

The University of Florida, Department of Material Science and Engineering
Nuclear Engineering Program

ENU 4612: Nuclear Radiation Detection and Instrumentation

Fall Semester 2017

Catalog Description: Physics and electronics of radiation detection and instrumentation systems for application to nuclear energy, radiological sciences, radiation protection, medical physics and imaging, and industrial safety and control systems.

Credit: 3 hours

Instructor: Prof. Kyle C. Hartig, kyle.hartig@ufl.edu
352-392-4907

Office hours: Monday, 1240 – 1340
Tuesday 1045 – 1145

Note: Office hours may change due to laboratory schedule / upcoming travel schedule

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

Teaching Assistant: Christopher Greulich
Email: cgreulich@ufl.edu
Office hours: Scheduled via email; NSC 231

Textbook: G. Knoll, *Radiation Detection and Measurement*, Wiley, Fourth Edition, 2010
(978-0470131480)

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 chart of nuclides.

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

II. <http://atom.kaeri.re.kr> (This is a website maintained by the Korea Atomic Energy Research Institute – Recommended)

Recommended: I. Kenneth S. Krane, *Introductory Nuclear Physics*, Third Edition, 1988, John Wiley & Sons (978-0471805533)
II. Shultis and Few, *Introduction to Nuclear Science and Engineering*, Second Edition, 2007, CRC Press (978-1420051353)
III. Nicholas Tsoulfanidis, *Measurement and Detection of Radiation*, 2nd Ed., Taylor and Francis, 1995
Other online and print resources will be given out during lecture and on the Canvas site

Pre-requisites and Co-requisites:

Pre-requisites for ENU 4612:

- EEL 3003 Elements of Electrical Engineering
- ENU4605 Interaction of Radiation with matter

Course Objectives:

Provide students with the opportunity to learn the principals of radiation interactions with matter, radiation detection techniques and characteristics of different radiation detectors; Development of communication skills including technical writing and oral presentations; Prepare students for independent research and/or design projects.

Contribution of Course to Meeting the Professional Component (ABET only)

- a. Graduates will have successful careers in Nuclear Engineering and related disciplines.
- b. Graduates will pursue continuing education or advanced degrees.

Relationship of Course to Program Outcomes (ABET only)

This course supports the following program outcomes:

- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic,
- (e) an ability to identify, formulate, and solve engineering problems
- (l) an ability to apply advanced mathematics, science, and engineering science, including atomic and nuclear physics, and the transport and interaction of radiation with matter, to nuclear and radiological systems and processes
- (m). an ability to measure nuclear and radiation processes
- (n). an ability to work professionally in one or more of the areas of: nuclear power; nuclear instrumentation and measurements; nuclear materials; and radiation sources, shielding, and protection.

Meeting Times & Schedule:

MWF 0935–1025, Aug 21 – Dec 6, 2017

Laboratory: ENU4612L laboratory sections will be assigned/scheduled during first week of classes based upon students' schedules.

Note: adjustments to this regular schedule could be made periodically and announced in advance in class and through the class website/email. Occasionally, the lecture may be recorded and the students instructed to watch a video on the course Canvas site instead of meeting for class.

Meeting Location

Lecture: Keene-Flint Hall 0115

Laboratory: Reactor Classroom (Nuclear Science Building)

Material and Supply Fees

None.

Web Tools: <https://lss.at.ufl.edu/>

The course Canvas site will be used to distribute the syllabus, announcements, slides, grades, etc.

I will place course notes ahead of lectures on Canvas. The notes I post will only contain fragments of the entire lecture. Students are required to attend class and fill in the blanks as necessary, according to written lecture notes dictated in class. Canvas will also be the location to download other posted course materials, such as homework, solution sets, and sample problems.

Grading:

Your performance in both the lecture and laboratory will be graded separately as they are two different courses. Below is a breakdown for the grading in the lecture and laboratory:

Lecture:

Homeworks - 20%
Pop Quizzes - 10%
Midterms (2) - 30%
Final Exam - 40%

Laboratory:

Short Reports - 30%
Worksheets (7) - 30%
Quizzes (7) - 30%
Presentation - 10%

Homework Sets

There will be about 7-8 homework sets covering the major course topics handed out throughout the semester. Due dates will be indicated on the problem sets I hand out. Homework solutions must be prepared by computer (Office, Pages, Latex, etc...). The homework must be turned into the class site drop box in PDF format prior to the deadline to avoid a late penalty (note: there is a time stamp associated with the drop box submission, so please upload your assignment before the due date and time). Homeworks are graded based on the specifications and criteria distributed separately and posted on class site for each HW. Homeworks that fail to meet the specifications will not be graded. Graded homeworks will be distributed electronically through the Canvas site drop box.

