MEDICAL PHYSICS (MED PHYS)

MED PHYS/PHYSICS 265 – INTRODUCTION TO MEDICAL PHYSICS
2 credits.

A general interest survey that introduces the principles and applications of medical physics. Topics include biomechanics, energy usage and temperature regulation, pressure, sound and hearing, ultrasound, electricity in the body, optics and the eye, ionizing radiation in diagnosis and therapy, radiobiology, and nuclear medicine.
Requisites: PHYSICS 104, 202, 208, or 248
Course Designation: Breadth - Physical Sci. Counts toward the Natural Sci req
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Apply physics concepts, such as force, energy, and pressure, to the study of human physiology Audience: Undergraduate

2. Describe the relevance of physics concepts to the etiology of major disease, such as heart failure, sudden cardiac death, obstructive lung disease, and nerve conduction disorders Audience: Undergraduate

3. Explain the principles of medical imaging based on x-rays, gamma rays, sound, and other physical phenomena Audience: Undergraduate

4. Understand the principles of radiobiology that underlie radiation sickness and radiation therapy Audience: Undergraduate

MED PHYS/H ONCOL 410 – RADIOBIOLOGY
2-3 credits.

Effects of ionizing radiations of living cells and organisms, including physical, chemical, and physiological bases of radiation cytotoxicity, mutagenicity, and carcinogenesis; lecture and lab.
Requisites: Graduate/professional standing or (PHYSICS 202 or 208 and ZOOLOGY/BIOLOGY/BOTANY 152 or 153)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Gain an understanding of the physical, chemical and molecular basis of the action of radiation on biological systems Audience: Both Grad Undergrad

2. Describe the radiobiological principles forming the basis for the use of radiation as a cancer therapy Audience: Both Grad Undergrad

3. Understand the potential deleterious short and longer-term effects of radiation on normal tissues and organs and on the whole body Audience: Both Grad Undergrad

4. Describe how chemotherapy and molecularly targeted agent can alter response of biological systems to radiation. Audience: Both Grad Undergrad

5. Understand the principles of radiation protection Audience: Graduate

MED PHYS/B M E/H ONCOL/PHYSICS 501 — RADIATION PHYSICS AND DOSIMETRY
3 credits.

Interactions and energy deposition by ionizing radiation in matter; concepts, quantities and units in radiological physics; principles and methods of radiation dosimetry.
Requisites: (PHYSICS 323, 449 and MATH 320) or graduate/professional standing or declared in Medical Physics VISP
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Use the physics of microscopic structures of nucleus, nuclear decay, electronic structure of atoms to calculate nuclear decay lifespan and solid state energy band structure Audience: Both Grad Undergrad

2. Calculate the radiation power spectrum for an accelerating charge particle under different physical conditions Audience: Both Grad Undergrad

3. Calculate cross-sections for the following interaction processes between photons and matter: Rayleigh scattering, photoelectric effect, Compton scattering, and pair production Audience: Both Grad Undergrad

4. Calculate the scattering cross-section of Coulomb scattering and energy transfer cross-section in collisions processes and radiative energy loss processes Audience: Both Grad Undergrad

5. Calculate radiation dose for both external photon beams, neutron beams, and charged particle beams Audience: Both Grad Undergrad

6. Identify open research topics in radiation imaging, radiation therapy, and radiation protection fields Audience: Graduate

MED PHYS/N E 506 — MONTE CARLO RADIATION TRANSPORT
3 credits.

Use of Monte Carlo technique for applications in nuclear engineering and medical physics. Major theory of Monte Carlo neutral particle transport is discussed. Standard Monte Carlo transport software is used for exercises and projects. Major emphasis is on analysis of real-world problems.
Requisites: N E 305 and (N E 405, N E 408, PHYSICS/B M E/H ONCOL/MED PHYS 501 or N E/MED PHYS 569) or graduate/professional standing
Course Designation: Breadth - Physical Sci. Counts toward the Natural Sci req
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MED PHYS 510 — FUNDAMENTALS OF CELLULAR, MOLECULAR, AND RADIATION BIOLOGY
3 credits.

Cellular, molecular, and radiation biology principles and their common application in medical physics.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Explore a new phenomenon or modality in the medical physics area and apply the knowledge gained to research in the field Audience: Both Grad Undergrad

2. Describe fundamental biomolecule and molecular biology principles and their common applications in medical physics. Audience: Both Grad Undergrad

3. Describe fundamental cellular biology principles and their common applications in medical physics. Audience: Both Grad Undergrad

4. Describe fundamental radiation biology principles and their applications in medical physics. Audience: Both Grad Undergrad

5. Describe fundamental immunology principles and their applications in medical physics. Audience: Both Grad Undergrad

6. Demonstrate an ability to integrate key fundamental principles of immunology and cellular, molecular, and radiation biology in medical physics applications in both imaging as well as therapy. Audience: Both Grad Undergrad

7. Propose and discuss example medical physics applications of fundamental principles of immunology and cellular, molecular, and radiation biology. Audience: Graduate

MED PHYS/B M E 535 — INTRODUCTION TO ENERGY-TISSUE INTERACTIONS
3 credits.

