WAYNE STATE UNIVERSITY
DEPARTMENT OF RADIATION ONCOLOGY
ROC 6710 PHYSICS IN MEDICINE
Winter Semester 2017

TIME/DAYS:

Monday and Wednesday, 2:30-4:00 PM

LOCATION:

Gershenson ROC Large Conference Room

INSTRUCTORS:

MS – Michael Snyder, Ph.D., Assistant Professor, Radiation Oncology
msnyder@med.wayne.edu

JB – Jay Burmeister, Ph.D., Assoc. Professor, Radiation Oncology
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OM – Otto Muzik, Ph.D., Professor, Pediatrics & Radiology
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MJ – Michael Joiner, Ph.D., Professor, Radiation Oncology
joinerm@wayne.edu

OFFICE HOURS: By appointment.

REFERENCES:

- Introduction to Physics in Modern Medicine, Second Edition, *Suzanne Amador Kane*

References/Additional Reading material shall be posted on the blackboard periodically or handouts may be given in class as per the discretion of each instructor.

EXAMINATIONS AND QUIZZES:

Two Section Examinations will be given according to the established schedule. These exams will be constructed to cover the specific content addressed in that section of the course; however, some content may inherently involve cumulative knowledge and/or skills.

GRADING POLICY:

The course grade will be primarily determined according to the following:

Midterm Exam	45%
Final Exam	45%
Final Project	10%

The instructor will utilize the grading guidelines stated below in the determination of the final course grade. The quality of the student's class participation may be considered in the determination of the final course grade.

Grades will be determined based on the following scale:

A	88-100%	B-	68-73%
A-	83-88%	C+	63-68%
B+	78-83%	C	58-63%
B	73-78%	F	<58%

The instructor reserves the right to scale the grades at the end of the term. A lower course grade will not be assigned based on such scaling. Final course grades will NOT be rounded to the nearest whole number. A grade of "I" (Incomplete) will be given only in the most extraordinary of circumstances.

ACCOMODATION POLICY:

If you have a documented disability that requires accommodations, you will need to register with Student Disability Services for coordination of your academic accommodations. The Student Disability Services (SDS) office is located at 1600 David Adamany Undergraduate Library in the Student Academic Success Services department. SDS telephone number is 313-577-1851 or 313-577-3365 (TDD only). Once you have your accommodations in place, I will be glad to meet with you privately during my office hours to discuss your special needs. Student Disability Services' mission is to assist the university in creating an accessible community where students with disabilities have an equal opportunity to fully participate in their educational experience at Wayne State University.

COURSE WITHDRAWAL POLICY:

The instructor will not permit withdrawal from the course as per the Wayne State University guidelines.

ACADEMIC DISHONESTY POLICY:

In any instance of academic dishonesty, occurring in this course as defined in Section 3.0 of the University Student Due Process Statute, the provisions of 10.1 of the Statute will be implemented as follows.

The grade for the course will be reduced to a "D" or to an "E" if the grade status would otherwise have been a "D". In addition, charges MAY be filed, as provided for in-section—10.2 of the Statute which may lead to further sanctions up to and including expulsion from the College or University.

LEARNING OUTCOMES:

The class is designed to introduce the technically minded student to the manner in which basic physics concepts have been used to implement various technologies throughout the medical field. At the conclusion of the course the student is expected to:

- Understand the basic atomic physics involved in x-ray generation
- Understand the basic nuclear physics involved in radionuclide treatments and imaging
- Describe the physical concepts of various imaging modalities including Ultrasound, Computed Tomography, MRI, SPECT and PET
- Be familiar with the methods and machinery utilized in radiotherapy
- Understand the role of DNA damage in control of malignant tumors using radiotherapy techniques and be able to provide a statistical simulation of that damage as it related to cell death.

Upon the completion of the course the student will have a broad background in how technology is actively used in a clinical setting, and be able to describe the physics principles that allow that technology to be successful in advancing patient care.

<u>COURSE OUTLINE:</u>

Mon. Jan. 9 **<u>COURSE INTRODUCTION</u>** **MS**

Wed. Jan. 11 **<u>BASIC ATOMIC AND NUCLEAR PHYSICS</u>** **MS**

Atomic Structure, Rutherford Nuclear Atom, Bohr Atomic Model, Excitation and Ionization, Modifications of the Bohr Atom, Periodic Table of Elements, Characteristic X-rays, Auger Electrons*, Wave Mechanics Atomic Model, The Neutron and Nuclear Force, Isotopes, The Atomic Mass Unit, Nuclear Binding Energy, The Nuclear Liquid Drop Model, The Nuclear Shell Model, Nuclear Stability.

