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Overview of the course package on core modelling for core design

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Summary

This document gives an overview of the course package on Core Modelling for Core Design. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

Approval

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Abbreviations and Acronyms

Acronym	Description
ECTS	European Credit Transfer and Accumulation System
JiTT	Just-in-Time Teaching
LMS	Learning Management System
SOUL	Smart Open Universe of Learning
WP	Work Package
NPP	Nuclear Power Plant
PWR	Pressurized Water Reactor
BWR	Boiling Water Reactor

Executive Summary

This document gives an overview of the course package on Core Modelling for Core Design. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

Keywords

Active learning; blended learning; flipped classroom; hybrid teaching; nuclear reactor modelling; deterministic modelling; two-step approach; Monte Carlo modelling; PWR; BWR; core design and steady-state operation.

1. Introduction

The EU-funded GRE@T-PIONEeR project aims at developing a specialized education in reactor physics and nuclear reactor safety for PhD and postdoc students, for nuclear engineers, and taken as advanced courses for MSc students. The education encompasses both theory and hands-on training exercises, the latter heavily relying on the use of research/training reactors and of computer-based modelling environments. The aim is for the students to be able to perform nuclear reactor safety simulations understanding all the approximations on which such simulations rely. This is considered essential knowledge in the education of highly skilled nuclear safety analysts. The use of pre-recorded lectures and electronic teaching resources allows students to learn at their own pace and get prepared for the hands-on training sessions. Those sessions, offered both on-site and remotely, use active learning methods under the close supervision and support of the teachers, thus promoting student learning.

In this report, an overview of the course package on core modelling for core design offered as part of the Work Package 4 (WP) is given. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

2. Objectives of the course package

The objective of this course package is to develop a set of educational materials concerning simulation and experimental measurements at core level in steady-state conditions.

The simulation of the transport of neutrons in nuclear reactors at the core level is performed using either deterministic or probabilistic methods. Although probabilistic (i.e., Monte Carlo) methods represent a more straightforward approach compared to deterministic methods in terms of ease of and flexibility in modelling, they suffer from large computing times for core calculations. Probabilistic methods are thus mostly used for reference calculations whereas deterministic methods are used for core design, operation and safety analysis. Deterministic methods, on the other hand, rely on many approximations. This WP thus aims at developing course materials giving the students a full and comprehensive overview of:

- The principles of probabilistic methods in steady-state conditions for core calculations.
- The principles of deterministic methods in steady-state conditions, their approximations, and their range of validity for core calculations.
- The use of those methods for reference calculations or for core design, operation and safety analysis.

Hands-on training exercises include the development and implementation of some of the deterministic methods and the use of both deterministic and probabilistic tools used by the nuclear industry. These exercises are combined with measurements at research reactors to demonstrate the most important phenomena and to illustrate the use of the calculation methods.

A deep understanding of the contents of this course package and the acquisition of the associated competences are essential for professionals in different areas such as reactor physics, new techniques (Small Modular Reactors, Generation IV reactors), nuclear operations, …

It should be stressed that core design and operation of nuclear reactors rely on computational simulations. Calculated results allow operators to predict the core parameters that cannot be measured and, in this way, guarantee the compliance of safety margins. That is why it is crucial to master the different aspects related with computational simulation at the core level covered in this course package. After this course students will be able to: i) understand the methods used for the core modelling in steady-state conditions; ii) know how those methods are implemented in codes and how those codes are used to analyze the core design and operation, especially for PWR and BWR; iii) know how to perform measurements at research reactors and how computational results are validated against experimental measurements.

In order to achieve the proposed goals, WP4 where the course is embedded was divided into tasks. The following graph shows the main links among the tasks.

