Course Syllabus

Reactor Analysis and Computation I

ENU 4103

Class #: 13279

Sections: 2B30

Class Periods: M,F|Period 9 (4:05 PM - 4:55 PM), W|Period 8-9 (3:00 PM - 4:55 PM)

Location : NEB 0100 : Spring 2021

Welcome to the Course

(Official catalog version) Four one-hour lectures discussing neutron reactions, fission chain and criticality and neutron transport/diffusion for nuclear reactors. Neutron thermalization and thermal scattering kernels. Dynamic analysis of reactors including point and space-time models. Feedback and reactor dynamics and control. Short-term transient analysis and long-term time-dependence.

Key Course Elements

Course Objective

The focus of this course is an understanding of the modern practice of reactor physics. This entails both an understanding of classic deterministic reactor theory and concepts and governing equations that goes into computational techniques, and how they are applied to the analysis of real reactors.

This course will require some facility with programming in a high level language (C++, FORTRAN, Matlab, Python, etc) to solve problems related to radiation transport and to apply concepts learned into applied problems and evaluations (often as self-study or homework, the benefit of such exercises is thus highly dependent on the effort exerted by each student). You are responsible for familiarizing yourself with these topics.

Classical Reactor Physics

- Introduction: Scope of Nuclear Engineering
- Atomic and Nuclear Physics
- Interaction of Radiation with Matter
- Neutron Energy Distributions

- The Fission Process
- Nuclear Reactors and Nuclear Power
- Neutron Diffusion and Moderation
- Nuclear Reactor Theory
- Numerical Solution to Neutron Diffusion
- The Time Dependent Reactor (Reactor Kinetics)

Course Structure

Instructor:

Dr. Justin Watson
178 Rhines Hall
Phone: 352-273-0241
Email: justin.watson@ufl.edu
Office Hours: By Appointment

Course TA:

None

Course Pre-Requisites/Co-Requisites:

ENU 4001 and ENU 4605 with minimum grades of C.

Materials and Supply Fees:

None

Professional Component (ABET):

This is a 4 credit engineering course that will:

1. Provide students with the ability to identify, formulate and solve engineering problems.
2. Provide students with the ability to use the techniques, skills and modern engineering tools, including modern computational skills and tools, necessary for nuclear and radiological engineering practice.
3. Provide students with the ability to apply advanced mathematics, science, atomic and nuclear physics and engineering to nuclear and radiological systems and processes.
4. Provide students with the ability to work professionally in one or more of the areas of: nuclear power reactors, nuclear instrumentation and measurement, radiation protection and shielding and radiation sources and applications.

Relation to Program Outcomes (ABET):

Outcome	Coverage
1. An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.	High
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Medium
3. An ability to communicate effectively with a range of audiences.	Low
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Low
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	

Required Textbook and Software :

- Introduction to Nuclear Engineering, Fourth Edition
- John R. Lamarsh and Anthony J. Baratta
- 2018
- 0134570057

Recommended Materials:

- James J. Duderstadt and Louis J. Hamilton, "Nuclear Reactor Analysis," 1976, 0-471-22363-8
- Weston M. Stacey, "Nuclear Reactor Physics," 2018, Third Revised Edition, 978-527-41366-9

Lecture Materials:

Lectures will be given synchronously at during the assigned class time. On occasion, asynchronous lectures, example problem solutions, or other course material may be provided. Students are expected to attend all lectures.

Course Schedule:

