NERS/ENSCEN-211: Introduction to Nuclear Engineering and Radiological Sciences

Last updated: April 7, 2023

Description: NERS studies the most violent and extreme form of matter. The discipline was born in the early 20th century when physicists discovered the atomic and nuclear world. Since then, numerous surprising phenomena have been discovered, and amazing technologies making use of this knowledge have been developed. This course will cover the basic principles of quantum mechanics and special relativity, the fundamentals of atomic and nuclear physics, and a number of important engineering applications enabled by these modern physics.

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Schedule:

Lectures:	MW, 12:00 – 13:30, DOW 1014
Discussion 1:	F, 8:30 – 9:30, DOW 1206
Discussion 2:	F, 9:30 – 10:30, DOW 1206
Office Hours:	Th, 5 – 6pm, 2906 Cooley (Baer Room) (Julia)
	F, 1 – 2pm, 3001A PML (Meredith)
	M, 4 – 5pm, 2912A Cooley (YZ)

All lectures, discussions, and office hours will be delivered in person. Remote options are only available to those with approved accommodations.

The Discussion is mandatory. We cover "conceptual content" during the Lectures and "examples" during the Discussion. Therefore, the Discussion is an integral and indispensable part of the course. The TAs (IAs or GSIs) will lead the discussions.

The office hours are the best time to ask homework-related questions. As much as we would like to help you with the homework, it's oftentimes not possible to explain in detail over email.

Course Website: https://umich.instructure.com/courses/582938

This Canvas website will serve as the central hub for all course communications, homework assignments, homework solutions, study materials, etc. Please check your canvas notifications regularly for updates. Enabling email or mobile notifications is strongly recommended.

Credit: 4 credits

Advisory Prerequisite: Preceded or accompanied by Math 216: Introduction to Differential Equations. Some basic knowledge of Linear Algebra could be helpful in understanding the course materials, but not required.

Grading: 1) Homework (40%).

Homework will be assigned once every 1.5 weeks on average. They will be posted, collected, graded, and returned on Canvas.

Each homework submission should be a single PDF file, with the problems/pages numbered and in the correct order. Up to 10% of the score will be reserved for the professional presentation of the homework. To receive full credit on this portion of the assignment, your work should be complete, neat, and straightforward to follow. Illegible work will not receive credits.

Late homework submissions will receive a 10% penalty per day. Every student will be granted one late submission with no penalty (up to 5 days late). To use this grace period, just note it at the top of your assignment. On rare occasions, additional extensions will be

granted for major conflicts (e.g., travel for university business, etc.). In such cases, requests must be made in advance. Resubmissions of homework are not allowed.

Discussions on the course material and homework assignments with peer students are encouraged, but the solution sets, computer codes, and computer-generated results that get submitted for grading must be prepared on your own. Suspected violations will be taken up with the Engineering Honor Council.

Solutions will be posted about one week after the due date.

If you believe an error was made in grading your assignment, contact the person who graded your assignment first. If there is still an issue, please contact the instructor via email.

2) Mid-term exam (25%).

3) Final exam (35%). The final exam will emphasize the second half of the class, but it may rely/build upon material taught during the first half of the class. More guidance and study tips will be provided as the exams draw nearer.

All exams will be closed-book. No solutions for the exams will be provided. If you need to miss an exam, let the instructor know as early as possible. There is no equitable way to do a makeup after the fact.

Letter Grades:

A+	98-100%	A	95-98%	A−	90-95%
B+	85-90%	B	80-85%	B−	75-80%
C+	70-75%	C	65-70%	C−	60-65%
D+	55-60%	D	50-55%	D−	45-50%
F	<45%				

The instructor reserves the right to adjust these grade ranges at the conclusion of the course such that students may earn higher grades for a given point value.