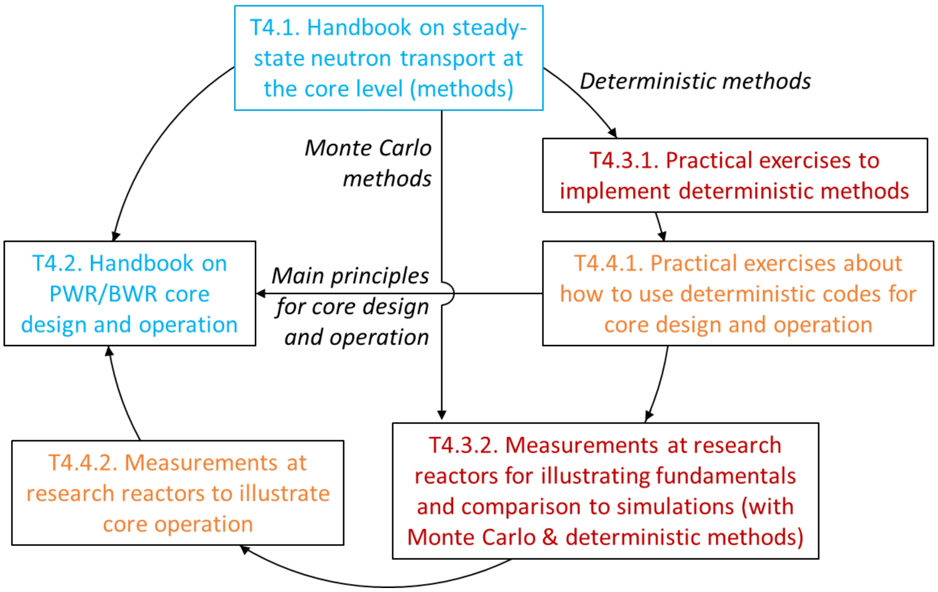

Figure 1. Illustration of connections among the tasks of WP4 where the course package is embedded.

3. Reminder about the pedagogical approach

This Section is a reminder of the pedagogical approach developed and applied across the GRE@T-PIONEeR project. This approach was already described in more detail in the deliverable D1.2 (Demazière, 2021).

3.1. Active learning as the core strategy

The pedagogical approach used and applied throughout the GRE@T-PIONEeR project essentially relies on the concept of *active learning*, according to which students learn much more efficiently when they participate to engaging activities in the classroom with the support from the teachers (Freeman et al., 2014).

Learning can be considered as a process. One paradigm often used to define the various learning steps is Bloom's revised taxonomy of the cognitive domain (Andersson et al., 2000). This process, illustrated in Figure 2, is defined as a sequence of various skills the students develop, starting from lower-order thinking skills to higher-order thinking skills. In the lower order thinking skills, students try to remember and understand the course concepts they were presented. In the higher order thinking skills, students try to utilize such concepts on their own. Those skills include applying, analysing, evaluating the course concepts and creating. What the various skills represent and contain is more precisely exemplified in Figure 2.

