

PHYS-490

Elective project nuclear engineering

Profs divers *

Cursus	Sem.	Type
Nuclear engineering	MA1, MA2, MA3, MA4	Opt.

Language of teaching	English
Credits	8
Session	Winter, Summer
Semester	Fall
Exam	During the semester
Workload	240h
Weeks	14
Hours	8 weekly
Project	8 weekly
Number of positions	

Summary

The elective project is designed to train the students in the solution of specific engineering problems related to nuclear technology. This makes use of the technical and social skills acquired during the master's program.

Content

The elective project has the purpose to train the students in the solution of specific engineering problems related to nuclear technology. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

It can be done during the first 3 semesters at EPFL, ETHZ or PSI.

Learning Outcomes

By the end of the course, the student must be able to:

- Analyze a technical problem

Transversal skills

- Write a scientific or technical report.

Assessment methods

Written project report and oral presentation

ME-409

Energy conversion and renewable energy

Maréchal François, Nguyen Tuong-Van

Cursus	Sem.	Type
Civil Engineering	MA1, MA3	Opt.
Electrical and Electronical Engineering	MA1, MA3	Opt.
Energy Science and Technology	MA1, MA3	Obl.
Energy minor	H	Opt.
Environmental Sciences and Engineering	MA1, MA3	Opt.
Managmt, dur et tech	MA3	Opt.
Minor in Engineering for sustainability	H	Opt.
Nuclear engineering	MA1	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	1 weekly
Project	1 weekly
Number of positions	

Summary

Introductory course to energy conversion technologies (thermal power cycles and renewable-based technologies) and their integration into energy systems

Learning Outcomes

By the end of the course, the student must be able to:

- Explain principles and limitations of the main energy conversion technologies
- Characterize fossil and renewable energy resources and their corresponding conversion technologies
- Explain the challenges related to energy: resources, energy services, economic and environmental impacts

Teaching methods

- Lectures : Flipped classroom based on readings and videos
- Exercices : 1 hour / week with support of TAs
- Project : 1 hour / week with support of TAs

Assessment methods

- Written exam at the end of the semester (60%)
- Intermediate and final project report (40%)

Supervision

Office hours No

Resources**Notes/Handbook**

The course material consists of the following:

- Course compendium (lectures, exercises, solutions, project and former exams with corrections), available as a .pdf and on a dedicated website
- Slides and Pre-recorded videos, available on Moodle and on a SWITCHtube channel

Note that the course compendium and the slides/videos present the same content, the main difference lies

in the addition of examples and further details in the coursebook in case of interest or need of explanations. This is done so that the interested student can choose the most suitable material and follow the course in case of conflict with other courses.

Moodle Link

- <https://go.epfl.ch/ME-409>

ME-453

Hydraulic turbomachines

Vagnoni Elena

Cursus	Sem.	Type
Energy Science and Technology	MA1, MA3	Obl.
Energy minor	H	Opt.
Mechanical engineering minor	H	Opt.
Mechanical engineering	MA1, MA3	Opt.
Mechanics		Opt.
Nuclear engineering	MA1	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	4 weekly
Courses	3 weekly
Exercises	1 weekly
Number of positions	

Summary

Master lectures on Hydraulic Turbomachines: operating principles, design and innovation of impulse and reaction turbines, industrial pumps and pump-turbines.

Content

- Fundamental equations for turbomachines operation: mass conservation and specific energy equation for turbulent flows, mechanical power balance in a hydraulic machines, moment of momentum balance applied to the runner/impeller, generalized Euler equation.
- Hydraulic characteristic of a reaction turbine, a Pelton turbine and a pump, losses and efficiencies of a turbomachine, real hydraulic characteristics.
- Similitude laws, non dimensional coefficients, reduced scale model testing, scale effects.
- Cavitation, hydraulic machine setting, operating range, adaptation to the piping system, operating stability, start stop transient operation, runaway.
- Reaction turbine design: general procedure, general project layout, design of a Francis runner, design of the spiral casing and the distributor, draft tube role, CFD validation of the design, reduced scale model experimental validation.
- Pelton turbine design: general procedure, project layout, injector design, bucket design, mechanical problems.
- Centrifugal pump design: general architecture, energetic loss model in the diffuser and/or the volute, volute design, operating stability.
- Innovations in hydraulic machinery.
- Sustainability in turbomachines manufacturing and operation.

Learning Prerequisites**Recommended courses**

Fluids Mechanics
Introduction to turbomachines

Learning Outcomes

By the end of the course, the student must be able to:

- Formulate the operating point of a hydraulic turbomachine
- Specify a type of hydraulic turbine

- Sketch the layout of a hydraulic turbomachine
- Select appropriately the dimensions of a hydraulic turbomachine
- Design the layout of a hydraulic turbomachine
- Specify types and components of hydraulic turbine
- Describe The flow phenomena and instabilities in turbomachines

Transversal skills

- Use a work methodology appropriate to the task.
- Communicate effectively with professionals from other disciplines.
- Assess one's own level of skill acquisition, and plan their on-going learning goals.

