Elements of Nuclear Engineering
UEA – 495, KSU - NE495

Prerequisites: MATH 221 (Calculus II) and PHYS 213 (Engineering Physics I) or permission of the instructor.

Description: Survey of nuclear engineering concepts and applications. Nuclear Reactions, radioactivity, radiation interaction with matter, reactor physics, risk and dose assessment, applications in medicine, industry, agriculture and research.

In practice, this course (1) is the bridge for students in our department to learn about and, hopefully, choose to pursue our nuclear option, (2) highlights the importance of nuclear science in many engineering applications, and (3) provides students an opportunity to learn and practice engineering problem solving skills.

Instructor

Dr. Jeremy Roberts
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Official office hours: Mondays and Wednesdays from 3:30–4:30pm
To meet with off-campus students, I use Skype (id: roberts1605). I plan to be online at least for the normal on-campus office hours. You may also schedule another time to chat. If there are several students from one university enrolled, I highly recommend you choose a leader to set up a group account. *Your success in this course is my priority, and I guarantee that consistent communication with me via office hours and other channels will help you succeed. This applies to ALL students.*

Required Text

J.K. Shultis and R.E. Faw, Fundamentals of Nuclear Science and Engineering, 2nd edition, ISBN: 978-1-4200-5135-3, CRC Press, Boca Raton FL, 2008.
Publisher: CRC Press

Although electronic versions may suffice, note that exams are open book. Errata are available from: http://www.mne.ksu.edu/~jks/books.htm. Supplemental materials will be made available electronically when needed.

Course Description and Goals

1. Explain a variety of nuclear phenomena using concepts of modern physics
2. Estimate magnitudes of atomic and nuclear properties from macroscopic data
3. Calculate nuclear reaction energetics from atomic mass data
4. Predict properties of radioactive materials
5. Design and analyze various applications of radioactivity
6. Describe characteristics of charged-particle, photon, and neutron interactions with matter
7. Quantify attenuation of and reaction rates for neutral radiation particles
8. Assess efficacy of different radiation protection techniques
9. Calculate doses, infer subsequent health risks to humans, and assess compliance to federal standards
10. Describe and quantify the neutron cycle in a reactor
11. Expound on the many uses of nuclear technology in society
12. Elucidate, in words a politician or business executive could understand, the importance or physical meaning of nuclear jargon terms introduced in the course, such as flux, binding energy, etc.
13. Use basic computer software to help solve engineering problems and visualize (i.e., plot) the corresponding solutions

Course Policies and Administration

1. **Recitation -** We have tentatively been granted funds for a teaching assistant. If this comes to fruition, in the first week of class we will determine the best two times during the week to offer one-hour recitations. These sessions are not required but provide a forum for homework questions and provides examples beyond those provided in lecture.
2. **K-State Online (KSOL) Message Board -** Please submit homework questions to the message board rather than by email. I try to answer questions within a day of their posting, but I do not always answer questions that suggest a student has not prepared before attempting a problem.
3. **Use of Computers for Solving Problems -** Long and tedious calculations might be expedited using MATLAB (free for students) or Python (free for all). Spreadsheets (e.g., Excel) are fine, to - pick a tool and use it effectively. We'll set up computer tutorials early in the semester.
4. **Quizzes -** Short, low-stakes quizzes will be given every lecture or every other lecture (via KSOL). These quizzes will cover material from lectures and/or the reading completed prior to the quiz due date. To do well on these quizzes you must keep up with both the lecture and reading material. The quizzes will most often be multiple choice, and students will be given two chances to answer all questions correctly. Quiz dates will be noted in the KSOL calendar. The lowest quiz score is automatically dropped. *****Students may earn an additional low-score drop by attending one of several (≈3) outside lectures to be identified by the instructor and by *typing* a 250-word summary of the lecture to be submitted to KSOL within 48 hours of the event.
5. **Homework -** Homework will be assigned approximately every two weeks. All homework submissions *must use the provided cover sheet*, *follow the example format to be provides*, and are *due at the beginning of class* on the due date by turning it in class or uploading it to KSOL. *All late homework will be assigned a zero grade!* Students may work in groups of up to three students. For students who decide to work in a group, each *group* will submit a *single* report. In addition, each group member *must* write at least one solution to earn credit for the assignment. Beware: if you count on a member who does not finish his or her portion, you are responsible to finish those portions. If you suspect a homework grade has a mistake, please bring it to my attention no later than one week from the day it was returned.
6. **Exams -** There will be *three midterm examinations and one final examination*.
   An example exam will be distributed to students before the first exam. Each midterm examination will cover one-fourth of the course material. The final examination will focus on the latter one-fourth of the course but should be considered cumulative. The examinations are

