Spring 2024

NE 501-601
Reactor Analysis and Design
(Distance Education Course)

Instructor's Name: Dr. Dmitriy Y. Anistratov
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On-Campus Class Schedule: TuTh 4:30 - 5:45 pm (EST)
Office Hours: by appointment

- **Course Structure:** Lectures, 2 75 minute classes per week
- **Text (required)**: *Nuclear Reactor Analysis*, J.J. Duderstadt and L.J. Hamilton, John Wiley & Sons, 1st edition, 1976 (to check the price and order the book of the preferable form and condition go to http://shop.bookstore.ncsu.edu/).
- **Course website**: https://wolfware.ncsu.edu/
- **Teaching Assistant** :
  - Yesim Kutlu (ykutlu@ncsu.edu)
- **Prerequisites**
  - NE 401: MA 401, *C*- or better in NE 301, and CSC 112
  - NE 501: NE 520, MA 401, and CSC 112
  - knowledge of a computer language (Fortran, MATLAB, Phyton) and basic programming skills
- **Course Description**

  Elements of nuclear reactor theory for reactor core design and operation. Includes multi-group neutron transport and diffusion models, analytical and numerical criticality search, and flux distribution and calculations for homogeneous and heterogeneous reactors, slowing down models, introduction to perturbation theory. Credit for both NE 401 and NE 501 is not allowed.
- **Student Learning Outcomes**

  By the end of the semester, students will be able to:
  - apply the basic physical and mathematical models of particle transport that are behind basic theory of nuclear reactors
  - interpret the areas of application of these models,
  - apply these models for analysis of model reactors
  - perform basic calculations of flux distribution and criticality parameters (eigenvalues).

- **Major Topic**

1. Differential scattering cross section
   (a) The solid angle
   (b) The differential scattering cross section in angle
   (c) The differential scattering cross section in energy
   (d) The double differential scattering cross section
2. Introduction to neutron transport theory
   (a) Derivation of the time- and energy-dependent 3D neutron transport equation as a detailed particle conservation law
   (b) Concepts of the neutron angular density function, angular flux, scalar flux, current and their physical interpretations
   (c) Boundary and initial conditions for the transport equation
   (d) The transport equation for some special cases
   (e) The k-eigenvalue problem for the transport equation
   (f) The neutron transport equation for 1D slab geometry
   (g) The solution of the 1D slab geometry transport equation with the known total source term
   (h) The concept of the angular flux $\psi^{(n)}$ of neutrons that have had exactly n collisions and the equations for $\psi^{(n)}$.
   (i) The multigroup transport equations
3. Foundation of neutron diffusion theory
   (a) Derivation of the time-dependent one-speed 3D diffusion equation from the transport equation
   (b) Boundary and initial conditions for the diffusion equation
   (c) The analytic solution of the time-dependent one-speed 1D slab geometry diffusion equation for a homogeneous reactor
   (d) The k-eigenvalue problem for the diffusion equation
      i. Eigenvalues and eigenfunctions
      ii. The multiplication factor and fundamental mode
      iii. 1D slab bare homogeneous reactor
      iv. 3D parallelepiped bare homogeneous reactor
   (e) Multigroup diffusion equations
      i. Derivation of the multigroup diffusion equations
      ii. Group-averaged cross sections for the multigroup diffusion equations
   (f) Two-group diffusion equations
   (g) Numerical methods for solving the multigroup diffusion equations
      i. an iteration method for solving multigroup diffusion equations
      ii. Discretization of the diffusion equation in 1D slab geometry

4. Introduction to neutron slowing down theory
   (a) The slowing down equation for an infinite homogeneous medium
   (b) Two-body kinematics, elastic scattering
   (c) s-wave, p-wave
   (d) Slowing down in hydrogen with no absorption
   (e) Slowing down for an isotope with $A > 1$ with no absorption
   (f) Slowing down in hydrogen with massive absorber
   (g) Slowing down for an isotope with $A > 1$ with resonance absorption
5. Introduction to perturbation theory
   (a) Functions, inner products, operators
   (b) Adjoint operator, adjoint equations
   (c) A detector response problem
   (d) A perturbation problem for evaluating a variation of a detector response in case of 1D slab geometry one-speed diffusion theory
   (e) First-order perturbation theory for evaluating a variation of the multiplication factor

- **Recommenced books**
  - W. Stacey, Nuclear Reactor Physics,
  - R. A. Rydin, Nuclear Reactor Theory and Design,
  - P. F. Zweifel, Reactor Physics,
  - A. Henry, Nuclear Reactor Analysis,
  - K. O. Ott and W. A. Bezella, Introductory Nuclear Reactor Statics.

