Master in Nuclear Engineering – M2

UNIVERSITE PARIS-SUD 11
Field: Science Technology Health
Annotation: Fundamental and Applied Physics

CEA-INSTN

Academic responsibility for the programme: UFR Sciences UPS, CEA-INSTN
Administrative responsibility (student registration): UFR Sciences, CEA-INSTN

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Course venues: UFR Sciences UPS and INSTN CEA/Saclay
Towns: Orsay, Gif-sur-Yvette – CEA/Saclay
Department code: 91
1. Context:

Energy production is a crucial question in the industrial world and a global issue. World population growth (demographic forecasts estimate a 50% increase in 50 years) combined with the strong economic development of highly populated countries which are not yet big energy consumers could double the world’s energy consumption by the year 2050 (see Table 1). In parallel, an international consensus has been reached to implement policies for the massive reduction of greenhouse gas emissions, primarily CO\textsubscript{2}. In this context, nuclear energy will make a significant contribution to the energy mix in the coming decades (see Figure 1), requiring nuclear capacity to be increased by a factor of 3 or 4 between now and 2050.

![Trend in the distribution of primary energy consumption](source: TOTAL)

<table>
<thead>
<tr>
<th>Energy requirements (Gtep)</th>
<th>2005</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear primary energy (Gtep)</td>
<td>0.7</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Nuclear capacity (GWe)</td>
<td>360</td>
<td>650</td>
<td>1400</td>
</tr>
<tr>
<td>Capacity of water reactors (GWe)</td>
<td>320</td>
<td>550</td>
<td>1200</td>
</tr>
</tbody>
</table>

**Forecast energy requirements and contribution of nuclear energy** (Source: J. Bouchard)

France, like many other countries such as Japan, China, etc., has chosen to develop nuclear energy production. The major French industrial partners (EDF and AREVA in particular) are strong players in the worldwide industrial nuclear market.

In the coming decade, the development of the nuclear industry is set to go forward with renewed impetus, most notably with the construction of Generation III/European Pressurised Water Reactors. At the same time, projects are underway to design Generation IV reactors. These projects are motivated in particular by the quest for sustainable development, which is crucial in the realm of energy: reduced consumption of raw materials, reduced volume of waste generated.

The nuclear industry has expressed a major need for technicians and engineers. Correlated to this, are the R&D upstream of and in support of industrial deployment going on in nuclear research organisations such as the CEA and in certain universities, such as Université Paris Sud 11 at Orsay.

This is the context in which Université Paris Sud 11 at Orsay (UPS) and Institut National des Techniques Nucléaires (INSTN) (National Institute of Nuclear Science and Technology) of the Commissariat à l’Energie Atomique at Saclay (CEA/Saclay) (Atomic Energy Commission) are offering a second-year Master specialisation called **Nuclear Engineering-M2** within the Master of Fundamental and Applied Physics programme to students wishing to work in the field of nuclear energy. This diploma can lead to employment directly following this 5th year of post-secondary study or to continuing study and research in the context of a doctoral thesis. Because of
deliberate policy of opening this programme up to international participants, this Master of Nuclear Engineering will be taught in English.

2. Course Objectives and Content

The objective of the Nuclear Engineering speciality is to provide in-depth training in the field of nuclear reactor physics for the purpose of using existing tools, developing and installing third-generation reactors, and designing and developing the future systems still known as 'integrated systems'.

Objectives such as these require a systematic and overall vision to provide a grasp of the whole dimension of civil nuclear power for which reactor-related problems are closely connected to the problems of the fuel associated with it. This requires the joint teaching of a variety of disciplines with content that is both scientific and technological. Thus, the area of nuclear reactor physics alone calls for skills in neutron physics, thermo-hydraulics and metallurgy & materials. As for the field of the nuclear fuel cycle, to a large extent it calls upon the chemistry of hydrometallurgical processes, which requires at least some knowledge of solution chemistry, separative chemistry, and radiochemistry. The following table summarises the courses in the Master of Nuclear Engineering broken down into course units (UE) representing a volume of 405 hours excluding the compulsory internship placement:

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Hours</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE1 Introduction to Nuclear Engineering</td>
<td>65</td>
<td>5</td>
</tr>
<tr>
<td>UE2 Neutron Physics – Part I</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>UE3 Neutron Physics – Part II</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>UE4 Heat Exchange – Nuclear reactor thermal</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td>hydraulics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UE5 Nuclear Materials</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>UE6 Use of codes, mini-projects</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>UE7 Description and operation of pressurised water reactors, Other reactor types, ADS</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>UE8 Nuclear fuel cycles, Safety &amp; Criticality, Radiation Protection</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>405</td>
<td>40</td>
</tr>
</tbody>
</table>

By selecting their internship placement, students can obtain more specialised training in the technologies and tools used in the nuclear industry, thus preparing for immediate professional insertion into multinational corporations covering all aspects of nuclear industrial activity.