Teaching methods

ex cathedra lectures with working case studies

Expected student activities

attendance at lectures completing exercises and reading written material

Assessment methods

written exam

Resources

Bibliography

P. HENRY: Turbomachines hydrauliques - Choix illustré de réalisation marquantes, PPUR, Lausanne, 1992.

Franc, Avellan et al., Cavitation, EDP Grenoble, 1994

Handout and Scientific Literature from LMH, Industry, International Association

Ressources en bibliothèque

- [Find the references at the Library](#)

Notes/Handbook

slides handout Handbook

Moodle Link

- <https://go.epfl.ch/ME-453>

Prerequisite for

Cavitation, Hydroacoustic, Master Project

MICRO-511

Image processing I

Preti Maria Giulia, Unser Michaël, Van De Ville Dimitri

Cursus	Sem.	Type
Computational and Quantitative Biology		Opt.
Computational science and Engineering	MA1, MA3	Opt.
Computational science and engineering minor	H	Opt.
Computer science	MA1, MA3	Opt.
Cybersecurity	MA1, MA3	Opt.
Data Science	MA1, MA3	Opt.
Digital Humanities	MA1, MA3	Opt.
Environmental Sciences and Engineering	MA1, MA3	Opt.
Life Sciences Engineering	MA1, MA3	Opt.
Microtechnics	MA1, MA3	Opt.
Minor in Imaging	H	Opt.
Minor in life sciences engineering	H	Opt.
Neuro-X minor	H	Opt.
Neuro-X	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Photonics minor	H	Opt.
Robotics, Control and Intelligent Systems		Opt.
Robotics	MA1, MA3	Opt.
SC master EPFL	MA1, MA3	Opt.

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	Written
Workload	90h
Weeks	14
Hours	3 weekly
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

Introduction to the basic techniques of image processing. Introduction to the development of image-processing software and to prototyping using Jupyter notebooks. Application to real-world examples in industrial vision and biomedical imaging.

Content

- **Introduction.** Image processing versus image analysis. Applications. System components.
- **Characterization of continuous images.** Image classes. 2D Fourier transform. Shift-invariant systems.
- **Image acquisition.** Sampling theory. Acquisition systems. Histogram and simple statistics. Max-Lloyd quantization (K-means).
- **Characterization of discrete images and linear filtering.** z-transform. Convolution. Separability. FIR and IIR filters.
- **Morphological operators.** Binary morphology (opening, closing, etc.). Gray-level morphology.
- **Image-processing tasks.** Preprocessing. Matching and detection. Feature extraction. Segmentation.
- **Convolutional neural networks.** Basic components. Operator-based formalism. CNN in practice: denoising and segmentation.

Learning Prerequisites**Required courses**

Signals and Systems I & II (or equivalent)

Important concepts to start the course

1-D signal processing: convolution, Fourier transform, z-transform

Learning Outcomes

By the end of the course, the student must be able to:

- Exploit the multidimensional Fourier transform
- Select appropriately Hilbert spaces and inner-products
- Optimize 2-D sampling to avoid aliasing
- Formalize convolution and optical systems
- Design digital filters in 2-D
- Analyze multidimensional linear shift-invariant systems
- Apply image-analysis techniques
- Construct image-processing software
- Elaborate morphological filters
- Exploit the multidimensional Fourier transform
- Select appropriately Hilbert spaces and inner-products
- Optimize 2-D sampling to avoid aliasing
- Formalize convolution and optical systems
- Design digital filters in 2-D
- Analyze multidimensional linear shift-invariant systems
- Apply image-analysis techniques
- Construct image-processing software

Transversal skills

- Use a work methodology appropriate to the task.
- Manage priorities.
- Use both general and domain specific IT resources and tools

Assessment methods

- 70% final exam
- 30% IP labs during semester

Resources**Moodle Link**

- <https://go.epfl.ch/MICRO-511>

PHYS-455

Introduction to medical radiation physics

Bochud François

Cursus	Sem.	Type
Nuclear engineering	MA1	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	3 weekly
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

This course covers the physical principles underlying medical diagnostic imaging (radiography, fluoroscopy, CT, SPECT, PET, MRI, US), radiation therapy and radiopharmacy. The focus is not only on risk and dose to the patient and staff, but also on an objective description of the image quality.

Content**Ionizing radiations in medical physics**

- Order the regions of the electromagnetic spectrum by increasing photon energy and explain the main types of interactions each region can have with water
- Explain the concepts of absorbed dose and effective dose, discuss their usefulness in a medical context, and estimate typical dose levels encountered in diagnostic imaging and therapeutic procedures
- Describe the main stochastic effects and tissue reactions associated with ionizing radiation exposure, and calculate an approximate indicator of possible risk based on the effective dose
- Describe the operating principles of an ionization chamber and a semiconductor detector, and cite examples of their applications in medical physics

Production of x-rays and image quality

- Describe the image formation chain in X-ray imaging, from X-ray production (tube physics, beam shaping) to detection and digital image display
- Interpret the key image quality parameters (contrast, resolution, noise) and relate them to acquisition parameters.
- Discuss the trade-offs between image quality and patient dose in the task-based approach

2D projection x-ray imaging

- Describe the physical principles and technical components of radiographic, mammographic and fluoroscopic systems
- Define and interpret common dose quantities such as dose area product (DAP), entrance surface air kerma (ESAK) and average glandular dose (AGD)
- Identify the basic principles of time, distance and shielding in radiation protection scenarios and explain the connection between radiation protection for patients and for personal.

