MIE407H1F/1129H – Nuclear Reactor Theory & Design Fall 2023

Outline

A first course in nuclear reactor theory, which introduces students to the principles of nuclear fission chain reactions and lays a foundation for the application of these principles to the nuclear design and analysis of reactor cores. Topics covered include basic nuclear concepts, nuclear fission, neutron propagation and interaction with matter, neutron thermalization, the diffusion model of a nuclear reactor, criticality, the multigroup neutron diffusion equation, reactivity effects, and nuclear reactor kinetics.

Syllabus

Topic	Description
1	The atomic nucleus, stability of isotopes, radioactive decay, binding energy, nuclear reactions, and nuclear fission.
2	Parameters describing the interaction of neutrons with matter, including cross-sections, neutron flux, and reaction rates.
3	Propagation of a neutron beam in a passive medium. Mean free path. Scalar neutron flux, and neutron current.
4	The one-speed neutron diffusion equation.
5	Solution of the neutron diffusion equation for passive media with an external neutron source.
6	Elastic scattering kinematics.
7	Slowing down of neutrons in a thermal nuclear reactor.
8	Neutron multiplication factors, critical state, bare homogeneous spherical reactor, geometric buckling, and the criticality equation.
9	Homogeneous thermal reactors. Fermi age, four- and six-factor formula, and neutron migration length.
10	Inhomogeneous reactors. Neutron spectrum in fast and thermal reactors. Reflected spherical reactor.
11	Multigroup theory. Solution of the multigroup neutron diffusion equation. The transverse leakage approximation and the zero-dimensional solution.
12	Reactor kinetics. Point kinetics equation, neutron lifetime, and delayed neutrons. Solution of the point kinetics equation. The inhour equation.
13	Reactivity feedback.
14	Nuclear fuel depletion.

References

J.R. Lamarsh, *Nuclear Reactor Theory*, American Nuclear Society, LaGrange Park, 2002.

J.P. Ligou, *Elements of Nuclear Engineering*, Routledge, New York, 2008.

A.E. Waltar *et al.*, *Fast Spectrum Reactors*, Springer, New York, 2012.

Evaluation

	Undergraduates	*Graduates*
Problem sets	30%	20%
Numerical problem†		10%
Midterm test	30%	30%
Final examination	40%	40%

† Numerical solution of the multigroup neutron diffusion equations.

Prerequisites

All mathematical formulations will be explained in the lectures. However, students are expected to have good knowledge of differential and integral equations. The course will be taught at a level appropriate for masters-level students with reduced expectations for senior undergraduates.

Important Sessional Dates

Lectures:	Thursdays	noon -2 pm	BA-B025
	Fridays	1-3 pm	BA-B025
Tutorials:	Mondays	11 am - 12 noon	BA-2159

Duration: Thursday, September 7 - Wednesday, December 7

Add/Drop: Wednesday, September 20 / Monday, November 6

Fall Study Break: Monday, November 6 – Friday, November 10

Teaching Staff

Instructor: (Dr.) Julian Lebenhaft, P.Eng. julian.lebenhaft@utoronto.ca

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