Week 1:	***Introduction*** ***Atomic and Nuclear Physics :*** Atomic structure; nuclear forces; binding energy and mass defect; nuclear stability; excited states; magic numbers; nuclear decay
Week 2:	1/18/2021 Martin Luther King , Jr. Day (No Class) ***Atomic and Nuclear Physics :*** Atomic structure; nuclear forces; binding energy and mass defect; nuclear stability; excited states; magic numbers; nuclear decay ***Interactions of Neutrons with Matter :*** Neutron cross sections and interactions rates; compound nucleus, resonances and excited states; absorption and scattering cross sections; calculation of atom densities; scattering kinematics
Week 3:	***Interactions of Neutrons with Matter :*** Neutron cross sections and interactions rates; compound nucleus, resonances and excited states; absorption and scattering cross sections; calculation of atom densities; scattering kinematics
Week 4:	***Neutron Distributions in Energy :*** Fast, slowing down and thermal energy distributions; Maxwell-Boltzmann distribution and spectrum hardening; energy-averaged reaction rates, infinite medium multiplication factor
Week 5:	***Neutron Distributions in Energy :*** Fast, slowing down and thermal energy distributions; Maxwell-Boltzmann distribution and spectrum hardening; energy-averaged reaction rates, infinite medium multiplication factor ***Nuclear Fission Process :*** Fission energetic including critical energy; fertile versus fissile nuclides; odd-even phenomenon; fission products and fission parameters (nu, alpha, and eta); prompt and delayed neutrons; fission rate and power production
Week 6:	***Nuclear Power and Power Reactors*** ***2/17/2021 Exam 1***
Week 7:	***Nuclear Fission Process :*** Fission energetic including critical energy; fertile versus fissile nuclides; odd-even phenomenon; fission products and fission parameters (nu, alpha, and eta); prompt and delayed neutrons; fission rate and power production ***Introduction to the Neutron Transport Equation and Diffusion Theory :*** Connectivity of neutron transport theory to diffusion theory approximation; Fick's Law; neutron current and neutron leakage; boundary conditions; point, plane and line sources in infinite media
Week 8:	***Introduction to the Neutron Transport Equation***
Week 9:	***Multigroup Neutron Diffusion Theory***
Week 10:	***Introduction to Monte Carlo Theory and Finite Difference Methods :*** Numerical Methods for Solving Neutron Diffusion Eq.; Finite Difference Boundary Conditions and Solution Methods; Reflected Reactors & Multigroup Finite Difference

Week 11:	***Introduction to Monte Carlo Theory and Finite Difference Methods :*** Numerical Methods for Solving Neutron Diffusion Eq.; Finite Difference Boundary Conditions and Solution Methods; Reflected Reactors & Multigroup Finite Difference ***Criticality Calculations and Problems*** ***3/24/2021 Recharge Day (No Class)***
Week 12:	***Criticality Calculations and Problems*** ***3/31/2021 Exam 2*** ***Neutron Diffusion Theory in Homogeneous Multiplying Media :*** Fission chain reaction and neutron multiplication factor; infinite multiplying media; finite multiplying media; four and six factor formulas; material and geometric buckling; slab, spherical and cylindrical reactors; one group, modified one-group and two group calculations; reflected reactors
Week 13:	***4/5/2021 Project Part 1 Due*** ***Heterogeneous Reactors*** ***Homogenization*** ***Neutron Diffusion Theory in Homogeneous Multiplying Media :*** Fission chain reaction and neutron multiplication factor; infinite multiplying media; finite multiplying media; four and six factor formulas; material and geometric buckling; slab, spherical and cylindrical reactors; one group, modified one-group and two group calculations; reflected reactors
Week 14:	***Time Dependent Reactor :*** Point kinetics; control rods and chemical shim; reactivity feedback; fission product poisons ***4/16/2021 Project Report Due***
Week 15:	***Time Dependent Reactor :*** Point kinetics; control rods and chemical shim; reactivity feedback; fission product poisons
Week 16:	***4/27/2021 Final Exam***

See Modules page for additional information.

F2F Course Policy in Response to COVID-19

We will have face-to-face instructional sessions to accomplish the student learning objectives of this course. In response to COVID-19, the following policies and requirements are in place to maintain your learning environment and to enhance the safety of our in-classroom interactions.

- You are required to wear approved face coverings at all times during class and within buildings. Following and enforcing these policies and requirements are all of our responsibility. Failure to do so will lead to a report to the Office of Student Conduct and Conflict Resolution.
- This course has been assigned a physical classroom with enough capacity to maintain physical distancing (6 feet between individuals) requirements. Please utilize designated seats and maintain appropriate spacing between students. Please do not move desks or stations.
- Sanitizing supplies are available in the classroom if you wish to wipe down your desks prior to sitting down and at the end of the class.
- Follow your instructor's guidance on how to enter and exit the classroom. Practice physical distancing to the extent possible when entering and exiting the classroom.
- If you are experiencing COVID-19 symptoms (Click here for guidance from the CDC on symptoms of coronavirus), please use the UF Health screening system and follow the instructions on whether you are able to attend class. Click here for UF Health guidance on what to do if you have been exposed to or are experiencing Covid-19 symptoms.
- Course materials will be provided to you with an excused absence, and you will be given a reasonable amount of time to make up work. Find more information in the university attendance policies.

