

**The University of Florida, Department of Materials Science and Engineering  
Nuclear Engineering Program**

**ENU 4930: Introduction to the Nuclear Fuel Cycle**

**Class Periods:** MWF 1040-1130

**Location:** BLK 0415

**Academic Term:** Fall 2021

**Catalog Description:** Fuel cycle from mining through waste management including economics and policy concerns/constraints. Physical and chemical processes in the conventional nuclear fuel cycle: uranium mining and milling, conversion, enrichment, fuel fabrication, reactor operations, interim storage, reprocessing and recycling, waste treatment and disposal. Nonproliferation, nuclear forensics, alternative fuel cycles and future prospects will also be considered.

**Credit:** 3 hours

**Instructor:** Prof. Kyle C. Hartig, [kyle.hartig@ufl.edu](mailto:kyle.hartig@ufl.edu)  
180 Rhines Hall; 352-392-4907  
*Office hours:* TBD

Note: Office hours will be offered as a combination of in-person in my office/conference room or virtually through Zoom following all current UF best practices and guidelines. Office hours may change due to conflicts (e.g., upcoming travel schedule). Office hours will be scheduled the first week of class.

Note: For all course-related questions a preferred mode of interaction is to visit with the professor during office hours (in-person or virtual) and refrain from using email.

**Teaching Assistant/Supervised Teaching Student:** None

**Required Textbooks and Software:**

N. Tsoulfanidis, *Nuclear Fuel Cycle*, American Nuclear Society, 2012 (978-0894484605)

Available for free through the university library (<https://app.knovel.com/s.v?nbyClFxP>).

MCNP 6.2-EXE and ORIGIN 2.2 available for free by request on RSICC

(<https://rsicc.ornl.gov/Default.aspx>) See canvas page for details.

Chart of Nuclides: You will need access to a chart of nuclides during the course. Feel free to use any one of the numerous resources available (so long as it is accurate). Below are a couple of suggested charts of nuclides.

I. Joseph R. Parrington, et al., *Nuclides and Isotopes*, 15th Ed., Lockheed Martin/GE Nuclear, 1996.

II. <http://atom.kaeri.re.kr> (Recommended)

**Recommended:**

I. T. Pigford *et al.*, *Nuclear Chemical Engineering*, McGraw-Hill 1981 (978-0070045316)

II. Kenneth S. Krane, *Introductory Nuclear Physics*, Third Edition 1988, John Wiley & Sons (978-0471805533)

III. Shultis and Few, *Introduction to Nuclear Science and Engineering*, Second Edition 2007, CRC Press (978-1420051353)

IV. Neutronics texts (such as from ENU 4103, 4104, or 6106)

*Other online and print resources will be given out during lecture and on the Canvas site.*

**Pre-requisites and Co-requisites:**

Co-requisites: ENU 4605 and 4103 (i.e., senior status in nuclear engineering) or ENU 6051

**Course Objectives:**

- (i) Provide students with the opportunity to learn fundamental and applied principles of the nuclear fuel cycle;
- (ii) Provide students with an understanding of relevant codes/packages available for analysis of nuclear fuel cycle processes;
- (iii) Development of communication skills including technical writing and oral presentations;
- (iv) Prepare students for independent research and/or design projects.

**Material and Supply Fees:** None.

**Web Tools:** <https://ufl.instructure.com/courses/435585>

The course Canvas site will be used to distribute the syllabus, grades, and lecture materials. Additionally, the course Canvas site may be used to distribute quizzes, discussion topics, exams, projects, and all other course material. The site will be used to provide announcements. It is your responsibility to regularly check the course site as well as your email for any alerts to changes in the site or new announcements. I may place course notes ahead of lectures on Canvas. The notes I may post may only contain fragments of the entire lecture.

**Meeting Times, Location, & Schedule:**

MWF 1040-1130 BLK 0415 starting 8/25.

**Course Schedule** (subject to adjustments throughout semester)

Note: Adjustments to this regular schedule could be made periodically and announced in advance in class and/or through the class website/email.

Discussion board/in-class topics and other participation activities along with short quizzes will take place on a near weekly basis enabled through the Canvas course page or in-person during class. An emphasis on development of professional skills for nuclear engineers pursuing careers in the nuclear industry and/or research will be placed on all activities in this course. Special guest lectures will be provided by outside researchers, engineers, and policy makers throughout the course, which will be available for synchronous or asynchronous viewing on the Canvas course page. Several (individual and group) projects will be assigned throughout the duration of the course (that may have intermediate due dates to encourage timely completion of tasks and achieving objectives).