3D computed tomographic imaging

- Describe the physical principles and technical components of computed tomography systems.
- Interpret the influence of the acquisition and reconstruction parameters on the image quality.
- Define dose quantities such as CTDI and DLP and explain their significance and impact on dose management.

Advanced techniques and research in x-ray imaging

- Briefly describe the most promising advanced techniques in x-ray imaging
 - Details to be provided during the lecture

Radioisotopes and biokinetics in nuclear medicine

- Distinguish between the different types of radioactive decay and their potential use in nuclear medicine
- Illustrate the mechanisms of action of a radiopharmaceutical product and their methods of production
- Explain the concept of biokinetic models and internal dosimetry formalism and use them in applied settings.

Gamma-camera/SPECT and dosimetric devices

- Explain the main components of a gamma-camera/SPECT device and its functioning
- Explain the working principle of different dosimetric devices (activimeter, dose rate meter, spectrometer, contamination monitor)
- Identify the different fields of clinical and radiological protection applications

PET and radionuclide therapy

- Explain the main components of a PET device and identify the different fields of clinical applications
- Explain the workflow required to perform dosimetry in nuclear medicine
- Apply internal dosimetry concepts to real clinical scenarios

Advanced techniques and research in nuclear medicine

- Briefly describe the most promising advanced techniques in nuclear medicine
 - Details to be provided during the lecture

Treatment machines and patient flux in external radiation therapy

- Explain the objectives of radiation therapy
- Describe the general workflow of a patient in radiation therapy
- Describe the functioning of a medical linear accelerator

Treatment planning system and dosimetry

- Present the process and aims of treatment planning
- List the key components of a treatment planning system
- Cite and describe the main dose calculation algorithms

Imaging and motion management in external radiation therapy

- Explain the different uses of imaging in radiation therapy
- Compare different imaging modalities and explain their specific interest for radiation therapy
- Describe the principle of tracking, gating and motion management

Advanced techniques and research in external radiation therapy

- Briefly describe the most promising advanced techniques in x-ray imaging
 - Details to be provided during the lecture

Non-ionizing radiations in medical physics and the job of medical physicist

- Explain the function of the main components of an MRI system and describe the basic principles involved in acquiring an MRI image
- Describe the path of an ultrasonic wave in a medical imaging system, from the transmitter to the detector, and explain

how this information is used to generate an image

- Identify and describe several medical applications of optical radiation in both diagnostics and therapy
- Explain the role of a medical physicist in a hospital, describe their typical responsibilities, and identify the qualifications required for employment in a clinical setting

Keywords

medical imaging, radiation therapy, radiation in medicine

Learning Prerequisites

Recommended courses

This course has many synergies with the Radiation biology, protection and applications course (PHYS-450) where the basics of radiation physics and some aspects of radiation protection are very useful to follow the present course.

Learning Outcomes

By the end of the course, the student must be able to:

- Describe the main parts of an x-ray device from a physical point of view
- Describe the main differences between the radiography units and the fluoroscopy units
- Explain the principle of CT image acquisition

Teaching methods

Ex-cathedra with integrated individual exercises

The course includes not only lectures and classroom exercises at EPFL, but also illustrative visits to Lausanne University Hospital (CHUV).

Assessment methods

Written, Multiple Choice Question exam

Resources

Bibliography

- The Essential Physics of Medical Imaging, Third Edition, Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt Jr., John M. Boone, Lippicott 2012
- Physics in nuclear medicine, S.R. Cherry, J.A. Sorenson, M.E. Phelps, Saunders Elsevier 2012 (forth edition)
- Radiation Oncology Physics: a handbook for teachers and students, E. Podgorsak, IAEA, 2005, https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1196_web.pdf

Ressources en bibliothèque

- [Find the references at the Library](#)

Références suggérées par la bibliothèque

- [Radiation Oncology Physics: a handbook for teachers and students / Podgorsak](#)

Moodle Link

- <https://go.epfl.ch/PHYS-455>

PHYS-448

Introduction to particle accelerators

Pieloni Tatiana

Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Physicien	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The course presents basic physics ideas underlying the workings of modern accelerators. We will examine key features and limitations of these machines as used in accelerator driven sciences like high energy physics, materials and life sciences.