Professional document and figure standards will be enforced on all electronic submissions in this course. The onus is on you to figure out how to meet these standards in whatever programs you use to write the document and make figures. Excel may not be used to prepare figures (plots). It is suggested that students prepare figures (plots) in Python (GnuPlot), MatLAB, Mathematica, Igor Pro, or Origin Pro. I have exactly zero sympathy for those who select a word processor or computer program without knowing how to format their text or figures using it – complaints that the standards are not the same as a particular piece of software's defaults will fall on deaf ears.

For any question regarding the grading of homework assignments, please contact the TA or the instructor (during office hours or after class).

Note: the homework sets will involve both theoretical derivations and analysis of real data.

Pop Quizzes

I will randomly give out pop quizzes during the lecture periods. These will consist of one or two relatively short/simple questions in order to assess how well students have been paying attention to class concepts. They will also make up the attendance portion of the grade in order to ensure students attend every lecture, unless an appropriate excuse is given prior to missing a class.

Exams

Two non-cumulative mid-term exams will be given during the semester. The tentative dates for the weeks they will be given are listed in the course outline above but are subject to change. The midterm exam will be 2 hours in length and will be given from 8-10 PM in the evening (normal assembly exam times). I will give you a two-week advanced warning for the midterm exam. Make-up Exams are only allowed through prior requests or DOCUMENTED reasons pursuant to UF policy and the policy listed under the "make up work" section of this syllabus.

All exams will consist of an open book and closed book portion. The closed book portion will be given first and students will be given an hour to complete this section. The open book portion will be given to students after completion of the closed book section.

Textbooks, class notes, and home works will be allowed during the open book portion. However, no laptops or electronic devices (aside from calculators) will be allowed. The final exam is currently scheduled for Wednesday December 13th (1500 – 1700) and is cumulative. The same open book/closed book exam layout will apply to the final, as well. UF policy restricts make-up finals to Friday, December 15, 1500-1700 PM, barring a conflict at that time with another make-up in a course of higher number. This rule applies regardless of your personal business; such as travel times. I strongly discourage you from making hard-to-change travel plans such as flight reservations before Friday evening.

For each exam, you will receive an Exam Preview, intended to prepare you for taking the exam (both technically and procedurally). The preview will also include the specific topics addressed by the problem (for most problems), the way points are distributed among problems, and a brief list of topics within the scope of the exam.

Examinations are due at the end of the examination period. No collaboration is permitted during examinations, although you may prepare for these however you choose. Use of any unauthorized materials or any communication (including mobile phones, laptops, or face-to-face with classmates in the room) is grounds for immediate and final collection of your exam with no more work permitted and any work already completed that, in my judgement, was aided by said materials/communication not considered in grading.

In the unlikely event you (1) are unable to complete the exam at the time originally scheduled for allowed reasons, (2) are unable to make the UF-appointed make-up exam time for allowed reasons, (3) do not make-up the exam at some other time prior to the finalization of grades on December 18, and (4) are on pace to pass the course, you will receive a grade of I (Incomplete). In the (also unlikely) case that the first three of these conditions apply but you were on pace to fail the course, UF policy requires that I assign a failing grade with the notation that you stopped participating before the end of the term. This may have implications on financial aid beyond a simple “E” grade.

Workload: The instructor is aware that senior students and new graduate students have extremely busy semesters. Reasonable accommodations on homework and requirements will be made for professional commitments (conference attendance, taking the candidacy exam, grad school visits, etc.). Some deadlines may be moved back due to other courses.

Disabilities: 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 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 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 all assignments, lecture notes, etc. will 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.

Schedule: (subject to small adjustments throughout semester)

Week	Topics	Reading	Lab
21-Aug	Introduction. Syllabus and Sources of Radiation	Ch 1 & 2	
28-Aug	Radiation Interactions and Counting Statistics	Ch. 3	
4-Sep	Labor Day (Mon). Counting Statistics (cont.)	Ch. 3	Lab 0: Intro. & Safety
11-Sep	Error Analysis and Pulse Shaping	Ch. 3 & 16	Lab 1: OScope Usage
18-Sep	Pulse Shaping & Processing and NIM Electronics & Circuits	Ch. 16 & 17	Lab 2: Nuc. Instruments Electronics
25-Sep	Multi-Channel Analyzers and General Detector Properties	Ch. 18	
2-Oct	General Detector Properties and Gas Detectors (ion chambers) (Exam 1 - this week?)	Ch. 4	
9-Oct	No Class (10/9 and 10/11) - SciX Conference. Gas Detectors (ion chambers)	Ch. 5	
16-Oct	Gas Detectors (G-M tubes & proportional counters), Scintillators (inorganic)	Ch. 6 & 7	Lab 3: G-M Detectors
23-Oct	Scintillators (inorganic & organic), Photomultiplier Tubes & Photodiodes, and Radiation Spectroscopy.	Ch. 6, 8, & 9	Lab 4: Gas-Flow Prop. Detectors
30-Oct	Radiation Spectroscopy, Semiconductor Detectors No Class, ANS Winter Conference (M - W)	Ch. 9 & 10	
6-Nov	Semiconductor Detectors and Silicon & Germanium Detectors (Exam 2 - this week?)	Ch. 10 - 12	Lab 5: NaI Scintillation Detectors
13-Nov	Neutron Detection	Ch. 14 & 15	Lab 6: High-Purity Germanium Detectors
20-Nov	Thanksgiving holiday		
27-Nov	Neutron Detection (thermal and fast)	Ch. 14 & 15	Lab 7: Neutron Detectors
4-Dec	Special Topics*, Jeopardy Exam Review, and Final Thoughts		
11-Dec	Final Exam (Dec. 13th 1500-1700)		

