Multi-Physics of Nuclear Reactors

This course is focused on reactor multi-physics methods and techniques for multi-dimensional reactor analysis. It consists of five major topics: fundamentals of reactor multi-physics; short-time multi-physics phenomena in nuclear reactor cores; simplified multi-physics modeling; traditional multi-physics modeling; and novel multi-physics modeling. The theory lectures and assignments will be complemented with demonstration exercises and examples.

16 hours (within 3-4) days

By the end of the course, the students would be able to: (1) Understand multi-physics interactions in reactor systems; (2) Define and classify time phenomena in nuclear reactors; (3) Differentiate between prompt and delayed neutron behavior; (4) Explain feedback mechanisms; (5) Apply space-time multi-physics methods; (6) Interpret verification and validation techniques for multi-physics simulations and uncertainty quantification in multi-physics modeling.

• Course Objectives

By the end of this course, the student should be able to understand and apply the concepts and principles of:

- Multi-Physics Interactions in Reactor Systems;
- Time Phenomena in a Nuclear Reactor;
- Prompt and Delayed Neutron Behavior;
- Feedback Mechanisms;
- Space-Time Multi-Physics Methods;
- Verification and Validation of Multi-Physics Simulations;
- Uncertainty Quantification in Multi-Physics Modeling.

• Course Requirements

In class quizzes: five quizzes
Homework: three assignments.

• Required Textbook

No required textbook; class-notes and reading material will be provided.

• Reference Textbooks

1. K. Ott and R. Neuhold, Introductory Nuclear Reactor Dynamics, American Nuclear Society, 1985 (ISBN: 0-894-48029-4) or any new edition of this book
2. W. M. Stacey, Nuclear Reactor Physics, John Wiley & Sons, 2001 (ISBN: 0- 471-39127-1) or any new edition of this book

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• Instructors

Dr. Maria Avramova, Professor
Dr. Kostadin Ivanov, Professor

Multi-Physics of Nuclear Reactors
COURSE OUTLINE

Topic # 1 - Introduction & Fundamentals of Reactor Multi-Physics		***Assignments***
Lecture 1 (L1)	Multi-Physics of Nuclear Reactors Basic Topics and Nomenclature Time-Dependent Phenomena in Nuclear Reactors Multi-Physics Interactions in Reactor Core Classification of Multi-Physics Modeling and Simulation Tools	
Topic # 2 - Short-Time Multi-Physics Phenomena in Reactor Core		
L2	Dynamic Equation & Simplified Neutron Cycle Prompt and Delayed Neutrons Total Delayed Neutron Yields & Yields of Delayed Neutron Groups Emission Spectra of Delayed Neutrons Theoretical Background for Calculation of Kinetics Data	***Quiz #1***
L3	Preliminary Formulation of the Point Kinetics: *Prompt Neutron Balance Equation* *Intuitive Point Kinetics Equation* *One-Group Point Kinetics Equation* Reactivity in the Exact PKEs; Effective Delayed Neutron Fractions Point Reactor Model	***Quiz #2*** **Homework 1 (HW1)**
L4	Prompt Reactivity Feedback Phenomena: Core Power Models and Fuel Temperature Calculations Prompt Reactivity Feedback Phenomena: Transient at Small Times Prompt Reactivity Feedback Phenomena: Asymptotic Transients	***Quiz #3***
L5	Super prompt-Critical Excursion Following Step Reactivity Insertion Super prompt-Critical Excursion Following Ramp Reactivity Insertions	**HW2**
L6	Delayed Reactivity Feedback Phenomena: Moderator / Coolant Feedback Effects Reactor Noise and Instabilities; General Reactor Stability	
Topic # 3 – Simplified Multi-Physics Modeling		
L7	Pre-Traditional Multi-Physics Coupling Schemes Thermal-Hydraulics Codes with Point Kinetics Models	**HW3**
L8	Neutronics Core Simulators with 1-D Thermal-Hydraulics Models Neutronics and Thermal-Hydraulics Models in Fuel Performance Codes	
Topic # 4 - Traditional Multi-Physics Modeling		
L9	3D Nodal Kinetics Models in Thermal-Hydraulic Analysis	***Quiz #4***
L10	Heat Conduction and Fuel Rod Modeling in Subchannel and System Thermal-Hydraulic Codes	
L11	Space-Energy Dependent Dynamics: General Discussion of the Dynamics Problem; Flux Factorization	
L12	Space-Energy Dependent Dynamics: Quasi-Static Methods	***Quiz #5***

	& Dynamic Reactivity Coefficients	
L13	Coupled Thermal-Hydraulics and Neutronics Simulations	
Topic # 5 – Novel Multi-Physics Modeling		
L14	High-Fidelity Neutronics, Thermal-Hydraulics and Fuel Performance models; Feedback Parameters	
L15	Spatial & Temporal Coupling - Multi-Physics Platforms	
L16	Verification and Validation of Multi-Physics Simulations Uncertainty Quantification in Multi-Physics Modeling	