Content

Overview, history and fundamentals
 Transverse particle dynamics (linear and nonlinear)
 Longitudinal particle dynamics
 Synchrotron radiation and related dynamics
 Linear and circular accelerators
 Acceleration and RF-technology
 Beam diagnostics
 Accelerator magnets
 Medical application of accelerators
 Future projects

Learning Outcomes

By the end of the course, the student must be able to:

- Design basic linear and non-linear charged particles optics
- Elaborate basic ideas of physics of accelerators
- Use a computer code for optics design
- Optimize accelerator design for a given application
- Estimate main beam parameters of a given accelerator

Transversal skills

- Communicate effectively with professionals from other disciplines.
- Use both general and domain specific IT resources and tools

Teaching methods

lecture based teaching using slides and blackboard,
 occasionally inquiry based learning,
 using Jupiter notebooks to simulate accelerator dynamics,

Application of knowledge through concrete exercises and provision of individual feedback in tutorials

Expected student activities

working on weekly problems, submitting the solutions and participation in the computer tutorials

Assessment methods

written exam

Resources

Moodle Link

- <https://go.epfl.ch/PHYS-448>

ME-454

Modelling and optimization of energy systems

Maréchal François

Cursus	Sem.	Type
Civil Engineering	MA1, MA3	Opt.
Energy Science and Technology	MA1, MA3	Opt.
Energy minor	H	Opt.
Ing.-chim.	MA1, MA3	Opt.
Mechanical engineering minor	H	Opt.
Mechanical engineering	MA1, MA3	Opt.
Minor in Integrated Design, Architecture and Sustainability	H	Opt.
Nuclear engineering	MA1	Opt.
Systems Engineering minor	H	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Oral
Workload	120h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The goal of the lecture is to present and apply techniques for the modelling and the thermo-economic optimisation of industrial process and energy systems. The lecture covers the problem statement, the solving methods for the simulation and the single and multi-objective optimisation problems.

Content

- Concepts of Computer Aided Process System Engineering methods to tackle the problems of energy conversion systems modelling and optimisation. The students will acquire a methodology to state the problem, identify the solving procedure, solve the problem and analyse the results;
- Definition of the basic system modelling concepts : state variables, energy and mass balances, simulation parameters and equations, degree of freedom analysis, different types of specifications, inequalities, objective functions;
- Energy systems equipments models;
- System models : flowsheets, degrees of freedom, sequential or simultaneous solving approach, numerical methods and their implications;
- Calculating systems performances : operating cost, efficiency, environmental impact, investments, thermo-economic and environomic performances;
- Stating and solving optimization problems : decision variables, objective functions and constraints, solving strategies, numerical methods and their implications;
- Realization of a technology system integration project

Keywords

Process system engineering, Process simulation, optimization

Learning Prerequisites**Important concepts to start the course**

- Understand energy conversion
- Master the concepts of mass, energy, and momentum balance, E1 (Thermodynamique et énergétique I)
- Compute the thermodynamic properties of a fluid, E2 (Thermodynamique et énergétique I)
- Master the concepts of heat and mass transfer, E3 (Heat and mass transfer)
- Understand the main thermodynamic cycles, E5 (Thermodynamique et énergétique I)
- Notion of optimization (Introduction à l'optimisation différentiable)

Teaching methods

The course is given as a group project realisation together with the ME-451 course (advanced energetics).

Theory is given as a set of video, Q&A sessions concerning the theory will be organised during the semester.

Project description: "Considering the sustainable development goals, the goal of the project is to study the decarbonisation strategy of an industrial production process to be integrated with a new data center in a urban district. The decarbonisation strategy includes the definition of the system configurations, i.e. the investment to be made and the associated material and energy flows generated and the calculation of the associated key sustainability performance metrics."

It will be realised by a group of 3 students with the following milestones:

- **Analyse** : problem statement, data collection and generation of possible options
- **Generate**: use of computer aided models to generate system configurations
- **Interpret**: compare the generated system configurations and study the integration of a specific technology in the system
- **Report**: report the decarbonisation strategy for the system

The work will be supported by open source computer tools for modeling, optimisation and reporting.

Expected student activities

Motivated students will realise a project as a team work. Each student will have to report the integration of a specific technology and compare it to the alternatives.

They will have to organise their work in the 4 steps:

- Data collection, brainstorming, bibliography search and model development for options identified
- Distribute and coordinate the tasks,
- Realise calculations : understanding of the theory to apply and application with practical tools
- Calculate the sustainability performance indicators
- Present the milestones
- Write the final report and the specific technology integration assessment chapter

Each student will review the report of another project.

Assessment methods

40%: Project Report & supporting information: Team report

40%: Technology integration assessment chapter: individual contribution

20%: Review a technology integration assessment report of another student

Supervision

Office hours	Yes
Assistant.e.s	Yes
Forum	Yes
Others	

Students are free to organise themselves for realisation of their project
 3 intermediate progress meetings (remote)
 1. Problem statement
 2. System configurations
 3. Technology integration assessment

Resources

Virtual desktop infrastructure (VDI)

Yes

Moodle Link

- <https://go.epfl.ch/ME-454>

PHYS-640

Neutron and X-ray Scattering of Quantum Materials

Lacmann Tom, Rønnow Henrik M., Schmitt Thorsten

Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Physicien	MA1, MA3	Opt.
Physics		Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Oral
Workload	120h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Remark

Next time: Fall

Summary

Neutron and X-ray scattering are some of the most powerful and versatile experimental methods to study the structure and dynamics of materials on the atomic scale. This course covers basic theory, instrumentation and scientific applications of these experimental methods.

