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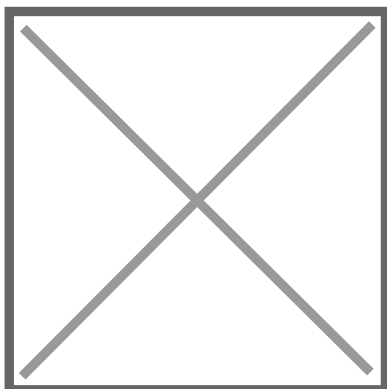
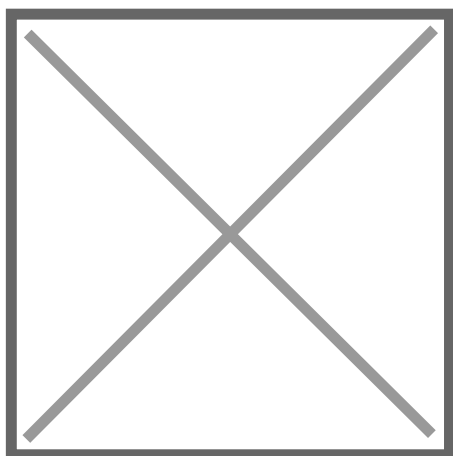
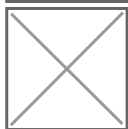
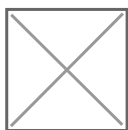
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Add to Compare

M1 Nuclear Engineering



Master's degree

Specialisation Nuclear Energy

Enrolment type

Full-time academic programmes Life-long learning

Language(s) of instruction

English

An international high-level degree, fully taught in English, training tomorrow's engineers and researchers in the field of civil nuclear energy.

Combining **scientific excellence**, **technical expertise**, and a **global vision of energy challenges**, the program equips students to address the key issues of the energy transition: low-carbon electricity production, safety and security of nuclear facilities, waste management, and the design of next-generation reactors.

The *Master in Nuclear Engineering* is a high-level international degree fully taught in English. It is designed for French and international students aiming to become engineers and researchers able to address challenges in operation, safety, design, decommissioning, and the future of nuclear facilities, contributing to low-carbon electricity generation.

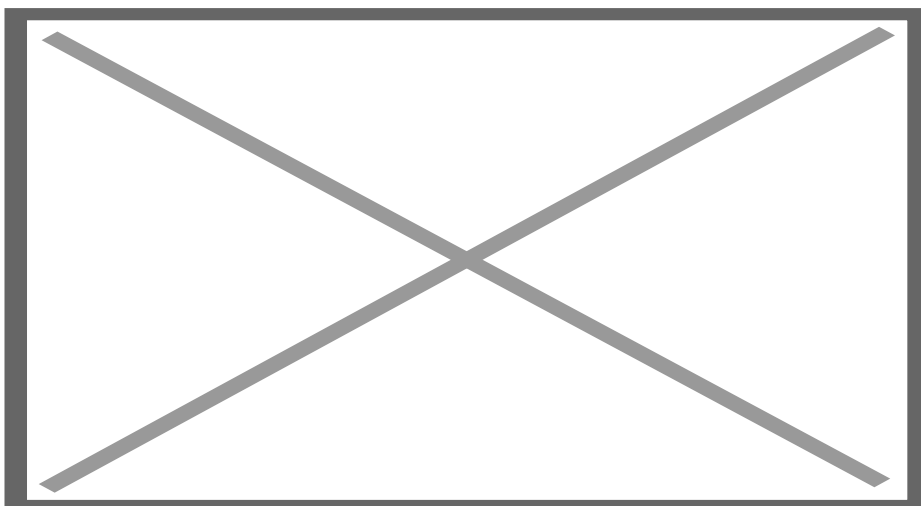
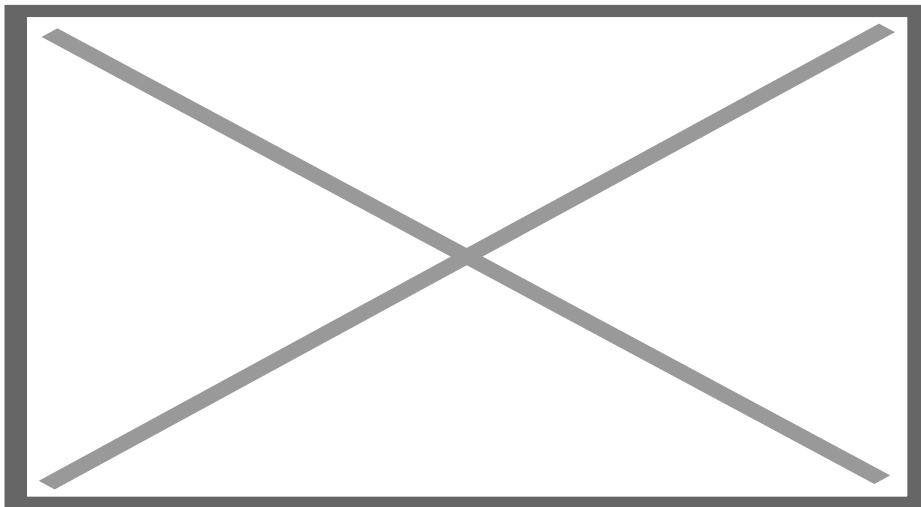
The two-year program includes:

- **M1**: two tracks, **Physics** and **Chemistry**, to build essential foundations.
- **M2**: five specializations in key areas of civil nuclear energy: **Fuel Cycle, Decommissioning and Waste Management, Operation, Nuclear Plant Design, Nuclear Reactor Physics and Engineering**

This progressive structure provides students with strong scientific and technical expertise, while fostering a global understanding of the industrial, environmental, and societal challenges of nuclear energy.

