable development, taking the environment into account in all its dimensions, and the understanding of the complexity of the environment both natural and modified by humans, a complexity related to the interaction of its biological, physical, socio-economic and cultural aspects.

Syllabus

Introduction: why training on environment?
Questions on environment
History of the demonstration of chemical origin pollution at a global scale
From the taking into account of environmental problems to sustainable development
How to understand environmental problems and need for multi-discplinary approach
Current chemical pollutions
The tools
Regulation and directives
The REACH programme
Analysis of life cycle
Notions of ecotoxicology and ecotoxicity
Ecosystems and matter cycles
Human population growth problems
Notions of ecotoxicity (the various transport and transformation routes of polluants, their effect on the function and structure of ecosystems)
Example of aquatic ecosystem perturbation: eutrophisation phenomena
Examples of persistent organic polluants (POP) contamination: hydrocarbons, PCB, dioxins, organochlorine insecticides

Effect of human activities on the atmosphere
Greenhouse effect and climate change
Stratospheric ozone
Tropospheric atmosphere
Air quality monitoring: AirParif
Aquatic systems diffuse pollution: example of pesticides
General characteristics, physical-chemistry, toxicity and ecotoxicity, transfer, transformation and contamination of aquatic systems and soil, environmental risk estimate methods, establishment of monitoring lists.
Site follow-up case study: consequences on the knowledge of the transport in surface and underground water. Example of atrazine and its transformation products.
Importance of degradation products.
Elimination of polluants during water treatment
Emerging contaminants: fire retardants, endocrine disruptors, drug residues, microalgue toxins, etc.

Lecturers

Marie-Claire Hennion, Michel Pailhes.

Research Laboratory

Laboratoire Environnement et Chimie Analytique

4.7 Colloidal matter and biomolecules

Optional course 3rd year

Lectures : 12 h -

Objectives

Biotechnologies and biophysics widely use colloids. For example, bioanalysis and imaging use colloids as markers, biophysics uses them to mechanically manipulate biological structures. The specific recognition between colloids grafted by antibodies and by antigens is the base of biological diagnostics (ELISA).

The course first describes the principles associated to this specific recognition. It then provides an outline of these applications and other potential applications in the field of immunodiagnostics. Finally it covers the elaboration of biomimetic materials.

Syllabus

Specific recognition: general aspects and definitions
Duration of life of an assembly and energy landscape
Formation of an assembly, 2 and 3 dimensional cases
Biological diagnosis application
Filament micromechanics application

Lecturers

Jerome Bibette.

Research Laboratory

Laboratoire ColloÔdes et Materiaux Divises

4.8 Identification of Organic Compounds

Core Curriculum 1st year

Lectures : 5 h - Problem classes : 6 h -

Objectives

This course presents the basic concepts in Nuclear Magnetic Resonance and Mass spectrometry that allow understanding the applications of these two techniques for the chemical characterisation of organic compounds.

Syllabus

Resonance magnetique nucleaire : The format retained for this part of the course is to present the main basic concepts of NMR of liquids and have the students manipulate them via the interpretation of numerous 1H and 13C spectra. NMR Principles. A- Nuclear spin and associated magnetic moment. B- Zeeman effect, resonnance phenomena. The main interactions found in liquid and solution NMR. A- Chemical shift. - screening constant and chemical shift. - how to measure the screening constant. - contributions to chemical shift. B- Indirect spin-spin coupling or J coupling - introduction (energy levels, multiplets, etc...). - homo and heteronuclear decoupling. - equivalence: chemically and/or magnetically equivalent nuclei. B- measurement conditions vs appearance of NMR spectra - spectrometer frequency. - temperature - pH - concentrations - detection of mobile protons Chemical exchange. - slow exchange/fast exchange (tautomer, conformational equilibrium etc..). - NMR time scale Introduction to impulse NMR and Fourier transform NMR. - 13C NMR. - impulse sequence, 1H decoupling - DEPT sequence Principe of 2D NMR. - 13C NMR. - impulse sequence, 1H decoupling - DEPT sequence

Spectrometrie de Masse : General principle of mass spectrometry. Electron impact ionisation. - Description of a standard device (magnetic deviation analyser) - recording of mass spectrum - use of low resolution and high resolution mass - fragmentation study Principe of chemical ionisation Introduction to GC-mass spectrometry coupling Illustration of the use of various techniques (IR, 1H and 13C NMR, Mass spectrometry) for the determination of two complex organic compounds

Laboratory Sessions

Students will measure and interpret 1H NMR, 13C NMR and Mass spectra of products synthetised in the Organic Chemistry laboratory course. They will thus have an experimental return on their Organic Chemistry laboratory experiments.

Lecturers

Veronique Bellosta, Corinne Soulie-Ziakovic, Arlette Trokiner, HelËne Montes.

Research Laboratory

Laboratoire de Physicochimie des PolymËres et Milieux Disperses

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4.9 Cristalline Materials

Core Curriculum 2nd year

Lectures : 20 h - Problem classes : 7 h - Supervisions : 4 h - Laboratory sessions : 45 h.

Objectives

The objective of this course is to provide students with the basic tools to describe the structure and properties of crystallised materials. The course starts by the crystallographic description of crystallised matter and the presentation of associated characterisation techniques. The second part emphasises the structure of ionic crystals and the deviations from a perfect crystal, in order to understand the relationships between crystalline solids structure and their physical properties.

Syllabus

Solid state
Crystal; point symmetry groups and space groups
X-ray crystallography; reciprocal network; structure factor; structure resolutions; experimental methods
Crystal structures; ionic crystal
Point defects; extended defects and dislocations
Structure/property relationship: Curie principle
Piezoelectric and ferroelectric materials
Magnetic properties of insulating solids

Laboratory Sessions

This course also includes a practical section on the synthesis of crystalline inorganic material (ceramics for electronics, mesoporous silica by sol-gel procedure, zeolites, iron and gold oxide nanoparticles) and characterisation of the materials synthetised (X-ray diffraction on monocrystal and powder, scanning electron microscope, BET, electric, magnetic and optical characterisations).

Supervisions

Structure, properties and synthesis of perovskites
Local atomic structure in glass oxides

Lecturers

Nicolas Lequeux, Patrick Bassoul, GeneviËve Vetter, Emmanuel Bertrand.

Research Laboratory

Laboratoire de ColloÔdes et Materiaux Divises

4.10 Macromolecular Materials

Core Curriculum 2nd year
Lectures : 17 h - Supervisions : 6 h -

Objectives

Macromolecular materials play an ever expanding role in our daily life. They range from the usual "plastics" intended to cover the needs of daily life, building and leisure activities to very elaborate polymers intended for the aeronautic and space industries.

The objective of this introductory course and its associated tutorials is to familiarise students with the specificities of polymers, and make them aware of the great variety of physical and mechanical behaviours they present, as a function of the chain structure and the temperature. Special emphasis will be placed on the relationships existing between polymer chemical structure and their properties.

No laboratory acrivity is associated with this course, which will have an extension in the industry training course at the beginning of the 3rd year.

Syllabus

Polymer material diversity
Variety of properties
Variety of states (thermoplastics, elastomer networks, thermo-hardening resins).
Variety of chemical structures (homopolymers et copolymers, chain or step polymerisation).
Variety of macrostructures and microstructures.
Characterisation of amorphous thermoplastic chains
Conformation of chains, conformational energy maps.
Size of chains in solution and in mass.
Distribution of chain lengths, mean molecular masses.
Viscosity of dilute solutions.
Steric exclusion chromatography.
Physical and mechnical properties of amorphous thermoplastics
Analysis of the vitreous transition Tg.
Properties of the vitreous state (secondary relaxation, plasticity).
Properties at temperatures higher than Tg (role of entanglement).
Semi-crystallin thermoplastics
Arrangement of macromolecular chains.
Influence of crsytallinity on physical and mechanical properties.
Properties of three-dimensional networks
Case of elastomer networks: the hyperelasticity phenomenon.
Tyre: an example of an elastomer reinforced by mineral fillers
Case of thermo-hardening resis.
Polymer composites - carbon fibre: introduction to the problems.
Insight into block copolymers
Shock resistance
Thermoplastic elastomers.
Use of polymers
Factors affecting the viscosity of "melted" thermoplastic.
Techniques of thermoplastic shaping (extrusion, injection, hollow-body blowing,...).
Shaping of thermo-hardening materials.

Supervisions

Conformations and properties in solution
Vitreous transition
Rubber elasticity
Entanglement

Lecturers

Jean Louis Halary.

Research Laboratory

Laboratoire de Physico-Chimie Structurale et Macromoleculaire

4.11 On-demand materials

Optional course 3rd year

Lectures : 30 h -

Objectives

The main objective of the course, oriented towards design, is to illustrate the current evolution of the world of materials which, from a stage in which the aim was to use the material available in the best possible manner (either wood or supraconductors), evolves to a stage in which the material is designed for the properties required. The inscription of properties in the composition and structure of the material occurs at all scales and results in a material that functions increasingly like a machine, a system or a device.

The inscription of properties, either structural or functional, in the core of the material does not only derive from the choice of components. In practically all cases, the final properties of the material are inseparable from the process that allowed the elaboration of the object that will be used. Present to various degrees in all the modules, this material-process couple will especially be illustrated in some of them.

Finally, even though it does not explicitly appear in the title of the course, numerous examples treated concern the fields of nanotechnology and nanomaterials.

Syllabus

From materials to object: textbook case
Traditional materials renewed: steel and concrete
From ultrahard to superplastic: ceramics and metals
Inspiration from nature: biomimetic materials
So-called ìintelligentî materials: adaptative, stimulatable, memory
Storage and production of energy: batteries, fuel cells, solar cells
Information storage: magnetic materials and photonic materials
Porous and ultradivided materials: absorbents, filters, catalysts, nanoparticles and nanotubes
Surface engineering: control of wetting, adhesion, friction, etc.
The body in spare parts: biomaterials

Lecturers

Henri Van Damme, A. Auibert-Hayet, A. Chateauminois, JB d'Espinose, B. Dieny, B. Dubertret, H. Hommel, M. Lagiere, R. Schach, JM Tarascon.

Research Laboratory

Physico-chimie des PolymËres et des Milieux Disperses

4.12 Soft Condensed Matter

Core Curriculum 3rd year

Lectures : 19 h - Supervisions : 7,5 h -

Objectives

The term Soft Matter designates a group of materials that ranges from plastic materials to liquid crystals including gels, colloid pastes, surfactant solutions, biopolymers, foams, etc. What do these materials, both solid and liquid, have in common? Like their name indicates, they have the capacity of deforming easily and reacting to weak physical or chemical demands. This property is due to the nature of the interaction forces whose amplitude is generally comparable to that of

Brownian forces. Entropy also plays a considerable role and could be at the origin of surprising phenomena. The competition between enthalpic and entropic forces is at the origin of self-assembly phenomena which lead to fascinating structures involving an entire hierarchy of length and time scales.

These materials are the basis of a multitude of technical and comfort industrial products. The mixtures of polymers and block copolymers lead to extremely effective plastic materials, recyclable elastomers, barrier films for packaging, adhesives, etc. Our display screens and devices contain liquid crystals that can be oriented by the simple application of an electrical field. The formulation of paints, print inks and cosmetics uses the association of surfactant molecules, colloids and polymers that allow attaining the physico-chemical properties required with low concentrations.

The Soft Matter and Development course, intended for physicists, chemists and physico-chemists, illustrates how a good knowledge of basic concepts in Soft Matter, an absolutely multi-disciplinary approach, as well as an awful lot of imagination, allow to tailor design and develop innovative materials and processes.

Syllabus

Ingenierie macromoleculaire
Polymer mixtures and alloys
Block copolymers
Microphase separation in block copolymers
Thermoplastic elastomers
Nanostructure materials
Control of nanostructuration
Analogy with surfactant phases
Cristaux liquides
Nematics, smectics, chiral phases
Defects and textures
Crystal liquid displays and other flat screen devices
Mise en forme des materiaux
Injection, extrusion, moulding and derived processes
Extrusion applicatins (pharmaceutical, ceramics)
Shaping of elastomers and polymer melts
Flow of polymers (linear and non-linear viscoelasticity)
Extrusion slip and instabilities
Cellular materials and polymer foams
Formulation en solution
Colloids, polymers and neutral gels: structure and dynamics
Loaded systems in Soft Matter and in Biology
Notions on polyelectrolytes
Poisson Boltzmann's equation, Manning's condensation, etc.
Hydrophobic skeleton polyelectrolytes
Polymers and polyelectrolyte gels

Supervisions

New multiblock copolymers for information storage
Block copolymers and nanoparticle based hybrids
Associative hydrosoluble polymers
Molecular recognition reactive membranes
Modular optic network using cholesterics

Lecturers

Michel Cloitre and Sophie Norvez.