- **Grading**

  The grading will go as follows:

Homeworks:	45%
Computational project:	10%
Midterm exam:	20%
Final exam:	25%

- **Grading Scale**:

$95 \leq A+ \leq 100$	$85 \leq B+ < 88$	$75 \leq C+ < 78$	$65 \leq D+ < 68$	$F < 57$
$90 \leq A < 95$	$80 \leq B < 85$	$70 \leq C < 75$	$60 \leq D < 65$	
$88 \leq A- < 90$	$78 \leq B- < 80$	$68 \leq C- < 70$	$57 \leq D- < 60$	

- **Schedule of Exams**
  - Midterm Exam: February 27, 2024
  - Final exam: April 30, 2024

- **Class Assignments**
  - All class assignments must be submitted electronically at Moodle space https://wolfware.ncsu.edu/ before the announced deadlines.
  - It is planned to give assignments that will be due during the last week of the semester.
  - The grade for an assignment submitted with a delay will change in the following way:
    * less than 24 hours after the deadline: -21%
    * more than 24 hours after the deadline: -41%

- **Honor Pledge**

  Your name or signature on any test or assignment indicates "I have neither given nor received unauthorized aid on this test or assignment."

- **Academic Honesty**

  See http://policies.ncsu.edu/policy/pol-11-35-01 for a detailed explanation of academic honesty.

- **Academic Integrity**

  Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at http://policies.ncsu.edu/policy/pol-11-35-01.

- Conversion from letter grading to credit only (S/U) grading is subject to university deadlines. Refer to the Registration and Records calendar for deadlines related to grading. For more details refer to http://policies.ncsu.edu/regulation/reg-02-20-15.

- **Policies on Incomplete Grades**

  If an extended deadline is not authorized by the instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student.

- **Missed Examinations and Quizzes**

  If you miss an examination or quiz without either a certified medical excuse or prior instructor approval, it will result in zero points for this exam or quiz.

- **Guidelines for Audio/Video Recording and Photography**

  Audio recording, video recording, and photography are not allowed in class.

- **Online class evaluations**

  All evaluations are confidential; instructors will not know how any one student responded to any question, and students will not know the ratings for any instructors.

  More information about ClassEval: https://oirp.ncsu.edu/classeval/

- **Statement for students with disabilities**

  Students with disabilities are invited to schedule an appointment with the instructor to discuss academic accommodations. "Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the Disability Services Office at Suite 2221, Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG02.20.01)". (http://policies.ncsu.edu/regulation/reg-02-20-01)

- **Statement on Transportation:** n/a

- **Statement on Safety and Risk Assumption:** n/a

- **Attendance Policies:** The course policies are consistent with NCSU attendance regulation (NCSU REG02.20.03).

- **N.C. State Polices, Regulations, and Rules (PRR)**

  "Students are responsible for reviewing the NC State University PRR's located at http://oucc.ncsu.edu/course-rights-and-responsibilities which pertains to their course rights and responsibilities. The URL's of pertinent PRR's is as follows:

  - Equal Opportunity and Non-Discrimination Policy Statement
    http://policies.ncsu.edu/policy/pol-04-25-05
  - Code of Student Conduct
    http://policies.ncsu.edu/policy/pol-11-35-01
  - Grades and Grade Point Average
    http://policies.ncsu.edu/regulation/reg-02-50-03
  - Credit-Only Courses
    http://policies.ncsu.edu/regulation/reg-02-20-15
  - Audits
    http://policies.ncsu.edu/regulation/reg-02-20-04