[Télécharger la fiche détaillée](#)

[Apply Now](#)





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Information

- [Overview](#)
- [Application requirements](#)
- [Schedule](#)

Présentation

Skills

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

- Identify the knowledge and tools required to analyze and solve complex problems in nuclear energy.
- Master the key disciplines involved in the industrial application of nuclear energy.
- Understand and explain the impacts of nuclear energy on humans and the environment, both in normal operation and in accident scenarios.
- Work effectively in teams and collaborate with professionals from diverse cultural, scientific, and technical backgrounds.
- Apply the fundamental principles of **safety culture** (prudence, questioning attitude, transparency, responsibility).
- Position nuclear energy within the global energy mix and compare it with other sources in terms of environmental, economic, and geopolitical impact.

Objectives

The Master aims to:

- Train specialists with strong scientific and technical knowledge to contribute to the safe and sustainable use of nuclear energy.
- Prepare students for careers in the nuclear industry or for research in reactor physics, modeling, radioprotection, or nuclear chemistry.
- Develop awareness of safety, security, and environmental issues associated with nuclear facilities.
- Provide a comparative and critical perspective of nuclear energy compared to other energy sources, in terms of sustainability, economics, and energy independence.

Débouchés

Career prospects

After a Master's or Master's + PhD: engineer (R&D, control, production, etc.)

After a Master's or Master's + PhD: researcher or lecturer

After a Master's or Master's + PhD: engineer (research and development, control, production, etc.) in the fields of health, pharmaceuticals, agri-food, biotechnologies, instruments and reagents, cosmetics, pollution control and the environment.

After a Master's + PhD: researcher or lecturer

After a Master's or Master's + PhD: engineer (Research & Development, control, production, etc.)

After a Master's degree: Research analyst

Ingenieur R&D

Business Manager

Safety engineer

design study engineer

chemical-environmental engineer

Nuclear R&D Engineer

Project Manager

Consulting

Design engineer in the industrial sector

Design engineer in the research / scientific sector

Design engineer industry / public research

Research and Innovation Manager

Project Manager

Research or Design Engineer

Lecturer (after a PhD)

Head of mission / projects

Prevention project manager

Further Study Opportunities

PhD

2nd year Master's

Calendar

Start of programme (indicative date)

01/09/2026

End of programme (indicative date)

09/07/2027

Admission

Admission Route

Physics

Chemistry
Physics, Chemistry
Mechanics
Civil Engineering
Engineering Sciences
Undergraduate double degree Mathematics - Physics

Capacity

Available Places

45

Target Audience and Entry Requirements

Bachelor in Physics, Bachelor in Chemistry

Période(s) de candidature

Inception Platform

From 15/01/2026 to 16/03/2026

Supporting documents

Compulsory supporting documents

Copy of the last diploma.

Copy of passport.

Motivation letter.

All transcripts of the years / semesters validated since the high school diploma at the date of application.

Certificate of English level (compulsory for non-English speakers).

Curriculum Vitae.

Certificate of English level (compulsory for non-English speakers) or GMAT / GRE test results.

Additional supporting documents

Certificate of English level.

VAP file (obligatory for all persons requesting a valuation of the assets to enter the diploma).

Recommendation letters.

Supporting documents :

- Residence permit stating the country of residence of the first country
- Or receipt of request stating the country of first asylum
- Or document from the UNHCR granting refugee status
- Or receipt of refugee status request delivered in France
- Or residence permit stating the refugee status delivered in France
- Or document stating subsidiary protection in France or abroad
- Or document stating temporary protection in France or abroad.

Programme

Basic Common Courses (block 1)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Thermodynamique	3	Semestre 1	18	9				

Thermodynamique

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 18

Directed study: 9

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Good knowledge of mathematics, derivatives, linear algebra and calculus. Basic knowledge of classical thermodynamics would be helpful.

Programme/contents

The course content is divided into 4 main chapters:

1. 1st and 2nd laws of thermodynamics

System and process (reminder of terminology and definitions), state functions properties, basic notions of temperature, pressure, heat and work, 1st law and energy conservation, concept of irreversibility, 2nd law and entropy creation.

2. Differential formulation, calorimetric and thermo-elastic coefficients

How to use these to solve a problem of thermodynamics, ideal gas model and real gases, Joule expansions.

3. Phase changes and phase diagrams of pure substances

Clausius-Clapeyron equation, reading and handling different diagrams [(P,T), (P,V), (T,S), and Mollier diagrams].

4. Heat engines, refrigerators and heat pumps

Operating principle, Raveau diagram, Carnot cycle, efficiency calculations, studying thermal cycles with chap. 3 diagrams, operating cycles (Otto, Diesel, Brayton, Rankine, Stirling).

Learning objectives

The objective of this course is to provide a clear view of the principles of Thermodynamics and its applications relevant to physics and engineering. The aim for the students is to acquire a valuable understanding of the fundamental concepts of Thermodynamics (such as energy exchange, reversible and irreversible processes, entropy creation etc.) and a good knowledge of the calculation method associated

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Méthodes mathématiques pour l'ingénierie	4	Semestre 1	18	0				

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Méthodes mathématiques pour l'ingénierie

ECTS : 4

Semester: Semestre 1

Detail

Lecture: 18

Directed study: 0

Tutored project 24

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Bachelor level in Mathematics

Notions of algorithmics

Notion of Python

Notions in Linux

Programme/contents

Introduction to Python

The language and existing numerical libraries.

