ENU 5615C
Nuclear Radiation Detection and Instrumentation
Spring 2015

1. Catalog Description

Interaction of radiation with matter, radiation-detection systems, pulse shaping, amplification, amplitude and time-analyzing circuitry; counting and measuring devices and control systems for nuclear reactors.

2. Pre-requisites and Co-requisites

Co-requisite: ENU 6051

3. 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.

4. Not Applicable

5. Not Applicable

6. Instructor

Dr. Andreas Enqvist, 174 Rhine Hall, 352 294 2177

enqvist@mse.ufl.edu

Office Hours: Monday, Period 7 (1:55 – 2:45 AM)
Wednesday, Period 3 (9:35 - 10:25 AM)
Friday, Period 3 (9:35 – 10:25 AM)
Note: Office hours may change due to laboratory schedule

7. Teaching Assistant

Enrique Wong

8. Meeting Times

Wednesday Period 4 (10:40 - 11:30 AM), Mondays period 3 & 4 (9:30 – 11:30 AM). Laboratory sections will be tentatively scheduled as student's schedules permits.

9. Class Schedule

Three (3) 50-minute lectures each week (Monday (2), Wednesday) – expect for noted holidays and cancelled classes one the noted dates in the class schedule. One (1) 3-hour laboratory session during particular weeks as noted on the course outline.

10. Meeting Location

Lecture: 2102 MCCB (Dan McCarty Hall B)

Laboratory: 125 NSC (Nuclear Science Building)

11. Material and Supply Fees

$43.05 for Spring 2013

12. Textbooks Required

Glenn F. Knoll, *Radiation Detection and Measurement*, 4th Ed., John Wiley & Sons, Inc., 1999.

Access to 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 chart of nuclides that I use frequently.

1. http://www.oecd-nea.org/janis/ JANIS 4 (Especially the Java based version which is extremely rich on information and plotting of the cross sectional data, can also be downloaded as a program. Recommended)

2. http://atom.kaeri.re.kr (This is a website maintained by the Korea Atomic Energy Research Institute – Recommended, cross section plotting tool)

3. http://www.nndc.bnl.gov/chart/ (Brookhaven national laboratory maintained)

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

Course Notes

I will place course notes ahead of lectures on the **Canvas** website. Feel free to download the course notes at UF's e-learning webpage. This will be the location to download other course materials from time to time (lab handouts, interesting papers I find, etc.).

13. Recommended Reading

1. Nicholas Tsoulfanidis, *Measurement and Detection of Radiation*, 4th Ed., Taylor and Francis, 2015.

2. G. G. Eichholz and J. W. Poston, *Principles of Nuclear Radiation Detection*, Ann Arbor Science, 1985.

3. J. Higginbotham, *Applications of New Technology: External Dosimetry*, MP Publishing, 1996.

4. *The Dosimetry of Ionizing Radiation*, K. R. Kase, B. E. Bjarngard, and F. H. Attix, Editors, Academic Press, 1990.

Example of useful formulae/physics/math/statistics models books:

5. *Physics handbook*, Nordling, Osterman, Studentlitteratur AB, 8th Ed. 2006

6. Mathematics Handbook For Science And Engineering, Rade, Westergren, 5th Ed, Springer, 1999

14. Course Outline (tentative!)

Date		Course Topic	Chapter	Lab Topic for that Week
January	6	Introduction, Course Goals and Objectives		
	11	Sources of Radiation, Radiation Interactions	1,2	
	13	No Class - SNF Conf/seminar		
	18	No class - Martin Luther King, Jr.'s Birthday		Introduction & Lab Safety
	20	Radiation Interactions, Counting Statistics	2,3	
	25	Counting Statistics, Error Analysis	3	Oscilloscope Usage
	27	Error Analysis	3	
February	1	Pulse Shaping and Processing	16	NIM modules
	3	NIM Electronics and Circuits	16,17	
	8	Nuclear Instrument Electronics, Multi-Channel Analyzers	17,18	
	10	In-Class Quiz #1		
	15	General Detector Properties	4	
	17	Gas Detectors (Ionization chambers)	4,5	Geiger-Mueller Detectors
	22	Gas Detectors (G-M Tubes, proportional counters)	7,6	

