

# Solution of the 3D Neutron Diffusion Benchmark by FEM

A. V. Avvakumov<sup>1</sup>, P. N. Vabishchevich<sup>2</sup>, A. O. Vasilev<sup>3(✉)</sup>,  
and V. F. Strizhov<sup>2</sup>

<sup>1</sup> National Research Center Kurchatov Institute, Moscow, Russia

<sup>2</sup> Nuclear Safety Institute of RAS, Moscow, Russia

<sup>3</sup> North-Eastern Federal University, Yakutsk, Russia  
haska87@gmail.com

**Abstract.** The objective is to analyze the neutron diffusion benchmark developed by the Atomic Energy Research community for verification of best-estimate neutronics codes. The 3D benchmark of Schulz models a VVER-1000 core in steady state. The assemblies are homogeneous, represented by given diffusion theory parameters. There are seven material compositions including four enrichments, burnable absorber, control rods and a reflector. The finite element method on tetrahedron computational grids is used to solve the three-dimensional neutron problem. The software has been developed using the engineering and scientific library FEniCS. The matrix spectral problem is solved using a scalable and flexible toolkit SLEPc. The solution accuracy of the benchmark is analyzed by condensing the computational grid and varying the degree of the finite elements.

## 1 Introduction

The physical processes in a nuclear reactor [1] depend on the distribution of the neutron flux, whose mathematical description is based on the neutron-transport equation [2, 3]. The equation, describing the process is of integro-differential form and the required distribution of neutrons flux depends on time, energy, spatial and angular variables. As a rule, simplified forms of the neutron transport equation are used for practical computations of nuclear reactors. The system of equations obtained by the multigroup diffusion approach is often used for reactor analysis [4, 5] and is applied in most engineering calculation codes.

The processes in a nuclear reactor are essentially non-stationary. The stationary state of neutron flux, which is related to the critical state of the reactor, is characterized by local balance between the neutron generation and absorption. This boundary state is usually described by the solution of a spectral problem (Lambda Modes problem,  $\lambda$ -eigenvalue problem) provided that the fundamental eigenvalue (the maximal eigenvalue) that is called  $k$ -effective of the reactor core, is equal to unity. In this case, the stationary neutron flux is a corresponding eigenfunction. Computations of  $k$ -effective of the reactor using the Lambda Modes problem are obligatory for reactor design calculations.

# Duderstadt Manual Solution Nuclear

**Ivan Lirkov, Svetozar Margenov**



## **Duderstadt Manual Solution Nuclear:**

*Fundamentals of Nuclear Engineering* Brent J. Lewis, E. Nihan Onder, Andrew A. Prudil, 2017-06-19 Fundamental of Nuclear Engineering is derived from over 25 years of teaching undergraduate and graduate courses on nuclear engineering. The material has been extensively class tested and provides the most comprehensive textbook and reference on the fundamentals of nuclear engineering. It includes a broad range of important areas in the nuclear engineering field: nuclear and atomic theory, nuclear reactor physics, design, control, dynamics, safety, and thermal hydraulics; nuclear fuel engineering and health physics; radiation protection. It also includes the latest information that is missing in traditional texts such as space radiation. The aim of the book is to provide a source for upper level undergraduate and graduate students studying nuclear engineering.

*Physics of Nuclear Reactors* P. Mohanakrishnan, Om Pal Singh, K. Umasankari, 2021-05-19 Physics of Nuclear Reactors presents a comprehensive analysis of nuclear reactor physics. Editors P. Mohanakrishnan, Om Pal Singh, and Kannan Umasankari, and a team of expert contributors combine their knowledge to guide the reader through a toolkit of methods for solving transport equations, understanding the physics of reactor design principles, and developing reactor safety strategies. The inclusion of experimental and operational reactor physics makes this a unique reference for those working and researching nuclear power and the fuel cycle in existing power generation sites and experimental facilities. The book also includes radiation physics, shielding techniques, and an analysis of shield design, neutron monitoring, and core operations. Those involved in the development and operation of nuclear reactors and the fuel cycle will gain a thorough understanding of all elements of nuclear reactor physics, thus enabling them to apply the analysis and solution methods provided to their own work and research. This book looks to future reactors in development and analyzes their status and challenges before providing possible worked-through solutions.