Part 1 : Simple functions

Elements of floating point numbers : IEEE 754 format, relative uncertainty, single / double precision.

Catastrophic cancelation, examples with solving the quadratic equation and computing geometric quantities

Evaluating elementary and special functions : interval reduction, Taylor's expansion

Estimating statistical quantities : variance in particular, critical to uncertainties estimations

Part 2 : Linear algebra

Linear systems, Cramer's rule and why one should avoid it,

Gaussian elimination (simple and full pivot), LU factorization, elements of error propagation ; why one should rely on factorization to evaluate determinants and geometric quantities

Eigenvalues and Eigenvectors

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Interaction et détection des rayonnements ionisants	3	Semestre 1	9	3	21			

Interaction et détection des rayonnements ionisants

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 9

Practical study : 21

Directed study: 3

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

The prerequisites for this module are:

- converting electromagnetic energies into wavelengths, speeds, and frequencies
- explaining atomic structure and its reactions when energy below the ionization threshold is transferred to it
- explaining the organization of atoms into molecules and crystals and citing the binding energies involved
- explaining all the origins of ionizing radiation emitted at the end of a nuclear reaction (spontaneous or induced by a particle or radiation)
- list the energy ranges conveyed by ionizing and non-ionizing radiation
- calculate the energy balance of a nuclear reaction and the kinetic energy of the products of this reaction
- explain the different modes of spontaneous nuclear transitions: radioactivity

Programme/contents

- Sources of ionizing radiation: kinetic energy spectra according to the origin of the radiation
- Energy losses of ionizing radiation in matter:
 - Directly ionizing radiation: charged particles: linear energy transfer, range, penetration, energy losses through ionization, excitation, heat transfer, and bremsstrahlung
 - Indirectly ionizing radiation: electromagnetic radiation:
 - scattering, absorption, cross section, mean free path, attenuation laws
 - Indirectly ionizing radiation: neutrons:
 - scattering and slowing down, captures and induced nuclear reactions
 - (radiative capture, activation, fission, (n,alpha) reactions, etc.)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Notions de Physique Nucléaire	4	Semestre 1	18	18				

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	practical class	directed study/practical class
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Notions de Physique Nucléaire

ECTS : 4

Semester: Semestre 1

Detail

Lecture: 18

Directed study: 18

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

None

Programme/contents

1. Discovery of the Atomic Nucleus

- From early atomic models to Rutherford's experiment and the discovery of subatomic particles.
- Identification of protons, neutrons, and isotopes; scale of atomic and nuclear dimensions.
- Introduction to natural nuclear units (energy, mass, charge).

2. Nuclear Masses and Binding Energy

- Mass defect, binding energy, and nuclear cohesion.
- Liquid-drop model and Bethe–Weizsäcker formula.
- Nuclear stability, mass parabolas, and reaction energetics (Q-value calculations).

3. Nuclear Structure and Models

- Mean-field potential and shell model concepts.
- Quantum numbers, spin, parity, and magic numbers.
- Collective vs single-particle models of nuclear behavior.

4. Nuclear Reactions and Cross-Sections

- Classification and notation of nuclear reactions.
- Definition of cross-sections, reaction rates, and mean free path.
- Compound nucleus formation and reaction mechanisms.

5. Nuclear Kinematics

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practic class
Chemical Engineering	4	Semestre 2	15	15	6			

Chemical Engineering

ECTS : 4

Semester: Semestre 2

Detail

Lecture: 15

Practical study : 6

Directed study: 15

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

None

Programme/contents

1. Fundamentals of chemical engineering (i) Mass and energy balances (ii) Ideal reactors (CSTR, BSTR, PFR) Reactor analysis and design (iii) Purification unit operations: example of solvent extraction in the spent fuel treatment process
2. Thermodynamics: i) Calculation of chemical equilibrium and phase equilibrium: models based on excess free enthalpies or equations of state ii) Thermodynamics of electrolyte solutions
3. Thermodynamics: i) Diagram and phase equilibrium of pure substances: chemical potential ii) thermodynamic models and equations of state, iii) energy and entropy balances with application to thermodynamic cycles (Rankine) and energy storage

Learning objectives

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

1. List the modes of mass transfer.
2. Identify the different modes of mass transfer (diffusion/convection) at work in a given configuration.
3. Write mass balances, taking into account chemical reaction kinetics if necessary.
4. Translate phenomena into equations using fundamental balances.
4. Translate phenomena into equations using fundamental balances,
5. Calculate chemical equilibrium and phase equilibrium
6. Apply thermodynamic fundamentals to electrolyte solutions
7. Understand a phase equilibrium diagram for pure substances

Opening Common Courses (Block 2)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery
Technologies de Production d'Énergie	3	Semestre 1	9	18					

Technologies de Production d'Énergie

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 9

Directed study: 18

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Students in mechanical engineering, chemical engineering, energetics. Good basis in thermodynamics is required, basic knowledge in chemistry is preferable.