**Week 1:** Introduction and Front-End Overview

**Week 2:** Core Design Criteria – Physics and Engineering and In-Core Aspects

**Week 3:** Reactor Types (e.g., HTGR, Fast Reactors, CANDU, LWR, etc.)

**Week 4:** Fuel Manufacturing and Engineering, Design & Fuel Performance During Irradiation

**Week 5:** Fuel Cycle, Operations, and Economics

**Week 6:** Back-End Overview

**Week 7:** Options for Actinide Management, Waste Classification, and Regulation

**Week 8:** Actinide Separation Technology I

**Week 9:** Actinide Separation Technology II

**Week 10:** Proliferation and Safeguards

**Week 11:** Nuclear Forensics

**Week 12:** Fuel Cycle Systems Simulation

**Week 13:** Advanced Computational Tools for Fuel Cycle Analysis (e.g. Machine Learning)

**Week 14:** Special Topics

**Week 15:** Project Presentations

### **Grading Scale**

The final grades will be assigned based on:

- A:  $\geq 92\%$
- A-:  $\geq 88\%$
- B+:  $\geq 84\%$
- B:  $\geq 80\%$
- B-:  $\geq 76\%$
- C+:  $\geq 72\%$
- C:  $\geq 68\%$
- C-:  $\geq 65\%$
- D+:  $\geq 62\%$
- D:  $\geq 59\%$
- D-:  $\geq 56\%$
- E:  $< 56\%$

Please note that following:

1. At the end of the course, students overall course grades may be curved up at my discretion.
2. Grading in this course is “plus-based”. That is, I award you points based on correct steps, rather than deducting points for errors.
3. There is no general protection against double jeopardy. Points are often allocated, particularly on exams, to each specific step and to obtaining the final, correct answer in each problem – a single error will prevent you from earning points at that step and for the final answer.
4. The grade cut-offs for A, B, and C are somewhat lower than the “high-school scale” (90, 80, 70, etc.) under which many UF courses and syllabi templates operate. This is not to grant inflated letter grades but rather to account for the challenging nature of the course material and to appropriately award genuinely excellent performances.

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

**Grading:** Below is a breakdown for the grading in the lecture:

Discussion and Participation - 10%  
Homework(s) - 25%  
Quizzes - 10%  
Project(s) - 40%

Final Exam - 15%

*Important Note:* Graduate students registered for ENU 5186 will have additional/more complex problems on assignments that they will be required to complete as they are graded in a completely different course than the undergraduate students.

**Students Requiring Accommodations:** Students with disabilities who experience learning barriers 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 me when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester. Please note that UF policy, clarified to faculty during the Fall 2016 term, states that no retroactive accommodations are available.

### UF Counseling Services

- Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:
- University Counseling Center, 301 Peabody Hall, 392-1575, Personal and Career Counseling.
- SHCC mental Health, Student Health Care Center, 392-1171, Personal and Counseling.
- Center for Sexual Assault/Abuse Recovery and Education (CARE), Student Health Care Center, 392-1161, sexual assault counseling.
- Career Resource Center, Reitz Union, 392-1601, career development assistance and counseling.

**Software Use:** All faculty, staff and student 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.

**Grade Appeal:** All appeals of grades, including those from clerical/grade-calculation errors, must be made within one week of return. (This may be modified for specific assignments near the end of the term. I will announce this via e-mail as needed.)

Grade appeals must be provided in the following format:

- Include your entire assignment unmodified.
- Attach (paper clip preferred) a written summary of which problem(s) or part(s) you believe were graded inaccurately. Be as specific as possible.
- Turn in your appeal to me (virtually or in-person) at class time or during office hours.

I will review your grade appeal, contact you via your ufl.edu e-mail address, and return the assignment in class. Fairly simple appeals provided to me during office hours may be decided upon while you wait, at my discretion.

Appeals will be considered for clerical errors, addition errors, and inconsistent scoring. Grade appeals will not be entertained if you simply do not like that (for example) Part 1 was worth only 2 points with Part 2 worth 5 points.

On very rare occasions, if I believe the student is not acting in a good faith belief that more points are deserved, I will deem the appeal frivolous. Following two frivolous appeals, your grade appeal privilege through this method will be revoked. Further appeals must be done through the petitions process, which requires formal paperwork and department/program level involvement.

### Electronic Communication and Course Website

The primary means of communication with the class outside of class time will be e-mail listserv. These listservs will send to your @ufl.edu address only. Any inquiries regarding grading will be directed towards your @ufl.edu address only, per FERPA.

The primary use of the Canvas website is for file storage, as assignments, lecture notes, etc. may be provided there. I take no responsibility for downtime of this service, nor for actions of University of Florida staff that affect the website (including Canvas upgrades). The gradebook on Canvas is used to enable you to look up grades quickly. Note that this gradebook is not official. I reserve the right to correct errors, including transcription errors, from the official (spreadsheet) gradebook, to which I alone have access, until finalization of grades with the registrar.

