جامعة قطر
QATAR UNIVERSITY

nuclear Physics 451 – Spring 2008

By

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Math and Physics Department

Radiation Physics 451
Course Information for Spring 2008

General Information:

Time: Monday, Wednesday, 11:00 – 12:30, Room SB 228

Course Lecturer:

Dr. Ilham Y. Al-Qaradwi, Associate professor, Physics Department.

How to contact me:

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Personal Web Page: http://www.ilhamalqaradawi.com
Course Web Page: http://www.ilhamalqaradawi.com/students-info/455.htm

Office Hours: Mondays and Wednesdays 12:30-13:30, Tuesdays: 12:00-13:00

(Other timings can be arranged by appointment only please)

During office hours I will be available in the positron lab room SA105, science building.

Midterm tests: Wednesday 23rd April, Monday 28th May 2008

Final Exam: Monday June 9th, 2008, 11:00-13:00.

COURSE DESCRIPTION:

The course presents a mixture of both theory and practice in a simple but applied format. It is intended to show the students detailed treatments of some nuclear related aspects, while in other cases a comprehensive survey of the topic is adopted. Industrial and medical aspects of the field are considered.
Lab experiments are designed to reinforce the major concepts that have been presented in class as well as to give the students a feel of using main types of detectors and gamma spectroscopy technique. Learning to cooperate and working in a team is also emphasized. The importance of expressing results in various types of graphs and dealing with statistics is stressed. Both manual and PC based calculations, analysis and graphing are enforced.

PREREQUISITES: Introductory Nuclear Physics 351

CO-REQUISITES: None

CREDIT HOURS: Three (3)

LECTURE HOURS PER WEEK: 3

LAB HOURS PER WEEK: 3

TEXTBOOKS:

- Nuclear and Particle Physics, Williams, Oxford.
- An Introduction to the Physics of Nuclei and Particles, Richard A. Dunlap, Thomson.
- Introductory Nuclear Physics, Kenneth Krane, Wiley.

Course objectives:

Provide the students with a solid understanding of the fundamentals of those aspect of low-energy nuclear physics that are most important to applications in such areas as nuclear engineering, nuclear and radiochemistry, geosciences, biotechnology, medicine etc as well as showing the new trends in high energy and particle physics.

COURSE OUTLINE:

1. Nuclear Reactions

i) Introduction
ii) Experimental methods
iii) Measured quantities
iv) Types of Reactions
v) Energetics of reactions
vi) Conservation laws
vii) Reaction Mechanisms:
viii) Direct reactions
ix) Compound nucleus reactions
x) Resonance reactions
xi) Cross sections
xii) Fission and reactors
xiii) Fusion and energy

2. Applications of Nuclear Physics

i) Medical applications
ii) Environmental applications
iii) Energy: Fission and fusion
iv) Materials applications

3. Nuclear Physics Today

i) High Energy Physics: labs around the world
ii) Families of Particles: Quarks and Leptons
iii) Accelerators: types and uses
iv) Colliding beams and fixed targets

4. Nuclear Models

i) Liquid Drop Model
ii) Shell Model
iii) Collective Model
iv) Uniform particle model

v) Optical Model

5. Neutron Physics

i) Neutron sources
ii) Absorption and moderation of neutrons
iii) Neutron detectors.
iv) Neutron capture

LEARNING OUTCOMES:

After studying this chapter a student should be able to:

1. express a nuclear reaction in equation format
2. understand how different accelerators operate, including the Van de Graff and the cyclotron
3. explain what is meant by entrance and exit channels of a nuclear reaction and how these are related to elastic and inelastic scattering
4. discuss the purpose in measuring experimental cross sections and set up the diagram of a beam scattering off a target into a differential solid angle dW
5. determine the differential and total cross sections of a scattering experiment
6. use conservation of energy to determine the energy release of a reaction
7. define threshold energy and calculate it for a given reaction
8. relate the lifetime of a nucleus to its energy width
9. discuss the neutron capture reaction including what affects the probability that it will be captured
10. define fission and fusion
11. note the similarities and differences between spontaneous and induced fission
12. calculate the ground-state Q value of a fission reaction
13. calculate the excitation energy of a given compound nuclei
14. describe the processes that lead to a subcritical, critical and supercritical chain reaction respectively
15. be familiar with the necessary components for a controlled nuclear reactor and the function of each
16. know how a breeder reactor produces more fissoinable fuel than it consumes
17. identify and explain the two main fusion cycles that produce energy in stars
18. list the three main conditions required for controlled nuclear fusion, and which ones have been reached
19. talk about what the confinement factor, ν_τ, says
20. describe the main ideas of magnetic and inertial confinement
21. be familiar with some of the many applications of nuclear science
22. Use nuclear models to predict low-energy level structure and level energies.
23. Use nuclear models to predict the spins and parities of low-lying levels and estimate their consequences with respect to radioactive decay.
24. Use nuclear models to understand the properties of neutron capture and the Breit-Wigner single level formula to calculate cross sections at resonance and thermal energies.