Explore physical interactions between thermal, electromagnetic and acoustic energies and biological tissues with emphasis on therapeutic medical applications.
Requisites: PHYSICS 202, 208, 248, or PHYSICS/MED PHYS 265, or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MED PHYS/I SY E 559 — PATIENT SAFETY AND ERROR REDUCTION IN HEALTHCARE
2 credits.

Techniques for evaluating and reducing risks in medical procedures, including probabilistic risk assessment methods, failure mode and effects analysis, human factors analysis, and quality management. Discussions of patient safety standards, recommendations from agencies, and continual quality improvement.
Requisites: Consent of instructor
Course Designation: Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2019
Learning Outcomes: 1. Demonstrate knowledge of quality tools used to improve patient safety and quality in healthcare through reading, discussion, individual assignments, and exams Audience: Both Grad Undergrad

2. Identify patient safety standards and agency recommendations Audience: Both Grad Undergrad

3. Apply techniques to evaluate and reduce risks in medical procedures through group participation in class Audience: Both Grad Undergrad

4. Investigate safety events and concepts and restate their relevance to healthcare in reading assignments Audience: Graduate

MED PHYS 563 — RADIONUCLIDES IN MEDICINE AND BIOLOGY
2–3 credits.

Physical principles of radioisotopes used in medicine and biology and operation of related equipment; lecture and lab.
Requisites: MATH 234 and (PHYSICS 241 or 249) or graduate/professional standing
Course Designation: Breadth - Physical Sci. Counts toward the Natural Sci req
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2018
Learning Outcomes: 1. Identify the components of radioactive decay that are relevant to nuclear medicine diagnostic imaging and radionuclide therapy. Audience: Both Grad Undergrad

2. Apply important nuclear physics concepts to understand the design of nuclear medicine imaging systems and scanners. Audience: Both Grad Undergrad

3. Differentiate the characteristics of radiotracers that make them suitable for research and clinical applications in human physiology. Audience: Both Grad Undergrad

4. Identify the defining strengths and limitations with utilizing the imaging modalities for conducting research investigations of human physiology and disease. Audience: Graduate

MED PHYS/B M E 566 – PHYSICS OF RADIOTHERAPY
3 credits.

Ionizing radiation use in radiation therapy to cause controlled biological effects in cancer patients. Physics of the interaction of the various radiation modalities with body-equivalent materials, and physical aspects of clinical applications.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Demonstrate knowledge of the potentials and limits, with respect to fundamental physics, of ionizing radiation production and therapy Audience: Both Grad Undergrad

2. Apply the concepts and/or techniques of radiation physics in cancer therapy Audience: Both Grad Undergrad

3. Accurately compute radiation dose and dose delivery for clinically acceptable conditions Audience: Both Grad Undergrad

4. Communicate applied concepts in a clear and understandable manner Audience: Undergraduate

5. Communicate complex applied concepts in a clear and understandable manner, including concepts of medical imaging, radiation biology, radiation production, and radiation detection as they apply to radiation physics in cancer therapy Audience: Graduate

MED PHYS/B M E 567 – THE PHYSICS OF DIAGNOSTIC RADIOLOGY
4 credits.

Physics of x-ray diagnostic procedures and equipment, radiation safety, general imaging considerations; lecture and lab.
Requisites: MATH 234 and (PHYSICS 241 or 249) or graduate/professional standing
Course Designation: Breadth - Biological Sci. Counts toward the Natural Sci req
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2018
Learning Outcomes: 1. Learn the physics and technology of medical x-ray system design and the parameters that determine image contrast, noise, spatial resolution, and patient radiation dose. Audience: Both Grad Undergrad

2. Gain a detailed knowledge of x-ray sources, x-ray detectors, and data acquisition strategies used in radiography, mammography, fluoroscopy, angiography and computed tomography. Audience: Both Grad Undergrad

3. Apply a knowledge of x-ray systems and physics to analyze and compare the performance of different medical x-ray imaging systems. Audience: Both Grad Undergrad

4. Through laboratory modules, receive hands on experience concerning the first three objectives. This includes learning the proper means for evaluating the performance and conducting measurements on x-ray systems which are commonly done by a clinical medical physicist. Audience: Both Grad Undergrad

5. Identify the defining strengths and limitations with utilizing the imaging modalities for conducting research investigations of human physiology and disease. Audience: Graduate

MED PHYS/B M E 568 – MAGNETIC RESONANCE IMAGING (MRI)
2 credits.