Research Laboratory

Laboratoire MatiËre Molle et Chimie

4.13 Reactivity

Chemistry major 3rd year

Lectures : 8 h - Supervisions : 4,5 h -

Syllabus

Methodes d'analyse

Field of study
Correlation diagrams
Frontier orbital theory
Applications ‡ la chimie organique
Electrocyclic reactions
MO correlation
State correlation
Cycloaddition reactions
Frontier orbital theory
Alderís rule
Effect *endo*
Applications ‡ la chimie de coordination
Review of MLn fragments
Study of de ML4 conformation (ethylene)
Description of major reaction types in homogeneous catalysis
Oxidative addition of H2
Carbene coupling

Supervisions

Application of theoretical methods (correlation diagrams and frontier orbital theory) in the study of reactivity in organic chemistry.
Structure of transition metals boryl complexes.
Theoretical study of nickelyacyclopentane reactivity.
Structure of borohydride complexes.

Lecturers

FranÁois Volatron.

Research Laboratory

Laboratoire de Chimie Theorique

4.14 Analytical et Bioanalytical Sciences

Core Curriculum 2nd year

Lectures : 20 h - Problem classes : 10 h - Supervisions : 6 h - Laboratory sessions : 60 h.

Objectives

There is practically no socio-economic or scientific field that can do without the contribution of analytical chemistry (food safety, environment, fraud and counterfeit, doping, historical and archaeological heritage). The characteristics of the demand are: speed, low cost, reliability, possibility to perform tests from microsamples (drop of blood, etc.), use on the field, determination of a large number of compounds from the same sample (oil products, proteomics), test of trace and ultra-trace amounts of compounds, speciation of elements, etc.

Analytical chemistry has evolved greatly in the last few years to be able to respond to these demands, partly thanks to technological advances in particular in the field of separative sciences and their coupling with mass spectrometry, but also thanks to the increasing development of bio-analytical chemistry with the use of biological tools (antibodies, receptors, enzymes, DNA strands, etc.) in various immunoassays, bioassays and biosensors. We have also seen a miniaturisation of analytical techniques, which allows faster analyses and consumes less reagents and solvents for fast diagnosis. The Lab-on-chips are in full development and use microfluids.

This course is intended to provide students with the basic knowledge required for solving an analytical problem, irrespective of the origin of the demand. It also aims at providing the concepts necessary for the development of new methodologies, often miniaturised, a sector which is currently in full expansion in the field of medical and environmental diagnosis.

It starts with the study of various types of interactions and interface transport methods. Irrespective of the information sought about a chemical substance (concentration, structure, chemical state, prediction of its transport or elimination, etc.) and the nature of the milieu in which it is found (chemical, biochemical, biological), the design of an analytical strategy always requires a good knowledge of the interactions that bind this substance to its own milieu and in most cases the use of a separation method. The fundamental aspects of separation methods and analytical electrochemistry are then briefely presented as they are examined more thoroughly in the tutorial sessions, while their practical aspects are approached in the laboratory course. This allows more importance to be given to the use of multi-dimensional separations for the analysis of complex mixtures and in particular for proteomic analysis, to bioanalytical chemistry (immunoassays, bioassays, biosensors) and the miniaturisation as lab-on-chip.

Syllabus

Definition of the characteristics of current analytical chemistry

Separation sciences

Introduction to chromatographic methods: fundamental magnitudes and various interactions used

Gas chromatography

Liquid chromatography (the different modes: adsorption, partitioning, ion exchange)

Detection modes and coupling with mass spectrometry

Electrokinetic methods (free capillary, micellar phase, electro-chromatography)

Trace analysis: sample treatment

Two-dimensional coupling for the separation of complex mixtures (chromatography, electrophoresis) - applications to the analysis of oil products and proteomic analysis

Electrochemistry

Fundamental aspects

Analytical electrochemistry

Bioanalytical methods

Based on structural recognition: immunoassays

Based on the mode of action: enzyme inhibition bioassays and cellular bioassays

Miniaturisation: integrated separation microsystems separatifs and lab-on-chip for total analysis

Biosensors

Laboratory Sessions

The four week laboratory course allows a hands-on experience of the different methods such as gas and liquid chromatography, electrophoresis and electrochemistry. These methods teach the fundamental magnitudes and different techniques (separation, detection, various coupled methods) that allow their implementation. The treatment of the sample associated with liquid chromatography and gas chromatography is also used on examples such as the analysis of pesticide traces in surface water and the characterisation of volatile compounds in wine.

The students will carry out fifteen different experiments during this lab course. In general each experiments deals with a specific case, apart from the more theoretical aspect of the method, of the characterisation/analysis of compounds from varied fields such as the environment, food industry, pharmaceutical and oil industry.

It is important to note that the students use the latest generation material if possible (example of liquid chromatography and mass spectrometry couple) so that they are afterwards rapidly operational both in an industrial setting and in research.

Supervisions

Supercritical fluid chromatography, advantages-disadvantages/interest in comparison with GC and LC.

LC: molecular species/ adsorption - normal partition - reverse partition

LC: ionic or ionisable species/ ion pairs - ion exchange

Analytical electrochemistry Sample treatment

Electrophoretic Methods / Microsystems

Lecturers

Marie-Claire Hennion Jose Dugay, Florence Chapuis, Valerie Pichon, JerÙme Vial.

Research Laboratory

Laboratoire Environnement et Chimie Analytique

4.15 Advanced Synthesis and Green Chemistry

Optional course 3rd year

Lectures : 13 h - Problem classes : 5 h - Supervisions : 4,5 h -

Objectives

Currently, selectivity and in particular enantioselectivity are essential in organic synthesis. Obtaining in a safe and economic way this and that enantiomer of a given molecule is the subject of major efforts, both in industry and in academia.

Syllabus

Enantioselectivity, diastereoselectivity definitions and reviews

Enantiotopy, diastereotopy. Absolute configuration and relative configuration.

Review on doublings: acids and bases of chiral pool, enzymes.

Diastereoselective synthesis. Nucleophilic additions on a carbonyl group with a stereogenic centre. Cram and Felkin-Anh models (reduction by LiAlH4 and nucleophilic addition). Case of chelated Cram.

RMgX, chelated or not, reactions. Case of RMgX+MgX2.

Enantioselective alkylation

Racemic series alkylation

Heathcock couple
Evansí oxazolidinones Nagao-Fujita Couple
Opolzer and Meyers couples.
Endersí couple (SAMP and RAMP)
Enantioselective aldolisation
Zimmermannís transition state.
Intermolecular aldolisation (Aldehydes and enolates without stereogenic centre).
Chiral enamine reaction (Michael). Imines (cat. Corey)
Conjugated addition: Sakurai (TiCl4), (use proline)
Enantioselective oxidation
Epoxidation: possibles reagents, m-CPBA, H2O2, oxone, N-sulfonyloxaziridines.
Katsuki-Sharpless epoxidation with mechanism model and kinetic resolution.
Jacobsen reaction (type Z olefins). (Comparison of different epoxidation methods)
VO(acac)2

Opening of epoxyde rings by nucleophiles. (BF3.Et2O, HBr, OH-, HBr, DIBAL-H, RedAl, cuprates)

Hydroxyepoxydes attack by nucleophiles (Ti, REDAL, LiCu(CH3)2). Payne rearrangement followed by nucleophile attack.

Opening of epoxyde ring with chiral bases (Simpkins).
Sharpless dihydroxylation
Olefins cut (O3, OsO4-NaIO4, OsO4/NMO and NaIO4, Pb(OAc)4)
Ketone oxidation (m-CPBA, O2, SeO2 and CrO3).
Reaction of olefins with a stereogenic centre, Reduction reactions
Houkís Model
Hydroboration of olefins with a stereogenic centre en.
Use of 9-BBN
Reducing agents: AlpineBorane, Boronate (avec Rh), Coreyís reducing agent, BINAL.
Enantioselective hydrogenations: Noyori, Knowles, Kagan (DIOP); ketone reduction.
Enaminoester gives active amino acid derivative.
Rearrangements [4+2] and sigmatropics [3+3]

Diels-Alder, normal reactions , intramolecular. Diels-Alder in optically active series (Ti(OR*)4). Diels-Alder on alkynes.

Heterogeneous Diels-Alder. Rearrangement of ylids, chelotropic rearrangement (SO2). Danishefsky diene [4+2] and [2+3], nitrile oxide, N-oxides, Thermal and photochemical cycloadditions [2+2]. Paterno-Buchi reaction. Ketene. [2+2] on enones

Cope, Claisen, oxy-Cope and ene-reaction.

Rearrangement of silylated hydroxyesters. Sigmatropics [2,3]. Ene sulphoxide/Zn, sulphur enylids, enaminiums (Simpkins).

Thermal eliminations: chelotropic agents (SO2), Wittig rearrangement. Decomposition of azo derivatives, selenium oxides and amine oxides.

Organometallics
Vinyllithium, synthesis (metal-metal exchange) and reactivity.
Transmetallation with vinylstannane (cis>>trans)
Equatorial attack RMgX on ketones.
Shapiro. Organometallic Weinrebís amide, RMgX attack on ester with TMSCl.
Reformatsky.
Activated diethylzinc. R2CuLi: SN' attack on allyl acetate
Organocadmium, Organocerium, Organocuprate compounds.
Palladium complexes on olefins (Trost, Tsuji, Stille and Suzuki), Wackerís reaction.
Electrodeficient intermediaries
LDA-TMSCl tBuBr on ketones, Friedel-Craft, Diazoketones.
Cascade reactions (Johnson).

Rearrangements: Pinacolic (acid and basic), Diazomethane on C=O, Halogenoketones, Halogeno sulphones, Grobb rearrangement.

Carbenes and nitrenes
Thermal or photochemical decomposition of diazo. Preparation of aziridines.
Carbenoids.
Nitrenes: Hofmann, Schmidt and Curtius rearrangements.

Supervisions

Study of major enatioselective reactions, their applications and the factors that rule them:
Enantioselectivity, enantioselective alkylations, enantioselective aldolisations
Enantioselective oxidations, reduction reactions, enantioselective reductions on alkenes with stereogenic centre, rearrangements (part one)
Rearrangements (end), organometallic compounds, electrodeficient intermediaries

Lecturers

Janine Cossy, Veronique Bellosta, Arthur Duprat, Domingo Gomez-Pardo, Sebastien Reymond, Sylvain Gilat.

Research Laboratory

Laboratoire de Chimie Organique

4.16 Organic Synthesis

Chemistry major 3rd year
Lectures : 12 h - Problem classes : 3 h - Supervisions : 6 h -

Objectives

Fine organic chemistry is everywhere, in medicinal products, perfumes, cosmetics, materials, etc. To know the bases of organic synthesis is essential for a chemist.

This course is intended for chemists and aims to initiate them in the new reactions used in organic syntheses. This work finds its application in the study of major syntheses of biologically active products. These studies additionally constitute a first relative approach to Organic Chemistry synthesis strategies.

