NSE
Nuclear Science and Engineering
science : systems : society
MIT

Spring 2016

22.S902
NEUTRON TRANSPORT THEORY
MONOENERGETIC 1D ANALYTICAL/NUMERICAL SOLUTIONS

3-0-9 Graduate Credit
TuTh 9:30 to 11:00AM
in 24-121

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Course Description

Neutron transport theory is a delicate blend of mathematics, numerical methods and computational strategies describing interactions of neutrons and nuclei best introduced in a 1D, monoenergetic setting. The simplicity of 1D monoenergetic neutron transport enables analytical solutions through a variety of mathematical approaches including Fourier and Laplace transforms, analytical recurrence, singular integral equations and eigenfunctions and coupled first order ODEs-- to name a few. While the mathematics yields the necessary analytical solution representations, numerical evaluation of these representations allows a full investigation of the 1D transport equation.

Course Objectives and Outcomes

The primary objective of the course is to acquaint students with various forms of the 1D transport equation, their origin and analytical properties and solutions including numerical evaluation. Special emphasis is given to generating highly precise numerical solutions, called benchmarks.

At the conclusion of the course, the student should be able to

+ Derive different forms of the 1D monoenergetic neutron transport equation
+ Construct analytical solution representations
+ Create a variety of numerical procedures for evaluation
+ Computationally implement the procedures
+ Deliver high quality verified benchmarks

Tentative course content by section*

+ Introduction of the mathematics, physics and origins of the neutron transport equation — ~6 Lectures
  - Reduction to the monoenergetic form
  - Reduction to 1D
+ Solution in an infinite medium — ~6 Lectures
  - Fourier transform solution
  - Case's method (?)
+ Solution in the half-space — ~4 Lectures
  - Invariant embedding (?)
  - Integral transport theory
+ Solution in a slab — ~6 Lectures
  - F_N Singular integral equation
  - Discrete ordinates
+ Time-dependent solutions in an infinite medium — ~3 Lectures
  - Fourier/Laplace transform
  - Multiple collisions
+ Monoenergetic solutions beyond 1D (?) — ~2 Lectures
  - Curvilinear geometries
  - Multi-D
  - Multigroup

* Each section (after the first) includes a presentation and demonstration of numerical methods through special in-class or programming exercises for hands on demonstrations.

Application of knowledge gained

The course material will find use in various forms. First, knowledge of analytical solutions increases one's awareness of what is available for prediction. While analytical solutions to idealized transport scenarios do not necessarily apply directly to operating nuclear systems, they do provide guidance and estimation. However, the most widespread use of the course material will be for the generation of benchmarking standards to which one compares results from proposed or legacy numerical algorithms, enabling operational testing and overall performance assessment of an algorithm.

Course Preparation

Students are expected to be familiar with reactor physics and mathematics including vector calculus, ODEs, linear algebra and complex variables. In addition, students should be familiar with common numerical methods and know how to program in at least one programming language (e.g., FORTRAN, C, C++, MATLAB™, MATHEMATICA™). Finally, students should come prepared for a challenge with an open mind and an expectation to learn new material related to what they already know.

Course Format

The course will meet 3 hours per week. There will be weekly homework or team project assignments totaling 9 hours per week-estimated effort. The assignments will be derivations, coding and solutions to problems. For the majority of the material, notes will be made available online.

Grading

Grades are based on performance on homework and team projects. In addition, one or two informal office consultations will be scheduled, where several general course related questions will be asked and the answers assessed.

References:

1. *Analytical Benchmarks for Nuclear Engineering Applications*, B. Ganapol, OECD © 2008, NEA No. 6292, Organisation for Economic Co-operation and Development (https://www.oecdnea.org/databank/docs/2008/db-doc2008- 1.pdf)
2. B. D. Ganapol, *The Infinite Medium Green's Function of Monoenergetic Neutron Transport Theory via Fourier Transform: REVISITED,* Nuclear Science and Engineering / Volume 180 / Number 2 / June 2015 / Pages 224-246. Technical Paper / dx.doi.org/10.13182/NSE14-55
3. B. D. Ganapol, *Chandrasekhar Polynomials and the Solution to the Transport Equation in an Infinite Medium*, V43, Issue 1-7, 2014.
4. *Nuclear Reactor Theory*, G. Bell and S. Glasstone, Van Norstrand and Reinhold, NY, 1970.