Content

The application of neutron and X-ray scattering spans from crystalline matter to bio-materials and engineering, including fields like magnetism and superconductivity. Similar to the vast possibilities with X-rays at synchrotron facilities like the Swiss Light Source at the Paul Scherrer Institute (PSI) in Switzerland, the European Synchrotron Radiation Facility in Grenoble, neutron scattering is a large-scale-facility technique with neutron sources among others at PSI in Switzerland, the Institute Laue-Langevin in Grenoble and a new joint European Spallation Source under construction in Sweden. The course provides an introduction to the dynamic experimental techniques of neutron and X-ray scattering and covers the following aspects:

- 1) Theory of the neutron scattering cross section
- 2) Neutron sources and neutron instrumentation
- 3) Neutron imaging, neutron reflectivity and neutron small angle scattering
- 4) Neutron diffraction, crystal structures
- 5) Inelastic neutron scattering, phonons
- 6) Magnetic neutron scattering, magnetic structures
- 7) Inelastic magnetic neutron scattering, magnetic dynamics
- 8) Theory of the interaction between X-rays and matter
- 9) X-ray sources and X-ray instrumentation
- 10) X-ray absorption spectroscopy
- 11) X-ray emission spectroscopy and Resonant Inelastic X-ray Scattering (RIXS)
- 12) Resonant Elastic X-ray Scattering (REXS)
- 13) Inelastic X-ray Scattering
- 14) Time resolved pump-probe X-ray spectroscopy

The course contains lectures and exercise sessions. Exercise sessions will contain derivation of relevant formulas, Monte-Carlo simulation of neutron scattering experiments, and discussions of representative scientific articles using X-ray and neutron scattering techniques.

The course includes performing a real neutron or X-ray experiment and a tour of the large-scale experimental research facilities at the PSI.

Keywords

Neutron Scattering, X-ray scattering, X-ray spectroscopy, diffraction, crystal structures, lattice vibrations, phonons, magnetism, spin waves, magnons, neutron imaging

Learning Prerequisites

Required courses

Solid State Physics 1 and 2, basic quantum mechanics and basic atomic physics

Recommended courses

Magnetism in Materials

Learning Outcomes

By the end of the course, the student must be able to:

- Plan, predict and interpret neutron scattering experiments
- Read and evaluate articles containing neutron scattering results
- predict and interpret neutron and X-ray scattering experiments.
- Read and evaluate articles containing neutron and X-ray scattering results
- Plan, predict and interpret neutron and X-ray scattering experiments.
- Read and evaluate articles containing neutron and X-ray scattering results.

Assessment methods

Oral

Resources

Bibliography

"Elements of Modern X-ray Physics"## by Des McMorrow and Jens Als-Nielsen (2nd edition)

"Neutron scattering - Theory, Instrumentation and Simulation"##, lecture notes by Kim Lefmann

Relevant scientific articles

Ressources en bibliothèque

- [Find the references at the Library](#)

Références suggérées par la bibliothèque

- [Neutron scattering : Theory, Instrumentation and Simulation / Lefmann](#)

Websites

- <https://lqm.epfl.ch>

Moodle Link

- <https://go.epfl.ch/PHYS-640>

PHYS-445

Nuclear fusion and plasma physics

Fasoli Ambrogio

Cursus	Sem.	Type
Auditeurs en ligne	H	Opt.
Energy Science and Technology	MA1, MA3	Opt.
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Physicien	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Oral
Workload	120h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The goal of the course is to provide the physics and technology basis for controlled fusion research, from the main elements of plasma physics to the reactor concepts.

Content

- 1) Basics of thermonuclear fusion
- 2) The plasma state and its collective effects
- 3) Charged particle motion and collisional effects
- 4) Fluid description of a plasma
- 5) Plasma equilibrium and stability
- 6) Magnetic confinement: Tokamak and Stellarator
- 7) Waves in plasma
- 8) Wave-particle interactions
- 9) Heating and non inductive current drive by radio frequency waves
- 10) Heating and non inductive current drive by neutral particle beams
- 11) Material science and technology: Low and high Temperature superconductor - Properties of material under irradiation
- 12) Some nuclear aspects of a fusion reactor: Tritium production
- 13) Licensing a fusion reactor: safety, nuclear waste
- 14) Inertial confinement

Learning Prerequisites**Recommended courses**

Basicknowledge of electricity and magnetism, and of simple concepts of fluids

Learning Outcomes

By the end of the course, the student must be able to:

- Identify the main physics challenges on the way to fusion
- Design the main elements of a fusion reactor
- Identify the main technological challenges of fusion

Teaching methods

Ex cathedra and in-class exercises

Assessment methods

oral examen (100%)

Resources

Websites

- <https://spcnet.epfl.ch/nucfus/>

Moodle Link

- <https://go.epfl.ch/PHYS-445>

MATH-468

Numerics for fluids, structures & electromagnetics

Cursus	Sem.	Type
Computational science and Engineering	MA1, MA3	Opt.
Computational science and engineering minor	H	Opt.
Ing.-math	MA1, MA3	Opt.
Mathématicien	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.