Syllabus

Alkylation reactions
Carbanion formation by deprotonation
Regioselective formation of enolates. Kinetic and thermodynamic conditions
Enolate stereochemistry (Z, E)
Alkylation of enolates and dianions (Nature alkylating agent, RX donor C-alkylation, O-alkylation with silylation and acetylation)
Use of silylated enol ethers (lithium ? monoalkylation)
Ester alkylation conditions (enolate E), amides (enolate Z), and nitriles
Action of carbonated nucleophiles on the carbonyl group.
Alkylation in basic medium
Formation and hydrolysis of enamines
Enamines condensation reactions (regioselectivity)
Aldolisation, Robinson
Mannich reaction
Knoevenagel reaction
Acylation of carbanions: Claisen reaction, Dieckmann cyclisation

Reactive intermediary: acyl imidazole
Conjugated additions: Michael reaction, Sakurai reaction, silylated enol ether (Mukaiyama)
Preparation of ?-ketoesters, Mander reagent (CNCO2Me)
Transformation of ester into ketone
Wittig, Wittig-Horner, and Peterson reactions
Nucleophilic sulphur ylids
Darzens reaction.
Interconversion of functional groups
Halides and sulphonic esters sulfoniques from alcohols
Solvent effects
Formation of nitriles, azides (Mitsunobu reaction)
Alkylation of amines and amides
Oxygenated nucleophiles: Mitsunobu reaction on alcohols
Sulphur nucleophiles
Protective groups (ROTHP, ROSiR3, ROBn, ROMe), formation and deprotection.
C-O bond breakage of esters and ethers (TMSI, BBr3, H2 pour OBn)
Interconversion of carboxylic acid derivatives: reagents for acylation (imidazoles, acid chlorides). Preparation of esters (DCC), and amides from esters, nitriles, acid chlorides. Formation of ketenes followed by capture (COCl +NEt3)
Electrophilic additions on double bonds. Oxidations and Reductions, Metathesis.
NBS, PhSeCl, Hg(OAc)2, iodolactonisation
Organoboranes, formation of amines from organoboranes.
Reduction: Diimide, LAH-NaBH4 and reduction of amides into amines NaBH3CN, Dibal-H, n-Bu3SnH (Barton). Dissolved metals, Clemmensen, Wolf-Kishner Shapiro Reaction
Oxidation: Swern, comparative PCC and PDC, Dess-Martin, allyl oxydation by SeO2. Formation of ???-unsaturated ketones using PhSeCl and PhSSPh, OsO4, Bayer-Villiger. Oxidative cleavage of diols
Reactive intermediaries
Rearrangements of carbocations: pinacolic rearrangement, Johnson cascades.
Ring enlargement by CH2N2.
Grob fragmentation. Favorski transposition
Hofmann, Schmidt, Curtius and Beckman rearrangements,
Metathese Reaction and applications

Supervisions

Based on the in-depth study of some major reactions integrated in multi-stage syntheses:
Alkylations, carbon nucleophilic additions to C=O double bond
Carbon nucleophilic additions (continuation), interconversion of functional groups, metathesis
Electrophilic additions to double bonds, oxidations and reductions
Reactive intermediaries, reviews

Lecturers

Janine Cossy, Veronique Bellosta, Arthur Duprat, Domingo Gomez-Pardo, Sebastien Reymond.

Research Laboratory

Laboratoire de Chimie Organique

4.17 Polymer Synthesis

Chemistry major 3rd year

Lectures : 8 h - Supervisions : 6 h -

Objectives

This course complements the 2nd year ìmacromolecular materialsî course for chemists in which the physical and mechanical properties of polymers are analysed with respect to the chemical structure and chain architecture. The course aims to specify the synthesis strategies as a function of the nature of the monomers and the desired chain characteristics. Concrete examples are proposed in tutorials from recent literature articles.

Syllabus

Polymerisation in steps
General principles of polycondensation and polyaddition.
Synthesis of linear macromolecules; examples of industrial polycondensates (polyesters, polyamides, polyurethanes, polycarbonates, silicones, polyimides).
Network synthesis (gelification, vitrification, TTT diagrammes); examples of industrial systems .
Conventional chain polymerisation methods
General principles (active site concept, polymerisation steps, thermodynamic aspects, temperature ceiling concept).
Free radical polymerisation.
Primers, kinetic equations, end reactions, transfer and retardation reactions, polymerisation techniques. Example of low density polyethylene polymerisation.
Anionic polymerisation.
Primers, ìlivingî polymer concept, consequences. Example of dienes 1,3 polymerisation.
Cationic polymerisation.
Primers, propagation reaction, end and transfer reactions. Example of poly(isobutene) polymerisation.
Coordination complexes polymerisation.
Ziegler-Natta ìCatalystsî, metallocene ssystems .
Example of high density polyethylene and isotactic polypropylene polymerisation.
Industrial interest of metallocenes.
Copolymerisation, grafting and cross-linking reactions
Copolycondensates.
Synthesis of alternate, statistics, block and comb copolymers.
Influence of monomer reactivity on chain structure.
Chain cross-linking methods. Example of rubber vulcanisation
Example of rubber vulcanisation.
Advanced methods of macromolecular synthesis
ìControlledî free radical polymerisation.
Advantages and limits with respect to conventional free radical polymerisation.
Conditions for a ìcontrolî of cationic polymerisations.
Synthesis of star polymers.
Anionic route. ìControlledî free radical route.
Complex architecture synthesis routes.
Dendrimers and hyper-branched polymers.
Organic ñ inorganic hybrids.

Supervisions

Polyurethanes (foams and paints)
Thermoplastic elastomers
Controlled free radical polymerisation methods
Star polymers
Macrocycle synthesis
Dendronised polymer synthesis

Lecturers

Jean Louis Halary.

Research Laboratory

Laboratoire de Physico-Chimie des PolymËres et des Milieux Disperses

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4.18 Physico-Chemical Thermodynamics

Core Curriculum 1st year

Lectures : 16 h - Problem classes : 8 h - Supervisions : 4 h -

Objectives

The objective of the course is to demonstrate how to use the very general and formal framework of thermodynamics to predict the behaviour and evolution of a chemical system composed of molecules, particles and interfaces, in which mixing, separation, reactions, state change phenomena or transport processes may occur. The course will go back and forth between potentials and major thermodynamic relationships and their decline in microscopic terms. The link with the statistical thermodynamics course is made by taking into account the internal complexity of molecules.

Syllabus

A first module introduces the diversity of molecular and particular matter states (gas, liquid, solid, soft matter, granular matter) and the tools to characterise it: pair potential, correlation functions. The major classes of intermolecular forces and surface forces are reviewed.

The second module is a review of basic thermodynamic concepts and relationships (phases, thermodynamic potentials, partial molar magnitudes, chemical potential, steady-state conditions, Gibbs-Duhem relationship, etc.) in a context enlarged by taking into account surface and interface phenomena.

The third module concerns solutions ñ liquid or solids ñ and mixtures. Starting from the ideal solution and its properties (vapour pressure, osmotic pressure, etc.) we progressively evolve towards more complex situations involving interacting molecules or particles. The process consists in carrying out in parallel a thermodynamic approach and statistical model (Bragg-Williams for regular solutions; Flory-Huggins for polymer solutions; Debye-H¸ckel for electrolyte solutions).

A fourth model concerns steady-states, transformations, separations and phase diagrams. Stability is analysed within the general framework of thermodynamic potential development and within the special regular solutions model framework. The two separation mechanisms which are nucleation ñ growth and spinodal decomposition are covered.

The fifth module concerns the systems in which chemical reactions take place. The core of the module is the description of equilibrium constants and affinity in terms of molecular partition functions.

The last module is an introduction to linear thermodynamics of irreversible processes: entropy production rate, transport phenomena, coupling, application to chemical process engineering and biology.

Laboratory Sessions

Common laboratory sessions with Statistical Thermodynamics.

Lecturers

Henri Van Damme, Yvette Tran, Helène Montès.

Research Laboratory

Laboratoire de Physicochimie des Polymères et Milieux Dispersés

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4.19 Molecular Characterisation Techniques

Core Curriculum 2nd year

Lectures : 47 h - Problem classes : 8 h - Supervisions : 6 h - Laboratory sessions : 45 h.

Objectives

The objective of this course is to provide students with the necessary bases to master characterisation tools. It covers the description of infrared and UV-visible absorption spectroscopy, Raman diffusion and fluorescence emission, nuclear magnetic resonance spectroscopy, mass spectrometery as well as X-ray diffusion analytical techniques.

Syllabus

Vibrational Spectroscopy (infrared absorption and Raman scattering): (7 hours of lectures + 5 hours of supervised work + 3 hours of tutorial, L. Bokobza)

Study of vibration-rotation spectra of diatomic molecules [selection rules that guide absorption and diffusion transitions; effects on spectra, vibrator anharmonicity, molecular parameters that can be deduced from the analysis of the spectra].

Vibrations of polyatomic molecules: treatment in classic mechanics and in quantum mechanics.

Application of group theory to vibration spectrometry: determination of vibration activities in infrared absorption and Raman diffusion from their symmetry properties.

Introduction to spectrochemistry: justification of the existence of frequencies characteristic of atom groups using simple mechanical models and spectra attribution methods of infrared absorption.

Near-infrared spectroscopy: potential of this technique for solving analytical problems in fields as varied as those of the food industry, petrochemistry or polymers.

Tutorial (3 hours) - Relationship between vibration spectra and molecule symmetry - Group frequency: justification of their existence from mechanical models - Le C=O vibration: parameters likely to modify its vibration frequency

Ultraviolet and visible spectroscopy; photoluminescence: (5 hours of lectures, L. Bokobza)

Electronic transitions of polyatomic molecules.

Dissipation of excitation energy by an isolated molecule: internal conversion, fluorescence, intersystem crossing, phosphorescence, non-radiative decay

Kinetic considerations: life time, quantum yield.

Effects of interactions between solvent and chromophores.

Fluorescence quenching mechanisms.

Examples of fluorescence probes in polymers, micelles and proteins.

Applications fluorescence microspectroscopy in biology.

Nuclear Magnetic Resonance (8 hours of lessons + 3 hours of supervised work + 3 hours of tutorial, A. Trokiner)

Introduction: Zeeman effect, steady-state populations, nuclear magnetisation; rotating frame, introduction to relaxation.

Experimental aspects: NMR signal and Fourier transform, quantitative aspects, measurement of relaxation times T1 and T2. NMR experiments in extreme conditions.

The interactions: dipolar interactions, chemical shift, scalar coupling and quadrupole interaction.

Review of liquid and solution NMR.

NMR in solid materials: effect of anisotropy on interactions, solid-specific methods: magic angle spinning (M.A.S.) and cross polarisation. Experimental aspects.

MRI: principle of Fourier transform imaging; space coding, types of images, T1 and T2 relaxation time-weighed images.

Tutorial (3 hours) - Spin-spin relaxation in a polymer - NMR Imaging

Light scattering : (10 hours of lessons, P. Levitz)

Geometry and organisation in the world of condensed matter.

Structural correlation and scattering

Structural correlation and scattering: Fraunhofer approximation; Babinet theorem; generalisation to 3D structures.

Experimental use: The main radiation used (X, neutrons, light); Concept of differential scattering and length section.

Qualitative analyse of scattering: Scattering spectrum calculation rule (q versus rc=1/q) ; Scattering and object size; Porodís Law and specific surface; scattering by a mass and surface fractal; scattering by polymers.

Scattering by a particle assembly in a dilute regime: Form factor; Guinierís regime.

Scattering by a particle assembly in a concentrated regime: Structure factor, swelling law.

Zimm Diagram (dilute regime)

Continuation of dynamics.v

Mass Spectrometry : (3 hours of lectures, J. Vinh)

Ionisation, and analysis methods, instrumentation.

Study of mass spectra, isotopic distribution, mass measurement and fragmentation.

Applications: environment, trace and metabolite analysis; chemistry and biology, structure determination; petrochemistry.

Laboratory Sessions

Infrared absorption spectroscopy

UV-visible and fluorescence emission spectroscopy

NMR of polymers, measurements of relaxation times associated with viscosity measurements (1H and 13C NMR).

Static light scattering, study of dilute polymer solutions, Zimm diagram (radius of gyration, second virial coefficient)

Correlation of photons (particle hydrodynamic radius)

Computer spectral simulation.

The laboratory work is a direct illustration of the theoretical teaching. They allow the student to be assimilated and further understand the teaching.

It is devoted to the analysis of structures and molecular interactions and especially aim at acquiring experience on the instrumentation and the experimental conditions for the optimisation of the spectroscopic response.

