<table>
<tr><th colspan="3">Course on “Neutronics for light water reactors”</th></tr>
<tr><th>Units and LO Statements</th><th></th><th></th></tr>
<tr><td rowspan="3">Unit 1 – Phenomenology
(30 hours)</td><td colspan="2">Responsibility / Autonomy</td></tr>
<tr><td colspan="2">Phenomena resulting from neutron-nucleus interactions inside a reactor core (EQF=7)</td></tr>
<tr><td>Skills</td><td>Knowledge</td></tr>
<tr><td>
Introductory nuclear physics: nucleus properties, radioactivity, nuclear reactions, cross-sections.
Introduction to neutronics: energy domains, neutron current, flux and spectrum, reaction rates, neutron balance.
Diffusion equation: Fick's law, one group diffusion theory, critical conditions, “geometrical buckling”.
Neutron slowing down and thermalisation: elastic and inelastic scattering, lethargy, resonance absorption.
Reactor kinetics: reactivity, prompt and delayed neutrons precursors, Nordheim's equation.
Temperature and poisoning effects, fuel evolution, Pu recycling.
</td><td>
Design, at a preliminary level, Light Water Reactors from a neutron physics point of view
Connect reactor physics to the operation of a Light Water Reactor
Analyse, at a preliminary level, the reactivity control safety function of a Light Water Reactor
</td><td>
Nucleus characteristics and nuclear models
Stable and natural radioactive nuclei
Radioactivity
Disintegration law, activity.
Conservation laws, cross-sections.
Fission and fusion reaction, energy release.
Elastic scattering - energy loss and lethargy
Radioactive decay and modeling, microscopic and macroscopic cross-sections, mean free path
Fission energy balance, prompt and delayed neutron emission, fission products.
Neutron energy domains and associated characteristics. The four factors formula, neutron leakage.
Diffusion approximation. Fick’s law.
One group diffusion theory, the homogeneous bare reactor.
Resonance neutron absorption, probability to escape, self-shielding and effective cross section.
Thermalisation equation, behaviour of the real spectrum.
Multiplication factor, reactivity, prompt and delay neutrons, kinetics, Nordheim’s equation.
Temperature and poisoning effects, Xenon and Samarium effect, spatial instability.
Fuel evolution, fluency, burn-up.
Fissile and fertile nuclei, conversion factor.
Core management with partial reloading. Plutonium recycling.
Multigroup theory.
</td></tr>
<tr><td rowspan="3">Unit 2 – Advanced models and application to reactors
(28 hours)</td><td colspan="2">Responsibility / Autonomy</td></tr>
<tr><td colspan="2">Neutronic phenomena under normal or accidental operation and their modelling (EQF=7)</td></tr>
<tr><td>Skills</td><td>Knowledge</td></tr>
<tr><td>
Neutron transport equation, multigroup theory.
Monte Carlo methods.
Calculation scheme with deterministic codes.
</td><td>
Take into account the main characteristics of a given water reactor technology
</td><td>
Approach to criticality, reactor start-up, divergence, doubling time, delayed neutron influence, reactivity control, load follow.
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• Reactor control and power distribution control.
• Reactivity accident.
• Comparisons of PWR, VVER, BWR and research reactors.
• Hands-on sessions:
  ○ On a PWR simulator
• Laboratory sessions:
  ○ Calculation with a deterministic code
  ○ Calculation with a Monte-Carlo code
	• Design, in a detailed way, Light Water Reactors from a neutron physics point of view
	• Connect reactor physics to the operation of a Light Water Reactor
	• Analyse in detailed the reactivity control safety function of a Light Water Reactor
	• Calculate reactor core characteristics
		• Neutron transport equation
		• Integral and integral-differential forms– principles of the deterministic and probabilistic methods.
		• Multigroup theory
		• Notions on the treatment of nuclear data – solving in two steps, assembly and core calculations – principle of the multi cell assembly calculation.
		• Cell calculation using the deterministic code APOLLO
		• Criticality calculation using the Monte Carlo code TRIPOLI
		• Functional description of VVERs, PWRs and BWRs
		• Safety constraints, the three barriers, operation at constant nominal power, load follow.
		• Temperature and power effects, Xe and Sm concentration, soluble boron, rod cluster control assemblies (RCCA).
		• Power distribution control.

Assessment criteria = to demonstrate mastery of neutron physics theory, as well as the neutron transport equation and numerical methods and software to solve it.		
Recommended assessment methods: Written test and/or oral face to face interview		

Course applicable (in part) for the following job profiles:

- 1.0.01: Nuclear Safety Manager
- 1.0.02: Safety Assessment Specialist
- 1.0.10: Safety Design Engineer
- 1.2.01: Design Manager
- 1.2.09. System Design Engineer
- 2.1.06. Engineering Manager
- 2.1.07. Operation Manager
- 2.1.04. Training Officer
- 2.2.01. Shift Engineer
- 2.2.02. Senior Reactor Operator/CRO
- 2.6.01. Safety and Security Manager
- 2.8.07. Reactor Physicist