Reading Assignment:

Introduction to Health Physics, III Edition by Herman Cember
Chapter 3, pp. 51-72
**Atoms, Radiation, and Radiation Protection, III Edition by James E. Turner*
pp. 45-47

Mon. Jan. 16 **<u>UNIVERSITY HOLIDAY</u> (Martin Luther King Day)**

Wed. Jan. 18 **<u>PRODUCTION OF X-RAYS</u>** **MS**

The X-ray Tube, The Anode, the Cathode, Focal spot size, Line Focus Principle, Basic X-ray Circuit, Voltage Rectification, Physics of X-ray Production, Bremsstrahlung Radiation, Characteristic X-rays, X-ray Energy Spectra, Kramer's Equation, Relationship between Output vs Filament Current, tube current, tube voltage.

Reading Assignment:

The Physics of Radiation Therapy, III Edition by Faiz Khan
Chapter 3, pp. 28-37

Mon. Jan. 23 **<u>RADIOACTIVITY</u>** **MS**

Basis for Radioactivity, Alpha Emission, Beta Emission, Positron Emission, Orbital Electron Capture, Gamma Ray Emission*, Internal Conversion*, Half-Life, Average Life, Activity, Specific Activity, Natural Radioactivity, Serial Transformation, Secular Equilibrium, Transient Equilibrium, No Equilibrium*.

Reading Assignment:

Introduction to Health Physics, III Edition by Herman Cember
Chapter 4, pp. 75-113

**Atoms, Radiation, and Radiation Protection, III Edition by James E. Turner*
pp. 68-72, 93

Wed. Jan. 25 **RADIOACTIVITY (contd…)** **MS**

Basis for Radioactivity, Alpha Emission, Beta Emission, Positron Emission, Orbital Electron Capture, Gamma Ray Emission*, Internal Conversion*, Half-Life, Average Life, Activity, Specific Activity, Natural Radioactivity, Serial Transformation, Secular Equilibrium, Transient Equilibrium, No Equilibrium*.

Reading Assignment:

Introduction to Health Physics, III Edition by Herman Cember
Chapter 4, pp. 75-113

**Atoms, Radiation, and Radiation Protection, III Edition by James E. Turner*
pp. 68-72, 93

Mon. Jan. 30 **RADIATION SOURCES FOR MEDICINE** **JB**

Applications of radiation in medicine, X-ray generators, linear accelerators, cyclotrons and other cyclic accelerators, radioactive nuclei for nuclear medicine, sealed and unsealed radioactive sources for medical applications.

Wed. Feb. 1 **RADIATION DETECTION/**
RADIATION MEASUREMENT QUANTITIES **JB**

Ionization and its fate, radiation quantities and units, exposure, dose, kerma, collision kerma, radiative kerma, RBE, dose equivalent, radiation detection, gas filled detectors, scintillation detectors, solid state detectors, thermoluminescent dosimeters, film, calorimetry, chemical dosimeters.

Mon. Feb 6 **INTERACTION OF RADIATION WITH MATTER I**
(PHOTONS & NEUTRONS) **JB**

Indirectly ionizing vs. directly ionizing radiation, interaction cross section, exponential attenuation, photoelectric effect, Compton effect, pair production, Rayleigh scatter, photodisintegration, neutrons, scattering kinematics, scattering cross section, resonance and compound nuclei

Wed. Feb. 8 **OPEN STUDY DAY**

Mon. Feb. 13 **INTERACTION OF RADIATION WITH MATTER II**
(CHARGED PARTICLES) **JB**

Types of charged particle interactions, stopping power, factors affecting stopping power, heavy and light charged particle interactions, Bragg peak, range.

Wed. Feb. 15	**<u>MIDTERM EXAM REVIEW</u>**	**MS**
Mon. Feb. 20	**<u>MIDTERM EXAM</u>**	**MS**
Wed. Feb. 22	**<u>PHYSICS OF MEDICAL IMAGING (X-RAYS)</u>**	**MS**
Mon. Feb. 27	**<u>PHYSICS OF MEDICAL IMAGING (CT)</u>**	**MS**
Wed. Mar. 1	**<u>PHYSICS OF MEDICAL IMAGING (ULTRASOUND)</u>**	**MS**
Mon. Mar. 6	**<u>PHYSICS OF MEDICAL IMAGING (MRI)</u>**	**MS**

The Larmor equation, the Bloch equation and the basics of generating a signal will be presented first. Once the signal is obtained method of reconstructing images will be discussed using Fourier transforms. Both 2D and 3D acquisition methods will be discussed as well as some of the basic MR contrast mechanisms.

MR discussion:
We will introduce the basic elements behind magnetic resonance imaging including: MR system components, bulk magnetic resonance, spin phase, spin phase refocusing, relaxation properties, and image contrast.