Programme/contents

Introduction to renewable energies - Cleantech -

Legal aspects

Solar energy

Wind energy

Energy storage

Energy efficiency

CO2 capture sequestration and valorisation

CO2 capture technologies

Oil and Gas

Combustion for energy production

Learning objectives

The objectives of the course are to:

have acquired a global knowledge of the current and future situation of power generation, essentially focused on fossil and renewable sources; possess an overview on current global market of oil and gas and its prospects for the future in the medium and long term; have acquired good technological and economical notions on wind and solar farms for renewable energy production; have acquired an advanced knowledge on the current and future generations of bio fuels, and the formation of atmospheric pollutants during their combustion; be able to understand the challenges of energy efficiency in buildings and industry; have acquired a knowledge of the main technologies of energy

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis le c
Gestion de Projet	3	Semestre 2	12						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/practical class
■									

Gestion de Projet

ECTS : 3

Semester: Semestre 2

Detail

Lecture: 12

Tutored project 18

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

none

Programme/contents

This course is an introduction to project management. It will provide the students with the essential milestones of project management.

- (1) Identification of needs and drafting of specifications
- (2) Organization and management of the project team
- (3) Identification and analysis of risks
- (4) Construction and monitoring of the schedule
- (5) Quality management (customer satisfaction and management of difficulties encountered)
- (6) Cost analysis and budget implementation
- (7) Choice of development model
- (8) Resistance management
- (8) Project monitoring and dashboard creation

Learning objectives

Managing a project: meeting customer expectations while staying within the allocated budget and schedule.

Overall organisation

Students form groups of 3-4 people. They choose a project they want to implement and work on: the skills required, the management approach

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis le c
Économie de l'énergie	2	Semestre 2	24						

Économie de l'énergie

ECTS : 2

Semester: Semestre 2

Detail

Lecture: 24

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

none

Programme/contents

The course is organized around 11 topics and chapters as follow:

- 1 Introduction and Background: Review of the Basics of Supply, Demand and Price Formation in Competitive Markets
- 2 Energy Demand: Short Run and Long Run Price and Income Elasticity's
- 3 Energy Supply and the Economics of Depletable Resources
- 4 World Oil Markets and Energy Security
- 5 Natural Gas Price Regulation, Deregulation and Markets
- 6 Electricity
- 7 Energy and Climate Change
- 8 Internalizing Environmental Externalities with a Focus on CO2 Emissions Cap and Trade Mechanisms
- 9 Coal
- 10 Nuclear Power
- 11 Renewable Energy Policies analysis

Learning objectives

This course explores the theoretical and empirical perspectives on individual and industrial demand for energy, energy supply, energy markets, and public policies affecting energy markets. It discusses aspects of the oil, natural gas, electricity, and nuclear power sectors and examines energy tax, price regulation, deregulation and policies for controlling emission.

Bibliography

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis le c
Notion de Physique des Réacteurs	1	Semestre 1	9						

Notion de Physique des Réacteurs

ECTS : 1

Semester: Semestre 1

Detail

Lecture: 9

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mathematics : resolution of first order differential equations

Programme/contents

The following elements will be seen:

- Brief review of nuclear physics for reactor physics: mass defect, binding energy, fission (spontaneous/induced), neutron/matter interactions, definition of cross-sections, radioactivity (natural/artificial).
- Neutron induced fission and self-sustaining chain reaction: introduction of the concept of criticality, definition of the multiplication factor. Focus on thermal neutron reactors with the four factor formula.
- Neutron energy spectrum in reactors: comparison of fast and thermal neutron reactors.
- Introduction of the different reactor types: different possible combinations of coolant, moderator, fuel and neutron spectra.
- Definition and impacts of the feedback: temperature effects (Doppler and moderator), expansion effects. Explaining their importance for the reactor stability.
- Fuel depletion: fission product poisoning (Xenon and Samarium effects), isotopic depletion, Bateman equations, definition of the burn-up to characterize the fuel depletion.
- Fuel management: brief review of the different strategies (fuel reprocessing vs. storage).

Learning objectives

The objective of the course is to provide a basic overview of reactor physics and the phenomena at work in the core of a reactor.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/learning
UE libre catalogue S1 et S2	2.5	Semestre 2							
■									

UE libre catalogue S1 et S2

ECTS : 2.5

Semester: Semestre 2

Language(s) of instruction

Français

Remote teaching

non

Type of assessment

Evaluation Terminale

Physics Speciality Course (Block 3)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/learning
Notion de Neutronique	1	Semestre 1	12	0					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/learning
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Notion de Neutronique

ECTS : 1

Semester: Semestre 1

Detail

Lecture: 12

Directed study: 0

Tutored project 0

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mathematics : resolution of first order

differential equations

Follow the course "Basic Reactor Operation"

Programme/contents

The following elements will be seen:

- Notion of neutron density, neutron flux, neutron current. Derivation of the full neutron balance equation (Boltzmann equation).
- Focus on spatial effects: monokinetics diffusion equation, external and internal boundary conditions, effect of a reflector, critical condition (critical size and critical mass).
- Time evolution of the neutron population: point-kinetics approximation, definition and importance of delayed neutrons, inhour equation.
- Understanding of neutron spectrum: neutron slowing down by elastic and isotropic scattering, lethargy variable, slowing down power of moderator materials, slowing down equation, notion of resonant absorption, thermalization.

Learning objectives

The objective is to deepen the knowledge covered in Basic Reactor Operation course. We will seek to gain a more precise understanding of neutronics in nuclear reactor cores. We will focus in particular on the energy, spatial, and temporal behavior of the neutron population.