The choice of internship placement will allow students to direct their training towards applied research in the field of nuclear energy should they wish to do so. In that case, they will be in contact with research teams, and the natural extension to their studies will be to write a thesis at the Université Paris-Sud, at another French university (Caen, Grenoble, Lyon, Montpellier, Nantes), or at the CEA.

The Master Nuclear Engineering-M2 therefore aims to satisfy a dual requirement:

- To put the knowledge acquired to immediate use on the job market on completion of the M2,
- Beyond the M2, to open up access to a research career in the field of cross-disciplinary nuclear reactor research.
The current and future professions catered for are therefore: engineer or project manager in the case of professional insertion immediately after the M2, and research scientist or research engineer for those who go on to complete a PhD.

3. European Partnership

The Master in Nuclear Engineering - M2 is supported by the European Nuclear Education Network (ENEN) Association (http://www.enen-assoc.org), an association with 44 members including about 40 European universities.

Its main objective is the preservation and further development of higher nuclear education and expertise by promoting cooperation between European universities, research centres and the nuclear industry. To meet with this objective, ENEN deliver the European Master of Science certificate in Nuclear Engineering and promote the PhD studies and establish a framework for mutual recognition.

This Master in Nuclear Engineering - M2 is organised in cooperation with Technical University of Munich, Germany, one of the ENEN members. In the framework of an agreement between the two institutions which is under preparation, students from the Technical University of Munich will be admitted to validate a full semester by following the different courses of this second year master in France. A similar agreement is under discussion with the University of Kaunas, Lithuania.

For the academic year starting in 2008, the access of students to the Master in Nuclear Engineering - M2 programme will benefit from a certain number of grants offered by CEA-INSTN under the auspices of the ENEN Association.

4. For whom is the Master in Nuclear Engineering-M2 intended?

This specialisation is equally suited to M1 university students in Fundamental and Applied Physics (or equivalent) and to students at engineering schools such as Ecole Polytechnique. It might also interest company executives in the context of continuing education.

Students who have passed the first year of the Master of Physics (in particular the Master of Fundamental and Applied Physics at the Université de Paris-Sud) or equivalent may apply.

In particular, the level of prerequisites obtained in applied nuclear physics, thermal engineering and metallurgy will be evaluated.

Applicants to Nuclear Engineering-M2 are chosen by a panel.

Note: Since 2007, Université Paris-Sud 11 has offered a ‘Nuclear Engineering’ option in the context of its first year Master M1 Fundamental and Applied Physics course. This option can prepare M1 students for entry into the ‘Nuclear Engineering’ speciality in year M2. (Note that first-year Master courses are taught in French.)

5. Organisation of the Programme

Instruction is given not only by CEA-INSTN and Université Paris-Sud 11 personnel, but also by members of the nuclear industry and foreign institutions.

The first semester contains the theoretical and practical courses shown in Table 1 (above).

The second semester of M2 involves a five-month internship at a research facility or in industry (according to the student’s career goals) in France or abroad.

A list of laboratories likely to offer work experience placements to interns is given in Section 6.

Internship proposals are sent to students in early November, and choices are finalised in January so that the necessary internship agreements with the host facility can be signed before the
Internships begin. Students wishing to suggest a topic for their work experience placement must have their proposal (topic and conditions of implementation) approved by the course co-ordinators at the beginning of the M2 year.

Internships give rise to a report and an oral presentation before a panel which will evaluate the work performed. Oral presentations are scheduled for early September. The internship is worth 20 ECTS.

6. Research Environment

The Nuclear Engineering specialisation is provided by the laboratories associated with the 'Radiation and Environment' doctoral school of Université Paris-Sud (UPS), particularly the CNRS IN2P3 laboratories.

Other laboratories within the UPS, the CNRS, the CEA, and Ecole Polytechnique also make a large contribution to the programme’s research and hosting capacity.

The programme will also rely on a network of European (ENEN) and international laboratories.

Finally, the programme is supported by two major industrial structures: AREVA and EDF.