### **Attendance**

Students shall attend each lecture in-person as quizzes, in-class work, and homework will occur sporadically throughout the semester based on the posted lecture materials. If the student must miss a class for an appropriate reason, it should be brought to the attention of the instructor as far in advance as possible.

If a student arrives late or leaves early, they are expected to do so with minimum level of disruption to the class in progress (primarily for presentations and panels). There is no tolerance for mobile phones or other electronic disruptions. Such disruptions will lead to the student being told to leave the room for the duration of the class period, including during examination periods. The same principle applies to office hours or appointments – if you stop by my office and your phone rings, you will be told to leave the room for the duration of that day's office hours (or your appointment will be considered over).

### **Make Up Work:**

Late-work excuses can be grouped into the categories of professional, medical, and personal.

*Professional:* Reasonable extensions for job/internship interviews, technical conferences, or other professional/career development reasons should be requested. Requests are typically granted, at my discretion, unless they would grant a student or group of students an unfair advantage over their peers, cause significant disruption to the course or grading schedule, or violate some UF policy.

*Medical:* Extensions will also be granted for (your own) medical reasons – please do not come to class if you are ill. Per UF policy, in the case of medical absences that are frequent or suspiciously- timed (e.g.; you are repeatedly, suddenly ill at deadlines), I may request a signed note from a physician or similar professional practitioner.

*Personal:* In addition, UF policies require accommodation for several non-academic, non- medical reasons. Extensions for these personal issues are strictly limited to those mandated by the letter of UF policies. If you have a question regarding your personal issue and if it qualifies under one of the excused absence/late-work policies, contact me in advance.

The 12-day rule will be enforced strictly. Note that the count of days is based on a per-student, not per-approved-activity basis. All requests for excused absence or extension must be submitted in writing, preferably via e-mail.

Pursuant to HWCoe policy, the following statement is required: Excused absences are consistent with university policies in the undergraduate catalog

<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx> and require appropriate documentation.

### **Collaboration**

The ground rules for collaboration should be decided by each group through compromise and consensus. However, regardless of the preferences of the group as a whole, each student retains the individual right to privacy and to maintain good mental and physical health. To this end, no student shall be compelled:

- To join a real-name social networking site or modify their existing use of such a site, or
- To accept a 24/7 or another onerous on-call policy.

That is: each member holds a unilateral veto on using Facebook (or some such) for your group's work or for being contacted at all hours of the day and night.

Inter-personal issues within your group stemming from deciding group rules must be brought to me promptly for arbitration. This arbitration will focus on the guidelines above and in forming an equitable compromise (essentially, equal marginal/new inconvenience) among group members and not on determining

whose activities outside this course (including personal pursuits, situations, and choices) are more meritorious.

The allowed level of collaboration on homework may vary and is specified on the assignment.

### **Course Evaluations**

UF expects students to provide feedback on the quality of instruction in this course by completing online evaluations at <https://evaluations.ufl.edu/evals>. 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/>.

### **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 TA in this class.

### **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:

<http://registrar.ufl.edu/catalog0910/policies/regulationferpa.html>

### **Changes to Syllabus**

Changes to this syllabus will be provided via the Canvas platform. Such changes may include those required by policy changes, my travel, changes in the speed of course coverage, university closure, errors in previous syllabus versions, and other reasons.

#### **COVID-19**

You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated.

If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email [covid@shcc.ufl.edu](mailto:covid@shcc.ufl.edu)) to be evaluated for testing and to receive further instructions about returning to campus.

If you are withheld from campus by the Department of Health through Screen, Test & Protect, you are not permitted to use any on campus facilities. Students attempting to attend campus activities when withheld from campus will be referred to the Dean of Students Office.

UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.

Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

### **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 (Justin Watson, [justin.watson@ufl.edu](mailto:justin.watson@ufl.edu))
- Jennifer Nappo, Director of Human Resources, 352-392-0903, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### **Additional University Policies**

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate during these recorded sessions are agreeing to, at a minimum, having their audio recorded.

#### ***Online Course Recording***

If we utilize online meetings for a part of our course (e.g., guest lecture or for when a student or faculty member is withheld from campus), these sessions may be audio visually recorded for students in the class to refer to and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared.

#### **In-Class Recording:**

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third-party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

## ***Campus Resources:***

### ***Health and Wellness***

#### **U Matter, We Care:**

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](mailto: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>, 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**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto: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/>.

### ***Academic Resources***

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu). <https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. 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/>.

**Writing Studio**, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. <https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** [https://www.dso.ufl.edu/documents/UF\\_Complaints\\_policy.pdf](https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf).

**On-Line Students Complaints:** <http://www.distance.ufl.edu/student-complaint-process>.