Topical Outline:

1. *Basic Quantum Mechanics and Special Relativity:* wave-particle duality, Schrödinger equation, statistical interpretation, uncertainty principle, special relativity
2. *Fundamentals of Atomic and Nuclear Physics:* atomic structure, nuclear structure and properties, radioactivity, nuclear reactions (binary, fission, fusion, chain), interaction of radiation (heavy and light charged particles, photon, and neutron) with matter, radiation detection and measurement, radiation dose and protection
3. *NERS Applications:* global energy industry landscape, nuclear fission reactors, nuclear fuel cycle, nuclear waste management, safety and risk analysis, nuclear fusion devices, plasma science and engineering, materials research and processing, nuclear weapons and non-proliferation, medical applications, radioisotope production and applications, particle accelerators, nuclear propulsion, regulation and policy, future applications

Recommended Textbooks:

1. D. Bodansky, *Nuclear Energy: Principles, Practices, and Prospects*, 2nd Edition (2004). An electronic version of this book is available through the university library: https://link-springer-com.proxy.lib.umich.edu/book/10.1007%2Fb138326
2. R. Murray and K. Holbert, *Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes*, 8th Edition, Butterworth-Heinemann (2019). An electronic version of this book is available through the university library: https://www-sciencedirect-com.proxy.lib.umich.edu/book/9780128128817/nuclear-energy
3. J. K. Shultis and R. E. Faw, *Fundamentals of Nuclear Science and Engineering*, 3rd Edition, CRC Press (2016). An electronic version of this book is available through the university library: https://ebookcentral-proquest-com.proxy.lib.umich.edu/lib/umichigan/detail.action?docID=4790076

Honor Codes and Academic Integrity:

Students are expected to adhere to the University of Michigan's policy on academic integrity and the Engineering Honor Code as defined by the Engineering Honor Council: https://ecas.engin.umich.edu/honor-council/honor-code/

Course Recordings:

Course lectures may be audio/video recorded and made available to other students in this course. As part of your participation in this course, you may be recorded. If you do not wish to be recorded, please contact the instructor the first week of class (or as soon as you enroll in the course, whichever is latest) to discuss alternative arrangements.

Students are prohibited from recording/distributing any class activity without written permission from the instructor, except as necessary as part of approved accommodations for students with disabilities. Any approved recordings may only be used for the student's own private use.

Services for Students with Disabilities (SSD) Accommodations:

The University of Michigan recognizes disability as an integral part of diversity and is committed to creating an inclusive and equitable educational environment for students with disabilities. Students who are experiencing a disability-related barrier should contact Services for Students with Disabilities https://ssd.umich.edu/; 734-763-3000 or ssdoffice@umich.edu). For students who are connected with SSD, accommodation requests can be made in Accommodate. If you have any questions or concerns please contact your SSD Coordinator or visit SSD's Current Student webpage. SSD considers aspects of the course design, course learning objects and the individual academic and course barriers experienced by the student. Further conversation with SSD, instructors, and the student may be warranted to ensure an accessible course experience.

Student Mental Health and Well-Being:

Students may experience stressors that can impact both their academic experience and their personal well-being. These may include academic pressure and challenges associated with relationships, mental health, alcohol or other drugs, identities, finances, etc. If you are experiencing concerns, seeking help is a courageous thing to do for yourself and those who care about you. If the source of your stressors is academic, please contact me so that we can find solutions together. For personal concerns, U-M offers many resources, some of which are listed at Resources for Student Well-being on the Well-being for U-M Students website. If you are unsure which office to contact, Counseling and Psychological Services (CAPS) https://caps.umich.edu/ is a good starting point. They provide services during and after hours, on weekends and holidays, or through its counselors physically located in schools on both North and Central Campus. You may also consult University Health Service (UHS) https://www.uhs.umich.edu/mentalhealthsvcs.

Additionally, the Michigan Engineering C.A.R.E. Center https://care.engin.umich.edu/ is the central hub to assist engineering students by providing genuine and practical support, both inside and outside of the classroom.

Sexual Misconduct Policy

Title IX prohibits discrimination on the basis of sex, which includes sexual misconduct — including harassment, domestic and dating violence, sexual assault, and stalking. We understand that sexual violence can undermine students' academic success and we encourage anyone dealing with sexual misconduct to talk to someone about their experience, so they can get the support they need. Confidential support and academic advocacy can be found with the Sexual Assault Prevention and Awareness Center (SAPAC) on their 24-hour crisis line, 734.936.3333 and at sapac.umich.edu. Alleged violations can be non-confidentially reported to the Equity, Civil Rights, and Title IX Office (ECRT) at institutional.equity@umich.edu

Inclusion Statement: It is my intention that students from all backgrounds and perspectives will be well served by this course, and that the diversity that students bring to this class will be viewed as an asset. I welcome individuals of all ages, races, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, socioeconomic background, family education level, ability, and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming, and inclusive environment for every other member of the class. Your suggestions are encouraged and appreciated. If you have any questions or concerns regarding Diversity, Equity, and Inclusion (DEI), you may contact the DEI leads in your home department: https://diversity.engin.umich.edu/about/our-people/dei-department-leads/.

