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INTERNATIONAL SCHOOL IN NUCLEAR ENGINEERING 2024

In France

18th EDITION

Internationally known expert lecturers mostly from the CEA, the leading research organisation in France for nuclear energy

6 Doctoral-level Courses in Nuclear Engineering

From January 15 to March 15, 2024

For each course, technical visits of CEA facilities are planned

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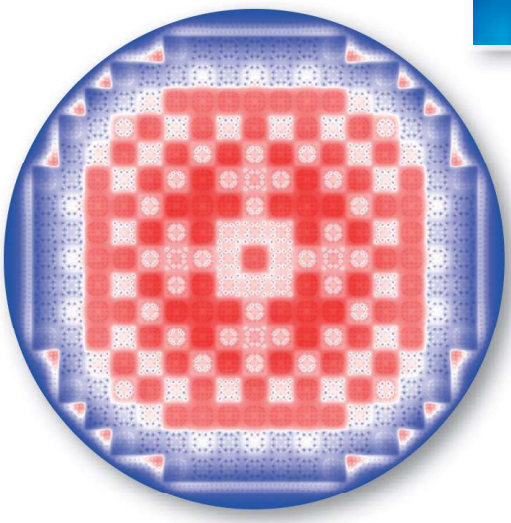
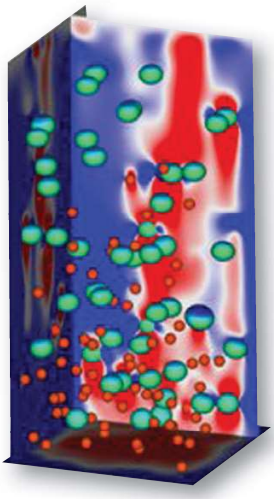
GFR, experimental reactor Allegro

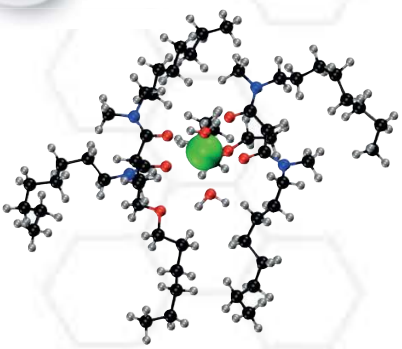
Pin-type fuel element of Gas Fast-cooled Reactor (GFR)



Neutronics calculation of EPR core with APOLLO^3



Large scale bubble simulation



Actinide complex solvated by extraction molecule

ABOUT THE SCHOOL

- INSTN, the French National Institute for Nuclear Science and Technology is organizing the International School in Nuclear Engineering, promoting knowledge in the field of nuclear sciences at a high education level.
- The 2024 edition will offer 6 one-week advanced courses in nuclear engineering to be held in France (Cadarache, Marcoule, or Saclay), from January to March 2024. Participants have the possibility to choose the course they want to follow, from only one to all six courses.
- The courses are designed for young researchers, PhD students, post-doctorates and engineers, already having a Master of Science in nuclear engineering as a back-ground. They present the international state-of-the-art in the main topics of nuclear engineering: Reactor core physics, thermal hydraulics, materials, fuels, fuel cycle and nuclear waste.
- 3 ECTS will be awarded for each successfully completed course (one week).

INFORMATION

Venue

The courses will be held at INSTN locations in Saclay (P5F3+J94 Saclay, 20 km southwest of Paris),
Cadarache (MQQ6+8C Saint-Paul-lez-Durance, 40 km from Aix-en-Provence) and Marcoule (4MRW+5R Bagnols-sur-Cèze, 30 km from Orange).

Registration deadline

December 1st, 2023 for all courses.

Registration fees

Professionals: €2,560 per course.
Special rates for each additional course, students, CEA and ENEN member institutions: please contact us for further details.
Fees include lectures, digital documentation, technical visits and lunches.