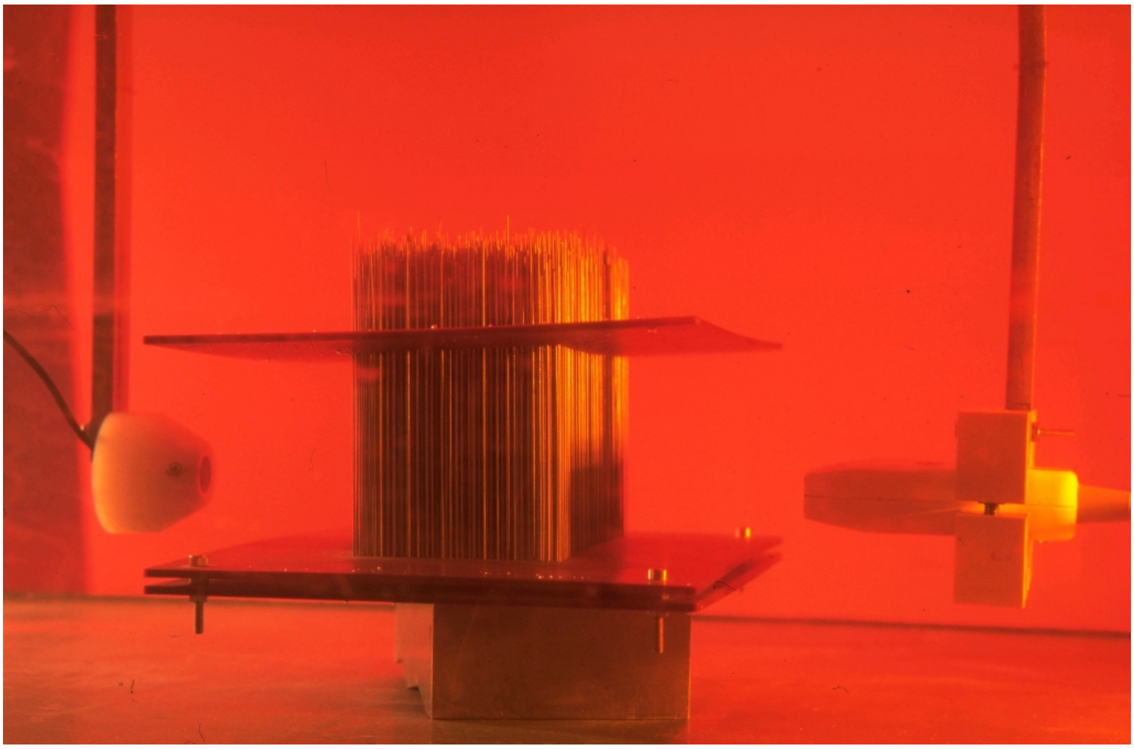
Lecturers

Liliane Bokobza, Arthur Duprat, Pierre Levitz, HelËne MontËs, Yvette Tran, Arlette Trokiner, Joelle Vinh.

Research Laboratory

Laboratoire de Physico-Chimie des Polymères et des Milieux Dispersés

5 Foreign languages , communication and economy



5.1 English

Core Curriculum 1st, 2nd and 3rd years

Lectures : 150 h -

Objectives

The Languages and Communication Department's activities are intended to provide student engineers and researchers with the pratical tools and the professional and cultural indicators necessary to complement their scientific training which will enhance their insertion into the world of corporate business both in France and in an international context. As proficiency in English is essential for any scientific and technical activity, students must achieve an excellent level in this language as shown by passing an international test, the TOEIC (with a target score of 750 points), regardless of any in-house achievement recorded. At the same time, practicing a second, but optional, modern language is strongly encouraged for this represents an additional asset. The school offers courses in German, Spanish and Japanese. Other languages can also be studied in collaboration with ParisTech's partner schools, including courses to perfect French for students who are not native speakers.

Syllabus

English courses, a required language, are organised in four level groups in various forms, with the participation of both native English speaking lecturers and individual coursework, conversation or self-training in the multimedia room (using CD-ROMs and the Internet).

Tailored support is provided to the weakest students including the "City of Paris" language scholarships for two to three week summer stays in an English speaking country.

Programme:

brushing up language basics: grammar, in-situation vocabulary

professional written and spoken communication: on the job company situations

scientific English

culture and intercultural communication

preparation for finding internships and jobs

The optional language teaching offered by ESPCI (German, Spanish and Japanese) is arranged in two proficiency level groups and the content is similar to that described for English.

Lecturers

Jean Le Bousse.

5.2 Introduction to business finance

Core Curriculum 3rd year

Lectures : 8 h -

Objectives

As a tool for monitoring operational performance or as a way to assist with strategic decision making, finance is a core company area. A manager's targets are often set out and measured in terms of a contribution to EBIT or EBITDA, how working capital is managed or investment TRI and even by Economic Value Added. Furthermore, we observe that financial logic often provides the basis for major consolidation and takeover moves which serve to redraw the contours of many industrial sectors.

Lasting only a short while (two half days), this course aims only to show how finance, once stripped of the hollow formalism of accounting standards and the somewhat outlandish terminology of financial engineering that often hides simple concepts, is actually a field that is easily approached by an engineering student used to working with far more complex concepts as well as being a fascinating and in many ways highly useful subject.

Syllabus

A quick survey

Companies: tools for creating value in a dismembered financial world, built on the primarily rational behaviour of investors seeking to defend and promote their own best interests.

Balance sheet, Profit and Loss Statement

Balance Sheet: a photograph of the company at regular intervals Assets Stakeholders and financial support = Liabilities Fixed Assets (Tangible and Intangible), Current Assets (Inventory, Account Receivable), Cash and Marketable Securities, Equity, Current Liabilities (Account Payable), Financial debt

The Profit & Loss P&L account: movements in growth and profitability Revenue, Gross Margin (GM), Depreciation and Amortisation (D&A), Marketing & Sales (M&S), General & Administrative (G&A), R&D, EBIT, EBITDA, Special Charges, Financial Charges, Net Income, Retained Earnings

Cash Flow Statement: a fundamental performance indicator, the crossroads between balance sheet and profit and loss statement, that represents the basis of modern corporate finance Gross and net operational cash flow (with the concept of variations in the need for Working Capital (or WC) Investment cash flow Free Cash Flow (FCF) Financing cash flow Changes in net debt

Simplified financial analysis

Invested Capital Liquidity and solvability ratios Debt ratios (with gearing and leverage concepts) Managing working capital (with the Cash Conversion Cycle concept) Profitability: the relationship between profitability and capital intensity Return on Invested Capital or ROIC Return on Equity or ROE Leverage

Case studies

Business valuation Private Equity financing Mergers and Acquisitions Leveraged Buy Outs (LBOs) Initial Public Offerings (IPOs) or secondary market issues Financial debt (bonds or bank loans)

Market value vs. accounting value (goodwill)

Discounted Cash Flow method Rewarding time Discounting and capitalising (TRI / IRR concepts) Risk premiums and the Capital Asset Pricing Model Impact of the financial structure (Modigliani & Miller) Choice of Cash Flows to discount (unlevered vs. levered) and final values

Economic Value Added (EVA)

Valorisation et theorie des options Call and Put Options: basic principles, built-in volatility Modelling to value debt (Put vision) and equity (Call vision) Estimating the odds of a default (ratings concepts, e.g. S&P, Moody's, Fitch, along with Credit Spreads and Credit Default Swap CDS)

Lecturer

Xavier Mace de Gastines.

5.3 Socio-economic lectures

Core Curriculum 1st year

Lectures : 12 h -

Syllabus

Lecture cycle:

Les fonctions de l'ingenieur. Aspects socio-economiques et juridiques

Planning and financing R&D projects by Bernard Montaron, Schlumberger

Social relations: a hindrance or an opportunity for a young engineer? by Vincent Meyer, Mediator and HR Consultant

A salaried engineer's rights and obligations by Ridha Ben Hamza, Universite de Paris I (Pantheon Sorbonne)

Innovation, methods and industrial perspectives

Intellectual property and patents by Jacques Lewiner, ESPCI

Quality management. What challenge does this represent for companies? by Michel Pailhes, Cosyma

An introduction to project management by Cecile Dubrovin, Thalès

Lecturers

Ridha Ben Hamza, Cecile Dubrovin, Jacques Lewiner, Vincent Meyer, Bernard Montaron, Michel Pailhes.

5.4 Communication & Social Relations. Module 1

Core Curriculum 1st year

Lectures : 15 h -

Objectives

The main objectives of this first module are:

- Discover the main functions within a company
- Discover the meaning of social relations within a company
- Understand the managerial relationship
- Get a better definition of a professional project and anticipate one's responsabilities as a future manager (rights and duties)
- Human Resources: how to work with them ?

The sessions include case studies, and an active participation from the students

Lecturer

Philippe Pierre.

5.5 Communication & Social Relations. Module 2

Core Curriculum 2nd year

Lectures : 15 h -

Objectives

The main objectives of this second module are:

- Savoir affirmer son projet professionnel en maitrisant les techniques/processus de recrutement
- Get a better understanding of Mieux comprendre les leviers individuels de motivation des collaborateurs en organisation
- Comprendre certains mécanismes d'adhésion et d'entraînement d'une équipe autour d'un but commun
- Etre sensibilisé à travailler en lien avec des personnalités et cultures différentes
- Prendre du recul et réfléchir à sa manière de s'intégrer dans une équipe

The sessions include case studies, and an active participation from the students.

Lecturer

Philippe Pierre.

5.6 Preparation to job search

Core Curriculum 3rd year

Lectures : 12 h -

Syllabus

This module is intended to prepare students for a job search. It comprises two parts: the first one includes workshops, in small groups, for seeking out information on companies, writing job applications and covering letters as well as CVs (curriculum vitae) as well as formatting a professional project and preparing students for job interviews. The module winds up with a one on one meeting with the group leader.

The second part takes place on-site with a simulated interview run by a Human Resources professional from one of the school's partner companies, chosen for their field of business that will match that of each student's professional project. This meeting corresponds to a real life professional situation approach, from the contact phase that sets up a meeting and following up with a debriefing with the recruiter to assess performance.

Lecturers

Coordinators: Jean Le Bousse, Roger Famery.

5.7 Economic intelligence

Core Curriculum 3rd year

Lectures : 6 h -

Syllabus

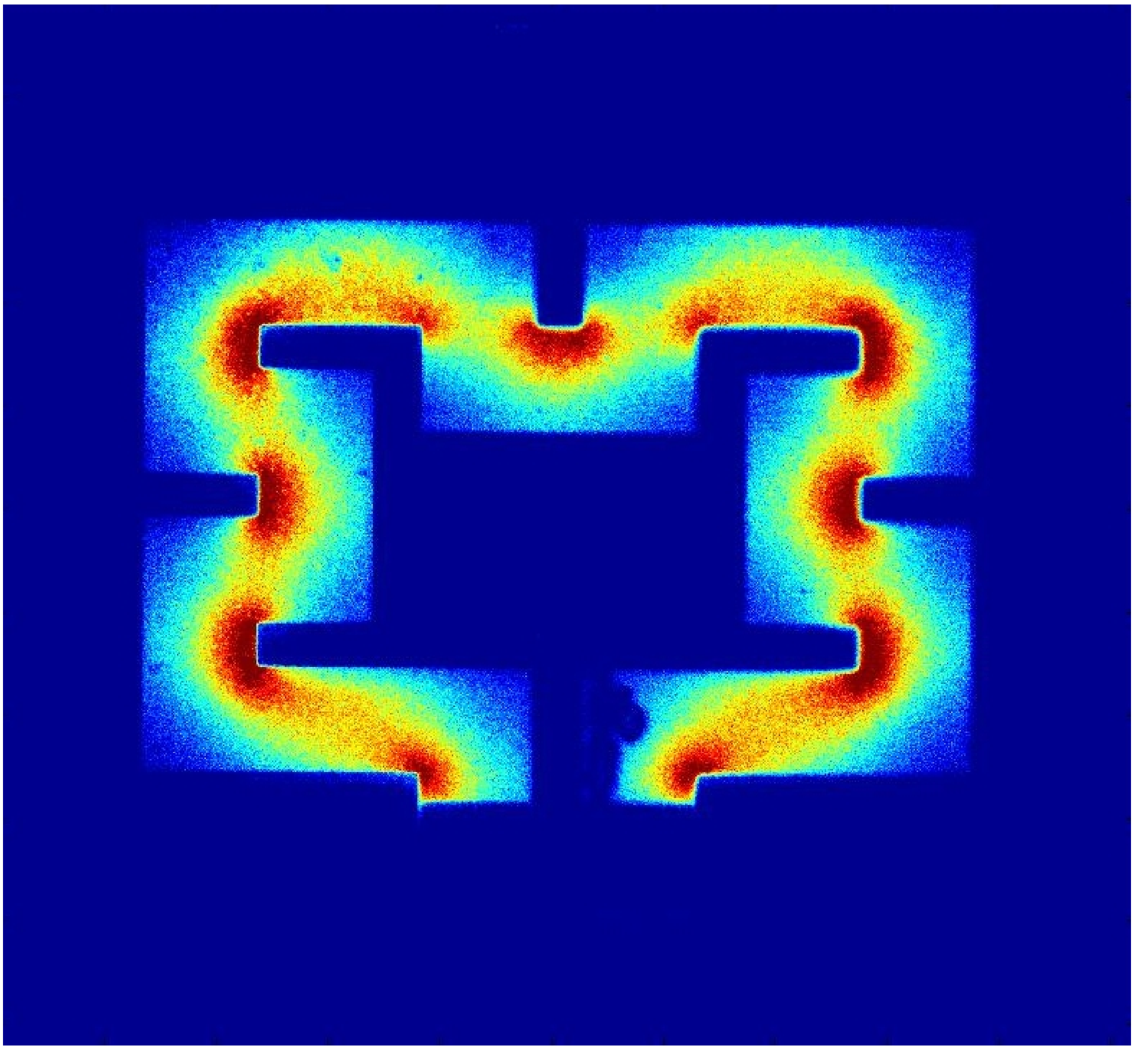
Economic intelligence is a management concern and one that involves techniques for managing and capitalising on strategic data that is useful to an organisation (from the company level to the national one). The process may be shown in the form of a trilogy: Data mining (seeking, collecting and analysing data and key knowledge) Protecting data assets and formulating strategic thinking (an innovation strategy and project management) Influencing (implementing offensive or defensive actions, leading influence networks, defining shared interest communities, evaluating effects) A capital element when it comes to strategic management, economic intelligence is essential to ensuring that companies remain competitive over the long term. This is why an awareness program is organised for students. It takes the form of a half day seminar led by a specialist in the field.