Core course covering the physics associated with magnetic resonance imaging emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and clinical applications. At the completion of this course, students should have an understanding of the technical and scientific details of modern magnetic resonance imaging and its use in diagnosing disease. Graduate students who have not taken MATH 222 and PHYSICS 202 at UW-Madison must have the equivalent coursework in order to be successful in this course.
Requisites: Graduate/professional standing or (MATH 222 and PHYSICS 202, 208, 241, 244, 248 or 249)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2022

MED PHYS/N E 569 – HEALTH PHYSICS AND BIOLOGICAL EFFECTS
3-4 credits.

Physical and biological aspects of the use of ionizing radiation in industrial and academic institutions; physical principles underlying shielding instrumentation, waste disposal; biological effects of low levels of ionizing radiation.
Requisites: MATH 234 and (PHYSICS 241 or 249), graduate/professional standing, or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Investigate theoretical concepts that are used in radiation safety practice. Audience: Both Grad Undergrad

2. Evaluate the effectiveness of radiation safety practice considering theoretical, economic, political, and societal perspectives. Audience: Both Grad Undergrad

3. Consider the ethical consequences of radiation safety regulations. Audience: Both Grad Undergrad

4. Integrate knowledge into research and/or clinical work Audience: Graduate

MED PHYS/B M E 573 – MATHEMATICAL METHODS IN MEDICAL PHYSICS
3 credits.

Mathematical fundamentals required for medical physics and biomedical applications, including signal analysis and mathematical optimization.
Requisites: (MATH 234 and 319), (MATH 234 and 320), or MATH 376 and (PHYSICS 202 or 208), graduate/professional standing, or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Summarize the utility of signal analysis in one and several dimensions Audience: Both Grad Undergrad

2. Identify and apply convolutions and Fourier Transforms in one and several dimensions Audience: Both Grad Undergrad

3. Illustrate the limitations of the Fourier transform, and recall the advantages of alternative signal analysis tools (e.g. wavelet transform) Audience: Both Grad Undergrad

4. Identify and apply probability concepts to model the stochastic nature of image signals. Audience: Both Grad Undergrad

5. Calculate image signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) Audience: Both Grad Undergrad

6. Evaluate image quality and diagnostic performance using statistical decision theory Audience: Both Grad Undergrad

7. Calculate the autocovariance and the noise power spectrum for different noise models Audience: Graduate

MED PHYS/B M E 574 – DATA SCIENCE IN MEDICAL PHYSICS
3 credits.

Concepts and principles of statistics and machine learning for medical physics-related research problems. Topics covered include probability and independence, discrete and continuous random variables and statistical distributions, random sampling and central limit theorem, inference for means, variances, proportions, moment generating functions, maximum likelihood, hypothesis testing, ANOVA, linear regression, correlation and basic design of experiments with application to quality assurance, reliability, and reproducibility.
Requisites: (PHYSICS/B M E/H ONCOL/MED PHYS 501 and B M E/MED PHYS 573) or (STAT/MATH 309 or 431) or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Identify various types of optimization problems (linear vs nonlinear, convex vs non-convex, etc.) Audience: Both Grad Undergrad

2. Distinguish formulations from algorithms Audience: Both Grad Undergrad

3. Cast an image reconstruction problem as an optimization problem Audience: Both Grad Undergrad

4. Implement computational solutions to image reconstruction problems(Audience: Both Grad Undergrad

5. Identify typical image transforms and deformations, cost functions, and optimization methods for rigid, affine, and deformable image registration Audience: Both Grad Undergrad

6. Apply basic processing methods for segmenting, encoding, and measuring digitized structures in images Audience: Both Grad Undergrad

7. Understand basic machine learning principles and methods and their application Audience: Graduate

MED PHYS/B M E 575 – DIAGNOSTIC ULTRASOUND IMAGING
2 credits.

Propagation of ultrasonic waves in biological tissues; principles of ultrasonic measuring and imaging instrumentation; design and use of currently available tools for performance evaluation of diagnostic instrumentation; biological effects of ultrasound.
Requisites: Graduate/professional standing or (MATH 234, 319, or 320 and PHYSICS 202 or 208)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2019

MED PHYS/B M E 578 – NON-IONIZING DIAGNOSTIC IMAGING
4 credits.