Language of teaching	English
Credits	5
Session	Winter
Semester	Fall
Exam	Oral
Workload	150h
Weeks	14
Hours	4 weekly
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Remark

Pas donné en 2026-27 *** Cours donné en alternance tous les deux ans.

Summary

Cours donné en alternance tous les deux ans

Content**Keywords**

Partial differential equations, saddle point problems, finite element method, Galerkin approximation, stability and convergence analysis.

Learning Prerequisites**Required courses**

Analysis I II III IV, Numerical Analysis, Numerical Approximations of PDEs

Recommended courses

Sobolev spaces and elliptic equations,

Important concepts to start the course

- Basic knowledge of functional analysis: Banach and Hilbert spaces, L^p spaces.
- Some knowledge on theory of PDEs: classical and weak solutions, existence and uniqueness.
- Basic concepts in numerical analysis: stability, convergence, condition number, solution of linear systems, quadrature formulae, finite difference formulae, polynomial interpolation.
- Basic information on finite element theory for elliptic problems

Learning Outcomes

By the end of the course, the student must be able to:

- Identify features of a PDE relevant for the selection and performance of a numerical algorithm.
- Assess / Evaluate numerical methods in light of the theoretical results.
- Implement numerical methods for saddle point problems

- Choose an appropriate method to solve a given differential problem
- Prove convergence of a discretisation scheme

Transversal skills

- Write a scientific or technical report.
- Make an oral presentation.

Teaching methods

Ex cathedra lectures, exercises in the classroom and computer lab sessions.

Expected student activities

- Attendance of lectures.
- Completing exercises.
- Solving problems with an academic software as Free FEM ++

Assessment methods

Oral

Supervision

Office hours	Yes
Assistant.e.s	Yes
Forum	Yes

Resources

Bibliography

- S.C. Brenner, L.R. Scott. *The Mathematical Theory of Finite Element Methods*. Springer 2007.
- A. Ern, J-L. Guermond, *Theory and Practice of Finite Elements*. Springer 2004.
- D. Boffi, F. Brezzi, M. Fortin *Mixed Finite elements and Applications*, Springer Verlag. 2013.

Ressources en bibliothèque

- [The Mathematical Theory of Finite Element Methods / S.C. Brenner & L.R. Scott](#)
- [Theory and Practice of Finite Elements / A. Ern & J-L. Guermond](#)
- [Mixed Finite elements and Applications / D. Boffi, F. Brezzi & M. Fortin](#)

Notes/Handbook

Notes for each lectures will be provided every week.

Moodle Link

- <https://go.epfl.ch/MATH-468>

Videos

- [http://Recording of the lectures will be provided after each lecture.](#)

PHYS-443

Physics of nuclear reactors

Hursin Mathieu, Manera Annalisa, Pautz Andreas

Cursus	Sem.	Type
Nuclear engineering	MA1	Obl.

Language of teaching	English
Credits	6
Session	Winter
Semester	Fall
Exam	Oral
Workload	180h
Weeks	14
Hours	6 weekly
Courses	4 weekly
Exercises	2 weekly
Number of positions	

Summary

In this course, one acquires an understanding of the basic neutronics interactions occurring in a nuclear fission reactor as well as the conditions for establishing and controlling a nuclear chain reaction.

Content

- **Brief review of nuclear physics**

- Historical: Constitution of the nucleus and discovery of the neutron
- Nuclear reactions and radioactivity
- Cross sections
- Differences between fusion and fission.

- **Nuclear fission**

- Characteristics - Nuclear fuel - Introductory elements of neutronics.
- Fissile and fertile materials.

- **Element of reactor design**

- flux and heat source distribution; properties of different coolants and technological consequences

- **LWR reactors technology**

- overview of the functional scheme of PWR and BWRs; fuel elements; compensation of excess reactivity in PWRs and BWRs (boron, etc.)

- **Neutron diffusion and slowing down**

- Monoenergetic neutrons - Angular and scalar flux
- Diffusion theory as simplified case of transport theory - Neutron slowing down through elastic scattering.

- **Multiplying media (reactors)**

- Multiplication factors - Criticality condition in simple cases.
- Thermal reactors - Neutron spectra - Multizone reactors - Multigroup theory and general criticality condition - Heterogeneous reactors.

- **Reactor kinetics**

- Point reactor model: prompt and delayed transients - Practical applications.

- **Reactivity variations and control**

- Short, medium and long term reactivity changes. Different means of control.

- **Advanced reactor designs**

- Breeding and transmutation; introduction into Gen-IV reactors

Learning Outcomes

By the end of the course, the student must be able to:

- Elaborate on neutron diffusion equation
- Formulate approximations to solving the diffusion equation for simple systems
- Classify nuclear reaction cross sections
- Develop for a nuclear reactor

Transversal skills

- Access and evaluate appropriate sources of information.
- Collect data.
- Use both general and domain specific IT resources and tools
- Write a scientific or technical report.