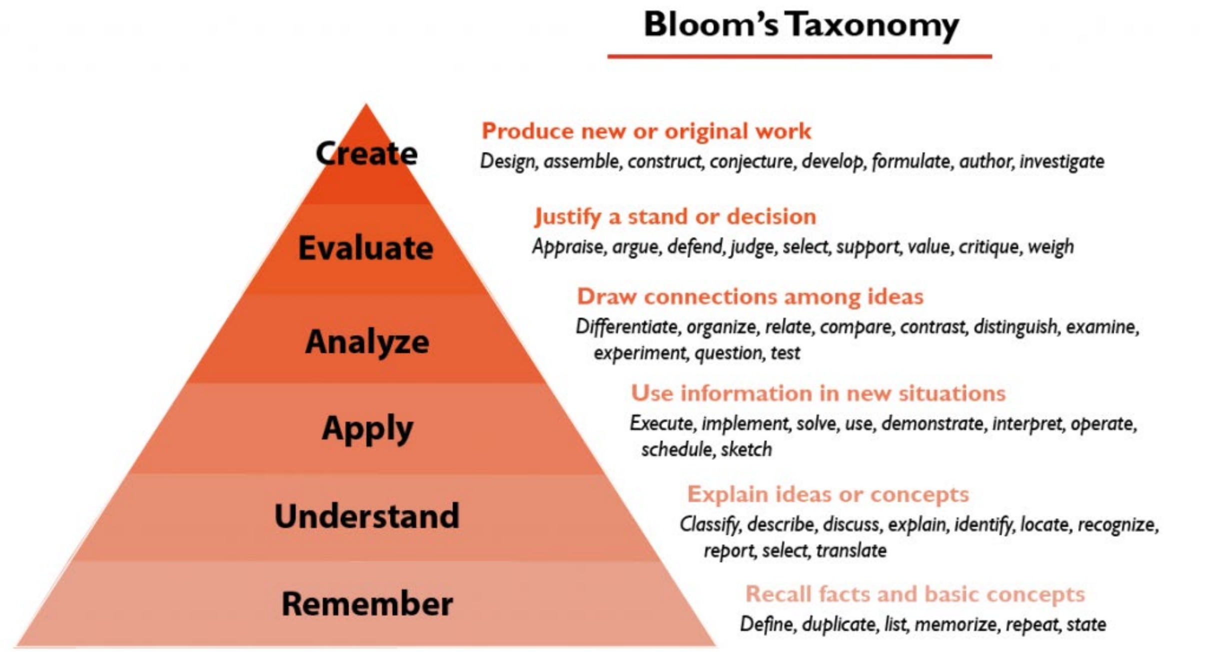

Figure 2. Illustration of Bloom's revised taxonomy for the cognitive domain, with higher order thinking skills at the top of the diagram – adapted from (The Vanderbilt University Center for Teaching, 2021).

In GRE@T-PIONEeR, teachers push the students to develop as high as possible thinking skills. Higher order thinking skills are triggered when students are given the possibility to utilize the concepts they were introduced to. This requires from the teachers designing some engaging activities in which the students are actively involved, during which active learning takes place. The main incentive is the fact that one learns much better by doing and experiencing oneself, a principle called in everyday' s jargon "learning by doing". Practice is the essence in reaching higher order thinking skills in Bloom's revised taxonomy.

Many definitions of active learning exist. The one generally accepted is given by Felder and Brent (2014) as follows: “Active learning is anything course-related that students in a class session are called on to do other than simply watching and listening to a lecture and taking notes.”

Many active learning techniques exist. A non-exhaustive list of examples is given in the GRE@T-PIONEeR deliverable D1.1 – Section 7.4 (Jaiyeola A. et al., 2021).

3.2. Flipping to increase pedagogical support

In order to make room for such activities, a flipped classroom is used, with the traditional delivery of lecture-based contents moved outside of the classroom: lecture and materials usually presented in class are instead made available to the students on the web and before (Bishop and Verleger, 2013).

In the flipped classroom model, students learn asynchronously as they can choose when and at what pace to watch/read the course material. In contrast to the traditional teaching format, low order thinking skills are practiced during this asynchronous phase before the students meet the teachers and other students for synchronous interactions. Therefore, the time spent with the teachers can be used more effectively to engage students in high order thinking activities, clarify difficult concepts and provide individual support.

Since the students attend the synchronous sessions much better prepared than in a traditional teaching set-up, flipped classrooms were demonstrated to lead to much better learning outcomes and to contribute to a deeper learning compared to traditional teaching (Bishop and Verleger, 2013; O’Flaherty and Phillips, 2015). The key aspect of flipped classrooms is freeing time in the classroom to organise engaging activities with the students under the teacher’s supervision, thus favouring active learning.

Another advantage of the above teaching set-up with respect to synchronous versus asynchronous learning is the possibility for the teachers to gather data about student learning before they meet the students for synchronous interactions. As a result and making use of a Just-in-Time-Teaching (JiTT) philosophy (Watkins and Mazur, 2010), the teachers are able to adjust their synchronous teaching sessions to the students’ needs. This further improves student learning.

3.3. Course package structure

The overall methodology for the course implementation relies on the following elements:

- *Handbooks* covering the theoretical aspects of the covered topics.
- *Pre-recorded lectures* (or *webcasts*) available for on-demand viewing and extracting the main features, results, and concepts of the handbooks. The webcasts are recorded with the teacher’s voice and, when possible and relevant, video, while using on-screen annotations, thus making the webcasts vivid.

- *Online quizzes* associated with the webcasts, focusing on conceptual understanding, with immediate feedback to the students on their learning. The quizzes are designed in such a way that thinking skills beyond merely remembering concepts are triggered, including the applying, analysing, and evaluating concepts in Bloom's revised taxonomy. Such active learning elements encourage a deep approach to learning. Moreover, embedding quizzes in the pre-recorded webcasts allows for splitting of the lectures (webcasts) into smaller chunks, increasing student attention and thus improving the conditions for learning. As an additional benefit, the quizzes allow the teachers to continuously monitor students' comprehension of key concepts.
- The possibility to *pose questions* to the teachers while watching the lectures. When possible, students are offered to rate, on a voluntary basis, the pre-recorded lectures and to provide comments. Such comments, at the lecture level, provide meaningful information about student learning and can also be used to improve the design of the handbooks, videos, and quizzes.
- *Active learning sessions* in forms of wrap-up and tutorials with synchronous interactions between the students and the teachers. Various active learning methods are implemented depending on the topics and the set-up of that particular course moment. Using JiTT, the synchronous sessions are also designed to address the students' needs.
- Use of *discussion fora* monitored by the teachers. The fora are utilised as a post-class activity to maintain engagement, favour collaboration between students and are also used for providing additional feedback and help to the students.