Covers the physics associated with magnetic resonance imaging and diagnostic ultrasound emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and spectroscopic localization. Ultrasound based topics covered include: propagation of ultrasonic waves in biological tissues, principles of ultrasonic measuring and imaging instrumentation, design and use of currently available tools for performance evaluation of diagnostic instrumentation, and biological effects of ultrasound. Gain an understanding of the technical and scientific details of modern non-ionizing medical magnetic resonance and ultrasound devices and their use in diagnosing disease.
Requisites: MATH 234, (MATH 319 or 320) and (PHYSICS 202, 208, 241 or 248), or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Accurately describe, using the correct mathematics and terminology, how the signals for MRI and ultrasound are generated, the sensitivity of these techniques to tissue variations Audience: Both Grad Undergrad

2. Accurately describe, using the correct mathematics and terminology, spatial encoding methods for MRI and ultrasound and trade offs in imaging parameter and hardware selection Audience: Both Grad Undergrad

3. Identify and develop strategies to mitigate common artifacts Audience: Both Grad Undergrad

4. Understand how to apply the knowledge to their own research projects Audience: Graduate

MED PHYS/B M E 580 – THE PHYSICS OF MEDICAL IMAGING WITH IONIZING RADIATION
4 credits.

Concepts and principles on the physics of medical imaging systems that form images using high energy photons are presented. Such systems are divided into two categories: (1) those based on the transmission of x-rays through the human body, including radiography, mammography, fluoroscopy, and computed tomography (CT), and (2) those based on the emission of gamma rays or annihilation radiation following radioactive decay of an internal radiolabeled molecule, including the gamma camera, single photon emission tomography (SPECT), and positron emission tomography (PET) and PET hybrid imaging systems. Emphasis is placed on understanding how physics, system design, and imaging technique determine image performance metrics such as contrast, signal-to-noise ratio, and spatial resolution. Clinical applications and radiation safety concepts are detailed for the different types of imaging systems.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501 and MED PHYS/B M E 573
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Identify the physical principles underlying imaging technologies used in radiology and nuclear medicine: radiography, mammography, fluoroscopy, computed tomography (CT), scintigraphy, single-photon emission tomography (SPECT), and positron emission tomography (PET). Audience: Both Grad Undergrad

2. Describe each imaging modality in terms of a general imaging framework in which (i) a form of energy or probe is introduced to the body, (ii) a clinically interesting signal is generated within the body, and (iii) this signal is detected and spatially localized to form an image. Audience: Both Grad Undergrad

3. Apply physics and engineering concepts to understand how the design and operation of an imaging system determines the contrast, noise, and spatial resolution of the images produced by the system. Audience: Both Grad Undergrad

4. Differentiate the characteristics of radiotracers that make them suitable for research and clinical applications in human physiology. Audience: Both Grad Undergrad

5. Identify the defining strengths and limitations with utilizing the imaging modalities for conducting research investigations of human physiology and disease. Audience: Graduate

MED PHYS 581 – LABORATORY FOR MEDICAL IMAGING WITH IONIZING RADIATION
1 credit.

Presents concepts and principles on the physics of medical radiographic imaging systems, based on the transmission of x-rays. Emphasis is placed on understanding the operation of imaging equipment and how it is used in clinical applications. Evaluation of imaging systems, optimization of their use and design and the solution of image quality problems is investigated.
Requisites: B M E/MED PHYS 580
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Identify the physical components of diagnostic x-ray imaging equipment\\n\\n Audience: Both Grad Undergrad

2. Summarize the operation and clinical uses of these imaging systems Audience: Both Grad Undergrad

3. Test and analyze the performance characteristics of diagnostic x-ray imaging equipment Audience: Both Grad Undergrad

4. Investigate factors that affect image quality and patient dose in x-ray imaging systems involving their use and design Audience: Both Grad Undergrad

5. Apply investigative thinking to the solution of image problems and artifacts Audience: Both Grad Undergrad

6. Apply what has been learned to their current research project Audience: Graduate

MED PHYS/PHYSICS 588 – RADIATION PRODUCTION AND DETECTION
4 credits.