Teaching methods

Lectures, numerical exercises

Assessment methods

oral exam - 25min closed book (50%)

project - coding exercise (50%)

Resources

Moodle Link

- <https://go.epfl.ch/PHYS-443>

PHYS-423

Plasma I

Theiler Christian Gabriel

Cursus	Sem.	Type
Energy minor	H	Opt.
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Physicien	MA1, MA3	Opt.

Language of teaching	English
Credits	6
Session	Winter
Semester	Fall
Exam	Oral
Workload	180h
Weeks	14
Hours	5 weekly
Courses	2 weekly
Exercises	3 weekly
Number of positions	

Summary

Following an introduction of the main plasma properties, the fundamental concepts of the fluid and kinetic theory of plasmas are introduced. Applications concerning laboratory, space, and astrophysical plasmas are discussed throughout the course.

Content**I Collisional and relaxation phenomena**

- Inelastic collisions: ionization and recombination, degree of ionization
- Elastic collisions: Coulomb collisions
- Isotropisation and thermalisation
- Plasma resistivity and the runaway regime

II Transport in plasmas

- Random walk and diffusion
- Ambipolar and cross-field diffusion
- Energy and particle confinement

III Waves in cold magnetized plasma

- Dielectric tensor
- Resonances and cut-offs
- Parallel and perpendicular propagation

IV Wave-particle interaction and kinetic description of waves in hot un-magnetized plasmas

- The Vlasov-Maxwell model
- Resonant wave-particle interaction and Landau damping
- Stability criteria and streaming instabilities
- Langmuir and ion-acoustic waves and instabilities

V Waves in hot magnetized plasmas**VI Examples of nonlinear effects****Learning Prerequisites****Recommended courses**

PHYS-324: Classical Electrodynamics, PHYS-325: Introduction to Plasma Physics

Learning Outcomes

By the end of the course, the student must be able to:

- Manipulate the fundamental elements of the plasma fluid and kinetic theory

Teaching methods

Ex cathedra and exercises in class

Assessment methods

oral exam

Resources

Moodle Link

- <https://go.epfl.ch/PHYS-423>

PHYS-451

Radiation and reactor experiments

Hursin Mathieu, Lamirand Vincent, Pakari Oskari Ville

Cursus	Sem.	Type
Nuclear engineering	MA1	Obl.

Language of teaching	English
Credits	6
Withdrawal Session	Unauthorized Winter
Semester	Fall
Exam	During the semester
Workload	180h
Weeks	14
Hours	4 weekly
TP	4 weekly
Number of positions	30

It is not allowed to withdraw from this subject after the registration deadline.

Summary

The reactor experiments course aims to introduce the students to radiation detection techniques and nuclear reactor experiments. The core of the course is the unique opportunity to conduct reactor experiments with the EPFL reactor CROCUS.

Content

- Radiation detector systems, alpha and beta particles
- Radiation detector systems, gamma spectroscopy
- Introduction to neutron detectors (He-3, BF3)
- Fast neutron detection via Pulse Shape Discrimination
- Approach-to-critical experiments
- Reactor period measurements
- Reactor power calibration
- Neutron noise experiment

Learning Outcomes

By the end of the course, the student must be able to:

- Apply measurement techniques for alpha, beta, gamma and neutron radiation detection.
- Carry out measurement techniques to obtain CROCUS reactor characteristics.
- Conduct both reactor power and control rod calibration.
- Plan the critical experiment.

Teaching methods

Instructions and supervision during lab work

Assessment methods

reports and oral examination during the semester

Resources

Bibliography

Handouts will be distributed

- James E. Martin, "Physics for Radiation Protection", Wiley-VCH (2nd edition, 2006)
- F.M. Khan, "The Physics of Radiation Therapy", Lippincott, Williams & Wilkins, (4th edition, 2010)
- G.C. Lowenthal, P.L. Airey, "Practical Applications of Radioactivity and Nuclear Reactions", Cambridge University Press (2001)
- K.H. Lieser, "Nuclear and Radiochemistry", Wiley-VCH (2nd edition, 2001)

Ressources en bibliothèque

- [Find the references at the Library](#)

Moodle Link

- <https://go.epfl.ch/PHYS-451>

PHYS-450

Radiation biology, protection and applications

Damet Jerome, Grilj Veljko, Pakari Oskari Ville

Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Obl.
Physicien	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	3 weekly
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

This is an introductory course in radiation physics that aims at providing students with a foundation in radiation protection and with information about the main applications of radioactive sources/substances in the industry. The course includes presentations, lecture notes and problem sets.

Content

- Radioactivity and interactions of ionising radiation in matter
- Health effects of ionising radiation
- Dosimetry and population exposure
- Space radiation dosimetry
- Operational radiation protection: Sources, Shielding, Calculations
- Internal and external exposure to radionuclides and radiation
- Emergency dosimetry and extreme radiological events
- International nuclear safeguards
- Industrial applications: food irradiation, radioisotope batteries, radiation imaging, etc.
- Applications in research: dosimetry for radiotherapy, metrology, etc.

