University of California, Berkeley
Department of Nuclear Engineering

NE-150 Introduction to Nuclear Reactor Theory (4 units)

Spring 2018

Lectures:	Tu Th 12:30 - 2:00 pm, 247 Cory
Discussion Groups:	Group I: W 12 -1 pm, 88Dwinelle Group II: F 12 -1 pm, 31 Evans

Instructor:	Prof. Jasmina Vujic, 4113 Etcheverry Hall, 643-8085, vujic@nuc.berkeley.edu
Office Hours:	Wednesdays, 3:00-4:00 pm, 4113 Etcheverry Hall
GSI:	Mitchell Negus, mitchell_negus@berkeley.edu, Office hours: TBD
Reader:	Brandon Kuhert, brandonkuhnert@berkeley.edu, Office hours: TBD

Prerequisites: Mathematics 53 and 54, NE-101 Nuclear Reactions and Radiation

The course uses the following knowledge and skills from prerequisite and lower-division courses:

- Solutions of linear, first, and second order differential equations.
- Vector calculus, special functions (Bessel functions, Exponential integrals).
- Basic nuclear physics.
- Basic interaction of radiation with matter, and concepts of cross sections.

Catalog Description:

Neutron interactions, nuclear fission, chain reaction in thermal and fast nuclear reactors. Diffusion and slowing down of neutrons. Criticality condition and calculations of critical concentrations, mass and dimensions. Nuclear reactor kinematics and reactivity feedbacks. Production and transmutation of radionuclides in nuclear reactors.

Textbook:

E. Lewis, "Fundamentals of Nuclear Reactor Physics," Academic Press (2008)

References:

1. J.R. Lamarsh, "Introduction to Nuclear Reactor Theory," 3rd edition, Prentice Hill (2001)
2. J. J. Duderstadt and L. J. Hamilton, "Nuclear Reactor Analysis," Wiley (1976)

Grading

Problem sets	40%;
Midterm Exam (2)	15% +15% = 30%
Final Exam	30%
Extra Credit	Participation in discussions
Late submission policy:	-20% the first day, -30% the following day, -40% the following day, etc.

Class Computer Lab Accounts:

All students will get class computer lab accounts at DECF.
The Davis Etcheverry Computing Laboratory: http://www.decf.berkeley.edu/
DECF computer laboratories: 1171 an 1111 Etcheverry Hall
License for MCNP6 is obtained through RSICC: http://rsicc.ornl.gov/Registration.aspx

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Course Outline

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Neutron interactions, nuclear fission, chain reaction in thermal and fast nuclear reactors. Diffusion and slowing down of neutrons. Criticality condition and calculations of critical concentrations, mass and dimensions. Nuclear reactor kinematics and reactivity feedbacks. Production and transmutation of radionuclides in nuclear reactors.

Course Objectives

- Review those aspects of neutron interactions with matter that are pertinent to understanding the establishment of a chain-reaction and of the neutron space- and energy-distribution in the nuclear reactor core.
- Show how the complex neutron transport and slowing-down processes can be described by simple, though approximate, analytical models.
- Develop the students' insight and understanding of neutron-related phenomena in nuclear reactors.
- Show how to quantify the space-dependence, energy-dependence and time-dependence of the neutron population.
- Acquaint the students with the neutronic design considerations and design constraints of nuclear reactors.
- Illustrate, with examples drawn from various reactor and other neutronic systems, how nuclear reactor theory can be used to quantify the behavior of these system under various conditions.
- Acquaint students with the specific features of different types of nuclear reactors, with particular emphasis on light water reactors (LWRs).

Topics Covered

- General description of nuclear reactors and statistics about worldwide nuclear power production.
- Review of the basic of neutron interactions: possible types of interactions; consequences of these interaction; interaction probability; microscopic and macroscopic cross sections, cross-section systematics; cross-section data.
- Slowing-down of neutrons: elastic scattering mechanics; energy loss; average logarithmic energy decrement; slowing-down time; effect of inelastic scattering; collision and slowing-down densities; resonance absorption.
- Fission chain reaction: chain reaction in thermal and fast systems; the four- and six-factor formulas; nuclear fuels; conversion and breeding.
- Neutron spectra: thermal equilibrium; typical neutron spectrum in thermal and fast reactors; effective spectrum averaged cross-sections; resonance integrals.
- Introduction to neutron diffusion theory: neutron flux and current, equation of continuity, Fick's law, transport corrections; the diffusion equation for monoenergetic neutrons, boundary conditions; elementary solutions of the steady-state diffusion equation, solutions for multiplying media, multi-group diffusion equations; solution of the two-group diffusion equation.
- Nuclear reactor theory: one-group reactor equation, criticality conditions; effect of reflectors; determination of critical concentration, dimension and mass; heterogeneity effects: fuel lumping and control-absorber lumping; calculation of thermal utilization, resonance escape probability, and fast fission factor.
- Point reactor kinetics: point reactor kinetics equations; prompt neutron lifetime; effect of delayed neutrons; definition and units of reactivity, the asymptotic reactor period versus changes in reactivity.
- Reactivity variations in operating reactors: effects of fuel and coolant temperature change; effect of coolant voiding; effect of fission products; effect of fuel depletion; BOL excess reactivity requirements for different reactor types.
- Methods for compensation of reactivity variations: control rods; coolant inlet temperature; chemical shim; burnable poison; in-core fuel management.