Fundamental physics of ionizing radiation production and detection applied to medical science. Topics: scintillator/semiconductor detectors, ionizing radiation detectors, charged and neutral particles for external beam radiotherapy, production of radionuclides with cyclotron and linear accelerators for diagnostic and therapeutic applications, radiochemistry, and X-ray tube physics.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Achieve competence in experimental measurement methods of radiation dose Audience: Both Grad Undergrad

2. Develop a functional understanding of the principles and operation of the major types of ionizing radiation detectors used in modern medical physics including ion chambers, scintillators, semiconductors, chemical detectors, and calorimeters. Audience: Both Grad Undergrad

3. Apply fundamental atomic and nuclear physics to radiation production using charged and neutral particles with accelerators and reactors, especially in the context of radionuclide production for medical application. Audience: Both Grad Undergrad

4. Integrate the physics of thermionic and field emission with electron flux production and transport in x-ray tubes; Apply fundamental physics and engineering concepts to the configuration of typical x-ray tubes; apply thermodynamic physical concepts to heat transfer processes and heat management techniques in x-ray tubes. Audience: Both Grad Undergrad

5. Apply physics and engineering concepts to understand the basic hardware configuration of an x-ray tube, the production of electrons by thermionic emission or field emission, the acceleration of electrons to a target material, and the physical interactions in the target resulting in x-rays. Audience: Both Grad Undergrad

6. Apply knowledge of the process of radionuclide production and radiochemistry to the context of clinical, theranostic application of these radionuclides in patients. Audience: Both Grad Undergrad

7. Apply what has been learned to their current research project Audience: Graduate

MED PHYS/B M E/PHMCOL-M/PHYSICS/RADIOL 619 – MICROSCOPY OF LIFE
3 credits.

Survey of state of the art microscopic, cellular and molecular imaging techniques, beginning with subcellular microscopy and finishing with whole animal imaging.
Requisites: PHYSICS 104, 202, 208, or 248 or PHYSICS/MED PHYS 265
Course Designation: Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MED PHYS/NTP 651 – METHODS FOR NEUROIMAGING RESEARCH
3 credits.

Provides a practical foundation for neuroimaging research studies with statistical image analysis. Specific imaging methods include functional BOLD MRI, structural MRI morphometry, and diffusion tensor imaging. Lectures and associated in-class computer exercises will cover the physics and methods of image acquisition, steps and tools for image analyses, the basis for statistical image analyses and interpretation of the results.
Requisites: Graduate/professional standing or (PHYSICS 104, 202 or 208)
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Develop a basic understanding of magnetic resonance imaging, anatomical imaging methods, functional BOLD MRI (fMRI), and diffusion tensor imaging (DTI). Audience: Both Grad Undergrad

2. Learn and apply basic methods for statistical image analyses. Audience: Both Grad Undergrad

3. Gain hands-on experience with tools for processing and analyses of fMRI, DTI and anatomic brain images. Audience: Both Grad Undergrad

4. Develop and demonstrate skills to independently process, analyze, troubleshoot and interpret MRI neuroimaging data Audience: Graduate

MED PHYS 662 — RAD LAB - DIAGNOSTIC RADIOLOGICAL PHYSICS
1 credit.

Provides hands on experience using and testing radiographic, fluoroscopic and mammographic x-ray systems. Imaging requirements, image quality, and radiation dose aspects of each modality are covered, along with practical methods for evaluating the performance of clinical units.
Requisites: MED PHYS/B M E 580 or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2019
Learning Outcomes: 1. Recall the basic operational functions of Radiographic, Fluoroscopic, and Mammographic imaging systems and the physical basis of these functions. Audience: Both Grad Undergrad

2. Summarize how image quality and patient dose are affected by the characteristics of the various components of these imaging systems and additionally how they are affected by variations of operator controlled settings. Audience: Both Grad Undergrad

3. Describe how to perform evaluations/ testing of the imaging systems for proper performance and compliance to state/federal regulations, Joint Commission requirements, and Accreditation requirements. Audience: Graduate

4. Illustrate how these evaluations/tests measure aspects of image quality and patient dose. Audience: Both Grad Undergrad

5. Perform these evaluations/tests in an accurate fashion. Audience: Both Grad Undergrad

6. Analyze the results of these tests. Audience: Both Grad Undergrad

7. Create a report of these results which document the findings and communicate them to someone who is not a scientist. Audience: Both Grad Undergrad

8. Properly use individual radiation protection techniques during the testing. Audience: Both Grad Undergrad

MED PHYS 663 — RAD LAB - NUCLEAR MEDICINE PHYSICS
1 credit.