Learning Outcomes

By the end of the course, the student must be able to:

- Explain the origin ionising radiation and give a few examples of the origin of neutron radiation.
- Explain interactions of ionising radiations in matter.
- Explain biological/health effects of the ionising radiations
- Explain the principles of dosimetry
- Explain population's exposure and cite exposure levels
- Explain the principles of radiation protection, cite the dose limits
- Explain the concept of risk
- Describe the protection means for external and internal exposure
- Explain radiation shielding and give examples
- Explain the use of radiation in industrial and research applications.

- Explain exposure to the general population and cite exposure levels
- Explain the origin of ionising radiation
- Explain interactions of ionising radiation in matter.
- Explain biological/health effects of the ionising radiation
- Design appropriate radiation shielding for a given source or application
- Contextualise extreme radiological events

Assessment methods

Written, Multiple Choice Question exam

Resources

Bibliography

- James E. Martin, "Physics for Radiation Protection", Wiley-VCH (2nd edition, 2006)
- G.C. Lowenthal, P.L. Airey, "Practical Applications of Radioactivity and Nuclear Reactions", Cambridge University Press (2001)
- K.H. Lieser, "Nuclear and Radiochemistry", Wiley-VCH (2nd edition, 2001)

Ressources en bibliothèque

- [Find the references at the Library](#)

Moodle Link

- <https://go.epfl.ch/PHYS-450>

PHYS-452

Radiation detection

Lamirand Vincent

Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Nuclear engineering	MA1	Opt.
Physicien	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Oral
Workload	120h
Weeks	14
Hours	3 weekly
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

The course presents the detection of ionizing radiation in the keV and MeV energy ranges. Physical processes of radiation/matter interaction are introduced. All steps of detection are covered, as well as detectors, instrumentations and measurements methods commonly used in the nuclear field.

Content

- **Interaction of radiation with matter at low energies:** X-rays/gammas, charged particles and neutrons up to MeV range, ionisation, nuclear cross sections.
- **Characteristics and types of detectors:** gas detectors, semiconductor detectors, scintillators and optical fibers, fission chambers, meshed and pixel detectors
- **Signal processing and analysis:** types of electronics, signal collection and amplification, particle discrimination, spatial and time resolution
- **Nuclear instrumentation and measurements:** principle of measurements, spectrometry, common detection instrumentations, applications in nuclear engineering and R&D.

Keywords

radiation detection; radiation-matter interaction; ionizing radiation; detector; signal processing; nuclear instrumentation; measurement methods

Learning Outcomes

By the end of the course, the student must be able to:

- Explain interaction processes of ionising radiation and matter
- Describe the production of a detection signal and its processing
- Explain the operation of all types of commonly used detectors
- Assess / Evaluate the detection system and method required for a specific measurement

Transversal skills

- Communicate effectively with professionals from other disciplines.

Teaching methods

Lectures, exercises, presentations, practice.

Expected student activities

Attendance at lectures and exercises, short presentations.

Assessment methods

Oral exam

Supervision

Assistant.e.s Yes

Resources

Bibliography

Radiation detection and measurement, Glenn F. Knoll. Wiley 2010
Practical Gamma-Ray Spectrometry, Gordon R. Gilmore, Wiley & Sons 2008

Ressources en bibliothèque

- [Find the references at the Library](#)

Moodle Link

- <https://go.epfl.ch/PHYS-452>

ETH-590

Semester Project Nuclear Engineering

Profs divers *

Cursus	Sem.	Type
Nuclear engineering	MA3	Obl.

Language of teaching	English
Credits	8
Session	Winter
Semester	Fall
Exam	During the semester
Workload	240h
Weeks	14
Hours	8 weekly
Project	8 weekly
Number of positions	

Summary

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

Content

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Learning Outcomes

By the end of the course, the student must be able to:

- Analyze a technical problem

Transversal skills

- Write a scientific or technical report.

PHYS-595

Stage d'ingénierie (master en Génie nucléaire)

Profs divers *

Cursus	Sem.	Type
Génie nucléaire	MA2, MA3, MA4	Obl.

Langue d'enseignement	
Crédits	8
Session	Hiver, Eté
Semestre	Printemps
Examen	Pendant le semestre
Charge	240h
Semaines	14
Projet	8 hebdo
Nombre de places	

Résumé

The main objective of the 12-week internship is to expose master's students to the industrial work environment within the field of nuclear energy.

Contenu

The main objective of the 12-week internship is to expose master's students to the industrial work environment within the field of nuclear energy. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Acquis de formation

A la fin de ce cours l'étudiant.e doit être capable de:

Compétences transversales

- Utiliser une méthodologie de travail appropriée, organiser un/son travail.
- Communiquer efficacement et être compris y compris par des personnes de langues et cultures différentes.

Méthode d'évaluation

an oral presentation could be asked by the company, not compulsory