NPRE 455: Neutron Diffusion and Transport

Class Time:	1:30 – 3:20, Tu/Th
Class Location:	138 Henry Administration Building
Instructor:	Prof. April Novak ajnovak2@illinois.edu
Teaching Assistants:	Harun Ardiansyah, haruna2@illinois.edu Nathan Glaser, nglaser3@illinois.edu Eli Capps, ecapps2@illinois.edu
Office Hours:	Monday: **4:00–5:00**, 131 Talbot (Prof. Novak) Tuesday: **4:00–6:00**, 131 Talbot (Eli) Wednesday: **10:00–12:00**, 131 Talbot (Nathan) **4:00–5:00**, 131 Talbot (Harun) Thursday: **3:30–5:00**, 131 Talbot (Harun)
Course Pages:	`https://canvas.illinois.edu/courses/53971`
Required Text:	*Nuclear Reactor Analysis*, J. Duderstadt and L. Hamilton

Course Description: Neutron migration, neutron slowing down and thermalization; neutron continuity equation, multigroup diffusion theory, homogeneous and heterogeneous medium, thermal and fast assemblies; numerical methods for multigroup diffusion equations; **Monte Carlo methods**; reactor dynamics, ~~perturbation theory~~; reactivity coefficients; introductory transport theory.

Course Communication: All course materials (e.g., homework assignments) and announcements will be sent through Canvas. Please make use of the office hours for getting help and for Q&A on lecture material, homework, computer projects, exams, policy, etc. But note that TAs, graders, and instructors are generally only available during standard business hours (e.g. 8 am – 5 pm), so plan ahead. Please refrain from email unless absolutely necessary – questions which require a substantial response should be asked during lecture and office hours.

For any requests for re-grading, submit that request directly through Gradescope (not as an email).

Prerequisites: This course builds upon your past learning, and requires proficiency in:

- NPRE 247, introductory nuclear physics concepts (e.g., *Fundamentals of Nuclear Science and Engineering*, J. K. Shultis and R. E. Faw). We will review the essentials during NPRE 455 lectures, but we will move quickly.
- MATH 285, differential equations (e.g., *Differential Equations and Boundary Value Problems*, C. H. Edwards and D. E. Penney). Additional reading materials are provided on Canvas as a refresher.

- CS 101, programming (e.g., *Effective Computation in Physics*, A. Scopatz and K. Huff). Any programming language is acceptable for the computer projects in this class. That said, for those who would like a refresher, the instructor will provide additional review of Python.

Learning Objectives: Upon completion of this course, students will be able to:

- Explain the neutron transport equation and understand its approximations (e.g., energy, angle, space, time)
- Derive the neutron diffusion equation and apply it to fixed source and multiplying media, using both analytical and numerical solution approaches
- Solve for the time-dependent behavior of multiplying systems, and apply to problems in fission reactor analysis
- Understand objectives and constraints related to fission and fusion reactor design

Textbook: The textbook for this class is an excellent resource on nuclear reactor theory. Note that a free online version is accessible through the University of Michigan: `https://deepblue.lib.umich.edu/bitstream/handle/2027.42/89079/1976_Nuclear_Reactor_Analysis.pdf`.

Grading: Grades will be assigned as a weighted sum of the following work.

Homework	25%
Computer projects (3)	30%
Exams (2 in-class, 1 final)	45%

Letter grades will be assigned as follows.

- A: 93.0 – 100.0%
- A-: 90.0 – 92.9%
- B+: 87.0 – 89.9%
- B: 83.0 – 86.9%
- B-: 80.0 – 82.9%
- C+: 77.0-79.9%
- C: 73.0 – 76.9%
- C-: 70.0 – 72.9%
- D+: 67.0 – 69.9%
- D: 63.0 – 66.9%
- D-: 60.0 – 62.9%
- F: 00.0 – 59.9%

Late assignments will not be accepted, except when documented by an absence letter from the Dean of Students or with a doctor's note from a qualified medical professional. This notice must be provided to Prof. Novak at least 24 hours before an assignment/exam is to be due/scheduled. The university policy for requesting such a letter is in the Student Code. Please note that such a letter is appropriate for many types of conflicts, but that religious conflicts require special early handling. In accordance with university policy, students seeking an excused absence for religious reasons should complete the Request for Accommodation for Religious Observances Form, which can be found on the Office of the Dean of Students website. The student should submit this form to the instructor and the Office of the Dean of Students by the end of the second week of the course to which it applies.

It is important that you understand and agree with the grade you receive on assignments and exams. If you would like to dispute your score, please submit a regrade request through Gradescope and provide your justification. Check grade entries on Canvas and report any corrections/inconsistencies. You have 2 weeks to correct any grades from the date the assignment/exam was returned.

Lectures: The majority of the lecture material will consist of in-person blackboard lectures, but a limited set of supplemental handouts will be provided. The lectures shall, for the most part, be closely tied to the material covered in the textbook. Lectures will be a valuable resource for you. Active participation is welcome – asking questions, discussing concepts, helps me to see your level of understanding and keeps class lively. Use of electronics, aside from digital notepads for note-taking, can be a distraction to other students.