*If time permits I will cover additional topics such as reactor instrumentation, medical imaging detectors, and/or health physics personnel dosimetry.

Attendance

Students are required to attend each class period with a percentage of the course grade dependent on random pop quizzes. If the student has to miss a class for an appropriate reason, it should be brought to the attention of the instructor as far in advance as possible.

In the event of an unexcused absence, it is the student's responsibility to obtain and review the material that was covered during that class period.

If a student arrives late or leaves early, he/she is expected to do so with minimum level of disruption to the class in progress. 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 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. The list of UF-approved personal reasons changes from time to time. 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.

For the purposes of this course, in the above-referenced list of approved absence reasons, the word “family” shall be taken to mean your parents, grandparents, great-grandparents (etc.); children, grandchildren (etc.); siblings; aunts/uncles; nieces/nephews; your spouse and the spouse of any of the above; and half- or step- “versions” of the above categories. More distant relatives (cousins, etc.), partners (excluding spouses), and pets are not included. Minor illnesses (guideline: anything meriting home care only or care at a walk-in clinic, as opposed to an ER) of family members, including minor children, do not count as serious family emergencies, nor do events such as birthdays, anniversaries, weddings, etc.

Political activities, including protests, demonstrations, and the like are considered personal matters and not generally permitted as excused absences. This includes activities related to nuclear engineering or nuclear power. Exceptions: (1) A student who is pursuing nuclear-related (whether pro- or anti-) politics as a career path may be granted excused absences, at my discretion, on condition of providing evidence of *bona fide* efforts to secure a full-time position or to secure admission to a relevant, non-STEM degree-granting

graduate program and (2) activities between October 28 and November 3, inclusive, that are connected to the ANS Conference will be taken as related to that professional activity and permitted as excused absences.

Further, be advised that any approved reasons for late work do not reduce the amount of work you are expected to complete, but merely rearranges the timing. For those issues that are predictable (interview, holidays, etc.), you should work ahead to avoid disruption. In the case where your approved make-up work adversely affects a group project, I may modify the assignment and/or groups for those concerned to minimize the disruption of one student's issues on other group members.

Collaboration

Laboratory work is to be performed in groups. I will assign the groups for each laboratory section. A peer review system is in place to assure equitable workload. In the event the workload is not equitable, I reserve the right to adjust individual grades to accurately reflect contributions to the work.

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 other 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.

Grading Scale

The final grades will be assigned based on:

- A: $\geq 86\%$
- A-: 84.5-85.99%
- B+: 83-84.49%
- B: 75-82.99%
- C: 67-74.99%
- E: $< 67\%$

I reserve the right to grant higher grades at the end of the course at my sole discretion, including the use of A-, B+, B-, and C+. Typically, the average GPA in ENU 4612, is between 2.9 and 3.3. Under no circumstances will grades of C- or any flavor of D be used.

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. As a result, a question such as, "Prof. Hartig, why did you take off 2 points here?" is both presumptuous and nonsensical, since you didn't have the points to begin with.
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 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>

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.

Letters of Recommendation/Evaluation Policy

To request a letter of recommendation/evaluation (for graduate school or otherwise), you must provide:

- A hard copy of your UF transcript.
- A hard copy of a resume (or CV).
- A hard copy of the following form: <http://www.registrar.ufl.edu/pdf/ferparelease.pdf>. You must check all four circles.

Letters are typically filed once per week. For students whom I know only through coursework, my letter typically focuses on an estimate of their rank-in-class and on their performance on projects and challenging problems.

I will only file one batch of letters per student during the term, for any student currently enrolled in a class with me. (This policy is designed to keep me from looking up slight changes in your rank/performance multiple times for multiple batches of letters.) I recommend that this batch occur as late as possible in the term to allow me sufficient information (sample size) on your performance to write a useful letter.

I reserve the right to refuse to provide a letter for any student and am not obligated to provide a reason for such refusal.