Provides an introduction to the technical skills required in nuclear medicine physics. This includes laboratory rotations in basic radiopharmaceutical production and quality control, basic operation and quality control testing on PET and SPECT scanners, time series image analysis of radiotracer studies and nuclear medicine dosimetry and radiation safety training. Gain a firsthand understanding of the professional duties performed by a nuclear medicine medical physicist.
Requisites: MED PHYS/B M E 580 or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2020
Learning Outcomes: 1. Identify the basic methods for the production of radionuclides used in nuclear medicine imaging, including cyclotron produced parent / progeny generators. Audience: Both Grad Undergrad

2. Illustrate how to perform evaluations/ testing of the nuclear medicine imaging systems for proper performance. This includes scanner characteristic measures that would be made for acceptance test and periodic QC measures. Audience: Both Grad Undergrad

3. Perform these evaluations/tests in an accurate fashion. Audience: Both Grad Undergrad

4. Analyze the results of these tests. Audience: Both Grad Undergrad

5. Create a report of these results which document the findings and communicate them to someone who is not a scientist. Audience: Both Grad Undergrad

6. Properly use individual radiation protection techniques during the testing. Audience: Both Grad Undergrad

7. Describe how radionuclides are synthesized into radiopharmaceuticals for human use. This includes how quality control tests are performed and the significance of each test. Audience: Graduate

MED PHYS 664 – RAD LAB - HEALTH PHYSICS
1 credit.

Uses project-based learning (PBL) as a powerful teaching method to address common challenges and solutions addressed by medical health physicists. Each semester, students work on a different project that addresses concepts that are important in the current health physics environment.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2017
Learning Outcomes: 1. Learn about health physics instrumentation through hands-on experiments Audience: Both Grad Undergrad

2. Operate health physics instrumentation to address relevant health physics problems Audience: Both Grad Undergrad

3. Learn statistical principles of laboratory data analysis. Audience: Both Grad Undergrad

4. Communicate lab results clearly and effectively through high quality written reports. Audience: Both Grad Undergrad

5. Integrate knowledge into other course material, research and/or clinical work. Audience: Graduate

MED PHYS 665 – RAD LAB - CT, MRI, AND DSA PHYSICS
1 credit.

Provides hands on experience using and testing computerized tomography (CT), magnetic resonance imaging (MRI), and digital subtraction angiography (DSA) systems. Image quality, MRI and radiation safety, accreditation, and regulatory compliance issues with these modalities are also covered.
Requisites: B M E/MED PHYS 580 and 578 or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Describe the major components and geometry of current computed tomography (CT) scanners and the factors affecting image quality and radiation dose in CT scans. Audience: Both Grad Undergrad

10. Understand dual-energy subtraction and its advantages and disadvantages compared to time subtraction. Audience: Graduate

2. Explain the characteristics of CT image quality including pixel values, contrast, noise, low contrast detectability and spatial resolution. Audience: Both Grad Undergrad

3. Describe the characteristics of radiation dose in CT scanning including: dose profiles, the CT dose index, average dose in the scanned volume and effective dose; as well as the effect of scan parameters on the radiation dose to the patient. Audience: Both Grad Undergrad

4. Perform a physicist’s evaluation of a CT scanner including measurements of geometric accuracy, image quality and radiation dose. Audience: Graduate

5. Explain the safety screening process that all patients must undergo in order to determine whether they are eligible to safely undergo an MRI exam. Audience: Both Grad Undergrad

6. Describe the function of i) the major components of the MRI system, including the main magnetic field, the radiofrequency transceiver, and the magnetic field gradients, ii) the elements included in every MRI room, including the radiofrequency shielding, the magnet rundown unit, and the cryogen exhaust system, and iii) patient safety considerations related to these components. Audience: Both Grad Undergrad

7. Understand some of the basic system tests, as recommended by the American College of Radiology (ACR), that are performed during routine quality assurance testing of an MRI system. Audience: Graduate

8. Identify the components of a digital subtraction angiography system. Audience: Both Grad Undergrad

9. Understand the basic properties of DSA systems; contrast, signal to noise ratio, image dynamic range, and logarithmic image processing. Audience: Both Grad Undergrad

MED PHYS 666 – RAD LAB - MEDICAL ULTRASOUND PHYSICS
1 credit.

Introduces concepts and methodology for measuring acoustic properties of materials and for operating and performing physics tests of state of the art clinical ultrasound scanners. Set up and operate a laboratory apparatus employing single element ultrasound transducers. This is followed by hands on experiments that challenge students to explain physical and engineering characteristics of clinical scanners, details of operator controls, features of Doppler and color flow modes, and resolution limitations. Practical scanning exercises provide familiarity with selected applications of clinical ultrasound equipment, both for diagnosis and for guiding interventions. Routine quality assurance tests done by medical physicists are also performed.
Requisites: MED PHYS/B M E 578 or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Provide a technical overview of ultrasound scanner operations, including relevant tissue properties involved in forming images, ultrasound transducer properties and types, signal processing, image frame rate limitations, and typical instrument controls. Audience: Both Grad Undergrad

2. Demonstrate basic operation of a, ultrasound scanner (GE Logiq E9 or Siemens Acuson Sequoia). This will be done using basic ultrasound QA phantoms. Audience: Both Grad Undergrad

3. Describe Doppler and color flow modes and indicate technical factors needed to measure blood flow accurately. Audience: Both Grad Undergrad

4. Show how instrumentation settings affect gray scale imaging and Doppler data from selected sites, such as the human carotid artery, the heart, or the abdomen. Audience: Both Grad Undergrad

5. Show the difference between cystic and solid lesions using phantoms; demonstrate image guided interventions using phantoms. Audience: Both Grad Undergrad

6. Complete the tests (i.e., system set up and scanning) and report writing for basic quality assurance testing following American College of Radiology (ACR) guidelines. Audience: Graduate

MED PHYS 671 – SELECTED TOPICS IN MEDICAL PHYSICS
1-4 credits.