25. calculate the kinematics of the interaction of photons with matter and apply stopping power to determine the energy loss rate and ranges of charged particles in matter
26. calculate the energies of fission fragments and understand the charge and mass distributions of the fission products, and prompt neutron and gamma rays from fission

List of experiments for nuclear physics lab 451

1. **Basic Identifications in Electronic measurement Systems**

    a. Observing direct and attenuated outputs of the pulser.
    b. Using the pulser as the linear input to a typical counting system.
    c. Using a single channel analyzer

2. **GAMMA-RAY SPECTROSCOPY USING NaI(Tl)**

a- Energy calibration
b- Energy analysis of an unknown Gamma source.
c- Spectrum analysis of ^{60}Co and ^{137}Cs.
d- Energy resolution.
e- Activity of a Gamma emitter (Relative method).
f- Activity of a Gamma emitter (Absolute method).
g- Mass absorption coefficient.
h- The linear gate in Gamma Ray spectroscopy.

3. ALPHA SPECTROSCOPY WITH SURFACE BARRIER DETECTORS

a- Simple Alpha-Spectrum and energy calibration with a pulsar.
b- Energy determination of an unknown Alpha source.
c- Energy calibration with two Alpha sources.
d- Absolute activity of an Alpha source.
e- dE/dx for Alpha particles in a Copper Foil.

4. TIME COINCIDENCE TECHNIQUES AND ABSOLUTE ACTIVITY MEASUREMENTS

a- Simple fast coincidence experiment.
b- Fast coincidence and the time to pulse height converter.
c- Determination of absolute activity by the coincidence method.

5. **GAMMA – GAMMA COINCIDENCE**

a- Overlap coincidence method for measuring gamma-gamma coincidence of ^{22}Na
b- Linear gate method for measuring gamma-gamma coincidence of ^{22}Na.

c- Time to pulse height converter method for measuring gamma-gamma coincidence of ^{22}Na.

d- Lifetime measurement using the delayed coincidence method.

Discussion Sessions (Tutorials)

There will be regular discussion sessions (tutorials), which will take place normally on the second half of the lecture time. Those sessions will focus on developing good problem solving ability, and concentrate on further explaining the more difficult subjects of the course. They are also a good chance for asking questions.

Relation to other courses in the curriculum:

This is an applied course with a prerequisite of nuclear physics 351. It is related to several other courses within the curriculum, therefore you are advised to take it as early as possible in your curriculum. Those courses are:

451 Nuclear Physics
453 Radiation Physics
455 Particle Physics
497 Independent Study (depending on topic)
498 Special Course (depending on topic)
499 Graduation Project (depending on topic)

Course Requirements

1. **Homework Assignments:**

Every week, a few homework problems will be assigned. Problems are to be returned on the date indicated. Problems returned after the deadline will receive a grade of 0. Solutions to the homework problems will be given in the discussion sessions in the classroom as well as posted on the Web. You are encouraged to work together with fellow students to **discuss homework concepts**, and you are allowed to work out the solutions together. Be aware that, when working together with a fellow student, you should actually attempt to solve the problems together, not just copy answers and solutions. Homework will account for 15% of the final grade.

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2. Projects

It is hoped that some active work on the students' side could be achieved to encourage students to search for information on a certain subject and then organize this information in an interesting way and present it with explanation to their fellow students during lectures or lab sessions.

Each student should prepare an essay, as well as a poster, a presentation or a website that explains the assigned subject in a clear, concise, and attractive way. There will be voting at the end of term for the best three projects. Those will be assigned 1st, 2nd, and 3rd places. The proposed subjects are part of the material that will be covered in this course. A tentative list follows:

1. Industrial applications of nuclear radiation
2. Neutron physics
3. Scintillation detectors
4. Nuclear fission reactors
5. Nuclear fusion reactors
6. Discovery of the top quark

The project grading however, does not depend only on how good it is compiled, but also on how much you have understood the subject and how good your presentation is. The main issue being preparing what you have been asked to prepare. If you prepare an essay or a poster on a different subject from the one allocated to you, your grade will be **zero** no matter how good your poster is.