The entire management of all electronic resources is done via the Learning Management System (LMS) SOUL from Tecnatom (Smart Open Universe of Learning).

All the collected information – the answers to the quizzes, the questions sent to the teachers, the rating of the pre-recorded webcasts, as well as additional comments provided by the students – are used to prepare the synchronous sessions designed to meet the students' needs, building on the concept of JiTT. The sessions contain four key parts: 1) providing a brief summary of the key concepts and their relation to the structure of the covered topic so that the students could relate the details to the overall picture, thus favouring a more holistic approach to learning; 2) answering the questions that the teachers received; 3) going through the quizzes in an interactive way and discussing different alternatives; and 4) going through specifically designed activities, exercises, tutorials or hands-on training. This last part of the synchronous sessions constitutes the most important part, both in terms of devoted time and impact on student learning. Moreover, this last part of the wrap-up sessions is where the degree of interaction between the students and teachers is highest.

For each of the studied topics, the learning sequence for the students is made of several parts, as illustrated in Figure 3. The first ones include studying the handbooks, watching the webcasts, and completing the online quizzes. Interactions with the teachers are only possible in an asynchronous fashion, using the communication channels of the LMS. Synchronous interactions become possible during the synchronous sessions. Various active learning techniques are used in such synchronous sessions, representing the course moments during which the students and the teachers interact the most. Finally, the students apply, analyse, and evaluate the studied concepts while solving assignments, thus using high order thinking skills in Bloom's revised taxonomy. Although the biggest part of the assignments is solved during the interactive sessions, the students may be given some extra time to finalize the assignments after the sessions. Discussion fora are also used for peer-instruction, with interventions from the teachers when necessary.

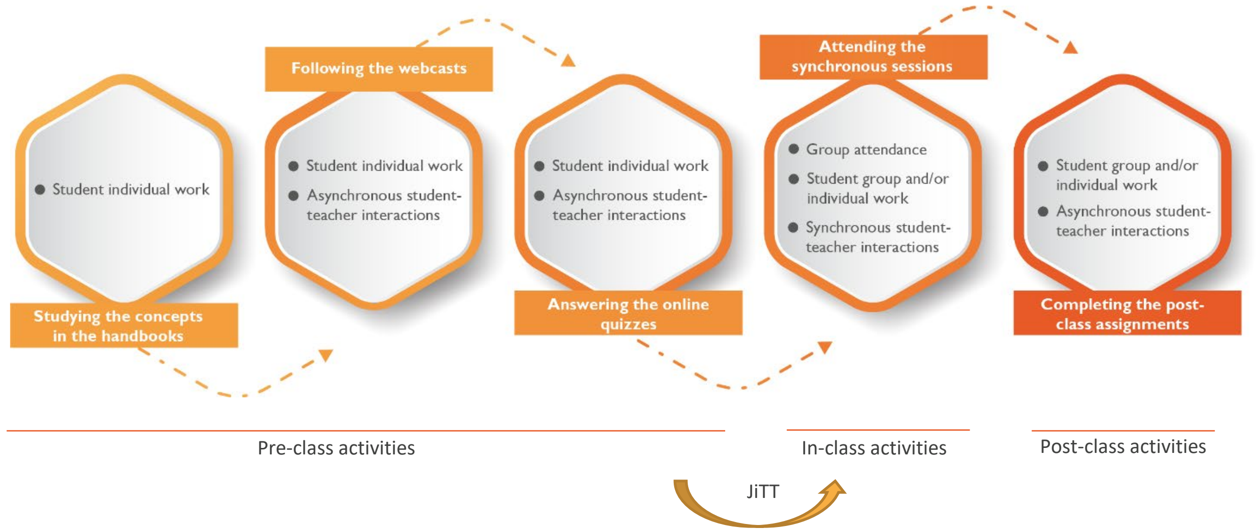

Figure 3. Illustration of the learning sequence.