Contacts

Technical Advisor: Claude Renault - claude.renault13@orange.fr
General coordination/Info.: Stéphane WISNIEWSKI – stephane.wisniewski@cea.fr

Cadarache

Course 4 - Nuclear Fuels for Light Water Reactors and Fast Reactors
January 15 to 19, 2024

Course 3 - Reactor Core Physics: Deterministic and Monte Carlo Methods
January 22 to 26, 2024

Contact for registration: Lorena Mei – lorena.mei@cea.fr

Saclay

Course 1 - Thermal Hydraulics and Safety
January 29 to February 2, 2024

Course 2 - Materials for Nuclear Reactors, Fuels and Structures
February 5 to 9, 2024

Contact for registration: Fany Guelah - irfana.guelah@cea.fr

Marcoule

Course 5 - Nuclear Fuel Cycle: from Strategy to Processes
March 4 to 8, 2024

Course 6 - Nuclear Waste Management
March 11 to 15, 2024

Contact for registration: Laura Raibaldi - laura.raibaldi@cea.fr

OUTLINE PROGRAMME OF COURSES

Course 1 - Thermal Hydraulics and Safety

(D. Bestion, F. Fichot, E. Studer)

Learning outcomes: *give practical and relevant examples of thermal hydraulics of light water reactors (LWR) and describe modelling and multi-phase phenomenology of severe accidents in LWRs.*

- Main two-phase flow phenomena in LWRs
- Multi-scale modelling of LWR thermal hydraulics
- System code modelling of reactor thermal hydraulics, including advanced modelling LWR transient analysis methodology with PIRT, Scaling, Code Development, Verification and Validation plus Uncertainty Quantification
- Application of the methodology to LOCA analysis
- Application of one-phase and two-phase CFD to reactor thermal hydraulic issues
- Multiphase phenomena and modelling of severe accidents in LWRs
- Hydrogen risk (production, dispersion, combustion, mitigation)

Course 2 - Materials for Nuclear Reactors, Fuels and Structures

(J-C. Brachet, E. Clouet, J. Garnier, F. Garrido, G. Gutierrez, E. Meslin)

Learning outcomes: *identify the major materials used in nuclear reactors : Steels, Zr alloys and carbides,analysis the mechanisms of the irradiation effects on the materials, describe the evolution of the microstructure and the impact induced by irradiation on the properties of the major materials.*

- Mechanisms of irradiation damage: neutrons, photons, electrons
- Behaviour of materials under irradiation: ferritic steels for reactor pressure vessel, austenitic stainless steels for internals or fuel cladding (FBR), Zr alloys for fuel cladding and fuel assemblies (LWR)
- Zr alloys in accidental conditions and Enhanced Accident Tolerant Fuel claddings
- Fuel materials (UO_2, PuO_2): irradiation-induced effects
- Materials for high temperature conditions: SiC, ZrC, low swelling alloys
- Materials for fusion: low activation materials, resistance to high-energy neutrons, breading blankets

Course 3 - Reactor Core Physics: Deterministic and Monte Carlo Methods

(A. Zoia, J. Tommasi, J-F. Vidal)

Learning outcomes: *identify advanced numerical methods to solve the Boltzmann equation for neutron transport and recent deterministic and probalistic methods APPOLO2/3 and TRIPOLI4 codes.*

- Chain reaction and neutron balance
- Neutron slowing-down and resonance absorption, self-shielding modelling
- The neutron transport equation and calculation schemes: the steady-state integro- differential transport equation. The neutron diffusion equation… Verification and validation of neutronics code package: process, sensitivity and uncertainty studies The Monte Carlo method for solving the transport equation
- Monte Carlo techniques: fixed source, variance reduction, criticality, perturbation calculations, adjoint calculation, applications to shielding