Lecturers

Didier Lallemand, a Senior Defence civil servant with the French Ministry of Economy, Finance and Industry (2006),

Bernard Carayon, Member of Parliament, Special Reporter for the Budget for Intelligence, the Defence Environment and Prospects, twice entrusted with reporting missions by the Prime Minister on economic intelligence (2007).

6 Mathematics and Numerical Methods Courses



6.1 Chemometrics

Chemistry major 3rd year

Lectures : 11 h -

Syllabus

Experimental methodology

Analysis of variance (ANOVA) - Analysis of variance with one control factor - Analysis of variance with two control factors: Interaction term Factorial plane and pyramidal plane Establishing and using sampling curves - Method of least squares and linear regression. Introduction to experimental design - Complete and fractional factorial design - Significance tests - Modelling Optimisation of analysis or procedure methods, e.g. formulation - Experimental design and response surfaces - Direct methods: Simplex method Validation of methods of analysis: selectivity, repeatability and reproducibility; precision, linearity, limits of detectability and quantifiability, robustness and stability.

Enseignant

Alain Jardy

6.2 Mathematical Methods I

Core Curriculum 1st year

Lectures : 18 h - Problem classes : 14 h - Supervisions : 7 h -

Objectives

The aim of the Mathematical Methods course is to present some of the mathematical methods required for a good grounding in physics and chemistry. These are not ”recipes” to be applied blindly, but mathematical tools to be properly mastered.

The first part of the course is devoted to the theory of holomorphic functions. The Cauchy approach, the idea of integration along a path in the complex plane, is very fertile and leads in particular to the method of residues and its many applications.

The second part of the course presents above all the rudiments of the theory of Lebesgue integration, and then discusses in detail the important ideas of the convolution integral, and Fourier and Laplace transforms.

The last part of the course is devoted to the theory of distributions developed by Laurent Schwartz around 1944. This theory has become an essential tool in many areas of mathematics and physics (We may cite, for example, the theory of partial differential equations studied during the course of the second year)

Syllabus

Holomorphic functions

Derivative of a function of a complex variable
Definition and properties
Integration in the complex plane
Residue theorem and applications
More on integration and integral transforms
Ideas of measure and Lebesgue integration
Convolution integral

Fourier transform
Laplace transform
Distributions
Definitions and general properties
Differentiation
Convolution
Fourier transform

Supervisions

Équations differentielles ordinaires
Analytic functions
Analytic functions
Fourier and Laplace transforms
Distributions

Lecturers

Elie RaphaÎl, Emanuel Bertrand,Emmanuel Bossy.

Research Laboratory

Mathematique Enseignement.

6.3 Mathematical Methods II

Core Curriculum 2nd year
Lectures : 18 h - Problem classes : 14 h - Supervisions : 5 h -

Objectives

This course follows on from the Mathematical Methods course in the first year. The first part of the course is devoted to probability theory. After introducing certain ideas and fundamental theorems, we will consider random variable distribution laws and limit theorems such as the law of large numbers and the central limit theorem.

The second part of the course is devoted to the calculus of variations, whose central problem is that of finding the function y(x) which minimises a given functional I[y(x)]. We will see how this problem leads naturally to the Euler-Lagrange differential equations. Classical mechanics will provide us with many examples, such as Hamilton's variational principle and the soap film between two rings, etc.

The last part of the course deals with partial differential equations. We will limit our attention to a small number of partial differential equations frequently encountered in physics. Various methods allowing solutions to be obtained which satisfy the given boundary conditions and initial conditions will be presented. Finally, the idea of Green's functions (which follow on from the first year course on distributions) will be introduced.

Syllabus

Probability
Fundamental ideas and theorems
Random variables and distribution laws
Continuation of random variables, limit theorems
Calculus of variations
Functional derivative.

Euler-Lagrange equations
Partial differential equations
Examples and classification
Methods of solution
Use of integral transforms
Green's functions

Supervisions

Introduction to tensor calculus
Probability
Calculus of variations
Équations aux derivees partielles

Lecturers

Elie RaphaÎl, Emanuel Bertrand,Emmanuel Bossy.

Research Laboratory

Mathematique Enseignement.

6.4 Computer Programming

Core Curriculum 1st year
Laboratory sessions : 75 h.

Objectives

The aim of this first-year course is to teach a well-developed programming language, (C), widely used in numerical simulation or computer calculation. The course is exclusively practical, and practical sessions will provide the opportunity to learn the basics skills of programming, following which they will be immediately applied to real situations.

Beyond learning an actual programming language, the accent is then on various numerical techniques, demonstrating all the rounding error problems found in floating point calculation. Different algorithms are suggested for implementing numerical techniques in the solution of differential equations, inversion of linear systems, etc.

Practical work will take place in a Unix environment, which will moreover allow students to familiarise themselves with this major family of operating systems. High performance compilation tools running under Unix are widely used.

Laboratory Sessions

During practical sessions students initially have the opportunity to work on various simple exercises allowing them to put the various elements of C programming into practice.

Subsequently, practical sessions will evolve gradually towards slightly more complex programs, allowing not only basic programming techniques to be applied but also specific aspects of numerical algorithms.

Lecturers

Didier Cassereau, Florent Krzakala, B. Quenet.

Research Laboratory

Laboratoire d'Ondes et Acoustique

6.5 Numerical Simulation

Optional course 3rd year

Laboratory sessions : 30 h.

Objectives

The aim of this optional course is to get a better understanding of programming techniques in C/C++ on Unix sytems, in particular for numerical simulations of physical phenomena. The focus is on team work and the students have to build together a coherent project.

The topic of the simulation project changes from year to year. In 2008, the aim will be the modeling of propagation of waves (sound or light waves) in different material structures

Lecturer

Didier Cassereau

Research Laboratory

Laboratoire d'Ondes et Acoustique

6.6 Group Theory

Core Curriculum 2nd year

Lectures : 10 h -

Introduction to Group Theory

Use of symmetry

Revision: interaction of two atomic orbitals.
Null recovery by symmetry
Molecular orbitals of BeH2.
Group of symmetry operrations
Description of symmetry operations.
Symmetry elements
Composition law
Inverse symmetry operation.
Group structure
Equivalence classes.
Examples.
Linear Representation of a Symmetry Group
Representation basis.
Matrix representation.
Representation reduction.
Irreducible representations.
Elements of Character Theory
Principle.
Character table.
Scalar product
Projection operator.

Applications

Computation of Molecular orbitals

MO (molecular orbital) and irreducible representations.
systems of unsaturated molecules.
Fragmentation method; MH4 square plane example.
Molecular Vibrations
General comments
Molecular motion
H2O example
Tensor product and applications
Definition.
Symmetry of a configuration.
Determination of a representation.
Evaluation of integrals; application to spectroscopy.

Electronic Structure of Molecules

Interactions with two orbitals

AH2 linear molecules.
Trigonal planar AH3 molecules
Tetrahedral AH4 molecules.
Interactions with three orbitals
Principle of interaction.
AH molecules.
AH2 bent molecules
AH3 pyramidal molecules.
Complex Molecules
Ethane
Dication of ethylene. Hyperconjugation.
Coordination Chemistry
General comments.
Electronic structure of ML6 (Oh) and ML4 (D4h) complexes.
Generalisation: the 16/18 electron rule.
Metal fragment ML5/ligand interactions.
donation; retro-donation.
Electronic structure of the L5M-ML5 dimer.

Lecturer

François Volatron.

Laboratoire associe

Laboratoire de Chimie Theorique

6.7 Applied Statistics

Core Curriculum 3rd year

Lectures : 10 h -

Syllabus

Elements de statistiques descriptives - Presentation and synthesis of observed data

Introduction ‡ l'analyse de donnees et ‡ l'analyse multivariee - Problems in data analysis - Correlation analysis - Principal component analysis - Hierarchical cluster analysis

Variables aleatoires et principales distributions utilisees en statistique Random samples and sampling distributions. Statistical estimation - Point and interval estimation. - Application to the classical laws of probability.

Les tests d'hypothËse - Construction of a hypothesis test. - Parametric tests: comparison of magnitudes or populations - Goodness of fit tests to a distribution model.

Enseignant

Alain Jardy

Syllabus

Elements de statistiques descriptives - Presentation and synthesis of observed data

Introduction ‡ l'analyse de donnees et ‡ l'analyse multivariee - Problems in data analysis - Correlation analysis - Principal component analysis - Hierarchical cluster analysis

Variables aleatoires et principales distributions utilisees en statistique Random samples and sampling distributions. Statistical estimation - Point and interval estimation. - Application to the classical laws of probability.

Les tests d'hypothËse - Construction of a hypothesis test. - Parametric tests: comparison of magnitudes or populations - Goodness of fit tests to a distribution model.

Enseignant

Alain Jardy

6.8 Statistics and Learning

Physics major 3rd year

Lectures : 11 h -

Syllabus

Elements of descriptive statistics - Presentation and synthesis of observed data

Introduction to data analysis and multivariate analysis

- Problems in data analysis - Correlation analysis - Principal component analysis - Hierarchical cluster analysis

Random variables and distributions used in statistics Random samples and sampling distributions. Statistical estimation - Point and interval estimation. - Application to the classical laws of probability.

Hypothesis tests - Construction of a hypothesis test. - Parametric tests: comparison of magnitudes or populations - Goodness of fit tests to a distribution model.

Lecturer

Alain Jardy

I - Introduction to statistical learning

1) A simple example of automatic classification

2) A simple example of prediction modelling

3) Elements of learning theory: Regression function, Bayes classifier, the bias-variance dilemma, Vapnik-Chernovenkis dimension, methods of model selection.

II - Linear regression
1) Method of least squares
2) Estimation of generalisation error, virtual leave-one-out
3) Selection of model variables: Gram-Schmidt orthogonalisation, test variable method. Application to spot weld modelling and to automatic speech processing.
III - Neural networks
1) Definition and properties of sparse approximation; application to temperature prediction of liquidus in industrial glasses
2) Teaching neural networks
3) Model selection
4) Application to prediction of oxidative stress
IV - Classification, support vector machines
1) Automatic classification: principle
2) The Perceptron rule, linear separability
3) Linear optimal classifier
4) Support vector machines (SVM) and kernel methods of classification
5) Application to automatic recognition of post-codes

Lecturers

Alain Jardy and Gerard Dreyfus.

Research Laboratory

Laboratoire d'Electronique

6.9 Linear Systems and Signal Analysis

Core Curriculum 1st year
Lectures : 10 h -

Objectives

The objective of the course is to familiarise students with the ideas and tools relating to linear systems. Pre-requisite technical tools (e.g. Fourier and Laplace transforms, theory of distributions, etc.) are dealt with in the first-year Mathematical Methods course. In as unified a manner as possible, the course aims to introduce ideas common to many topics, ideas which will often subsequently be grasped according to different context-related points of view and/or terminology. Courses in control, electromagnetism, telecommunications, optics and acoustics are particularly concerned.

Syllabus

The first part introduces in a general manner linear systems invariant under translation in time and space. In particular we show that such systems may be entirely characterised in physical space (time or space) by their impulse response, or in transformed space (Fourier or Laplace) by their transfer function. This first part ends with concrete examples of linear systems which will be encountered frequently during the course of study, such as wave propagation phenomena, control theory, electronic circuits, imaging, etc., using the terminology appropriate to each field.

The second part is devoted to time-domain systems, and in particular to the behaviour of systems described by a constant coefficient linear equation. Particular attention is paid to use of the Laplace transform, routinely used in control theory.