If you are or become ill, please communicate with me and the Dean of Students regarding your expected need for accommodation in this class. I am willing, able, and ready to make necessary accommodations.

Homework: This class will entail ≈weekly homework. The homework questions are designed to be similar to exam questions, and should be considered as dedicated time to deepen your knowledge of the material. All homework will be submitted online via Gradescope (accessible via Canvas). For any hand-written homework, please make sure your work is clean and in legible handwriting. You MUST match your page submissions to the question structure in Gradescope, as this greatly simplifies the grading. 2 points will be deducted from each question for failing to do so.

Your lowest scoring homework assignment will be dropped. However, I caution you that the homework is excellent practice to prepare for exams, and all material covered on homework is fair game for exam questions. It is advisable not to intentionally skip any assignment.

Homework assignments are to be completed independently and materials submitted as homework should be the result of one's own independent work. Please note that ChatGPT will make up incorrect information if you try to ask it to solve your homework questions!

Computer Projects: There are very few analytic solutions to the neutron diffusion and transport equations, and practical reactor analysis requires proficiency in numerical methods. As such, there will be 3 computer projects assigned in this class. These assignments can be completed in the programming language of choice for the student, but must be intelligible and clear for grading. One programming assignment will also entail use of the OpenMC Monte Carlo code, a widely-used tool for neutron transport research. The skills you build in this class will be extremely valuable to your future careers.

Computer projects are to be completed independently and materials submitted as computer projects should be the result of one's own independent work. ***AI-generated text will NOT be accepted as submissions***.

Exams: Two in-class cumulative exams and one final. For all exams, you may bring a single sheet of paper, double-sided, with your notes and formulas. Any necessary physics constants (e.g., mass of a neutron) shall be provided by the instructor as an additional supplement at the start of the exam. In total, these exams will constitute 45% of the total grade, but this 45% is determined as:

- 18% from the highest grade among your three exams
- 18% from the second-highest grade among your three exams

- 9% from the lowest grade of your three exams

Extra Credit: Extra credit opportunities may be offered throughout the class as determined by the instructor. Notices regarding extra credit will be made through lecture and/or Canvas.

A total of 1% extra credit will be offered through in-class quizzes. Five quizzes will be offered through the course of the semester, during lecture. These quizzes will cover prior lecture materials – the best way to prepare is to stay up-to-date on the class readings. In-person attendance is necessary to claim any extra credit, unless absence is documented with sufficient justification to Prof. Novak (see "Lectures" section).

For the duration of the class, one point of extra credit shall be offered any time a student identifies a mistake (typo in an equation, incorrect units, etc.) and notifies the instructor. Credit will only be given to the first student which submits the correction. This will help me to catch minor errors which could otherwise be confusing. Credit will not be given for trivial typos such as from grammar or spelling.

Nuclear Data: This class will use nuclear data (cross sections) as part of our study. There are many free and open resources where cross section data can be viewed, queried, and downloaded.

- Online ENDF database: `https://www-nds.iaea.org/exfor/endf.htm`
- The OpenMC Monte Carlo code has an excellent utility for exploring nuclear data.
  - Download a cross section library to your computer: `https://openmc.org/official-data-libraries/`
  - Install OpenMC: `https://docs.openmc.org/en/stable/quickinstall.html`
  - Plot nuclear data using Python! For an example script, see the Canvas page at: *Files/Nuclear Data/xs_ demo.py*

Expectations for All: The instructor, TAs, and students shall contribute towards a welcoming and inclusive environment for learning. All shall have respectful consideration of other's perspectives and open-mindedness to learning.

Expectations for Students:

- This class will require a strong foundation in nuclear science, differential equations, and some programming. Students are expected to dedicate effort at the start of the course to review this foundation in order to be prepared for the remainder of the class.
- Students are expected to attend lecture, and seek help when needed - please make use of office hours and ask questions during lecture.
- Students will succeed in this class if they keep on track with the reading assignments and lectures and make use of office hours. This course will require on the average 10 hours of your effort *outside of lecture*, which I expect you to spend on the reading assignments, homework, and reviewing material.

Expectations for the Instructor: The instructor shall provide a first-class experience for learning the foundations of reactor physics. The instructor shall be prepared, knowledgeable, enthusiastic, and dedicated to student success. Course materials shall be organized and lectures, assignments, and office hours shall be tailored to fit the learning needs of the students. All grading shall be conducted fairly and with recourse for corrections in a promptly manner.

Integrity: This is an institution of higher learning. Anyone undermining its integrity will be ejected from the course. Note the Student's Quick Reference Guide to Academic Integrity and the Academic Integrity Policy and Procedure.

Accessibility: The instructor is committed to upholding the vision and values of Inclusive Illinois in my classroom. Many accommodations resources are provided through the Division of Disability Resources and Educational Services. To request particular accommodations, please contact me as soon as possible.