Wed. Mar. 8	**<u>PHYSICS APPLICATIONS IN CLINICAL RADIOLOGY</u>**	**MS**
Mon. Mar. 13	**<u>UNIVERSITY HOLIDAY</u> (Spring Break)**	
Wed. Mar. 15	**<u>UNIVERSITY HOLIDAY</u> (Spring Break)**	

Mon. Mar. 20 **PHYSICS OF MEDICAL IMAGING (PET)** **OM**

Fundamental particles, Stability of the nucleus, Stochastic nature of radioactivity, Weak force, Positron decay, Creation of positron emitters, Cyclotron, Nuclear reaction cross section, Poisson distribution, Radiochemistry, PET tracers, Scintillation detectors, PET signal, Coincidence detection, Attenuation correction in PET, PET normalization, Dedicated PET scanner, 2D/3D imaging mode, Sinogram, True/scatter/random coincidence events, PET signal corrections, Whole body PET.

Wed. Mar. 22 **PHYSICS OF NUCLEAR MEDICINE** **OM**

Signal in Nuclear Medicine, Reconstruction from projections, Radon transformation, Fourier transformation, Simple and Filtered backprojection, Iterative reconstruction, OSEM, 3D reconstruction, Virtual projections, Noise Equivalent Counts (NEC), Partial volume effect, Gamma Camera components, Scintillation camera corrections, Quality control, Image contrast, Integral and differential uniformity, Spatial resolution, Modulation transfer function.

Mon. Mar. 27 **PHYSICS APPLICATIONS IN CLINICAL NUCLEAR MEDICINE** **OM**

Quantification in Nuclear Medicine, Dynamic protocols, Regions of Interest, Kinetic modeling,, Compartmental tracer models, PET/CT basics, PET/CT attenuation correction, MIRDOSE dose estimates, CT dose index, PACS, Examples of PET imaging in Neurology, Oncology and Cardiology.

Wed. Mar. 29 **RADIOBIOLOGY I** **MJ**

Basic Clinical Radiobiology, 4th Edition"
Eds MC Joiner and AJ van der Kogel.
Published by Oxford University Press, USA; expected February 15, 2009
ISBN-10: 0340929669
ISBN-13: 978-0340929667

Mon. Apr. 3 **RADIOBIOLOGY II** **MJ**

Basic Clinical Radiobiology, 4th Edition"
Eds MC Joiner and AJ van der Kogel.
Published by Oxford University Press, USA; expected February 15, 2009
ISBN-10: 0340929669
ISBN-13: 978-0340929667

Wed. Apr. 5 **RADIOBIOLOGY III** **MJ**

Basic Clinical Radiobiology, 4th Edition"
Eds MC Joiner and AJ van der Kogel.
Published by Oxford University Press, USA; expected February 15, 2009
ISBN-10: 0340929669
ISBN-13: 978-0340929667

Mon. Apr. 10 **RADIATION SAFETY** **MJ**

Wed. Apr. 12 **PHYSICS APPLICATIONS IN CLINICAL RADIATION ONCOLOGY I** **MS**

Medical Linear Accelerators, History, Principles of Operation, Operational/Auxiliary Systems, The Modulator, Klystrons and Magnetrons, Electron Gun, Accelerator Waveguide, Travelling Waveguide, Standing Waveguide, Energy Selection, Electron Energy, Beam Delivery, Bending Magnet Assembly, Target and Flattening Filter, MU chamber, Electron Beam Delivery, Collimation, Blocks, Multileaf Collimators (MLC), Wedges, Compensators, Electronic Portal Imaging Devices, On-Board Imaging Systems (OBI), Helical Tomotherapy, GammaKnife & Cyber Knife.

. *Reading Assignment:*

The Physics of Radiotherapy X-rays and Electrons by Metcalfe, Kron & Hoban, Chapter 1, pp 1-50.

Mon. Apr. 17 **OPEN**

Wed. Apr. 19 **NO CLASS (Study Day)**

Mon. Apr. 24 **FINAL EXAM** **MS**

Questions for consideration:

Wed. Mar. 11 **PHYSICS OF MEDICAL IMAGING (PET)**

1. Why is PET able to absolutely quantify activity concentration in tissue?
2. What is the difference between 2D and 3D PET acquisition?
3. How is the PET signal formed and processed?
4. What are the resolution limitations in PET and what is the achievable resolution?
5. How is the “blank” and the “transmission” scan used in PET to correct the “emission” scan for attenuation?

Mon. Mar. 23 **PHYSICS OF NUCLEAR MEDICINE**

1. Explain the problem of shift-invariance in 3D reconstruction and how it is solved
2. What are the advantages/disadvantages of the iterative reconstruction method?
3. Give the reason why the OSEM iterative reconstruction algorithm is faster than the regular EM iterative reconstruction algorithm.
4. Specify all corrections applied to a gamma camera system
5. How is image contrast defined?

Wed. Mar. 25 **PHYSICS APPLICATIONS IN CLINICAL NUCLEAR MEDICINE**

1. How is attenuation correction performed on a PET/CT scanner and what are the problems?
2. What is a helical CT acquisition and how is it related to the pitch?
3. Explain in detail how CT is used to allow attenuation correction for PET imaging.
4. What is the typical dose for an adult FDG PET/CT acquisition?
5. Describe the advantages and disadvantages of PET/CT scanning in comparison to PET scanning alone.