Hands-on training sessions are split into two categories. The first category typically corresponds to wrap-up sessions, discussions, tutorials, code usage and method implementation and are organized separately for each course module. The second category represents hands-on training exercises organized on one of the training reactors available to the consortium (CROCUS at EPFL, Switzerland; AKR-2 at TU Dresden, Germany; BME Training Reactor at BME, Hungary). It should be emphasized that such hands-on exercises are common to all course modules and are organized as a one week to ten days session given after all course modules were given.

The pre-class activities represent roughly one week of full-time studies. Likewise, the in-class activities also represent one week of full-time studies. The course modules are thus worth 3 European Credit Transfer and Accumulation System (ECTS) each. The attendance of the hands-on activities on the training reactors gives some extra ECTS depending on the length of the corresponding sessions.

Moreover, in GRE@T-PIONEeR, the synchronous sessions of the first category are offered in a hybrid learning environment: students can decide to travel to the host organisation for following the synchronous sessions, or they can follow such sessions remotely on the web. The synchronous sessions are organised in specifically designed interactive teaching rooms: one available at Chalmers University of Technology, Sweden (Demazière et al., 2017) and one at Universitat Politècnica de València, Spain. Such rooms are furnished with movable chairs, tables, and whiteboards enabling the use of a more student-centred pedagogical approach. This is of significance when a flipped classroom model is implemented, so that the in-class activities can focus on higher order thinking skills. In addition, the rooms are equipped with audio and video hardware and software that allow synchronous interactions between the on-site and off-site participants in form of digital content sharing, audio interactions, and video communication.

Such teaching rooms allow for courses to be offered to remote students in a pure virtual learning environment without any need to travel. The rooms make offering the synchronous sessions to both the on-site and off-site attendees possible. Furthermore, the two audiences can interact with each other.

The planning of the different hands-on sessions is summarized in Table 1.

Table 1. Summary of the synchronous hands-on training sessions.

WP	Course module	Week number/year	Location
2	Nuclear data for energy and nonenergy applications	46/2022 (November 14-18, 2022)	UPV, Spain (+ possible remote attendance)
3	Neutron transport at the fuel cell and assembly levels	50/2022 (December 12-16, 2022)	CHALMERS, Sweden (+ possible remote attendance)
4	Core modelling for core design	2/2023 (January 9-13, 2023)	UPV, Spain (+ possible remote attendance)
5	Core modelling for transients	6/2023 (February 6-10, 2023)	UPV, Spain (+ possible remote attendance)
6	Reactor transients, nuclear safety and uncertainty and sensitivity analysis	10/2023 (March 6-12, 2023)	UPV, Spain (+ possible remote attendance)
7	Radiation protection in nuclear environment	13/2023 (March 27-31, 2023)	CHALMERS, Sweden (+ possible remote attendance)
2-7	Exercises at AKR-2	April 2023 (+ backup in August/September 2023)	TUD, Germany (only some of the course elements will be made available to remote attendees)
2-7	Exercises at CROCUS	End of May/beginning of June 2023 (+ backup in September 2023)	EPFL, Switzerland (only some of the course elements will be made available to remote attendees)
2-7	Exercises at BME Training Reactor	June 2023 (+ backup in August/September 2023)	BME, Hungary (only some of the course elements will be made available to remote attendees)

4. Overall contents of the developed handbooks

Two handbooks have been specifically developed in WP4.

4.1. Handbook on steady-state neutron transport at the core level

The first handbook covers the two approaches than can be used for neutron transport simulation at the core level: deterministic methods and probabilistic methods, including all the approximations on which such simulations rely. The handbook consists of an introduction and two technical chapters and amounts to 63 pages.