	24	Scintillation Detectors (Inorganic)	8	Gas-Flow Proportional Counters
	29	No Class - Spring Break		
March	2	No Class - Spring Break		
	7	Scintillation Detectors (organic), Photomultiplier Tubes and photodiodes	8,9	NaI Scintillation Detectors
	9	Spectroscopy with Scintillators,	10	
	14	Thermoluminescent Dosimeters, Semiconductor Detectors	19 & Notes	High-Purity Ge Detectors
	16	Semiconductor Detectors	11	
	21	Silicon Detectors, Germanium Detectors	11, 12	Neutron Detection
	23	In-Class Quiz #2		
	28	Germanium Detectors, Neutron Activation Analysis	12, 19 & Notes	
	30	Thermal Neutron Detection	14	Pulse shape discrimination
April	4	(fast) Neutron Detection	15	
	6	Pulse Shape Discrimination	15, notes	
	11	**Final Exam (9:30-11:30 PM)**		
	13	Nuclear Security, Reactor Instrumentation(1)	Notes	
	15	**Final Lab Report Due (5 PM, Friday)**		
	20	No Class		
	22	No Class		

* - Make-up classes may be scheduled, depending on if the class has fallen behind schedule. I also reserve the right to hold make-up classes due to forced cancellations (e.g., hurricanes). Note: there may be 1-2 additional classes cancelled due to other unplanned travel. I will announce these in advance along with the makeup dates.

(1) – These are more advanced topics that will be covered if time allows.

15. Attendance and Expectations

Students are expected to attend each class period and perform each laboratory. Periods which may be missed should be brought to the attention of the Instructor as far in advance of the class period 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. Students must participate in each laboratory exercise and produce and individual laboratory report on each exercise. Students may make up experiments provided that valid medical reason or previously excused reason. Students must perform **ALL** laboratory experiments in order to receive a passing grade.

16. Grading

Your overall grade is based on your performance in both the lecture and laboratory, with each weighted equally. Note: you MUST receive a passing grade in both parts of the course in order to receive a passing grade (e.g., an A in lecture and an E in lab does not equal a C; it will be recorded as an E!). Below is a breakdown for the grading in the lecture and laboratory:

Lecture Grading		**Laboratory Grading**	
Quizzes (2)	40%	Lab Participation	10%
Mid Term Exam	20%	Lab Quizzes	10%
Final Exam	40%	(2) Worksheets	10%

(3) Short Reports	30%
(1) Formal Report	20%
(2) Oral Presentations	20%

Lecture Grading

Quizzes and Exams

Two non-cumulative quizzes will be given during the semester on dates to be determined later, but you can expect them around the dates tentatively shown in the schedule above. **I will give you a one-week advanced warning for each quiz, at minimum**. Each quiz will be given during normal class time. The midterm exam will be 2 hours in length and will be given from 6-8 PM in the evening on a date to be determined later, but expect it in late February/early March. **I will give you a two-week advanced warning for the midterm exam.**

The final exam currently scheduled on **Friday, April 11** (9:30-11:30AM) is cumulative. These exams are closed book - closed note, however you will be allowed to bring in notes as specified below:

Quiz #1 – one side of one sheet of 8.5x11 in2 of paper
Midterm Exam - one full sheet (both sides) of 8.5x11 in2 of paper
Quiz #2 – 1.5 sheets (three sides) of 8.5x11 in2 of paper
Final Exam – 2 sheets of 8.5x11 in2 of paper

Laboratory Grading

Quizzes

A quiz will be given at the beginning of each class. It is highly suggested that the students read the lab handout ahead of time to prepare for the lab.

Lab Participation

I expect all students to come to lab on-time and prepared to perform the experiment. I also expect students to contribute to the execution of each experiment/measurement (i.e., coming to lab and just sitting on your thumbs is not an effective form of lab participation). Students must perform **ALL** laboratory experiments in order to receive a passing grade.

