

NPRE-445: Interact of Radiation w/Matter-Section A

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<https://publish.illinois.edu/modeling-nuclear-materials/>
- Teaching Assistant:** Runxia Wen runxiaw2@illinois.edu
- Schedule:** Lectures: MW, 11:00 AM – 12:50 PM, 4039 CIF
Office Hours: TBD (TA will assign the specific time, and if you have additional questions, you can email me whenever you need)
- Course Website:** <https://canvas.illinois.edu/courses/50850>
- Credit:** 4 hours
- Prerequisite:** NPRE 200, MATH 285, PHYS 212.
- Grading:** 1) Homework (including in-class quiz) (40%). Late homework is acceptable, but 10% of the score will be deducted *per day* until 30% is reached. Homework will be due at the start of lecture on the due date specified. Please submit your homework to the TA in the classroom or upload on Canvas.
2) Mid-term exam (20%), Final exam (40%).
- Description:** The classical and quantum theories of the interaction of radiation (neutrons, photons, and charged particles) with matter are the core components of nuclear and materials science and engineering. At UIUC, we offer a sequence of two courses (445 and 521) at different progressive levels on this subject. The sequence, in the aggregate, aims to provide the students with solid trainings on essential physical principles, mathematical competence, and computational skills. In this course, we provide a quantitative introduction to introductory quantum mechanics, fundamentals of atomic and nuclear physics, and interaction of radiation (charged particles, photons, and neutrons) with matter. Besides the essential physics needed by NPRE students, the course also serves the purpose to strengthen the students' mathematical skills. The foundations the students acquire in this course enables them to take more specific and advanced courses in all nuclear, plasma, and radiological disciplines.

Learning Outcomes/Objectives:

1. Understand basic quantum mechanics principles
2. Understand fundamentals of atomic and nuclear physics
3. Understand how common ionizing radiations (charged particles, photons, and neutrons) interact with matter

Topical Outline:

1. *Introductory Quantum Mechanics:* limitations of classical theory (stable atomic model, black-body radiation, photoelectric effect, Compton scattering), wave-particle duality, operators, Schrödinger equation, eigen states, observables, statistical interpretation, probability conservation, bound/unbound states of square potential, uncertainty principle
2. *Fundamentals of Atomic and Nuclear Physics and corresponding terminology:* Atomic structure, discrete energy levels, absorption and emission of photons, nuclear properties, distributions of charge and mass, abundance, binding energy, separation energy, semi-empirical mass formula, liquid drop model, mass parabola, spin, nuclear force and nuclear structure, properties of nuclear force, deuteron structure, neutron-proton scattering, scattering length, differential cross section, exchange force model, nuclear shell model, nuclear magic numbers, radioactive decay, nuclear reactions.
3. *Interaction of Radiation with Matter:* neutron (neutron-proton scattering, energy dependence of cross section),

gamma radiation (attenuation, photoelectric effect, Compton scattering, pair production), heavy and light charged particle (stopping power, Bragg curve, range, ionization loss and radiation loss).

Recommended Texts:

1. (*Required) D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*, 3rd edition, Cambridge University Press (2018).
2. J. J. Sakurai, J. Napolitano, *Modern Quantum Mechanics*, 2nd edition, Addison-Wesley (2017)
3. S. Yip, *Nuclear Radiation Interactions*, World Scientific (2014).
4. W. E. Meyerhof, *Elements of Nuclear Physics*, McGraw-Hill (1967).
5. K. S. Krane, *Introductory Nuclear Physics*, 3rd edition, Wiley (1987).
6. R. D. Evans, *The Atomic Nucleus*, McGraw-Hill (1955).

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: wecare.illinois.edu.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: <http://studentcode.illinois.edu/>.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: <https://studentcode.illinois.edu/article1/part4/1-401/>. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at <https://odos.illinois.edu/community-of-care/resources/students/religious-observances/> to request appropriate accommodations. This should be done in the first two weeks of classes.

Disability-Related Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to <https://www.disability.illinois.edu>. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See <https://registrar.illinois.edu/academic-records/ferpa/> for more information on FERPA.

Anti-Racism and Inclusivity Statement

The intent is to raise student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility in creating an inclusive learning environment. The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community. The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or

intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (<https://bart.illinois.edu>). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.