- Chapter 1, "*Introduction*" (2 pages). In this chapter, the techniques used for modelling nuclear reactor systems are briefly introduced. Two approaches are touched upon: the deterministic approach and the Monte Carlo approach. The details of the techniques are presented in subsequent chapters.
- Chapter 2, "*Deterministic core modelling*" (37 pages). This chapter presents the main techniques used for determining the full core solution in steady-state conditions. Assuming that a set of macroscopic data representative of each fuel assembly constituting the core is available as function of burnup, instantaneous variables and history variables, various modelling techniques are presented. Depending on the choice of the angular discretization and of the spatial discretization, respectively, different methods exist and are presented in this chapter. Once the angular and spatial discretization schemes are chosen, the full core solution can be determined using a set of embedded iterative schemes, the innermost one aimed at resolving the angular and spatial distribution of neutrons within each of the energy groups considered.
- Chapter 3, "*Monte Carlo methods*" (24 pages). Monte Carlo methods are based on sampling probability distributions with the help of quasi random numbers. When applied for particle transport it is often considered as the simulation of random physical processes with known distributions. This approach is called analogous Monte Carlo. However, in a more general view the Monte Carlo methods are numerical methods which are used predominantly for the determination of integrals involving probability distributions. As such it can also be used for the solution of integral equations, like the one describing particle transport processes. This chapter of the book introduces this more theoretical, non-analogous approach to Monte Carlo methods. It presents the concept of integration and solution of integral equations by Monte Carlo methods, the Monte Carlo game to solve the Boltzmann transport equation and, based on that, the estimators for the particle flux and related quantities.

The table of contents of the handbook is as follows.

Table of contents of the Handbook on steady-state neutron transport at the core level

4.2. Handbook on core design and operation

The second handbook outlines the main principles for the design and operation in steady-state conditions of Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR), with emphasis on the guidelines for an optimal planning and surveillance of operational manoeuvres.

A member of the End Users Group, Ms. Raquel Suárez Hontoria, an engineer from the Spanish Nuclear Power Plant Almaraz, participated very actively in the revision of the handbook chapters related to PWR, providing very valuable feedback.

The handbook consists of an introduction and eight technical chapters and amounts to 160 pages:

- Chapter 1, "*Introduction*" (7 pages). This chapter introduces definitions, terms and abbreviations commonly used when illustrating the design and operation in steady-state conditions of PWR and BWR, and used in the rest of the handbook.
- Chapter 2, "*PWR core design and operation*" (41 pages). This chapter illustrates the steady-state operation of PWR. To that end, a typical 3-loop Westinghouse-type PWR has been chosen as reference case to describe the main characteristics of a PWR core and to present realistic parameters along operation. In particular, the core description, fuel assembly data and operation conditions correspond to the first cycle of Almaraz-II Spanish Nuclear Power Plant (NPP), whose specifications were published in the 90's by the IAEA as part of an international benchmark and are publicly available at the IAEA website. Some of the information given in this chapter is similar to the curves and tables that can be found in the nuclear design report of a NPP, where the most important parameters of the core are presented to allow the plant operation during the desired lifetime ensuring compliance with safety limits.
- Chapter 3, "*PWR technical specifications*" (15 pages). This chapter presents the Technical Specifications to be satisfied during the normal operation of a PWR to assure cladding and fuel integrity during normal and transient operations as well as to minimize fuel damage during postulated accidents.

