Particle Transport Theory, Methods and Applications
NSEG 6124

I -- Catalogue Description

The course discusses neutral particle interactions and related cross sections, Linear Boltzmann equation in “forward” and “adjoint” forms and their applications, perturbation and variational techniques for particle transport problems, different numerical methods for solving the linear Boltzmann equation, limitations of these methods for solving real-life problems, and discussion on parallel and serial implementations. Pre: 5124 (3H, 3C).

Course Number: 6124

ADP TITLE: Par. Trans Theo., MTh. & Appl.

II - Learning Objectives

Having successfully completed this course, the student will be able to:

- Understand processes resulting in neutral particles interactions with matter, and associated probability of interactions and differential and integral cross sections for different types.
- Effectively derive the necessary formulations for multi-variable differential cross-sections and their use.
- Understand the concept of multigroup cross sections and their generation methods and related issues
- Recognize the general Boltzmann equation, and understand its relation to the Linear Boltzmann Equation (LBE)
- Derive the Linear Boltzmann Equation (LBE) (integro-differential form), and understand its limitations, impact/role of various terms, boundary conditions, and issues related to solving the equation
- Derive the diffusion equation starting from LBE, and therefore understand situations in which diffusion equation is invalid.
- Understand the difference between neutron and gamma transport, and therefore the terms in LBE
- Derive the adjoint linear Boltzmann Equation using the adjoint function property
- Derive the “importance” function equation, and understand its relation to the “forward” and adjoint LBE. understand its limitations, impact/role of various terms, boundary conditions, and issues related to solving the equation
- Understand the physical meaning of the importance function, and its use for solving various real-world problems
- Understand the concept of linear perturbation theory and its limitations through derivation of a formulation for determination of change in reactor eigenvalue
- Understand the concept of variational methods in reactor analysis, and derive a formulation corresponding to a detector response, and how the method facilitate reactor analysis

- Derive the integral from of LBE from the integro-differential form, and understand its use and limitations for solving problems
- Derive analytical and semi-analytical formulations for integral LBE used for simple problems.
- Derive numerical formulations in 1-D using the Pn method, and understand its limitations, boundary conditions, and difficulties in 3-D geometries
- Derive the Simplified Pn (SPn) equations in multi-dimension geometries
- Understand the concept of Double Pn (DPn), its use for derivation of DPn equations in 1-D, and its limitations in multi-dimensional geometries
- Understand the concept of discrete ordinates (Sn), derive Sn equations in 1-D Cartesian and curvilinear geometries based on various spatial differencing schemes, and for different boundary conditions
- Derive the numerical formulation based on the method of characteristic for solving the integral LBE
- Discuss various hybrid techniques for solving real problems in real times
- Understand the limitations of the Sn method, and issues related to its numerical accuracy and convergence
- Derive different acceleration schemes, and angular quadrature types
- Understand the importance of parallel computing for solving LBE

III - Justification

Neutral Particle transport is encountered in all nuclear systems including reactors, detection systems for safety, security and safeguards, and radiation diagnostics, radiation therapy, and nuclear medicine. This requires NSEG 5124 as a prerequisite in which various concepts and formulations are introduced considering diffusion approximation. It is intended primarily for those who would become specialists in various areas such as particle transport methods and neutronics, reactor physics, radiation protection and shielding in nuclear systems, design of nondestructive detection and imaging systems, design of radiation-based medical devices. Mastery of this material provides the background for creating new concepts necessary for developing new systems and devices, and development more effective computational methods and codes. Moreover, the extensive treatment of neutral particle transport computational methods also provides an important component of the background necessary for specialists in astrophysics, and thermonuclear plasmas.

IV - Prerequisites and Corequisites

5124

V - Texts and Special Teaching Aids

- Lecture notes & handouts
- "Computational Methods of Neutron Transport," by E. E. Lewis and W.F. Miller, 1984, American Nuclear Society (optional)
- "Nuclear Reactor Theory," by G.I. Bell and S. Glasstone, 1970, Van Nostrand Reinhold Company (optional)
- "Methods for Steady-State Reactor Physics in Nuclear Design by R.J.J. Stammler and M.J. Abatte, 1983, Academic Press (optional)

VI - Syllabus

Topic	% of Course
Cross Sections	10
The Linear Boltzmann Equation (LBE) and its application for neutral particle (i.e., neutron and gamma) transport	13
The adjoint LBE, "importance" function and its applications	20
Introduction to linear perturbation theory and variational methods for particle transport	13
Integral form of the Boltzmann equation and its use for solving simple problems	7
Numerical methods and their associated issues for solving the Boltzmann equation	
· Pn & Simplified Pn (SPn)	7
· Double Pn (DPn)	3
· Discrete ordinates (Sn)	13
· Method of Characteristics (MOC)	3
· Hybrid methods	3
Introduction to acceleration methods for the Sn methods	2
Introduction to techniques for generation of quadrature sets for the Sn methods	2
Brief discussions on convergence, stability, and accuracy of the Sn methods	2
Brief discussion on parallel computing algorithms for Sn methods	2