In-depth examination of current and newly discovered modalities and/or phenomenons in medical physics. Critical reading of literature, hands-on lab work and exploration of medical issues related to discoveries will be included.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. Explore a new phenomenon or modality in the medical physics area and apply the knowledge gained to research in the field Audience: Graduate

2. Identify the physical principles underlying imaging technologies used in radiology and nuclear medicine: radiography, mammography, fluoroscopy, computed tomography (CT), scintigraphy, single-photon emission tomography (SPECT), and positron emission tomography (PET). Audience: Both Grad Undergrad

MED PHYS 679 – RADIATION PHYSICS METROLOGY
3 credits.

Metrology, the science of measurement, is a critical component of medical physics. Topics covered: measurement statistics, determination of uncertainty, characteristics of ionization chambers, electrometers and other ionizing radiation measurement devices. Effects of instrumentation on clinical measurements.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Integrate the physics and operation of ionization chambers and electrometers Audience: Both Grad Undergrad

2. Integrate the physics and operation of other instruments used for dosimetry Audience: Both Grad Undergrad

3. Analyze and apply the luminescent process and its use in metrology Audience: Both Grad Undergrad

4. Evaluate and demonstrate principles of uncertainty involved in metrology Audience: Graduate

MED PHYS 699 — INDEPENDENT READING OR RESEARCH
1-3 credits.

Provides opportunities for graduate students to gain experience using the scientific method to address specific scientific problems. This includes selection of a research topic, performing literature reviews to evaluate peer-reviewed and other publications, developing a research design, identifying possible pitfalls, and performing and reporting on experiments performed. Communication of the research findings within and outside the university is encouraged.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. Apply concepts learned in coursework to real life situations Audience: Both Grad Undergrad

2. Read and effectively analyze scientific literature Audience: Both Grad Undergrad

3. Develop critical, analytical, and independent thinking skills Audience: Both Grad Undergrad

4. Create literature reviews and publications Audience: Graduate

MED PHYS 701 — ETHICS AND THE RESPONSIBLE CONDUCT OF RESEARCH AND PRACTICE OF MEDICAL PHYSICS
1 credit.

Addresses the concepts of ethics in the daily practice of medical physics and other scientific disciplines and provide tools for identifying resources. Special emphasis will be placed in how these principles have to be applied to ensure the confidentiality of the patients, the safety of the research subjects (human and animals), differentiation between ethical and legal issues, as well as the understanding of the principles that deal with authorships, intellectual property in the academic- and industry- based environment.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and discuss the rationale behind the ethical principles governing medical physics practice Audience: Graduate

2. Apply these principles to ensure the confidentiality of the patients, and the safety and respect of the research subjects (humans and animals). Audience: Graduate

3. Ensure proper and honest data collection and analysis Audience: Graduate

4. Identify and prevent conflict of interest Audience: Graduate

5. Discuss and define authorships, and basic intellectual property concepts for the academic- and industry- based environment. Audience: Graduate

MED PHYS/PEDIAT 705 – WOMEN AND LEADERSHIP: SCIENCE, HEALTH AND ENGINEERING
2 credits.

Multiple professional and scientific groups have identified the underrepresentation and lack of advancement of women in academia as a national workforce problem. Review evolving perspectives of leadership and how unconscious assumptions about the behaviors and traits of men, women, and leaders impede women's advancement. Emphasizes the implications for women in the fields of science, health and engineering and explore the potential impact on the advancement of knowledge and improvements in health. Provides the opportunity to apply evidence-based perspectives using experiential methods.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Be conversant with several definitions and styles of leadership, as well as with research on how leadership and gender intersect/interact, particularly in an academic context. Audience: Graduate

2. Reflect on personal leadership goals and skills based on readings, discussion, and online reflection assignments. Audience: Graduate

3. Demonstrate knowledge of effective evidence-based leadership strategies. Audience: Graduate

4. Consider the integral link between women leaders and the advancement of women's health. Audience: Graduate

MED PHYS/B M E 710 – ADVANCES IN MEDICAL MAGNETIC RESONANCE
3 credits.