Overall organisation

All lectures are given by UE coordinator.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis lea co
Material Science and mechanics	4	Semestre 1	17	16	6				

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dissemination/co
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Material Science and mechanics

ECTS : 4

Semester: Semestre 1

Detail

Lecture: 17

Practical study : 6

Directed study: 16

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Bases of Solid mechanic

Notions of Chemistry

Programme/contents

At the end, student must be able to determine the mechanical properties of the materials, to describe and understand the physical phenomena leading to its failure, have a first approach to structural design.

Learning objectives

Materials play a major role in reliability and sustainability of nuclear power plant. The aim of this course is to provide a knowledge base for students to understand how material is generated and what is the impact on its mechanical behavior. Relationships between microstructure, deformation mechanisms or failure and mechanical properties and behavior are highlighted here. The problem of structure dimensioning is also discussed. The aspects studied here are crystallography, phase diagrams, mechanical behavior (tension, creep, relaxation, Low cycle fatigue, High cycle fatigue, fatigue cracks growth rate) the origin of the damage (plasticity, initiation and crack propagation). The various points are processed separately in form of lectures and tutorials classes. The link between the different courses is highlighted at each end of the lesson.

Bibliography

Ashby and Jones: Engineering Materials

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis lea co
Ingénierie Électrique	3	Semestre 1	21	6					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/practical class
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Ingénierie Électrique

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 21

Directed study: 6

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Basics in magnetism and electricity ; principles of automatic control

Programme/contents

Fundamentals in electrical power systems

Basic element models. Formal calculation for sinusoidal steady state at fixed frequency. Boucherot theorem.

Three phase systems.

Transformers

Principle, magnetic coupling, modelling.

Application to single phase and three phase systems

Principles of AC Machines

Description and utilization of alternating current machines based on rotating magnetic fields.

Induction machines

Constitution, principles. Steady state model. Torque characteristics. Starting issues. Asynchronous machines utilization.

Synchronous machines

Alternator structure. Simplified model. Performances of the coupling to an infinite power transmission network. Reactive power production capacity.

Electrical energy transmission grid

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis lea co
Notions de Mécanique Quantique	3	Semestre 1	17.5	12.5					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery/learning
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Notions de Mécanique Quantique

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 17.5

Directed study: 12.5

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Good knowledge of:

- Classical mechanics (forces, kinetic and potential energy, classical particle motion, rotations...)
- Oscillation and waves (harmonic oscillator wave propagation, interference, diffraction...)
- Linear algebra and calculus
- Basic knowledge of electromagnetism: electric and magnetic fields

Programme/contents

Programme détaillé / Course program

1. Classical physics shortcomings and the birth of quantum mechanics

2. Foundation of quantum mechanics

a. Linear algebra and operators

b. Shrödinger equation

3. One dimensional piece-wise constant potentials

a. Square well potential and discrete energy spectrum

b. Potential step and potential barrier: the tunnel effect

4. Quantum Harmonic oscillator

5. Spin and the two level systems

6. Special relativity : a brief introduction

7. Quantum entanglement and quantum

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis- semination co
Mécanique des Fluides et Transferts thermiques	4	Semestre 2	24	12					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	discovery learning
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Mécanique des Fluides et Transferts thermiques

ECTS : 4

Semester: Semestre 2

Detail

Lecture: 24

Directed study: 12

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Math and calculus (derivatives, integrals, solution to equations, some ordinary differential equations)

Mechanics of particles: the original theory of motion (kinematics) and forces (dynamics)

Basic thermodynamics: First and second principles

Programme/contents

The program combines fluid mechanics and heat transfer, and is sequenced as follows:

2.1 Introduction to fluid mechanics, 5*3h,
Nicolas Mallick, Lecturer, CentraleSupélec (CS)

1. Introduction. Conservation and diffusion of a physical quantity. Continuum hypothesis.

Introduction

to the study of fluid flow. Material derivative.

Example of particles (Fick's law) and moderation of nuclear reactions.

2. Navier-Stokes equation. Stress and strain tensors in Newtonian fluids. Establishment of Navier-

Stokes and Euler equations. Simple examples (Couette and Poiseuille flows).

3. Bernoulli's equation and applications.

General mechanical energy balance. Efficiency.

4. Macroscopic balance equations. Application to the determination of hydrodynamic forces and moments.

Propulsion applications.

5. Physics of boundary layers. Various types of shear flows. Approximations and boundary layers

modélisation.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis lea co
Détection appliquée à la physique	2	Semestre 2	2		16				

Détection appliquée à la physique

ECTS : 2

Semester: Semestre 2

Detail

Lecture: 2

Practical study : 16

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Basic Nuclear Physics knowledge (provided in the first semester)

Interaction of particle in matter (provided in the first semester)

Statistical analysis (provided in the first semester)

Programme/contents

1. Introduction à la radioactivité

- Définitions et rappel des grandeurs nucléaires (A , Z , J , π).
- Les processus α , $\beta^\pm$, capture électronique, désexcitation γ , conversion interne.

2. Notions de détection

- Détection γ : principe de la scintillation, structure du spectre, efficacité.
- Détection de particules chargées : principe de la jonction P-N, précautions d'utilisation.

3. Modules électroniques

- Preamplificateur, amplificateur, discriminateurs, unité de coïncidences, convertisseurs analogique-numérique.
- Chaîne électronique complète pour mesures nucléaires.