Expectations and Evaluation

Attendance:

Students are expected to attend all class lectures, barring meritorious professional or University-sanctioned personal reasons. Particularly meritorious reasons are expected for any absence from exams. Whether or not your justification for your absence is acceptable (other than those that are sanctioned by the University) is at the sole discretion of the Instructor. Notify the Instructor and check to see if it is acceptable as soon as you know you will be absent. Attendance will be taken at the beginning of each class and will be included as part of the course grading. In addition material will be covered during the lectures not covered in the text, it is the responsibility of the student to take notes during lecture.

Excused absences must be consistent with university policies in the undergraduate catalog (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx) and require appropriate documentation.

Class distractions such as cell phones are unacceptable and the use of such devices are are prohibited during the lectures. Students will ensure that any such device into the classroom will be turned off or put on silent mode. Such disruptions (including texting) will lead to the student being told to leave the room for the duration of the class period, including during examinations periods. NOTE: if a pop quiz is given after the student is asked to leave, they will receive a zero as a grade for that pop quiz. Laptops, tablets, iPads, etc are only allowed for note taking purposes. All other use is prohibited. If a student arrives late or leaves early, they are expected to do so with minimum level of disruption to the class in progress. If a pop quiz is given before or after the student is in the classroom, they will receive a zero for that pop quiz (no make-up).

All exams are cumulative, i.e. every topic that is covered prior to the exam day (including the latest class period) may be on the test. Your lowest exam grade will be dropped. If you are satisfied with your grade at the end of the semester, you may elect to not take the final exam.

Grading Policy:

Your course grade will be determined using a combination of course project, homework assignments, pop quizzes, and exams. Pop quizzes will not be announced. There will be two exams during the semester and one final exam. Your lowest exam score will be dropped. Weights towards the final grade are as follows:

Homeworks = 40%
Project = 25%
Exams = 30%

Quiz = 5%

Grades will be assigned according to the following scale and will be curved at the discretion of the instru ctor:

Grade	Percent	Grade Points
A	92 - 100	4.00
A-	88 - 91	3.67
B+	84 - 87	3.33
B	81 - 83	3.00
B-	78 - 80	2.67
C+	76 - 79	2.33
C	73 - 75	2.00
C-	70 - 72	1.67
D+	66 - 69	1.33
D	63 - 65	1.00
D-	60 - 62	0.67
E	0 - 59	0.00

Homework handed in up to 12 hours late will receive 30% off, homework handed in up to 24 hours late will receive 50% off. No homework will be accepted after 24 hours.

Requests for re-grading of any course document should be submitted as a written request within one week of the graded document being returned. After one week, re-grading requests will no longer be considered.

More information on UF grading policy may be found at: http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades (Links to an external site.)

Final Exam:

Final Exam: 4/27/2021 @ 5:30 PM - 7:30 PM

Students Requiring Accommodations:

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation:

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals (Links to an external site.). Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/ (Links to an external site.).

University Honesty Policy:

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment:

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of

discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html (Links to an external site.)

Health and Wellness

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc (Links to an external site.), and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance** (Links to an external site.), located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/ (Links to an external site.).

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml (Links to an external site.).

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/ (Links to an external site.).

Library Support, http://cms.uflib.ufl.edu/ask (Links to an external site.). Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/ (Links to an external site.).

Writing Studio, 302 Tigert Hall*,* 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/ (Links to an external site.).

Student Complaints Campus*:* https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf (Links to an external site.).

On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process (Links to an external site.).

About Your Instructor

 JUSTIN C. KYLE WATSON, PHD, ASSOCIATE PROFESSOR, received his B.S., M.S. and Ph.D. degrees in Nuclear Engineering from the Pennsylvania State University. He was the Head of the Computational Methods Development Department at the Applied Research Laboratory, the Pennsylvania State University and had dual title with the Nuclear Engineering Department where he taught classes for 9 years before joining the faculty in the Department of Materials Science and Engineering, Nuclear Engineering Program at the University of Florida in September of 2018.

Research Group: FAMMoS