I also expect students to keep a detailed lab notebook or binder that contains everything from the course. This should have at the minimum all of the data you record or print out that is associated with the course. Equipment information and sketches of experimental setup should also be included in the notebook, as should any important information that helps you explain your results. This will be help you prepare and write your reports. I suggest keeping a binder with all of the course material, sorted in an orderly fashion. It will help you keep track of material handed out in this course, and will be a helpful study guide for exams!

Keeping your "lab notebook" in electronic form is certainly acceptable, provided it is orderly.

Short Reports

Short reports are abbreviated formal reports. No abstract, theory section or procedure section is required, but the Results and Analysis section should be thorough and well written--just as you would write for a long (formal) report. Adequate explanation and discussion of all parts of the lab is necessary. I you give some notes for writing short reports. Short reports are due at the beginning of the lab session one week after the experiment is performed. You will have 3 short laboratory reports throughout the semester. These reports will be approximately 10 pages in length (assuming single spacing), with extensive use of figures, graphs, and tables to provide adequate explanation of the results from the experiment, including linking your observations with theory.

Long (Formal) Report

The formal report for experiment is essentially a report designed to demonstrate your knowledge of the experiment, from theory to data analysis and everything in between. The long report will include an abstract, theory section and a procedure section in addition to the sections mentioned for short reports. This report will be detailed in it description, and thus will be much longer than your previous reports. I will give you some notes for writing the long report later in the semester. Long reports are due two weeks after the experiment is performed (can be emailed, electronically submitted on Canvas).

Oral Presentations

To help you prepare for the real world, when you will need to make presentations to your supervisor or at a conference, you will prepare an oral presentation for a couple of the laboratory experiments. For these experiments you will prepare a 15 minute PowerPoint/Powerdot etc presentation about the experiment: the theory, your experimental setup, measurement results, and analysis of your results. You will then be asked a few questions by the Instructor and/or Teaching Assistant concerning what you should have learned during the experiment. Make sure you come to the presentation prepared (I suggest you look over the results and underlying theory) as these presentations will be done individually. You shall schedule the presentation DURING THE FOLLOWING WEEK after the experiment was performed.

Report Guidelines

1) Your **audience** is a nuclear engineer, unfamiliar with the experiment

This implies:

a) Explain **what** you are doing in each part of the lab. This does not mean a step-by-step description of the procedure, but rather a description of the general measurement. If a setup diagram makes the experiment clearer, then include one in the **body** of the report.

b) Explain **why** you are making a particular measurement. Provide a conceptual (and possibly theoretical) description of the experiment. The reader will require this knowledge so that he may understand your measured results.

c) Drawing from the conceptual description of each measurement, **predict** the expected result.

d) Present your result, with **quantitative** measures of its accuracy (e.g.percent deviation, R2)

e) **Analyze** your result. Address both the **magnitude** of the deviation and its **direction** (i.e. Is the measured number greater than or less than the proper result?).

*Your report should concentrate on the **analysis** of the results, not the results themselves. The particular number that you measure is less important than your ability to communicate a complete description of the experiment.*

2) Figures (Drawings and Plots)

a) Your goal is to make your reports as understandable as possible. Therefore, use drawings liberally.

b) Do not turn in a report with pencil drawings on it. If the best way to make a drawing is by hand (most of the time, it is not), then photocopy the report after you make the drawing and turn that in to me (so that the drawing and text will be the same in color and consistency).

c) When making plots, use a software package such as Matlab, MS Excel, SigmaPlot, or the like. Include axes labels (with units) and label each of the figures in your report.

3) Formal writing (textbook style).

a) Do not use a conversational tone (i.e. write in complete sentences, do a spell check)

b) Do not write in the first person.

c) Font size: 10 - 12

Successful Report Writing

I will evaluate your writing on a number of criteria: Content, Organization, Argument and Support, Style, and Mechanics. In order to be a successful writer, please look over the following rubric for guidance of on completing the requirements.