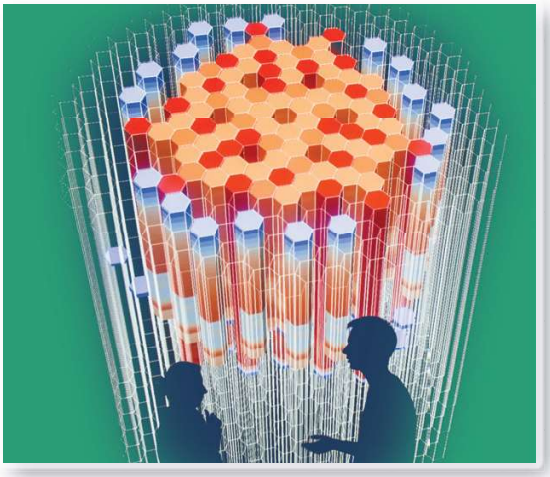
Course 4 - Nuclear Fuels for Light Water Reactors and Fast Reactors

(J. Noirot, Coordinator)

Learning outcomes: *describe the design and the fabrication of the nuclear fuels as well as the fuel thermal and mechanical behavior i, reactor operation, identify the main limiting phenomena (for safety and design).*

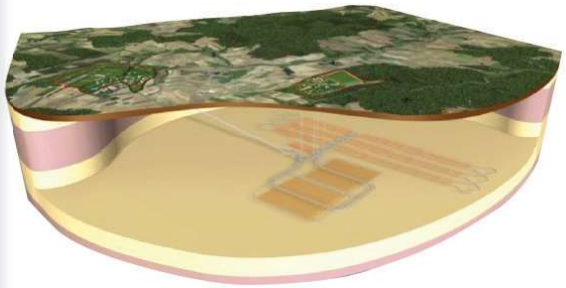
- Nuclear fuels fundamentals
- Fuel element thermal performance and temperature effects Nuclear fuel behaviour under irradiation
- Main limiting phenomena in the different types of fuels
- Fuel challenges for the future

ATALANTE facility



Neutronics and thermal-hydraulics Coupling for SFR simulation

The EPR



CIGEO project

Course 5 - Nuclear Fuel Cycle: from Strategy to Processes

(C. Sorel)

Learning outcomes: *describe the main stages in the fuel cycle and the chemical processes used for fuel reprocessing; identify the R&D and the possible improvements.*

- From uranium ore mining to spent nuclear fuel
- Fundamentals of fuel cycle: chemistry of actinides and fission products
- The current industrial process: scientific basis and process modelling
- Towards the 4th generation nuclear energy systems: scientific and industrial challenges associated to the Pu-multirecycling
- Minor actinide recycling as a potential option for waste management optimization

Course 6 - Nuclear Waste Management

*(C. Cau Dit Coumes, **S. Mougnaud,** M.Fournier, S. Gin, F.Lemont)*

Learning outcomes: *perform a critical analysis of the various waste management options and identify how scientific studies play a part in addressing the issues related to nuclear waste management.*

- Waste management options and related issues Treatment of radioactive organic waste
- Waste conditioning: concrete and vitrification
- Science contribution to economic, safety and societal issues
- Case study

MAIN LECTURERS

Lecturers are experienced in teaching in several Masters of Science and Engineering programmes. They also supervise PhD students in their research activities.

Dominique Bestion, Director of Research at the CEA, has developed two-phase flow models for the CATHARE system code for 35 years and has strongly involved in the development of the NEPTUNE multi- scale thermal hydraulic simulation platform including two-phase CFD capabilities. He coordinated thermal hydraulic activities of the EUROFASTNET, NURESIM, NURISP and NURESAFE European Projects for a nuclear reactor multi-physics and multi-scale simulation platform. He also coordinated Working Groups of OECD-NEA for the application of CFD to nuclear safety with Best-Practice Guidelines, V&V and uncertainty quantification. He is professor at Ecole Polytechnique. He also teaches at INSTN, ECP, ENSE3 and in international courses (ETH-Zurich Short Couse, IAEA training sessions, OECD THICKET Course, FJOH Summer Schools…).