4. Travaux pratiques

- **Expérience 1 : Spectrométrie γ**
 - Étude de spectres γ avec détecteurs NaI.
 - Calibration en énergie, résolution, efficacité, étude de schémas de désintégration.
- **Expérience 2 : Conversion**

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis lea co
Contrôle des systèmes dynamiques	3	Semestre 2	21	6	3				

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dissemination/leaving certificate
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Contrôle des systèmes dynamiques

ECTS : 3

Semester: Semestre 2

Detail

Lecture: 21

Practical study : 3

Directed study: 6

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Background in mathematics (real analysis, algebra, Laplace transform).

Programme/contents

Introduction – Generalities and basic concepts

Definitions – Fields of application – Historical data - Motivations - Classification: regulation and tracking - Structure of continuous and discrete time controlled systems – rejection and tracking dynamics – Block diagram of a feedback system.

Closed loop analysis

Notion and interest of feedback – Relations between open and closed loop – Closed loop stability: Nyquist criterion – Stability margins – Robustness and sensitivity functions – Relation between open loop frequency behavior and closed loop time domain behavior – Steady state error.

Regulation and P.I.D. controllers

Time domain features – Frequency domain features – Continuous time domain implementation: derivative action, anti wind-up mechanism...

Industrial regulation strategies

Cascaded control – Feed-forward actions – Control of delayed systems: Smith predictor – Conditioning of controllers

Numerical control

Sampler and zero-order hold devices – Continuous to discrete time transformations – Resulting algorithms and calculation time.

Learning objectives

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dis- seminar co
Mécanique des milieux continus	1	Semestre 1	11	4					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	dissemination/learning
■									

Mécanique des milieux continus

ECTS : 1

Semester: Semestre 1

Detail

Lecture: 11

Directed study: 4

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mathematics (vector and tensor calculus, , differential equations integral theorem, linear algebra..)

Classical mechanics (newton's law motion, static equilibrium, concepts of energy , work and Power..)

Physics (density, velocity field)

Elementary Thermodynamics

Programme/contents

At the end of this module, students will be able to understand and formulate the continuum hypothesis and its limits, model the mechanical behaviour of solid and fluid media, describe the fundamental quantities (stress, strain, deformation, velocity, energy, understand the notion of tensors (stress, strain, rotations, etc.), using conservation principles (mass, momentum, energy) and use the fundamental equations of motion of continuous media.

Learning objectives

The course of Continuous Media Mechanics aims to provide students with the theoretical and methodological basis necessary to model, analyse and understand the mechanical behaviour of materials considered as continuous media.

Overall organisation

From September to January at INSTN

Course assessment will be made based on a

final

Chemistry Speciality Courses 1 (Block 3)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di
Solution Chemistry 1: Speciation and process	3	Semestre 1	20	10					

Solution Chemistry 1: Speciation and process

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 20

Directed study: 10

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Properties of chemicals: Elements, Oxidation state,

Complexation of cations and ligands,

Chemical reaction: stoichiometry, ICE chart

Mass Action Law, Gibbs free Energy, Chemical activity,

Acido-basic reaction,

Dissolution-precipitation reaction, solubility,

Redox reaction, Nernst Law

Programme/contents

The following sessions cover a wide range of the fuel cycle, including mining industry, cooling circuit of PWR, waste management, environmental speciation, f-elements.

Session n°1: Chemical equilibria, Acid/base,

n°2: Multiphasic Equilibria, High T/P,

n°3: Equilibrium shifts and complexation,

n°4: Activity coefficients, High salinities,

n°5: Oxydoreduction & corrosion,

n°6: Applications & scientific articles,

n°7&8: Uranium chemistry,

n°9&10: Chemistry of Actinides.

Learning objectives

The objective is to describe the mechanisms driving speciation in solution chemistry and introduce to a numerical tool simulating chemical systems. Classical physico-chemical concepts are reviewed: thermodynamic equilibrium, reactivity, multi-phasic systems. Lectures go into more detail on these concepts and the underlying models & equations. Analytical reasoning allowing to put in an equation practical

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Radiolysis	2	Semestre 1	13	4	4				

Radiolysis

ECTS : 2

Semester: Semestre 1

Detail

Lecture: 13

Practical study : 4

Directed study: 4

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Bachelor level in Chemistry or Chemical Physics

Programme/contents

The program allows students to understand how water is broken down under ionizing radiation such as energetic photons and accelerated particles and which radicals are formed. The radiolytic yield of radicals as a function of time after energy deposition and as a function of the type of ionizing radiation are explained. In addition, the reactivity of some of these radicals as electron donors and acceptors is described. In practical work, the principles of chemical dosimetry are used to determine the dose in a ^{60}Co source.

- Ionizing radiation matter interaction: photon and neutral and charged particles. Energy deposition, clusters, traces, TEL (5h)
- Radiolysis of water, radical and molecular yields TEL effect (5h)
- Radiolysis of aqueous solutions, influence of concentration, temperature, pressure, pH, chemical dosimetry TEL. In particular Fricke dosimeter and super-Fricke dosimeter and the Cerium (2h)
- Practical course: dosimetry of gamma source (Fricke dosimeter) (5h)
- Radiolysis other solvents (polar and nonpolar, ionic liquid, ...) (2h)
- Radiolysis and processes of the nuclear industry: Purex process, radiolysis under the conditions of the reactors (2h)
- Gas Radiolysis (1h)
- solid Radiolysis : induced disorder, curing, concrete

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Chemistry of Nuclear Materials	4	Semestre 1	15	9	12				

Chemistry of Nuclear Materials

ECTS : 4

Semester: Semestre 1

Detail

Lecture: 15

Practical study : 12

Directed study: 9

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Bachelor level in solid state chemistry, fundamentals in physics: classical mechanics, electromagnetism.