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3. **Midterm Exams:**

There will be two closed book midterm exams, given **only** on the dates shown in the syllabus, each lasting an entire class period, and each counting 20% of the final grade. The exams will consist of various types of questions as well as problems.

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4. **Final Exam:**

The Final exam will be given **only** on the date shown in the syllabus. It will consist of multiple choice questions as well as short questions and problems addressing **all** the material covered in the course.

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5. Extras:

- Short assignments are given frequently during lecture or most probably at the end of a lecture in preparation for the next topic to be discussed. Those should normally be one page or less but need to be handed in the following lecture in most cases. This is useful for developing your search skills and can gain you some extra marks.
- Examples of items that will be considered for extra credit include, but are not limited to:
    1. A page, submitted to me, which indicates the time, date, and title of any seminars/talks or presentations (live or virtual) you attend/or see during the semester (QU campus or elsewhere – e.g. *Doha debates)*, of relevance to physics. The card should provide a paragraph of the relevant facts of the activity.
    2. A page, submitted to me, which details relevant news articles from contemporary literature or popular press or news (*Science* journal, *Al-Jazeera*, *BBC* broadcast, etc.). The card will provide a paragraph of the relevant facts of the activity.
    3. A survey of excellent websites of particular relevance to the course material indicating in a table the title of the website, the web address, and the topics covered.

Evaluation Methods:

1. Quizzes
2. Homework
3. Exams (open book and closed book)
4. Project
5. Lab reports
6. Excursion report

Extracurricular activity:

Excursion to radiology department at hospital or to an industrial company using radiation sources will be arranged.

A summer trip to CERN, the European Organization for Nuclear Research, the world's largest particle physics centre is being arranged to attend a one week summer school.

Grading:

Final grades will be determined by the following components:

Homework	10%
Project	5%
1^{st} midterm exam	15%
2^{nd} midterm exam	15%
Final exam	30%
Extras	not fixed
Lab	25%
TOTAL	100%

Reward system:

A reward system is going to be followed this semester to encourage excellence in this course. For those who obtain A grade; they will be rewarded by a membership of the Institute of Physics. For everyone who passes the course with a high grade a trip to CERN can be arranged.

Useful Web Sites:

- Radionuclide Search: http://nucleardata.nuclear.lu.se/nucleardata/toi/
- Atomic Spectra: http://physics.nist.gov/cgi-bin/AtData/main_asd
- National Nuclear Database: http://www.nndc.bnl.gov/index.jsp
- Radionuclide Decay Data: http://hps.org/publicinformation/radardecaydata.cfm

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Feedback:

Your comments, questions, and suggestions about this course are always welcomed. You may use either the attached form or during office hours or send an email.
If you wish you may send an email message to me to establish contact. You will receive some interesting sites and useful information whenever I come across them on the web.

Course Web Page:

You are encouraged to visit the course website at: http://www.ilhamalqaradawi.com/students-info/451.htm

You will find updated information about the course, which you may print or download. You will also find a number of educational links related to the course material which could be quite useful in emphasizing the theoretical ideas and principles. Some might contain solved problems and examples as well.

Course Calendar Spring 2008

Day / *Date*	Monday	Wednesday	Notes
March 11 – 15	Course overview	Units and definitions	
March 18 – 22	Radioactive sources	Accelerator based sources	
March 25 – 29	Synchrotron radiation	Sources of electromagnetic radiation	1st Assignment
April 1 - 5	Radiation interactions	Interactions of heavy charged particles	
April 8 - 12	Interactions of photons	Interactions of neutrons	
April 15 - 19	Dosimetry and radiation effects	**1st periodical test**	2nd Assignment
April 22 - 26	Definitions/ Exposure and absorbed dose	Standardization/ ICRP	
April 29 – May 3	Dose Equivilant / Effective Dose	Types of dosimeters	3rd Assignment
May 6 - 10	Detectors/ Gas filled detectors	Scintillation detectors	
May 13 - 17	Semiconductor detectors	Neutron detectors	4th Assignment
May 20 - 24	Other detector types	Pulse processing and shaping/ Multichannel pulse analysis	
May 27 – 31	Medical Applications	**2nd periodical test**	5th Assignment
Jun 3 - 7	Industrial radiography/	Welding/ Well logging	
Jun 10 - 14	**Final Exam**		6th Assignment
Jun 17 - 21			Exam papers back on Thu 21st Jun