The third part deals with the representation and manipulation of signals in the Fourier domain. The Fourier transform is presented not only as a calculation tool, but also as a tool for representing signals in the frequency domain, a natural and intuitive representation of many physical phenomena.

The last part is an introduction to signal sampling. We will demonstrate Shannon's theorem and the formula for reconstructing a continuous signal from its correctly sampled version.

Lecturers

Emmanuel Bossy.

Research Laboratory

Laboratoire d'Optique Physique

7 Physics Courses

8 Enseignements de Physique

8.1 Control of Processes

Core Curriculum 1st year

Lectures : 24 h -

Objectives

This course is intended to provide students with the general concepts and mathematical tools to enable them to analyse system dynamics, whether mechanical, electronic, chemical, biological, economic, or ecological, etc.; to design process control systems or to take part in defining their specifications and design.

Syllabus

Introduction to process control:
Laplace transform
Transfer function and complex gain
Signal-flow graphs
Temporal response of first and second order linear systems.
Modelling linear dynamical systems:
State variables
Equations of state of a steady state system
Dynamics of linear steady state systems (description of state and external description)
Discrete time linear system dynamics
Governability and observability of linear systems
Analysis of linear servo systems:
Specifications of a servo system
Implementation of specifications (location of poles and zeros of the transfer function)
Temporal response of servo systems
Frequency response of servo systems
Stability of servo systems
Servo design:
Design of feedback control
Servo design with cascade correction (PID, phase advance, phase lag)
Digital control.

Laboratory Sessions

Analysis and realisation of an analogue temperature servo
An investigation of digital control of an electric motor
Microprocessor control of stepper motors

Preceptorat

Principles of regulation
Analogue and digital proportional control
Control using reference model
Design in the frequency domain
Digital control

Lecturers

Gerard Dreyfus, Yacine Oussar, Remi Dubois, Isabelle Rivals, Pierre Roussel.

Research Laboratory

Laboratoire d'Electronique

8.2 Scales of Space and Time

Physics major 3rd year

Lectures : 16 h - Problem classes : 3 h - Supervisions : 10,5 h -

Objectives

To introduce unifying concepts and the careful use of shortcuts, to employ analysis tools in an approach to transposition, encourage the use of the simple approach and the use of analogies, to seek out invariance and universality. The course comprises two parts. Firstly, the description of critical phenomena demonstrates how scale invariance of these physical situations, (long seen as an unsurmountable obstacle), leads to a universal description due to renormalisation methods. The second part illustrates the use of this approach for disordered systems (percolation, polymers), living systems as well as describing dynamic non-linear systems; the notion of deterministic chaos.

Syllabus

The universality of phase transitions to equilibrium
- Mean field approaches and the Landau-Ginzburg theory
- Limit of validity of the mean field: Ginzburg criterion
- Widom scaling laws.
- Kadanoff decimation
- Renormalisation methods
- Tools: fixed points and stability
- Other methods - 4-d development
- Universal classification of phase transitions
- Application to other types of scale invariance
- Percolation transition
- Excluded volume of polymers
- Scaling laws in living systems?
- Superconductivity and superfluidity: a quantum transition
- Notions about dynamic systems
- Normal and abnormal diffusion
- Chaotic transition

Supervisions

The tutorial accompanies a dossier of personal scientific work. Subjects are concerned with current scientific research having some bearing on the idea of scaling.

Lecturers

Michel Lagues, Annick Lesne, David Lacoste, François Ladieu, Daniel Bonamy.

8.3 Electromagnetism and Telecommunications

Core Curriculum 1st year

Lectures : 15 h - Problem classes : 3 h - Supervisions : 6 h - Laboratory sessions : 60 h.

Objectives

This section is the first module in a course on telecommunications systems. Its aim, by way of an example, is to present the different physical aspects and architectures used in modern telecomms systems.

In the first (introductory) part, we introduce via the history of telecommunications the systems which led to the advent of telephony by wire.

Current telecomms systems are then presented under three headings: transport, information, and networks, by an approach exemplified as follows:

What happens when a voice message embedded in an e-mail is sent from a mobile GSM telephone to a correspondent with a computer connected to a business intranet, itself connected to an ADSL (broadband) line?

Syllabus

Introduction
- A little history
- Course structure
- Example
- Transport
- Analogy: the horse - staging posts
- Hertz (radio) waves
- Line propagation
- Impedance matching
- Information
- Introduction
- Characterisation of information
- Modulation, demodulation
- Adaptive modulation
- Architecture of a transmit-receive system for complex digital modulation
- Block schematic
- The IQ modulator
- The IQ demodulator
- Frequency synthesis
- Mixing and frequency transposition
- Antenna switching
- Diversity of receiving antennae
- Networks and protocols
- Network topology
- Layer decomposition
- TCP/IP protocol

Laboratory Sessions

Hyperfrequency (microwaves): (Smith chart, stationary waves)
- Transmission lines (pass band, group velocity, phase velocity, dispersion)
- Antennae
- Impedance matching (network analyser)
- Hyperfrequency simulation and impedance matching
- Digital spectrum analysis (FFT and sampling, filtering)
- Analogue spectrum analysis (spectrum analyser, analysis of simple modulation)
- Complex digital modulation (IQ)
- Study of a DECT-standard transmit-receive system
- Base band cable transmission - serial RS232 connection to Ethernet
- Frequency synthesis - study and application of a digital phase-locked loop (PLL)

Synchronous detection

Lecturers

Emmanuel Geron, Jacques Lewiner, Dominique Morisseau, JerÙme Lucas.

Research Laboratory

Laboratoire d'Electricite Generale

8.4 Electronics of Integrated Circuits

Core Curriculum 1st year
Lectures : 24 h -

Objectives

This course is intended to provide students with the fundamental tools necessary for them to analyse the workings of electronic systems, either digital (computers and microprocessors) or analogue (amplifiers and oscillators), which they will encounter during their professional lives, to design integrated circuits, or to participate in writing or designing the associated specification sheets.

Syllabus

General observations and revision: theorems of Thevenin and Norton, impedance matching, RC circuits, and equivalent circuits. Logic and digital functions: Boolean algebra (Karnaugh diagrams), fundamental logic circuits (combinatorial and sequential), TTL and MOS technology.

Diodes: properties and applications.

Design of MOS integrated circuits: physical elements of semiconductors, MOS transistors, characteristics of the CMOS inverter, technological aspects, dynamic characteristics of CMOS integrated circuits, asynchronous combinatorial CMOS circuits, sequential CMOS circuits (RAM).

Bipolar circuit design: fundamental properties of bipolar transistors, linear operation, common collector and common emitter circuits, differential amplifiers.

Operational amplifiers: fundamental properties, fundamental circuits, operation and characteristics of the operational amplifier.

Some major electronic functions: oscillators, A to D (analogue to digital) and D to A conversion.

Microprocessors: internal architecture, organisation of a microcomputer, peripherals.

Laboratory Sessions

Design of digital circuits and FPGA integration

Design and implementation of analogue circuits

Operational amplifiers

SPICE simulation of analogue circuits

Supervisions

Design of digital circuits

MOS switching technology

Analogue MOS technology

Analogue bipolar technology

Oscillators, filters, converters and other functions

Lecturers

Gerard Dreyfus, Yacine Oussar, Remi Dubois, Isabelle Rivals, Pierre Roussel.

Research Laboratory

Laboratoire d'Electronique

8.5 Electrotechnics and Electrical Properties of Materials

Core Curriculum 1st year

Lectures : 12 h -

Objectives

Fundamentals of electrotechnics

The aim of this course is to provide students with the basic ideas of electrotechnology. The components taught are useful not only in a professional, but also in a personal, context, especially in terms of system optimisation and electrical safety.

Electricity transmission networks are considered, in particular within the framework of deregulation. Basic laws of physics impose certain constraints which exercise a powerful influence on the distribution of electricity.

Some economic aspects of the consequences of deregulation are presented.

Electrical properties of matter

The objective of this course is to explain the electrical properties of matter (gases and solids). More elaborate models will be studied in the 3rd year by the physicists.

Syllabus

Electrotechnics (5h)

Production
Transmission
Distribution
Safety
Economic aspects of deregulation

Electrical properties of matter (7h)

Electrical properties of gases
Electrical properties of solids

Lecturers

Jacques Lewiner.

Research Laboratory

Laboratoire d'Electricite Generale

8.6 Nuclear Engineering

Optional course 3rd year

Lectures : 21 h -

Syllabus

Nuclear Physics

Structure of the atom - Chemical elements Nuclear structure - Isotopes Radioactivity - Types of radiation, kinetics of radioactivity Mass deficit - Nuclear energy Nuclear reactions Characteristics of neutrons - energy domains Neutron interactions Effective cross-sections

Principle of nuclear reactors

Fusion and fission - Energy liberated Fission products Chain reaction - multiplication factor Choice of fuel Choice of moderator Moderation ratio - the under-moderated reactor Choice of heat transfer medium Reactor technology type

Reactor kinetics

Reactivity Retarded neutrons - Precursors Neutron lifetimes Kinetic equations Fast neutron kinetics (hypothetical) Kinetics of a group of retarded neutrons The Nordheim relation and curve Evolution of neutron population as a function of reactivity Doubling time Principles of reactor operation Neutron poisons - Xenon and Samarium Effect on reactivity due to temperature variations Sub-critical approach before reactor start-up

Pressurized Water Reactors

Operating principle and description: structures, primary, secondary and tertiary circuits, ponds, control room. Presentation of certain auxiliary and safeguard circuits.

EPR

European Pressurized water Reactor: Presentation of details of the EPR in relation to current reactors.

Nuclear players in France

Principal nuclear players in France: Government, DGEMP, ASN, IRSN, ANDRA, CEA, AREVA, ALSTOM and EdF

Nuclear fuel cycle and waste management

Nuclear fuel for PWR type reactor

Uranium; nuclear, chemical and physical aspects

U, chemical element; actinide family, electronic configuration, oxidation states U radio-element; isotopes and half-lives, daughter products, fissile/fertile, natural/enriched/depleted Uranium, reactor/isotope type.

Uranium; at the heart of the PWR

What chemical form? Why? What sort of packaging? Assembly, rods, granules, UO2 powder. The needs of the electronuclear parc in France Fuel fabrication industry; some aspects. From new to spent fuel; nuclear reactions, production of new chemical elements, corrosion aspects

From mine to fuel fabrication

From mine to fuel fabrication; a logical sequence of steps.

Objective of the 3 steps; extraction - concentration, conversion, enrichment. Uranium in several chemical forms and states. Global mining resources, conversion and enrichment plants.

Uranium enrichment; a physical separation process

Principles of separation by gaseous diffusion; unit operation, cascade, separation factor. Composition of a gas diffusion (GD) module. Comparison of GD / gas ultracentrifuge processes. George Besse 1 plant and George Besse 2 project.

Spent fuel and waste management

Stages dependent on an end of cycle strategy

Open cycle / closed cycle; explanation of the choices made by some countries. Decommissioning strategy - recycling: industrial implications. The decommissioning and recycling industry; MOX, reprocessed, and enriched uranium fuels. Decommissioning strategy - recycling: implications for end of cycle waste management. The situation today.

Treatment process for spent fuels: the PUREX (Plutonium and Uranium Recovery by Extraction) production lines

Radioactive waste management: the situation today in France

Origin, classification, annual production. Surface storage of low and very low level short-lived waste (Very low level, and short-lived low and medium level) R&D associated with management of high and medium level long-lived waste.

Management of high and medium level long-lived waste: the French perspective, and strategies developed by our neighbours.

Lecturers

François Foulon, Patrick Jouenne, Pascal Dannus.

8.7 Biomedical Instrumentation

Optional course 3rd year

Lectures : 21 h -

Objectives

The aim of this option is, by means of an introduction to some methods of medical imaging, to examine the concepts and performance of associated instruments. We have chosen this area since it is here that instrumentation is most often pushed to its physical or technological limits.

Syllabus

The three main chapters of the course will revolve around:

Acoustics, with nonlinear image contrast, compression and shear waves, control of wavefront quality etc.

MRI (Magnetic resonance imaging). The existence of a particularly high performance imaging machine at ESPCI will provide the opportunity to revisit this technique and to follow up how it has developed.

Optics, at conventional scale (e.g cell) microscopy, as well as the challenges posed by imaging in deep tissue (e.g for the detection of tumours or brain activity).

Lecturers

Mathias Fink, Claude Boccara, Arnaud Tourin, François Ramaz and Julien de Rosny.

8.8 Light and Images

Core Curriculum 2nd year

Lectures : 16 h - Problem classes : 4 h - Supervisions : 5 h - Laboratory sessions : 37 h.