- Chapter 4, "*PWR operational maneuvers*" (16 pages). This chapter presents the main aspects to be considered for the monitoring and analysis of operational maneuvers in PWR in a baseload operation mode. Guidelines for an optimal planning of maneuvers are given, aiming to satisfy three goals: safety (compliance with the technical specifications), minimum waste generation and maximum availability. The problem of xenon oscillations in PWR triggered by power distribution perturbations is analyzed as well. Representative maneuvers for a typical 3-loop Westinghouse-type PWR at equilibrium cycle are illustrated.
- Chapter 5, "*PWR incore fuel management*" (16 pages). This chapter introduces the role of the in-core fuel management to operate a PWR power plant safely and economically. The different types of fuel loading patterns are examined. In addition, core designs, fuel assembly designs and burnable absorber designs different from the ones illustrated in Chapter 2 along with current trends are presented to provide a more general picture of PWR design and operation.
- Chapter 6, "*BWR core design and operation*" (29 pages). This chapter illustrates the steady-state operation of BWR and presents the main parameters to be tracked during operation. The section starts by describing the GEN-II BWR characteristics, identifying the differences between the BWR and the PWR designs, with special emphasis on the cross-section dependences and multi-scale aspects of these types of reactors. The second part of the section describes the elements that comprise a lattice physics code used to generate cross-section data for nodal codes, where the nodal codes are used to model the coupled neutronics and thermal-hydraulics behaviour of the entire reactor core during steady-state operation.
- Chapter 7, "*BWR technical specifications*" (10 pages). This chapter presents the Technical Specifications to be satisfied during the normal operation of a BWR to assure cladding and fuel integrity during normal and transient operations as well as to minimize fuel damage during postulated accidents. In this chapter the reader will learn about the physical parameters that must be constantly monitored since they are related to thermal limits. The section also presents the thermal limits established to allow the plant operation during the desired lifetime ensuring compliance with safety limits: the Dryout, the Peak Cladding Temperature, the Critical Power Ratio, the Linear Heat Generation Rate, and the Average Planar Linear Heat Generation Rate limit.
- Chapter 8, "*BWR operational maneuvers*" (16 pages). This chapter presents the main aspects to be considered for the monitoring and analysis of operational maneuvers in a BWR. Details of power control using the recirculation flow rate during steady operation are given, with the consequently thermalhydraulic and nuclear variations in the core. Moreover the chapter presents the guidelines for the optimal planning of maneuvers during plant startup and shutdown operation in which the balance between power, pressure, and flow rate is crucial.
- Chapter 9, "*BWR incore fuel management*" (10 pages). This chapter introduces the role of the in-core fuel management to operate a BWR power plant safely and economically. Different types of fuel assembly designs and core designs are presented to provide a more general picture of BWR design and operation. Details about loading patterns are also provided in the chapter.

The table of contents of the handbook is as follows.

Table of contents of the Handbook on core design and operation

5. Overall contents of the hands-on training exercises

As earlier mentioned, the hands-on training exercises are divided into a one-week long set of synchronous session specific to the considered WP and three sets of hands-on activities common to all WP and offered at each of the training reactors – see Section 3.3 and Table 1.

The details of the WP-specific hands-on exercises during the synchronous sessions are detailed in Table 2, whereas the planning of the activities is given in Table 3.

Table 2. Description of the hands-on exercises offered during the WP-specific synchronous sessions.

Exercise	Responsible organization/ person	Format	Background knowledge	Restrictions
Neutronics of a one-dimensional heterogeneous reactor in multi-group diffusion theory + inner/outer iterations + acceleration methods	CHALMERS/ Christophe Demazière	Hybrid Using MATLAB Grader	Provided in the T4.1 handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
Use of deterministic codes (demonstration of a deterministic model for CROCUS)	BME	**Arranged in connection with the experimental hands-on at BME** Using SPNDYN Onsite Possibility of hybrid format (audio/video sharing)	Provided in the T4.1 handbook	4-5 participants/ group with max. 2 groups in parallel
	EPFL/ Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	**Arranged in connection with the experimental hands-on at EPFL** Using PARCS Possibility of hybrid format (audio/video sharing)	Provided in the T4.1 handbook	Max. 4-6 onsite participants
Use of Monte Carlo codes	BME	**Arranged in connection with the experimental hands-on at BME** Using OpenMC	Provided in the T4.1 handbook	4-5 participants/ group with max. 2 groups in parallel

		Onsite Possibility of hybrid format (audio/video sharing)		
(demonstration of a Monte Carlo model for CROCUS	EPFL/ Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	**Arranged in connection with the experimental hands-on at EPFL** Using Serpent Possibility of hybrid format (audio/video sharing)	Provided in the T4.1 handbook	Max. 8 onsite participants
(demonstration of a Monte Carlo model for AKR-2)	TUD/Carsten Lange and Alexander Knospe	**Arranged in connection with the experimental hands-on at TUD** Using Serpent Possibility of hybrid format (audio/video sharing)	Provided in the T4.1 handbook	Max. 8 onsite participants
Exercises on core designs and core operational problems to gain physical understanding (control rod worth, boron worth, reactivity coefficients, xenon oscillations, partial reloading strategies)	CHALMERS/ Christophe Demazière	Hybrid Using CASMO/SIMULATE complemented by simple analytical models	Provided in the T4.1 handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
BWR Peach Bottom exercises	UPV/Rafa Miró	Hybrid Using POLARIS as lattice code and PARCS/TRACE (or PARCS/PATH) for steady-state core simulations	Provided in the T4.2 handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
PWR Almaraz-II NPP exercises	UPM/Nuria García-Herranz	Hybrid Using tables and curves similar to the ones to be found in the Nuclear Design Report of the NPP	Provided in the T4.2 handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants

Table 3. Planning of the various activities during the WP-specific synchronous sessions.