Tentative Lectures and Exams Schedule:

LECTURE	DATE	CONTENT
1	1/4, W	Course Overview
2	1/9, M	Birth of Modern Physics
3	1/11, W	Quantum Mechanics I
	1/16, M	**MLK Day, No Class, No Office Hours**
4	1/18, W	Quantum Mechanics II
5	1/23, M	Special Relativity I
6	1/25, W	Special Relativity II
7	1/30, M	Atomic Structure
8	2/1, W	Nuclear Structure
9	2/6, M	Radioactivity
10	2/8, W	Nuclear Reactions
11	2/13, M	Nuclear Fission
12	2/15, W	Nuclear Fusion
13	2/20, M	Interaction of Radiation with Matter I: neutron
	2/22, W	**Midterm Exam (during lecture period)**
	2/27–3/3	**Spring Break, No Class, No Office Hours**
14	3/6, M	Interaction of Radiation with Matter II: photon and charged particles
15	3/8, W	Radiation Detection and Measurement
16	3/13, M	Radiation Dose and Protection
17	3/15, W	Nuclear Fission Reactors I
18	3/20, M	Nuclear Fission Reactors II
19	3/22, W	Radioactive Waste Management
20	3/27, M	Nuclear Fusion Devices
21	3/29, W	Plasma Science and Engineering
22	4/3, M	Particle Accelerators and Applications
23	4/5, W	Medical Applications, Radioisotope Production and Applications
24	4/10, M	Nuclear Propulsion
25	4/12, W	Nuclear Weapons and Non-proliferation
26	4/17, M	Regulation and Policy, Prospects and Review
	4/27, Thur.	**Final Exam (10:30 am – 12:30 pm)**

Reading Materials:

Lecture 2: Birth of Modern Physics
https://en.wikipedia.org/wiki/History_of_physics#20th_century:_birth_of_modern_physics

Lecture 3-4: Quantum Mechanics
Shultis-Faw 2.3, 2.4

Lecture 5-6: Special Relativity
Shultis-Faw 2.1

Lecture 7: Atomic Structure
https://en.wikipedia.org/wiki/Hydrogen-like_atom
https://en.wikipedia.org/wiki/Atomic_orbital
Shultis-Faw 2.5.2, 2.5.3

Lecture 8: Nuclear Structure
Shultis-Faw 3.2.5, 4.1, 4.6
https://en.wikipedia.org/wiki/Semi-empirical_mass_formula
https://en.wikipedia.org/wiki/Nuclear_binding_energy

Lecture 9: Radioactivity
Shultis-Faw 5.2, 5.5
Murray-Holbert Chapter 3

Lecture 10: Nuclear Reactions
Shultis-Faw 4.5, 6.1, 7.1
Murray-Holbert 4.4, 4.5

Lecture 11: Nuclear Fission
Murray-Holbert Chapter 6
Bodansky Chapter 6

Lecture 12: Nuclear Fusion
Murray-Holbert Chapter 7
Shultis-Faw 6.7

Lecture 13-14: Interaction of Radiation with Matter
Shultis-Faw Chapter 7
Murray-Holbert Chapter 5

Lecture 15: Radiation Detection and Measurement
Murray-Holbert Chapter 10

Lecture 16: Radiation Dose and Protection
Murray-Holbert Chapter 16 & 21

Lecture 17 & 18: Nuclear Fission Reactors
Murray-Holbert Chapter 11

Lecture 19: Radioactive Waste Management
Murray-Holbert Chapter 22

Lecture 20: Nuclear Fusion Devices
https://en.wikipedia.org/wiki/Fusion_power

Lecture 21: Plasma Science and Engineering
https://en.wikipedia.org/wiki/Plasma_(physics)

Lecture 22: Particle Accelerators and Applications
https://en.wikipedia.org/wiki/Particle_accelerator

Lecture 23-24: More Nuclear Applications: Medical Applications, Radioisotope Production and Applications, Nuclear Propulsion
Murray-Holbert Chapter 18, 20

Lecture 25: Nuclear Weapons and Non-proliferation
Murray-Holbert Chapter 26

Lecture 26: Regulation and Policy, Prospects and Review
Murray-Holbert Chapter 23, 24, 25