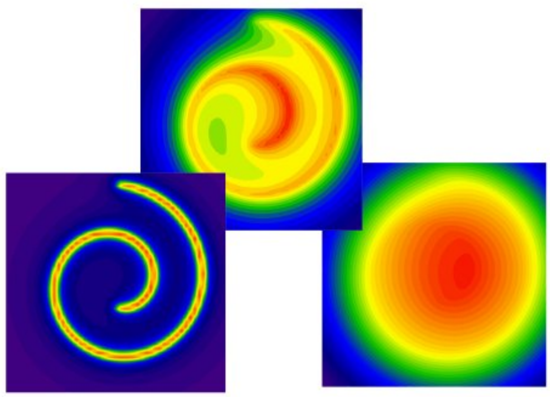
Contact Mrs. C. ROCHER-THROMAS (programs@oecd-nea.org)
to register and for further information

A SHORT COURSE
on
ONE-DIMENSIONAL ANALYTICAL METHODS FOR VERIFICATION OF NEUTRON TRANSPORT ALGORITHMS



OECD/NEA
Paris, France
18-22 June 2018

Instructor: B.D. Ganapol
Professor
Department of Aerospace and Mechanical Engineering
University of Arizona
Ganapol@cowboy.arizona.edu

Visiting Professor
Department of Nuclear Engineering
Texas A&M University
Bganapol@tamu.edu

Course Text: *Analytical Benchmarks for Nuclear Engineering Applications*
B. Ganapol, OECD © 2008, NEA No. 6292
Organisation for Economic Co-operation and Development

Reference Texts: *Nuclear Reactor Theory*
G. Bell and S. Glasstone, Van Norstrand and Reinhold
NY, 1970

COURSE MOTIVATION

The study of the neutron transport equation is a delicate blend of theoretical mathematics, numerical methods and computational strategies describing the interaction of neutrons and nuclei. Not only do we gain valuable physical insight from solutions of the transport equation, but we also create new analytical and numerical methods. Neutron transport theory, regarded as a branch of applied mathematics, can play a significant role in the design and analysis of nuclear systems. For instance, highly precise numerical evaluation of analytical solutions to the transport equation serve as standards, called benchmarks, providing verification of numerical methods and coding of comprehensive algorithms for reactor analysis. With the passage of time however, ever-increasing computational advances and success of Monte Carlo probabilistic transport, analytical methods of neutron transport theory is fast becoming a theory of the past.

The solution of the transport equation has been considered by some of the most creative and accomplished scholars of our time, including S. Chandrasekhar, E. Wigner, G. Plazcek, K. Case, N. Weiner and P. Zweifel to name only a few. During the 60's and into the 70's, there was hardly an issue of *Nuclear Science and Engineering* or *Annals of Nuclear Energy* that did not contain at least two articles on the subject. Now, such articles are relatively infrequent at best and an ever-decreasing number are found primarily in applied mathematics journals. Understandably, we are in danger of losing a beautiful and elegant theory, which, along with introducing analytical 1D benchmarks, is the primary reason for offering a course on analytical methods in neutron transport theory.

In this course, we will concentrate on transforming theoretical solution representations of the 1D neutron transport equation into numerically useable forms to generate highly precise solutions. While 1D theory is an idealized theory, it does provide meaningful features of transport solutions to enable benchmarking of neutron transport algorithms. As will be demonstrated, 1D solutions can also provide 2D and 3D solutions.

COURSE OBJECTIVES

The main course objective is to provide a basis for understanding the fundamental concepts of numerical evaluation of the solutions of the 1D neutron transport equation. Included will be recent theoretical as well as numerical advances in analytical benchmarking. Course attendees will become familiar with

+ derivation of the 1D transport equation and its various forms
+ 1D analytical solutions and convergence acceleration
+ numerical solutions yielding high order precision
+ development of semi-analytical benchmarks

…. and more.

To facilitate the course objectives, specially designed exercises encourage participants to engage in the physics and numerical methods used in generating semi-analytical benchmarks. In addition, several lessons have GUIs illustrating the programs in the suite of benchmarks that accompany the text. In this way, participants become acquainted with the accompanying benchmark library as well as experience the satisfaction of solving several relevant problems of analytical transport theory.

APPLICATION OF COURSE KNOWLEDGE

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 1D- neutron transport scenarios do not necessarily apply directly to operating nuclear systems, they do provide guidance regarding operation of portions of a system. 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-- thus enabling operational testing of an algorithm as well as overall assessment of performance. To this end, as emphasized, the course includes several demonstrations of analytical benchmarks as well as exercises in analytical benchmarking practice.

COURSE PREPARATION

Participants should be familiar with reactor physics and the operation of nuclear systems. In addition, familiarity with mathematics through vector calculus and linear algebra is expected. The participant should also be familiar with elementary numerical methods and have some experience with computer programming. Finally, participants should come with an open mind awaiting new information.

COURSE CONTENT

We will consider neutron transport theory starting from the general to the specific of 1D transport theory. The course will cover the following topics:

The derivation of the neutron transport equation	**(~ 4 Hours)**
Multigroup theory	**(~ 3 Hours)**
Green's functions in the PN and BN approximations	**(~ 5 Hours)**
Monoenergetic reactor theory	**(~ 6 Hours)**
Multidimensional transport theory	**(~ 4 Hours)**

Each participant will receive a copy of the textbook and a commemorative flash drive with the current analytical benchmark library and additional benchmarks.