closed-book and notes. However, students are allowed one handwritten page, front and back, for each midterm examination and two such pages for the final examination, and a calculator. Any data (e.g., from textbook appendices) required to solve problems will be provided on the exam - cellphones, computers, and any other potential tools are not allowed. The *lowest score of three midterm exams will be dropped - no makeups will be offered*. Students with a "C" grade or better before the final exam may opt out of the final. Students with a "D" or "F" must take the final exam or they will earn an "F." Pre-final exam grades will be available to students by the end of the last day of class. If a student has a valid conflict with the final examination date, that conflict must be brought to my attention at least two weeks before the last day of class with written proof on official letterhead from a coach, doctor, etc. An alternative time will be set up to take the (possibly different) makeup exam. All students are assigned to write corrections for each midterm examination within two class periods. Corrected exams will be counted as a quiz score. Exam keys will be provided after all exams are taken. Exam solutions may be provided after the exam correction due date. **Exams for Students Enrolled through K-State Global Campus (online course)** Students taking the course online are required to *set up a proctor at least two weeks before a scheduled examination date*. This applies even if you are an on-campus, K-State student who needed the online version because of scheduling. You may select with your proctor a suitable time to complete the examination, but the date must be _ 2 business days from the on-campus date unless the proctor informs me of a schedule conflict with your home institution. I must be informed of all times at least two weeks in advance. If you fail to set up a proctor and, hence, miss taking the test, you will not be offered a makeup exam.

7. **Grading -** Grades will be computed based on the following:
   homework (20%), quizzes (20%), three exams (20% each)
   A > 75%, B > 65%, and C > 55%
   Because these grade cutoffs are fixed, grades are not competitive, i.e., everyone could in theory—earn an "A." For reference, recall that K-State defines A-level work as "excellent," B level work as "good," and C-level work as "fair."
8. **Attendance -** Attendance is not formally considered in grading, but be aware that not all the material covered in lecture is from the book. Students are responsible for all material, whether they show up to class or not. Based on previous experience, students who attend lecture regularly perform better on examinations.
9. **Extra Credit -** No "extra credit" is available in NE 495.
10. **Amount of Study -** A student with average reading and analytical abilities will need to spend about 6 hours per week outside of class doing reading, homework, and online quizzes in order to earn a "C," commensurate with "fair" work. Of course, this number will changes as assignments are due and as tests loom. However, in an average week, students should be spending about one hour on quizzes, two hours on reading (with notes), and three hours on homework or other problems. To earn a better grade, students should expect to spend 9 hours per week outside of class.
11. C**ourse Calendar -** The following is a *preliminary* schedule of lectures and readings. Readings are to be done *prior to class*. Supplemental reading will be available from the course website. The dates on which an assignment is *given* and *due* are also denote d. Quiz due dates will be found on the KSOL calendar once a quiz is assigned.
12. **If You Are Overwhelmed by or Get Behind in the Course**
    This course is *not* easy, and it is OK to feel somewhat overwhelmed at times. If you feel lost about the material, *you are responsible for seeking help from me*, the TA (if we have one), or other students. Similarly, *I am responsible* for helping you when stuck, but I cannot fulfill that responsibility if you do not get in touch. Specifically, if you have several bad quizzes in a row or "bomb" an exam, I *highly encourage* you to see me in office hours. Do not wait until the end of semester to try catching up with the material.