Cover image: Kaiga Atomic Power Station, Units 1 & 4, Karnataka, India. In 2018, Unit 1 of the Kaiga Station surpassed the world record of continuous operation at 962 days. Image courtesy of DAE, India. Includes methods for solving neutron transport problems, nuclear cross-section data, and solutions of transport theory. Dedicates a chapter to reactor safety that covers mitigation, probabilistic safety assessment, and uncertainty analysis. Covers experimental and operational physics with details on noise analysis and failed fuel detection.

Nuclear Science Abstracts, 1975

**Reactor Physics Calculations For Applications In Nuclear Technology - Proceedings Of The Workshop** Dermott E. Cullen, R. Muranaka, J. J. Schmidt, 1991-01-30 This workshop was designed to meet the needs of those currently involved in or are planning a nuclear programme involving research and/or power fission reactors. The workshop had a broad scope including not only fission reactor core calculations but also safety, fuel management, waste disposal, reactor licensing. The lectures and computer exercises covered almost all aspects of the operation of fission reactors. This workshop introduced participants to the methods currently used in fission reactor calculations and to some computer codes in which these methods are used.

**Large-Scale Scientific Computing** Ivan Lirkov, Svetozar Margenov, 2018-01-10 This book constitutes

the thoroughly refereed post conference proceedings of the 11th International Conference on Large Scale Scientific Computations LSSC 2017 held in Sozopol Bulgaria in June 2017 The 63 revised short papers together with 3 full papers presented were carefully reviewed and selected from 63 submissions The conference presents results from the following topics Hierarchical adaptive domain decomposition and local refinement methods Robust preconditioning algorithms Monte Carlo methods and algorithms Numerical linear algebra Control and optimization Parallel algorithms and performance analysis Large scale computations of environmental biomedical and engineering problems The chapter Parallel Aggregation Based on Compatible Weighted Matching for AMG is available open access under a CC BY 4.0 license *Transactions of the American Nuclear Society* American Nuclear Society,1981 **A Nodal Method for Multigroup, Multidimensional Nuclear Reactor Dynamics with Thermal-hydraulics Feedback** Thuy Trong Le,1990 **Nuclear Science and Engineering** ,1993 **Introduction to Nuclear Reactor Kinetics** Daniel Rozon,1998 *Computational Methods in Reactor Shielding* James Wood,2013-10-22 *Computational Methods in Reactor Shielding* deals with the mathematical processes involved in how to effectively control the dangerous effect of nuclear radiation Reactor shielding is considered an important aspect in the operation of reactor systems to ensure the safety of personnel and others that can be directly or indirectly affected Composed of seven chapters the book discusses ionizing radiation and how it aids in the control and containment of radioactive substances that are considered harmful to all living things The text also outlines the necessary radiation quantities and units that are needed for a systemic control of shielding and presents an examination of the main sources of nuclear radiation A discussion of the gamma photon cross sections and an introduction to BMIX a computer program used in illustrating a technique in identifying the gamma ray build up factor for a reactor shield are added The selection also discusses various mathematical representations and areas of shielding theory that are being used in radiation shielding The book is of great value to those involved in the development and implementation of systems to minimize and control the dangerous and lethal effect of radiation *Computational Solid Mechanics For Oil Well Perforator Design* Wen Ho Lee,2018-06-05 This book presents the computational methods for solving the solid mechanic problems in the oil well perforator design Both Lagrangian and Eulerian methods are used to solve the pertinent stress strain equations and the shock wave running through the materials Seven good performance oil well perforators and two conical shaped charges for defeating the reactive armor are included in this book as references The computer programs written in Fortran for the calculation of high explosive burn time and burn distance shear modulus and yield strength for many materials as well as MATLAB plotting programs for many perforators are available online as supplementary materials for the book **Time Dependent Neutronics Studies in Inertial Confinement Fusion** Fred Beranek,1978 [Subject Guide to Books in Print](#) ,2001 [A Half Century of Health Physics](#) Michael T. Ryan,John W. Poston, Sr.,2006-03-30 Jubil umsskrift udgivet i anledning af Health Physics Society s 50 rs jubil um Bogen indeholder oversigtsartikler omhandlende en række radiologiske

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**Analysis of Transmutation Analysis Problems** Adimir dos Santos,1984      **Proceedings of the International Topical**  
**Meeting on Advances in Mathematical Methods for the Solution of Nuclear Engineering Problems, Hilton**  
**International München, April 27-29, 1981 ...** ,1981      **Boiling Water Reactor In-core Probe Analysis** Mark Richard  
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