Day 1	Day 2	Day 3	Day 4	Day 5
Start of the course: introduction of the teachers and participants, schedule for the week (1 h)	Use of core modelling tool: investigation of given phenomena and comparison with analytical consideration (4 h)	Steady-state neutron transport core modelling using Monte Carlo methods: interactive discussions (4 h)	Core design and operation on PWR: interactive discussions and hands-on exercises (4 h)	Core design and operation: hands-on exercises (4 h)
Deterministic core modelling: interactive discussions on overall strategy + traditional methods (3 h)	Deterministic core modelling: hands-on on SP3 code (3 h)	Monte Carlo modelling: hands-on exercise on OpenMC (3 h)	Core design and operation on BWR: interactive discussions (3 h)	Closing of the course: course certificates and course evaluation (1 h)
Method implementation: development of a 1-D multigroup neutronic solver (3 h)				

The details of the hands-on exercises on the training reactors are given in Table 4.

Table 4. Description of the hands-on exercises offered during the hands-on exercises on the training reactors.

Exercise	Responsible organization /person	Format	Background knowledge	Restrictions
Control rod calibration at AKR-2	TUD/Carsten Lange and Alexander Knospe	3 h to one day Onsite Possibility of hybrid format (audio/video sharing)	Dedicated set of lecture notes provided	Max. 8 onsite participants
Critical experiment at AKR-2	TUD/Carsten Lange and Alexander Knospe	3 h to one day Onsite Possibility of hybrid format (audio/video sharing)	Dedicated set of lecture notes provided	Max. 8 onsite participants
Radial neutron flux distribution	TUD/Carsten Lange and	3 h to one day Onsite Possibility of hybrid	Dedicated set of lecture	Max. 8 onsite participants

measurements at AKR-2	Alexander Knospe	format (audio/video sharing)	notes provided	
Measurements of radial/axial traverses with fission chambers at CROCUS	EPFL/ Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	4 h Onsite Possibility of hybrid format (audio/video sharing + remote control of acquisition systems)	Basics in reactor physics and radiation matter interaction	Max. 4-6 onsite participants
Measurements of control rod worth at CROCUS	EPFL/ Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	4 h Onsite Possibility of hybrid format (audio/video sharing + remote control of acquisition systems)	Basics in reactor physics and radiation matter interaction	Max. 4-6 onsite participants
Measurements of axial thermal flux distribution (Dy wire irradiation) at the BME Training Reactor	BME	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/ group with max. 2 groups in parallel Radiation protection briefing required before entire the first time
Criticality experiment/rod calibration (with fuel movement) at the BME Training Reactor	BME	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/ group with max. 2 groups in parallel Radiation protection briefing required before entire the first time
Determination of kinetic parameters using Feynman-alpha measurements at different levels of subcriticality at AKR-2	TUD/Carsten Lange and Alexander Knospe	3 h to one day Onsite Possibility of hybrid format (audio/video sharing)	Dedicated set of lecture notes provided	Max. 8 onsite participants
Determination of kinetic parameters	EPFL/ Alessandro	4 h	Basics in reactor	Max. 4-6 onsite participants

using branching noise measurements at CROCUS	Scolaro, Vincent Lamirand and Mathieu Hursin	Onsite Possibility of hybrid format (audio/video sharing + remote control of acquisition systems)	physics and radiation matter interaction	
Measurement of the moderator temperature coefficient (heating up of the coolant) at the BME Training Reactor	BME	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/ group with max. 2 groups in parallel Radiation protection briefing required before entire the first time
Estimation of the effective fraction of delayed neutrons by the Feynman method at the BME Training Reactor	BME	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/ group with max. 2 groups in parallel Radiation protection briefing required before entire the first time

6. Conclusions

As demonstrated in this report, the handbook on core modelling for core design was developed as a collective effort between different teachers and is already available. Likewise, the planning and content of the corresponding synchronous sessions were established. Beyond the development of such sessions, the coming months will also be devoted to the development of the webcasts, quizzes and on the structuring of all electronic resources on the LMS.

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