Date	Lecture	Reading	Description
Mon 08/25	1	syllabus, 1.1–1.2	Administrative. Review of SI units. Review of matter, atom, and nucleus.
Wed 08/27	2	1.2–1.3	Atomic quantities. The size and density of atoms and nuclei. **HW 1 GIVEN**.
Fri 08/29	3	2.1, 2.4	The special theory of relativity. $E = mc^2$
Mon 09/01			**NO CLASS: University Holiday**
Wed 09/03	4	2.2	Particle-wave duality.
Fri 09/05	5	2.3, 2.5	Quantum mechanics (is the cat alive?).
Mon 09/08	6	3.1	Atomic models and the origins of quantum theory. **HW 1 DUE**.
Wed 09/10	7	3.2	Properties of nuclei. Semi-empirical mass formula. Nuclear shell model. **HW 2 GIVEN**.
Fri 09/12	8	4.1–4.2	Nuclear binding energy. Nucleon separation energy.
Mon 09/15	9	4.3–4.7	Nuclear reactions and the Q-value. Energy density of fuels.
Wed 09/17	10	6.1–6.4	Kinematics of binary reactions. Conservation of mass, energy, and momentum.
Fri 09/19	11	5.1–5.4	Overview of radioactivity and types of decay.
Mon 09/22	12	5.5	Half-lives,decay constants, and other features of decay. **HW 2 DUE**.
Wed 09/24	13	5.6	Complex decay chains. Counting experiment. **HW 3 GIVEN**.
Fri 09/26			**EXAM I. Covers lectures 1–10.**
Mon 09/29	14	5.7–5.8	Radionuclides in nature and their use in radiodating. **NOTICE: Last day to drop NE 495 without a W.**
Wed 10/01	15	6.5	Neutron scattering kinematics.
Fri 10/03	16	6.6, supplement	Nuclear fission. Fission products and energy release.
Mon 10/06	17	6.7	Nuclear fusion. Energy production in stars. [Guest lecture] **HW 3 DUE**.
Wed 10/08	18	7.1	Introduction to radiation interactions. Nuclear cross sections. **HW 4 GIVEN**.
Fri 10/10	19	7.2	Computing interaction rates. Particle density and flux. Phase space.
Mon 10/13	20	7.3	Photon interactions. Compton scattering, the photo-electric effect, and pair production.
Wed 10/15	21	7.4	Neutron interactions. Elastic/inelastic scattering. "1/v" absorption. Resonances.
Fri 10/17	22	7.5	Charged particle interactions. Range and stopping power.
Mon 10/20	23	supplement	Particle interaction laboratory. Aspects of shielding. ALARA. **HW 4 DUE**.
Wed 10/22	24	8.1–8.2	Overview of radiation detectors. Gas-filled detectors.
Fri 10/24			**EXAM II. Covers lectures 11–22.**
Mon 10/27	25	8.3, 8.6	Semiconductor detectors. Practical aspects of measuring
Wed 10/29	26	9.1–9.2	Radiation in history. Radiation dosimetry. Dosimetric quantities. **HW 5 GIVEN**.
Fri 10/31	27	9.3–9.4	Health effects from large doses. Cellular effects. Lethal exposures. **NOTICE: Last day to drop NE495.**

Mon 11/03	28	9.5–9.7	Hereditary effects and cancer risks. The hormesis debate.
Wed 11/05	29	supplement	Basics of nuclear reactor physics. The neutron life Cycle. Criticality.
Fri 11/07	30	supplement	The four-factor formula.
Mon 11/10	31	supplement	Engineering decisions in reactor physics.
Wed 11/12	32	supplement	Temperature effecs on reactor physics. Temperature coefficients of reactivity.
Fri 11/14	33	supplement	Basics of nuclear reactor engineering. Thermodynamics. Heat removal.
Mon 11/17	34	11.1–11.3	Introduction to nuclear power. Basics of light water reactor systems. **HW 5 DUE**.
Wed 11/19	35	supplement	Studying the dynamic behavior of a PWR using the PRISM simulator. **HW 6 GIVEN**.
Fri 11/21			**EXAM III. Covers lectures 23–32.**
Mon 11/24			**NO CLASS: Student Holiday**
Wed 11/26			**NO CLASS: Student Holiday**
Fri 11/28			**NO CLASS: Student Holiday**
Mon 12/01	36	supplement	Nuclear reactor safety. Nuclear accidents. Three-mile island.
Wed 12/03	37	11.4–11.5, supplement	Next-generation nuclear reactors.
Fri 12/05	38	11.6, supplement	The nuclear fuel cycle. Mining and enrichment. Nuclear waste policy. **HW 6 DUE**.
Mon 12/08	39	12	Nuclear applications in space exploration. [Tentative]
Wed 12/10	40	13, supplement	Radiation applications in agriculture and industry. [Tentative]
Fri 12/12	41	14	Medical applications of radiation. [Tentative]
Wed 12/17			**FINAL EXAM. 4:10am–6:00pm in normal room.**

Statement Regarding Academic Honesty

Kansas State University has an Honor System based on personal integrity which presumes sufficient assurance that, in academic matters, one's work is performed honestly and without unauthorized assistance. Undergraduate and graduate students, by registration, acknowledge the jurisdiction of the Honor System. The policies and procedures of the Honor System apply to all full and part-time students enrolled in undergraduate and graduate courses on-campus, off-campus, and via distance learning. The honor system website can be reached via the following URL: www.ksu.edu/honor. A component vital to the Honor System is the inclusion of the Honor Pledge which applies to all assignments, examinations, or other course work undertaken by students. The Honor Pledge is implied, whether or not it is stated: "On my honor, as a student, I have neither given nor received unauthorized aid on this academic work." A grade of XF can result from a breach of academic honesty. The F indicates failure in the course; the X indicates the reason is an Honor Pledge violation.

Statement Regarding Students with Disabilities

Students with disabilities who need classroom accommodations, access to technology, or information about emergency building/campus evacuation processes should contact the Student Access Center and/or their instructor. Services are available to students with a wide range of disabilities including, but not limited to, physical disabilities, medical conditions, learning disabilities, attention deficit disorder, depression, and anxiety.

Manhattan or Olathe campuses: accesscenter@k-state.edu, 785-532-6441

Salina campus: acac@k-state.edu, 785-826-2649.