Fall 2025

NRE 4210

Nuclear Reactor Theory

Location	Boggs 3-47 (seminar room)
Time	TR, 9:30–10:45 pm
Instructor	Dan Kotlyar
Office Location	Virtual (Teams/Zoom) ; Boggs 3-73
Office Hours	TR 2:00–3:00 pm, (by appointment)
E-mail	dan.kotlyar@me.gatech.edu

Course Description: This course covers the physical theory of nuclear reactors.
Prerequisites: NRE 3208 (Intro Reactor Phys.), MATH 2403 (Differential Equations)
Credit Hours: 3

Textbook: *Nuclear Reactor Analysis*, **Authors** J. Duderstadt and L.J. Hamilton; Wiley (1976)
Reference: *Nuclear Reactor Physics*, **Author** W.M. Stacey; Wiley (2007)
Reference: *Applied Reactor Physics*, **Author** A. Hebert; Presses Internationale Polytechnique (2016)

Course Objectives:
At the completion of this course, students will be able to:

1. Explain the relationships among variables underlying the theory of nuclear fission reactors using mathematical models and their associated physical behaviors.
2. Solve static reactor physics problems in one-speed and multi-group diffusion theory and the concepts related to group cross sections in the thermal, resonance, and fast energy regions.
3. Analyze reactor kinetic and dynamic problems using point kinetics and quantify the cause and effect of core composition changes.
4. Master various numerical tools to solve differential equations.
5. Understand the approach to the full core solution. The course will present the direct and the 2-stage methods.
6. The students should understand the important feedback mechanisms that must be considered in solving full core problems.

Grade Distribution:

Assignments $\times(4)$	16%
Project $\times(6)$	73%
Final Exam	11%

Tentative Breakdown of Assignments:
Home assignments can be hand-written.

1. (4%)Transport equation.
2. (5%)Delayed neutrons and point kinetic equations (PKEs)
3. (3%)Depletion and fission product poisoning.
4. (4%)Multi-group Diffusion.

Tentative Breakdown of Projects:
Projects must be all typed and submitted in a pdf format.

1. (10%)Numerical, multi-region and one-group-energy diffusion, solver.
2. (13%)Point kinetics with dynamic analysis.
3. (8%)Depletion analysis (Bateman equations).
4. (14%)Energy Condenser.
5. (14%)Numerical, multi-region and multi-energy diffusion, solver.
6. (14%)Slowing down theory.

General submission instructions:

1. Hand-writing is allowed for home assignments (not projects), however figures must be scientifically plotted. No sketching is allowed.
2. Submission must be through a single file, which must be properly submitted via Canvas.
3. If requested, supplementary material must also be submitted in a separate/additional file (or files).

Course Policies:

- **General**
  - Students are expected to attend classes in-person. Virtual (Teams/Zoom) invitations will be distributed before every office hours.
  - Lecture (incomplete) notes are provided before each class. These notes will assist you to follow the lecture while completing the missing equations.
  - Interactive workshops will be provided in advance.
  - Office hours will be conducted virtually.
- **Assignments**
  - Students are expected to work independently. Offering and accepting solutions from others is an act of plagiarism, and all involved parties will be penalized according to the Academic Honesty Policy. Discussion among students is encouraged, but when in doubt, direct your questions to the professor.
  - No late assignments will be accepted under any circumstances, unless communicated with me in advance.
  - You must make sure the assignments are properly scanned and submitted via Canvas.
  - Only a single pdf file is allowed to be submitted, unless instructed otherwise. The file name must include the assignment number and your name (e.g. NRE4210_SOL4_FirstLast.pdf)

- **Attendance and Absences**
  - Students are responsible for all missed work, regardless of the reason for absence. It is also the absentee's responsibility to get all missing notes or materials.
  - The office hours is a great opportunity to explain any material that was not well understood or missed.

Honor Code:

Scholastic Dishonesty is any act designed to give an unfair academic advantage to a student, or the attempt to commit such an act. This includes copying from another student's exam; possessing or using unauthorized materials during an exam; using, buying, stealing, transporting or soliciting a test or the answer key; collaborating with another student during a test; copying someone else's homework or assignment; and permitting someone to take a test for you. The falsification of academic records is also an act of scholastic dishonesty. Students who participate in scholastic dishonesty will be reported and dealt with in accordance with Institute regulations. Specific instructions will be provided on projects. Specific instructions will be given when the project(s) is assigned as to what is acceptable interaction between student teams. The complete Georgia Tech Honor Code is found at http://www.policylibrary.gatech.edu/student-affairs/academic-honor-code.

Mental Health & Wellness:

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, depression, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. GT offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know is experiencing any of the issues noted above, consider utilizing the confidential mental health services available on campus. I encourage you to reach out to GT CARE (www.care.gatech.edu, 404-894-3498) or the Counseling Center (www.counseling.gatech.edu, 404-894-2575) for support. An on-campus counselor or after-hours services are available to assist you.

Tentative Course Outline:
The weekly coverage might change as it depends on the progress of the class.

Topic	Content
Topic 0	**Mathematics relevant for reactor physics** 1st and 2nd order ODEs, Laplace transform,etc.
Topic 1	**Introduction to transport theory** Derivation of the transport equation, solutions in 1-D geometry,derivation of diffusion equation from transport theory, the one-speed diffusion equation, differential scattering cross-sections.
Topic 2	**Unbalanced core** Delayed neutrons, kinetic equations, solution of the point reactor kinetics equations, the inhour equation. Analysis with one-group of delayed neutrons, reactor period, reactivity insertion, prompt critical conditions.
Topic 3	**Reactivity control** This section will also include review of 4- and 6-factor formulas, Inherent reactivity effects, and control mechanisms.
Topic 4	**Reactor dynamics** Control theory and stability, dynamic systems, stability of feedback systems, temperature and density feedback, reactor dynamics with feedback.
Topic 5	**Fuel burnup** Changes in fuel composition, fuel depletion, transmutation and decay chains, burnup equation, Xe and Sm poisoning
Topic 6	**Multi-group diffusion theory** Derivation of the multi-group equations, solution principles of multi-group diffusion equation, criticality calculations, diffusion equation in 2 energy groups, numerical solution of the multi-group problem.
Topic 7	**Group constants** Slowing down of neutrons, energy dependent flux solutions in various media.
Topic 8	**Thermal spectrum and cross sections** Maxwell-Boltzman distribution, neutron thermalization and thermal spectrum analysis.
Topic 9	**Fast spectrum and cross sections** Slowing down in vicinity of resonances, Resonance absorption and fast group constants.