	SATISFACTORY	**UNSATISFACTORY**
CONTENT	Papers exhibit at least some evidence of ideas that respond to the experiment/laboratory topic with complexity, critically evaluation the results, and provide at least an adequate discussion with basic understanding of experiment.	Papers either include a central discussion that is unclear or off-topic or provide only minimal or inadequate discussion of the experimental results. Papers may also lack sufficient or appropriate discussion of the results, with little or no tie-in with the underlying theory.
ORGANIZATION AND COHERENCE	Documents and paragraphs exhibit at least some identifiable structure for topics, including a clear thesis statement but may require readers to work to follow progression of ideas. Figures, tables and graphs are used in a logical manner to properly explain results, with these items being placed within a logical manner/progression of the experimental result. An outside nuclear engineer should be able to understand your report, and be able to repeat at least some of the experiment.	Documents and paragraphs lack clearly identifiable organization, may lack any coherent sense of logic in associating and organizing ideas, and may also lack transitions and coherence to guide the reader. Poor use of figures, graphs, and tables do not provide any cohesion with the discussion in the report.

ARGUMENT AND SUPPORT	The reports use persuasive and confident presentation of ideas, strongly supported with experimental evidence (including comparisons with what your theoretical expectations). At the weak end of the Satisfactory range, documents may provide only generalized discussion of the experimental results or may provide adequate discussion but rely on weak support for arguments.	Documents make only weak generalizations, providing little or no support, as in summaries or narratives that fail to provide critical analysis. No crucial comparisons with the underlying theory of the experimental results.
STYLE	Documents use a writing style with word choice appropriate to the context, genre, and discipline. Sentences should display complexity and logical sentence structure. At a minimum, documents will display a less precise use of vocabulary and an uneven use of sentence structure or a writing style that occasionally veers away from word choice or tone appropriate to the experiment/topic. Figures, tables and graphs follow an appropriate style/format, and that style is used consistently throughout the document. For additional information on style and format, you can consult the writing formats for a variety of publications, including Nuclear Instruments and Methods in Physics Research, IEEE Transactions on Nuclear Science, or Journal of Health Physics.	Documents rely on word usage that is inappropriate for the context, genre, or discipline. Sentences may be overly long or short with awkward construction. Documents may also use words incorrectly. Figures, tables and graphs are poorly constructed with little adhesion to a consistent format.
MECHANICS	Reports will feature correct or error-free presentation of ideas. At the weak end of the Satisfactory range, reports may contain some spelling, punctuation, or grammatical errors that remain unobtrusive so they do not muddy the paper's argument or points.	Papers contain so many mechanical or grammatical errors that they impede the reader's understanding or severely undermine the writer's credibility.

I will provide more details on report grading at the first meeting for the lab sections.

17. Grading Scale

The grading scale is generally as follows:

Lecture Grading Scale		Laboratory Grading Scale	
88-100	A	92-100	A
84-87	A-	88-91	A-
80-83	B+	85-87	B+
76-79	B	82-84	B
72-75	B-	79-81	B-
68-71	C+	76-78	C+
64-67	C	73-75	C
60-63	C-	70-72	C-
56-59	D+	67-69	D+
53-55	D	63-66	D
50-52	D-	60-62	D-
0-49	E	0-59	E

Note: this scale may be adjusted depending on topics covered and difficulty of exams. As noted before, you must receive a passing grade in both components in order to receive a passing grade.

18. Make-up Exam Policy

Make-up Exams are only allowed through prior requests or DOCUMENTED medical reasons. In cases where students will be out of town, a reasonable attempt to take the exam before the scheduled exam date will be performed.

19. 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 (http://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.

Note that failure to comply with this commitment will result in disciplinary action compliant with the UF Student Honor Code Procedures. See http://www.dso.ufl.edu/sccr/procedures/honorcode.php

20. Accommodation for Students with Disabilities

Students requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.

21. UF Counseling Services

Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, http://www.counseling.ufl.edu/cwc/Default.aspx, counseling services and mental health services.
- Career Resource Center, Reitz Union, 392-1601, career and job search services.
- University Police Department 392-1111

22. 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.

23. Course Feedback

Students are expected to provide feedback on the quality of instruction in this course based on 10 criteria. These evaluations are conducted online at https://evaluations.ufl.edu. 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.