Jean-Christophe Brachet is a CEA International Expert on nuclear materials and Professor at INSTN. His expertise covers physical metallurgy of chromium-rich ferritic-martensitic steels, Zr alloys and Enhanced Accident. Tolerant Fuel claddings (LWR). He authored more than 60 papers and participated to numerous internatio-nal symposiums or workshops as lecturer or as chairman of specific sessions. He is inventor or co-inventor of 5patents.

Dr Céline Cau Dit Coumes is an international expert at the CEA. She has been involved in radioactive waste management for more than 20 years and works in a laboratory devoted to the design and characterization of cement-based materials for the conditioning of low and intermediate-level radioactive wastes. She is the author (or co-author) of 50 papers published in peer-reviewed international journals, 7 book chapters, and 3 patents. She has been involved in several international research projects (IAEA, Chinese Atomic Energy Agency, IFIN-HH Roma-nia). She also performs expert evaluations on request of waste producers and teaches cement chemistry at Montpellier University.

Emmanuel Clouet is Senior Expert in the Phy-sical Metallurgy Lab of the Department for Nu-clear Materials at CEA Paris-Saclay. His research activity pertains to the multiscale materials modeling to study plasticity in metals and alloys and kinetic evolution of materials under irradia-tion, with a special emphasis on zirconium and titanium alloys. He also is an associate editor for Acta and Scripta Materialia journals.

Florian Fichot, international Expert on severe accidents in nuclear reactors at Institut de Radio-protection et de Sûreté Nucléaire (IRSN). He has been working for 25 years in the field of physical modelling and numerical simulation of severe accidents in nuclear reactors, particularly in the modelling of core degradation, thermal-hydraulics and corium behaviour. Most notably, he took part in the development of the ICARE/CATHARE and ASTEC codes. His expertise covers the two-phase flow in porous media, the phase change of multi-component mixtures and in- vessel or ex-vessel melt retention strategies for Light Water Reactors. He was coordinator of the European project IVMR (2015-2020). He teaches in the frame of European NUGE- NIA courses and IAEA summer schools.

Maxime Fournier is a Research Engineer at the CEA and Lecturer at INSTN. His expertise covers the chemical durability of nuclear glasses destined to deep geological dispo- sal and conventional glasses for industrial applications, the formulation and charac- terization of glassy materials for the confi- nement of waste from decommissioning and dismantling operations. He has been involved in the coordination of Theramin and PreDisposal RadWaste European projects. He co-authored more than 20 publications. He supervises PhD students and teaches to Master degree students at Montpellier University, ENSCM, Aix Marseille University, Chimie ParisTech, Grenoble Alpes University and Sorbonne University.

Jérôme Garnier is Research Engineer and expert on nuclear materials at the CEA. He is in charge of the material research and development programme in support of the realization of the core vessel and internal structures of the new Jules Horowitz Materials Testing Reactor (JHR). In 2012, he was awarded the J. Gaussens SFEN (French Nuclear Society's) prize, in particular for his work on the austenitic stainless steels.

Frederico Garrido is Professor of Materials Chemistry at the Université Paris-Saclay, Orsay. He is an expert in the interaction of energetic particles with matter and radiation damage physics, especially applied to nuclear ceramic materials used as transmutation matrices (oxides and carbides). He has co-authored over 100 scientific papers in peer-reviewed journals. He became also a recipient of the Bronze Medal of the French National Centre for Scientific Research. In addition he is co-Director of the Master Nuclear Energy, which is run by the Paris-Saclay University.

Stéphane Gin received a PhD degree from Poitiers University, France, in 1994. Since 1995, he has been working at the CEA Marcoule. In 2001, he took the lead of the "Long term behaviour of HLW glass" group. This CEA team of 25 people focuses on fundamental and applied issues related to the geo- logical disposal of high-level and intermediate level waste glass. From 2012 to 2013, he was visiting scientist at Pacific Northwest National Laboratory, USA. Dr Gin is also part of advisory boards on high-level waste management in Belgium, the UK, and the USA. He is author and co-author of about 100 papers and wrote acclaimed books on nuclear waste management for the general public.