Programme/contents

The course of Chemistry of Materials addresses inorganic materials from a structure versus property treatment, with a peculiar emphasis put on relevant materials for nuclear applications both during and after in-reactor operations. Nuclear materials encompass virtually all classes of materials – metals, ceramics, glasses – that are used as structural materials, fuels, transmutation matrices, as well as immobilization matrices. Nuclear materials exhibit the fascinating feature of their radiation tolerance far from any thermodynamically stable condition. The topic is tackled from the Chemist's viewpoint. Lectures are organised in four main chapters, which concentrate in structures and bonding in solids, on the interplay between crystal and electronic structure in determining their properties. Imperfection in solids plays a considerable role in nuclear materials. Finally, the exciting field of radiation-induced defects and processes by which solids tolerate a large amount of structural disorder whilst preserving their crystalline structure is discussed. This course also includes labworks at the MOSAIC accelerator facility at IJCLab, Orsay campus.

Content

1 – Solid state chemistry

Atomic bonding in solids: bands formed from overlapping of atomic orbitals; primary

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Solution Chemistry 2: Separation Chemistry	3	Semestre 2	12	12					

Solution Chemistry 2: Separation Chemistry

ECTS : 3

Semester: Semestre 2

Detail

Lecture: 12

Directed study: 12

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Aqueous solution chemistry reviewed in 1st semester:

Thermodynamic equilibria: Gibbs, energy, chemical reactions, equilibrium constant, ICE charts,

Reactivity: Acid/base, redox, dissolution/precipitation (solubility), complexation,

Quantification of the effects of secondary reactions on the primary reaction,

Speciation of ions, including actinides and f-elements.

Programme/contents

Sessions n°1-4 : Solvent Extraction (SE):

To remind the operational variables used to optimize the extraction system,

To underline the drawbacks of single-stage operation & detail counter-current cascade,

To introduce the chemical phenomenon influencing extraction system,

To justify the usual classification of the extraction systems & write a global reaction for each,

To quantify the distribution ratio for each class, highlighting the factors effects & optimization

Sessions n° 5-8: Ion Exchange (IE):

To extend Gibbs thermodynamic to surface-solution systems & describe equilibria

To introduce the theoretical background & characteristics of ion exchange resins (IER)

To introduce IER implementation, from laboratory to industrial scale

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Chimie Analytique des Éléments Radioactifs	4	Semestre 2	6	3	30				

Chimie Analytique des Éléments Radioactifs

ECTS : 4

Semester: Semestre 2

Detail

Lecture: 6

Practical study : 30

Directed study: 3

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

This course unit consists of 9 hours of lectures and 30 hours of practical work. It is therefore a very experimental course. To take this course unit, it is preferable that students have previously had practical training (preparation of samples at given concentrations, use of laboratory equipment, precision balances, micropipettes, etc.). They must have a basic understanding of solution chemistry and know how to calculate pH values, concentrations, dilution factors, etc.

Programme/contents

Cet UE comprend 3 cours de 3h et 5 séances de TP de 6h. Les cours sont les suivants : Radiation safety (C1), The analytical chemistry: application to the radioelements (C2) et Nuclear Energy: The nuclear fuel cycle from the chemical point of view (C3). Les TPs sont les suivants : Introduction to radioactivity and radiation protection (TP1), PERALS spectrometry for U and Th analysis (TP2), Uranium target preparation (TP3), UV-visible spectroscopy for U and Th analysis (TP4), Thorium fluoride synthesis (TP5).

Learning objectives

To introduce the different analytical methods which take place in the nuclear industry and research
To classify these methods considering their applications, detection limit, accuracy, repeatability
For each method : to describe the physic and chemistry involved in the measurements
To introduce the industrial processes and environmental applications of these

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Spectroscopie Atomique et Moléculaire	3	Semestre 2	15	15					

Spectroscopie Atomique et Moléculaire

ECTS : 3

Semester: Semestre 2

Detail

Lecture: 15

Directed study: 15

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

The prerequisites for this course are Atomistics (electronic configuration, orbital representation); Valence Electron Pair Reputation (VSEPR) theory; Group theory; Quantum mechanics (Molecular orbital model).

Programme/contents

Group theory contribution to crystal field/ligand field model (spectroscopic terms/states, crystal field levels). Perturbation methodology. Electronic transitions/selection rules. Spectroscopy of d and f elements. Orgel and Tanabe/Sugano diagrams. Nephelauxetic and Jahn Teller effects. Single configuration-coordinate diagram. Electron/vibration coupling. Spectroscopy and speciation of 5f elements (introduction).

Learning objectives

This course aims to provide the various tools needed to describe transition metal complexes. These transition metal complexes will be described from the perspective of their electronic structure. Particular emphasis will be placed on the effects of ligands and the orbital chemistry of transition metal complexes. The goal will be to understand the spectra of these complexes and to assign the observed electronic transitions.