Objectives

To understand the principal phenomena which govern the propagation of light by means of simple systems for image-formation, energy transport, interferometry or spectroscopy. We shall use the very convenient Fourier optical formalism to describe the linear behaviour of numerous systems such as imaging devices, spectrometers, interferometers, holography, coder-decoder systems, etc.

This course makes use of the idea of distributions (1st year maths) and numerous linear electronic circuit analogies (1st year).

Syllabus

Laws and principles of geometric optics
Image quality
Optical systems and components
Transport of light energy
Optics: spectroscopy and imaging
Coherence in optics
Interferometric and grating spectrometers
Diffraction and aperture synthesis
Optical signal processing
Object-image relations
Optical filtering
Holography - Coding - Recognition

Laboratory Sessions

Spectroscopye
Measurement of the hyperfine structure of a spectral line using a Fabry-Perot interferometer.
Broad spectra measurement using Fourier transform spectroscopy.
Investigation of the performance of a grating spectrometer
Interferometry and Image Processing
Fibre optic interferometer
Microscopic scale 3-D imaging using digital holography.
Spatial filtering of an image in the Fourier plane.
Diffraction by an ultrasonic wave
Laser granularity

Supervisions

The single lens reflex
Fourier transform spectroscopy
Fabry Perot interferometry
The grating spectrometer
Optics of Gaussian beams

Lecturers

Claude Boccara, Sylvain Gigan, François Ramaz, Jean Paul Roger, Gilles Tessier.

Research Laboratory

Laboratoire d'Optique Physique

8.9 Light and Matter

Core Curriculum 2nd year

Lectures : 20 h - Problem classes : 6 h - Supervisions : 7 h - Laboratory sessions : 30 h.

Objectives

To introduce the interaction of light with matter at different levels. Treatment may be phenomenological to understand the operation of radiation detectors, or may be based upon classical electromagnetism (in linear or nonlinear, isotropic or anisotropic media), or on quantum physics. We will also introduce the elements required to understand the principles of the most important lasers and their applications.

This course draws on the electromagnetism taught in the 1st year, 1st and 2nd year quantum physics, and 2nd year spectroscopy.

Syllabus

Light and image detectors
Signals and noise
Basic physical principles of detection
Examples: Flux detectors and image detectors
Classical electromagnetism
Isotropic media (dielectrics and metals)
Anisotropic media, propagation and interference
Application to transmission of information
Nonlinear optics
Quantum and laser optics
The semi-classical approach and its limits
The interaction Hamiltonian
Laser physics: Excitation - Relaxation - Beam width
Principal modes of laser operation (single-mode, multimode, relaxed locked mode, synchronous mode)
Principal laser types (gas and solid)
Applications of lasers

Laboratory Sessions

Lasers
Making a He-Ne laser
Dye tunable laser
Nd:YAG laser, intercavity second harmonic generation
Measurement of small birefringence
Using polarised light spectroscopy
Using polarisation modulation and synchronous detection
Application to the study of polymers and rotation induced by a magnetic field.
Interferometric measurement of roughness at the picometre scale
Light-matter interactions
Effect of a magnetic field on energy levels: the Zeeman effect
Mirage effect in a photo-induced temperature field
Photorefractive effect: photochromism and autodiffraction

Supervisions

Ellipsometry
Polarisation interferometer
The electro-optic effect
Second harmonic generation
Optical amplification by fibres in telecommunications
Temporal coherence of a laser

Lecturers

Claude Boccara, Sylvain Gigan, François Ramaz, Jean Paul Roger, Gilles Tessier.

Research Laboratory

Laboratoire d'Optique Physique

8.10 Applied Mechanics

Core Curriculum 1st year

Lectures : 8 h - Laboratory sessions : 30 h.

Objectives

The purpose of this course is to provide students with those basics in mechanics necessary for effective communication with specialists such as mechanics, technicians and design engineers within a framework of research-oriented project design. It will revolve around 3 main axes: design, manufacture and stress analysis.

Syllabus

Design

The techniques represented not only have the aim of reading documentation, but also of writing for actual implementation. Establishing a set of specifications (CdC) is the objective of a specific course in which ideas of basic requirements, operation and techniques for ending up with constructive solutions are given. The thinking around these topics is all about research-specific mechanical design, the way experiments evolve, means of fabrication limited to everyday machines ignoring ideas of industrialisation such as cost and the market. Before starting a specific case study, a presentation of basic practical solutions is given: assembly, rotational and translational control, sealing. Choice of materials is presented with a quick review of functional chains (actuators, reducers, transmitters), the last ideas to be put into place.

Machining

An introduction to the techniques of mechanical forming by removal of material, illustrated by the different machines to be found in a basic research laboratory workshop, e.g. lathes, milling machines, pillar drills. Also considered are the mechanics of chip formation and rupture, different tools and their usage, and the choice of cutting conditions.

Students should put into practice a simple prototype mechanical assembly similar to one produced in the DO. Use of lathes, milling machines and drills will provide basic ideas about fabrication, and a wide range of techniques such as surface finishing, starting off, drilling, boring, tapping and threading. Elementary ideas of metrology will arise naturally. Final assembly will illustrate the problems of adjustment between components.

Stress analysis

Basic ideas on the strength of materials, stress and elastic deformation, are introduced during a 5 hour course. The response of deformable materials under simple influences will be studied: tension/compression (Hooke's law, elastic constants, strain gauges), flexure (bending equation of a beam, calculation of deflection), simple shear, pure shear, torsion. The course is completed by tutorials where solutions to concrete mechanical problems are put forward.

Laboratory Sessions

For practical reasons, the courses, tutorials and practicals are contained within a single "Practical" module, passing from one to the other during the course of the instruction.

Design office (DO): Project implementation (design, specifications, technical drawings)

Building: fabrication of parts as per the DO project

Strength of Materials: Illustration of the principles of strength of materials: determination of elastic constants, e.g. Young's modulus, shear modulus, Poisson's ratio, by extensiometer testing of samples in tension, bending and torsion; determination of the stress field by photoelastic methods such as isocline grids, isochromes and isostatics on simple geometric models in tension or compression.

Lecturers

Pascal Kurowski, Denis Vallet

Research Laboratory

Laboratoire de Physique et Mecanique des Milieux HeterogËnes

8.11 Fluid Mechanics

Core Curriculum 2nd year

Lectures : 19 h - Problem classes : 5 h - Supervisions : 5 h - Laboratory sessions : 45 h.

Objectives

This course is a general introduction to fluid mechanics for physicists and chemists. It aims to provide the fundamental ideas for an understanding of flow dynamics and of mass and heat transfer. It is oriented particularly towards physical/chemical hydrodynamics and complex fluids such as suspensions, emulsions and polymer solutions. The accent is on appropriate orders of magnitude, and on the judicious use of dimensionless physical parameters such as Reynolds number.

Syllabus

Viscosity and momentum transfer

Kinematics: streamlines, flowline trajectories. Local flow deformations.

Stresses in a viscous fluid. Navier-Stokes equation. Reynolds number and dynamic similarity.

Non Newtonian fluids. Rheological liquids, viscoelasticity.

Flow at low Reynolds number. Lubrication, porous media, suspensions, low Reynolds number propulsion.

Flow at high Reynolds number, lift, laminar boundary layers.

Instability: principal types of hydrodynamic instability.

Ideas of turbulence: turbulent boundary layer, scaling laws in developed turbulence.

Ideas of heat and mass transfer: Peclet number, diffusion boundary layer, Taylor dispersion.

Supervisions

Scaling law analyses

Animal propulsion

Avalanches and gravity flow

Elastic fluid-structure interaction.

Understanding and interpretation of various flows using videos

Laboratory Sessions

Techniques of velocimetry: the laser Doppler velocimeter, hot wire anemometry, particle displacement velocimetry.
Flow visualisation
Porous media, suspensions
Surface waves
Viscometry, rheometry
Numerical simulation using finite elements
Flow in granular media

Lecturers

Marc Fermigier, Jose Bico, Pascal Kurowski.

Research Laboratory

Laboratoire de Physique et Mecanique des Milieux Hétérogènes

8.12 Mechanics of Solids

Core Curriculum 2nd year

Lectures : 19 h - Problem classes : 5 h - Supervisions : 4 h - Laboratory sessions : 45 h.

Objectives

This course in the Mechanics of Solids is oriented towards the mechanical properties of materials. After an introduction to the fundamental concepts of stress, deformation and energy, we shall develop the principal types of behaviour showing their physical origins. Viscoelastic and plastic characteristics, and fracture of large classes of materials are considered in parallel with a study of the corresponding equations which govern their behaviour. A study of simple inputs will lead to ideas guiding the choice of a particular material depending on the application envisaged (e.g. structure and loading).

Syllabus

General observations
Strength of materials: structure and input
The history of the Science of Materials: emergence of modern concepts.
Stress and deformation
Stress tensor, fundamental equation of equilibrium.
Deformation tensor: Properties.
Work of deformation, principles of finite elements.
Fundamental behaviour
Crystalline elasticity and high elasticity: stiffness of atomic bonds
Linear elasticity: elastic moduli, Lame equation
2-D problems and experimental stress analysis techniques
Theoretical shear strength, plasticity criteria.
Perfect plasticity, work hardening, creep
Ductility of metals: dislocations.
The paradox of the theoretical breaking strength.
Local criterion: stress intensity factor (Irwin).
Energy criterion: Griffith length and work of fracture.
Crack stopping and propagation. Brittle materials.

Materials and structures
Buckling: load coefficient (structure), efficiency (material).
Inhomogeneous materials: inclusions, composites.
Contact, adhesion and mechanics of fracture.

Laboratory Sessions

Associated practicals deal with:
Simple inputs: tension, bending and torsion
Experimental stress analysis: straingauge extensometry and photoelastic measurement
Vibration: eigenmodes, demonstration of plastic behaviour and fracture in pull tests.

Lecturers

Jean-Claude Charmet, Pascal Kurowski.

Research Laboratory

Laboratoire de Physique et Mecanique des Milieux Hétérogènes

8.13 Microfluidics

Optional course 3rd year

Lectures : 16 h - Supervisions : 8 h -

Objectives

The aim is to introduce students to the multidisciplinary realm of microfluidics. The course includes a general introduction to microsystems, MEMS, the "lab on a chip", DNA chips, etc. We will explain how the equilibria of "ordinary" systems are upset by miniaturisation. We will concentrate therefore on flow in microsystems, and the phenomena of adsorption, dispersion and separation in microfluidic systems. There will follow a description of electrokinetic phenomena, often exploited in microsystems for fluid transport or molecular separation. Finally, at an elementary level, we will present those current microfabrication techniques based on silicon or other materials which enable microsystems to be built.

Syllabus

General introduction to microsystems
The physics of miniaturisation
Flow in microsystems
Adsorption and mixing phenomena; applications to separation in microsystems
Electrokinetic phenomena: electro-osmosis, electrophoresis, dielectrophoresis
Introduction to microfabrication techniques

Preceptorats

Analysis of an article and demonstration of the corresponding experiment, for example:
Analysis of a chemical reaction in a microchannel.
Breakup of droplets in a microchannel
Structure of microdroplets in a microchannel

Lecturers

Patrick Tabeling.

Research Laboratory

Laboratoire de Microfluidique, MEMs et Nanostructures

8.14 Waves and Acoustics

Core Curriculum 2nd year

Lectures : 19 h - Problem classes : 6 h - Supervisions : 5 h - Laboratory sessions : 30 h.

Objectives

This course is intended to provide students with the concepts which will allow them to understand the propagation of waves, in particular acoustic waves in various media such as fluids, waveguides, cavities and biological media, etc. Monochromatic and impulse theories of diffraction will be presented, and then the effect of boundary conditions on propagation will be studied. On a more practical basis, imaging theory will be treated by means of a comparison of holographic techniques with lens imaging and echography. The principles of sonar and radar will be discussed, and aperture synthesis and pulse code techniques will be described. Finally, at the end of the course we will deal with the particular case of nonlinear propagation.

Syllabus

Linear systems
Impulse response and transfer function.
The wave equation as a linear system.
Integral Representation of Wave Fields and Diffraction Theory
The integral theorem in a homogeneous medium
Green's function: spatial uniqueness and reciprocity
Monochromatic theory of diffraction: near field and far field, Fresnel and Fourier transforms.
Impulse theory of diffraction. Geometric waves and edge waves.
Elements of imaging and sonar theory
Imaging Theory
Lenses
Holography
Sonar and radar pulse compression.
Synthetic apertures
Effets des conditions aux limites sur la propagation
Modal basis field decomposition and Green's functions.
Method of images
The cavity. The waveguide.
Theory of non linear propagation

Supervisions

Passive listening techniques: array gain.
Time reversal mirrors and disordered media.
Submarine acoustic ray tracing.
Ultrasound and medical imaging.
The subject of the last tutorial is left to the tutor (e.g. negative refractive index materials, time reversal and telecommunications, ultrasonic non-destructive testing).