At Université Paris-Sud (UPS):
L’Institut de Physique Nucléaire d’Orsay (IPNO) (Orsay Nuclear Physics Institute)
Le Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (CSNSM) (Nuclear Spectrometry and Mass Spectrometry Centre)
L’Institut de Chimie Moléculaire et des Matériaux d’Orsay (ICMMO) (Orsay Institute for Molecular Chemistry and Materials)

At IN2P3 (CNRS):
Le Centre d’Etudes Nucléaire de Bordeaux Gradignan (Bordeaux Gradignan Nuclear Research Centre)
Le Laboratoire de Physique Corpusculaire de Caen (Caen Particle Physics Laboratory)
L’Institut de Physique Nucléaire de Lyon (Lyon Nuclear Physics Institute)
Le Laboratoire de Physique Subatomique et Corpusculaire de Grenoble (Grenoble Particle and Subatomic Physics Laboratory)
Le Laboratoire SUBATECH de Nantes (The SUBATECH Laboratory at Nantes)
L’IPHC de Strasbourg (IPHC, Strasbourg)

At the Commissariat à l’Energie Atomique (CEA):
- At Saclay,
Les services du Département de Modélisation et de Simulation des Structures: le Service d’Etudes des Réacteurs et de Mathématiques Appliquées, le Service d’Etudes Mécaniques et Thermiques, le Service Fluides Numériques, Modélisation et Etudes (The units of the Structure Simulation and Modelling Department: the Reactor Research and Applied Mathematics Unit, the Mechanical and Thermal Research Unit, the Numerical Fluids, Modelling and Research Unit)
Les services du Département des Réacteurs et des Services Nucléaires (The units of the Department of Reactors and Nuclear Services)
Les services du Département des Matériaux pour le Nucléaire (The units of the Department of Nuclear Materials)

- At Cadarache,
Les services du Département d’Etude des Réacteurs: le Service de Physique des Réacteurs et du Cycle, le Service de Réalisation d’essais en Sûreté, le service de Physique Expérimentale, le service d’Etude des Systèmes Innovants, le Service de Simulation en Thermo-hydraulique (The units of the Department of Reactor Research: the Reactor and Cycle Physics Unit, the Testing and Safety Unit, the Experimental Physics Unit, the Innovative System Research Unit, the Thermal Hydraulics Simulation Unit)
Les services du Département de Technologie Nucléaire (The units of the Nuclear Technology Department)
Les services du Département d’Etudes du Combustible (The units of the Fuel Research Department)

At the Ecole Polytechnique:
Le Laboratoire de Mécanique des Solides (Solid Mechanics Laboratory)
Le Laboratoire des Solides Irradiés (Irradiated Solids Laboratory)
Le Centre de Mathématiques Appliquées (Applied Mathematics Laboratory)

**At EDF:**
Le Centre de Recherches des Renardières (Renardières Research Centre)
Le Centre de Recherches de Clamart: R&D/SINETICS,... (Clamart Research Centre: R&D/SINETICS, etc.)
Le SEPTEN de Lyon (SEPTEN, Lyon)
L’UNIE de Lyon (UNIE, Lyon)

**At AREVA:**
AREVA/NC-SGN
AREVA/NC-TNI
AREVA/NP (formerly Framatome, La Défense)
AREVA/NP (formerly Framatome, Lyon)

**Europe-wide:**
All of the research laboratories at the universities in the ENEN network can offer internship projects. There are currently 40 such laboratories; the main universities called upon are:

- Katholieke Universiteit Leuven
- Université Catholique de Louvain
- Université Libre de Bruxelles
- Université de Gand
- Helsinki University of Technology
- Lappeenranta University of Technology
- Technische Universitaet Muenchen
- Universitaet Stuttgart
- Universidad Politecnica de Madrid
- Escola Tecnica Superior d'Enginyeria Industrial
- KTH – Stockholm
- Uppsala Universitet
- Swiss Federal Institute of Technology (ETH), Zurich
- Swiss Federal Institute of Technology (EPFL), Lausanne
- University of Manchester
- University of Birmingham
- Delft University of Technology
- CIRTEM – a consortium of Italian universities
- Budapest University of Technology and Economics

The following nuclear research centres are Associate Members of ENEN and can also offer internship projects:

- SCK*CEN – Nuclear Research Centre – Mol Belgium
- Nuclear Research Institute Rez – Czech Republic
- "Jozef Stefan" Institute, Ljubljana, Slovenia.

**Internationally:**
Students in the Master course can also benefit from student exchange programmes with the following universities and research centres, which already have contact with INSTN:

- Massachusetts Institute of Technology (MIT)
- University of California, Berkeley
- University of Michigan
- Texas A&M University
- Penn State University
- Ecole Polytechnique de Montréal.
- Argonne National Laboratory (ANL)
- Oak Ridge National Laboratory (ORNL)
- Idaho National Laboratory (INL)
- Rensselaer Polytechnic Institute

Close ties exist with some of the organisations listed above and international organisations such as the IAEA based in Vienna and the NEA/OECD (Nuclear Energy Agency) based in the Paris Region.
which, amongst other things, play a very important role internationally in the dissemination and preservation of scientific heritage in the nuclear field.