Overall organisation

The EU is divided into lectures and tutorials. Written exam (70%) + consideration of participation in tutorials (30%)

Bibliography

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	di le c
Chimie dans le cycle électro-nucléaire	2	Semestre 1	24						

Chimie dans le cycle électro-nucléaire

ECTS : 2

Semester: Semestre 1

Detail

Lecture: 24

Language(s) of instruction

Anglais

Remote teaching

non

Programme/contents

Modul content :

1) Lectures :

\- Intro Nuclear Fuel cycle (The essential role of chemistry in controlling waste),

\- Nuclear Fuel reprocessing

\- non conventional solvents + intro molt salts for nuclear fuel reprocessing (Chemistry, for fourth-generation reactors)

\- The chemistry of water in its various stages of use

\- Basics Corrosion

\- Radionuclides in Environment (intro Nuclear toxicology) (Lecture)

\- Numerical Simulation Radiolysis (Lecture)

\- Numerical Simulation DFT (structure of actinide complex), Numerical simulation in Nuclear Chemistry

2. Group work on one of the topics

Learning objectives

This module aims to introduce the chemical engineering aspects related to the Nuclear industry. Through reading, lectures, problem solving and class debates.

Overall organisation

Lectures and project

Type of assessment

Evaluation Continue non Intégrale

Internship (Block 4)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	distance learning courses
Stage	10	Semestre 2							
■									

Stage

ECTS : 10

Semester: Semestre 2

Detail

Tutored project 300

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

none

Type of assessment

Evaluation Continue non Intégrale

Teaching Location(s)

BURES SUR YVETTE

ORSAY

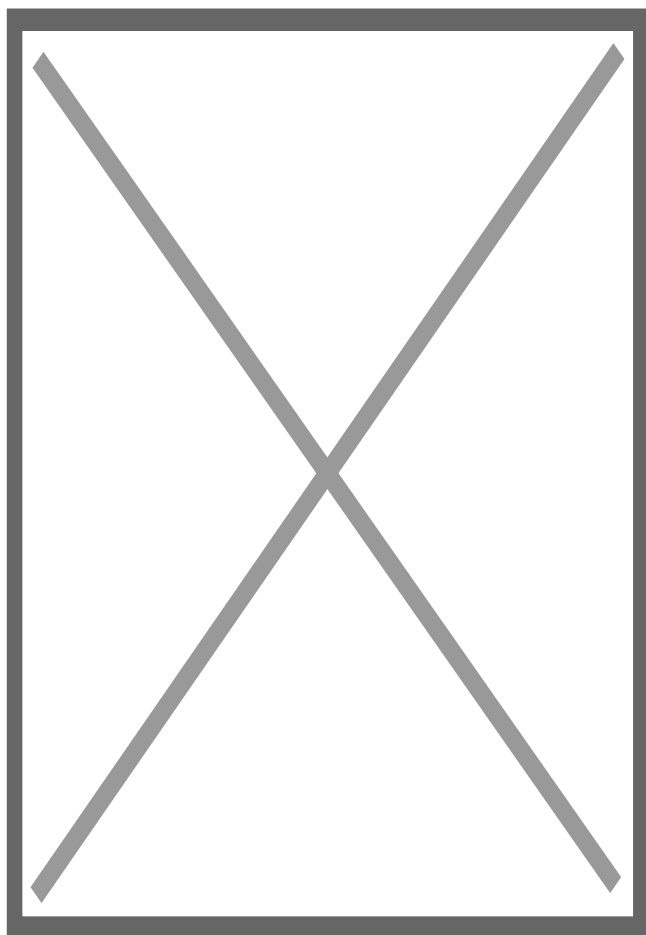
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Academic Partner(s)

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Training campus

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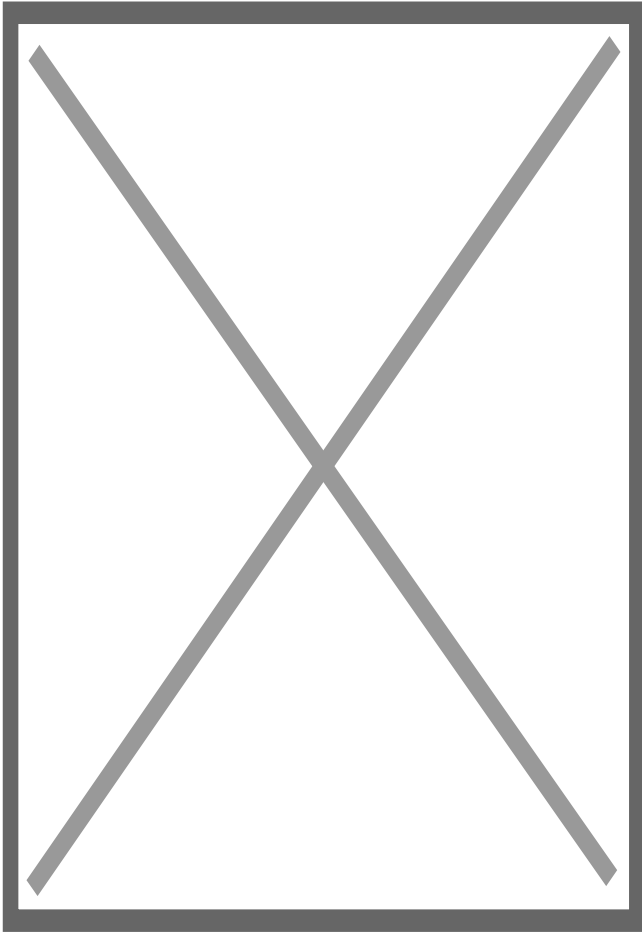
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Sports facilities

Student residence

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