Laboratory Sessions

Étude du comportement d'un transducteur ultrasonore

Experimental characterisation of a piezoelectric transducer.

Plane transducer, concave transducer.

Numerical investigation (using Matlab) of a plane circular transducer.

Propagation acoustique guidee

Experimental part: Investigation of the propagation of an acoustic wave in a waveguide; Time reversal experiment in a waveguide.

Numerical part (using Matlab): investigation of shallow water directed propagation in the ocean.

Sonoluminescence

Experimental part: setting up and conducting an experiment in sonoluminescence.

Numerical part (using Matlab): simulation of forced oscillation of a bubble.

Lecturers

Mathias Fink, Arnaud Tourin, Gabriel Montaldo.

Research Laboratory

Laboratoire Ondes et Acoustique

8.15 Physics of Microelectronics Circuits

Optional course 3rd year

Lectures : 12 h -

Objectives

This course is intended to explain the physical workings of those electronic components which have been studied and used during the course and first year electronic practical classes; it also describes the technology and manufacture of integrated circuits and microsystems.

Syllabus

Semiconductors in equilibrium and non-equilibrium states: law of mass action, injection and extraction, creation-recombination centres.

The p-n junction; static characteristics, direct and inverse polarisation, recovery time, differential capacitance.

MOS transistors: field effect, properties of MOS structure (differential capacitance, channel resistance), static current-voltage characteristics of MOS transistors.

Bipolar transistors: static model of the bipolar transistor, high frequency behaviour, saturated regime, Early effect.

Fabrication technology for circuits and integrated systems: lithography (optical and electronic), diffusion, epitaxy, oxidation, cathodic spray, ion implantation.

Lecturers

Jean-Jacques Ganem

Research Laboratory

Laboratoire d'Electronique

8.16 Quantum Physics

Core Curriculum 1st year

Lectures : 24 h - Problem classes : 8 h - Supervisions : 8 h -

Objectives

The aim is to provide a basic understanding of mechanics at the atomic scale. This understanding will be developed within other courses such as optics, chemistry, physics of solids, etc. The idea of the course is to introduce the principles and concepts which underlie quantum physics, and to demonstrate how they may be applied experimentally.

Syllabus

Waves and particles: energy levels
Principles of Quantum Mechanics
Some common systems: oscillators, tunnel effect, etc.
Atomic levels
Kinetic moment and spin

Supervisions

Tutorial sessions will deal with numerous areas of contemporary physics, both fundamental and applied, where quantum mechanics plays a major role.
Wave-particle duality. Application to matter probes and to atom-scale optics.
Colour centres in ionic crystals (F-centres).
WKB method. Application to the tunnel effect and the Gamow alpha emission model.
Formation of interstellar molecular hydrogen.
Neutron interferometry. Application to spin rotation and gravitational effect.
Factorisable quantum states, entangled quantum states. Application to quantum cryptography and to principles of qubit teleportation.

Laboratory Sessions

Optical pumping of Cs and Rb
Electronic paramagnetic resonance
Nuclear Magnetic Resonance: PAKE doublet
Tunnelling microscope: atomic imaging of graphite
Radioactivity and deceleration power
Atomic Force Microscopy: surface imaging
Introduction to vacuum techniques

Lecturers

JerÙme Lesueur, Dominique Bonnin, Jean Baptiste d'Espinose, Hubert Hommel, Daniel Marchand.

Research Laboratory

Laboratoire de Physique Quantique

8.17 Solid State Physics

Physics and Chemistry majors 3rd year

Lectures : 24 h - Supervisions : 14 h -

Objectives

When we seek to describe the electrical, magnetic, optical or thermal behaviour of solids, taking into account the large number of atoms per unit volume, it is not possible to carry out a precise analysis based on the behaviour of each atom.

Solid state physics allows us to construct models which, when experimentally verified, may be considered as representative.

The formalism constructed to this end has numerous applications. Examples in diverse fields and which sometimes appear very far from the physics of solids will be given.

Syllabus

Diffraction

Elastic vibrations in solids
Dispersion relations
Phonons
Specific heat
The Debye model
Phonon phonon interaction
Electronic properties of solids
Free electron models, nearly free electron models, and strongly bound electron models.
Band models
Electrical properties of solids
Different types of solid
Non-equilibrium phenomena
Transport equation
Application examples
Superconductivity
Magnetism

Supervisions

Periodic systems

Vibrations and phonons
Specific heat, paramagnetic susceptibility, the nearly-free electron
Strong binding forces, eg. La2 CuO4
Semiconductors and the P-N junction - applications.
The field effect transistor and the 2-D electron gas.
The quantum Hall effect

Lecturers

Jacques Lewiner.

Research Laboratory

Laboratoire d'Electricite Generale

8.18 Rheology

Chemistry and Physico-Chemistry majors 3rd year

Lectures : 10 h -

Objectives

The rheology course is aimed at 3rd year students of chemistry and physical chemistry. Its objective is to enable future engineers to characterise the flow properties of complex media such as solutions containing polymers and colloidal particles, emulsions, or wet pastes formed from non-colloidal particles. These problems arise in a great number of areas of industry such as agro-foodstuffs, paints and coatings, pharmaceutical or cosmetic formulations, suspension polymerisation processes and mineral transport. The course presupposes that the ideas of mechanics of fluids have been well grasped during the preceding years, and that the student is familiar with the language of rheology (e.g. stress, deformation, rate of shear, dynamic measurement, frequency spectra, transient and stationary measurement). Previous lectures on polymers will also have allowed the student to understand linear viscoelasticity of solutions and melts, and its interpretation in terms of molecular parameters.

Syllabus

Brief revision of basic rheological ideas. Making aware of ideas of rheometry: choice of measurement geometries for rotary rheometers (classical geometries, non standard geometries, ribbed or helical). Problems of slippage at boundaries and break-up of structured media.

Rheology of colloidal suspensions: dilute, semi-dilute, or concentrated media.

Rheological behaviour and structural interpretation. Solutions of rigid spheres without interaction, variable volumetric fraction, (Keiger-Dougherty, Quemada, Brady). Complex suspensions: the Quemada simplified model approach. Some ideas on the rheology of non colloidal suspensions and pastes.

Gelling or sol-gel transition and the percolation analogy. Some examples of rheology-structure relationships in real systems.

Rheology of emulsions and foams: The Princen model. Examples. Rheology of immiscible mixtures of melts or separated solutions: The Palierne linear model. Examples.

Travaux diriges

Rheology of complex fluids

Modelling and rheology of suspensions

Rheology of emulsions and gels

Lecturers

Madeleine Djabourov.

8.19 Signals and Images

Physics and Chemistry majors 3rd year

Lectures : 18 h - Supervisions : 6 h -

Objectives

Signaux

The aim of this course is to allow students to gain ideas about signal to noise ratio within an analogue or digital signal processing chain.

Images

This course describes the methodologies and tools required to solve complete problems in acquisition and pre-processing for image recognition and measurement. An experimental approach based on practical work and concrete examples is favoured.

Syllabus

Signaux

Revision of signals and linear systems.
"Classical" analogue processing: synchronous detection, averaging filter and spectrum analyser.
Digital processing: sampling and quantification, digital filtering and digital spectrum analysis.
Images
Introduction: applications and examples of image processing.
Image formation: from physical phenomena to the digital image.
Image degradation: origins of degradation and noise models
Image restoration: photometric and geometric correction.

Supervisions

Wavelets
Speech recognition
Position sensor
Cameras

Lecturers

DaniËle Fournier, Catherine Achard.

Research Laboratory

Laboratoire d'optique physique

8.20 Energy Producing Systems

Optional course 3rd year

Lectures : 21 h -

Syllabus

Schedule of lectures:
Energy conversion and storage; electrochemical systems (J.M. Tarascon, 9h)
Petroleum and energy issues (M. Orivel, 3h)
Oil and gas recovery (P. Bichet, 3h)
Oil exploration (J.P. Roy, 3h)
Exploitation of deposits (A. Couturier, 3h)
Energy systems for tomorrow? (E. Blaustein, 3h)
Renewable energies (E. Blaustein, 3h)

Lecturers

J.-M. Tarascon, M. Orivel, P. Bichet, J.P. Roy, A. Couturier, E. Blaustein

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8.21 Advanced Telecommunications

Optional course 3rd year

Lectures : 13 h -

Objectives

The essential aim of this course is to provide a deeper understanding of several aspects of telecommunications. It also includes an introduction to electromagnetic compatibility (EMC) in this field.

This module takes on board the tools necessary for the understanding of new standards in wired and wireless, public and private, communication, also the methods used to make the associated electronic components and equipment.

Syllabus

Advanced Telecommunication Systems (10h)

Requirements
Private telecomms - public telecomms (speech and data)
Interaction between systems
Increasing data rate and new modulation schemes (narrow band, broad band)
Spatial allocation (intelligent antennae)
"Universal communication": WiFi and Bluetooth
Alternative pathways: (powerlines)
Worldwide standardisation
The future

Electromagnetic Compatibility (CEM) (3h)

Physical magnitudes
Electromagnetic susceptibility
Parasitic transmissions
Electrostatic discharge
Measurement methods
Standardisation

Lecturers

Emmanuel Geron, Jerôme Lucas.

Research Laboratory

Laboratoire d'Electricite Generale

8.22 Thermodynamics

Core Curriculum 1st year

Laboratory sessions : 45 h.

Objectives

Practical work takes place over 3 weeks, and is intended to illustrate the courses on Chemical Thermodynamics and Physical Statistics through experiment. We hope we have also retained a certain independence in the choice of course related subjects in order to introduce some important ideas which are not necessarily taught in the first year at ESPCI.

Syllabus

Differential thermal analysis : freezing and melting of water and nucleation phenomena, metastability, the influence of cooling speed on the formation and melting of ice, and measurement of enthalpy of fusion. Thermoporometry. Crystallization of paraffins of different mass.

Phase transitions in ferroelectrics and liquid crystals.

Black-body infra-red radiation. Planck's Law.

Brownian diffusion measured by a localised photo-bleaching technique.

Study of Langmuir films at the water-air interface. Description of an isotherm (identification of phases, notions of equilibrium and relaxation), effects of the nature (eg. hydrogenated and fluorinated fatty acids) and length of carbon chains on isotherms, study of mixtures and departure from ideal mixtures, determination of the critical temperature from isotherms.

Lecturers

Madeleine Djabourov, Arlette Trokiner, Yvette Tran, Emanuel Bertrand.

Research Laboratory

Laboratoire de Physique Thermique

8.23 Statistical Thermodynamics

Core Curriculum 1st year

Lectures : 24 h -

Objectives

This course is an introduction to the general ideas of statistical physics. Particular attention is paid to basic concepts (statistical entropy, temperature) and to pertinent methods used in other disciplines such as economics, finance, biology or information theory. We will discuss certain classical examples (e.g perfect gas, paramagnetism, elasticity of polymers) along with the physics of phase transitions and collective phenomena. We will evoke equilibrium dynamics and Monte-Carlo methods together with quantum statistics, and will attempt to maintain a (difficult) balance between an intuitive approach to phenomena and more rigorous calculation.

Syllabus

General introduction and revision: probability

Chaotic dynamics and Boltzmann entropy. The second law.

Temperature and the "microcanonical" ensemble

Canonical system at equilibrium with a heat reservoir, free energy

Chemical potential and "major-canonical" ensemble

Applications: paramagnetism and elasticity in polymers

Equilibrium approach using the governing equation and Monte-Carlo method

The perfect gas

Interacting systems, para- and ferromagnetic transition

Gas lattice and the liquid-gas transition

Spatial fluctuations, surface tension and nucleation

Quantum statistics, Fermions and Bosons, Bose condensation.

Supervisions

Tutors have considerable freedom in their choice of subjects, which may include: Brownian motion, phonons, numerical simulation of phase transitions. The aim is to deepen understanding of the ideas in the course (for whoever completes the tutorials) and to explore some of the more specialised topics.

Laboratory Sessions

Common laboratory sessions with Physico-Chemical Thermodynamics.

Lecturer

Jean-Philippe Bouchaud.