Gaëlle Gutierrez is a research engineer in the Physical Metallurgy Lab of the Department for Nuclear Materials at the CEA Paris-Saclay. Her research activity is focused on the radiation damage effect, especially applied to nuclear ceramic materials such as oxides (UO2, CeO2) and carbides (B4C, SiC, Graphite). She has authored and co-authored over 30 scientific articles in peer-reviewed journals. She is also the operation manager of the JANNUS Saclay irradiation platform.

Florent Lemont is Research Director at the CEA and Professor at INSTN. He has worked for over 25 years in the field of high temperature chemistry applied to the separation of radioelements in molten salt media, to the combustion of solid or liquid contaminated organic materials, to the production of hydrogen by thermochemical cycles, to the gasification of biomass, to the optimization of plasma technologies and to the fabrication of Mox fuels. He is author or co-author of 50 papers published in peer-reviewed international journals and 16 patents.

Estelle Meslin, Senior expert at the CEA on nuclear materials. She has 15 years of experience in the field of physical metallurgy of materials under irradiation, especially on Fe-based materials (Reactor Pressure Vessel steels, ferritic/martensitic steels, ODS and Eurofer steels) but also on W or Al alloys. In 2014, she was awarded the J. Rist medal of the SF2M (Société Française de Métallurgie et Matériaux) awarded to young scientists. She has authored or co-authored more than 30 papers published in peer reviewed international journals and participated to numerous international symposiums or works- hops as lecturer or as chairman of specific sessions.

Jean Noirot is International Expert at the CEA. He has been working for more than 20 years in the field of nuclear fuel post-irradiation examination. With techniques going from gamma-scanning to micro-analyses, he has gained a wide experience on fuel behaviour, fast breeder reactor fuel, pressurized reactor fuel, including MOX, or dedicated experimentation on fuel in French or foreign test reactors. He has authored or co-authored more than 40 publications and book chapters.

Christian Sorel, CEA International Expert and Associated Professor at INSTN. He has been involved for more than 25 years in the modelling and the flowsheet design of separation processes by solvent extraction devoted to the recovery and the purification of metals (actinides, rare earths and other strategic materials). He is the author (or co-author) of more than 30 papers published in peer-re- viewed international journals and 7 patents.

Etienne Studer is International Expert at the CEA in fluid mechanics and hydrogen risk issues. He has 30 years of experience working in the field of hydrogen risk in nuclear power plants. He is currently involved in experimental programmes (MISTRA facility) and model- ling activities (CAST3M CFD code). He has participated to international experimental programmes, international working groups and state-of-the-art reports. He takes part to the "European Hydrogen Safety Panel".

Jean Tommasi is Senior Expert at the CEA for fast reactor neutron physics. He has been involved in fast reactor core design and minor actinide transmutation studies and is currently working in the fields of code validation against experiments and calculation methods. For several years now, he has been active in tutorial classes on neutronics at INSTN. He authored or co-authored over 80 publications in these fields.

Jean-François Vidal is Senior Expert at the CEA in neutronics. He has 30 years of experience in developing calculation schemes for various reactor applications (fast and thermal ones). He is currently responsible for the R&D of the APOLLO3 deterministic transport code developed at the CEA. He teaches transport methods at INSTN and has authored or co-authored more than 50 publications in peer-reviewed journals and international conferences.

Andrea Zoia holds a MSc (2005) and a PhD (2008) in nuclear engineering from Politecnico di Milano (Italy). Since 2008 he has been working at the CEA/Saclay, in the development team of the Monte Carlo transport code TRIPOLI-4, and he is currently Monte Carlo group leader. His main research focus is on stochastic processes and Monte Carlo methods for eigenvalue problems in reactor physics and for variance reduction in radiation shielding.