Addresses the theory and applications of magnetic resonance (MR) in medicine, by providing the necessary theoretical background to understand advanced MR techniques including magnetic resonance imaging (MRI).
Requisites: MED PHYS/B M E 568 or 578
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and apply principles of MR signal generation, relaxation, echo generation, and spatial encoding. Audience: Graduate

2. Compose and test concepts of advanced MR image reconstruction concepts including partial Fourier MRI, parallel MRI, non-Cartesian MRI, compressed sensing. Audience: Graduate

3. Apply and judge image processing methods for the analysis of MR images for biomarkers such as T1 and T2 mapping and metabolite maps. Audience: Graduate

4. Summarize and organize advanced MR applications used in the clinic and research including quantitative MRI, BOLD MRI (fMRI), MR Angiography with and without contrast agents, motion sensitive MRI, perfusion and diffusion MRI, PET-MRI, hyperpolarization, and spectroscopy. Audience: Graduate

5. Organize and compose concepts on sampling theory, signal-to-noise, artefacts, and pulse sequences to design protocols for MRI data acquisition, reconstruction, or processing. Audience: Graduate

6. Demonstrate scientific communication skills for MRI research by composing oral presentations, written reports, and critiquing the work of others. Audience: Graduate

MED PHYS/B M I/COMP SCI/E C E 722 – COMPUTATIONAL OPTICS AND IMAGING
3 credits.

Computational imaging includes all imaging methods that produce images as a result of computation on collected signals. Learn the tools to design new computational imaging methods to solve specific imaging problems. Provides an understanding of the physics of light propagation and measurement, and the computational tools to model it, including wave propagation, ray tracing, the radon transform, and linear algebra using matrix and integral operators and the computational tools to reconstruct an image, including linear inverse problems, neural networks, convex optimization, and filtered back-projection. Covers a variety of example computational imaging techniques and their applications including coded apertures, structured illumination, digital holography, computed tomography, imaging through scattering media, compressed sensing, and non-line-of-sight imaging.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No

MED PHYS/B M E/CHEM 750 – BIOLOGICAL OPTICAL MICROSCOPY
3 credits.

Covers several aspects of state-of-the-art biological and biophysical imaging with an emphasis on instrumentation, beginning with an overview of geometrical optics and optical and fluorescence microscopy. The bulk of the course will focus on advanced imaging techniques including nonlinear optical processes (multi-photon excitation, second harmonic generation, and stimulated Raman processes) and emerging super-resolution methods. Special emphasis will be given to current imaging literature and experimental design. Knowledge of physics-based optics [such as PHYSICS 202] strongly recommended.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2021

MED PHYS 770 – ADVANCED BRACHYTHERAPY PHYSICS
3 credits.

The use of radioactive sources for radiotherapy including: materials used, source construction dosimetry theory and practical application, dosimetric systems, localization and reconstruction. Covers low dose rate, high dose rate and permanently placed applications.
Requisites: MED PHYS/B M E 566
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Demonstrate an understanding of common brachytherapy source isotopes, including energy, source construction, and half-life, as well as their clinical use in the treatment of gynecological, breast, prostate, and other cancer types. Audience: Graduate

2. Create clinical treatment plans for gynecological, breast, and prostate brachytherapy treatments. Audience: Graduate

3. Explain and understand each component of the TG-43 brachytherapy dose calculation formalism Audience: Graduate

4. Gain familiarity with HDR afterloaders and the required quality assurance Audience: Graduate

5. Demonstrate an understanding of LDR brachytherapy concepts including safe source handling, calibration, and quality assurance Audience: Graduate

6. Understand radiation protection concepts relevant to brachytherapy including state/national regulations and the components of a quality management program for brachytherapy Audience: Graduate

MED PHYS 772 — ADVANCED RADIATION TREATMENT PLANNING
3 credits.

Physics of clinical, computer-based radiotherapy planning is taught. Topics include dose algorithms, measurement data, commissioning, contouring and volume definition, beam placement, modifiers and apertures and plan evaluation. Forward based and inverse planning (including IMRT optimization) are taught.
Requisites: MED PHYS/B M E 566 and graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2022
Learning Outcomes: 1. Design simple and intermediate forward-based photon and electron external beam plans using beam arrangements/energy, wedges and blocks intelligently with regards to underlying physics Audience: Graduate

2. Create target and region at risk planning volumes, setup objectives for, and optimize, inverse planned intensity modulated plans. Audience: Graduate

3. Evaluate dose distributions using a variety of metrics. Audience: Graduate

4. Understand beam model commissioning process and limitations including data requirements and processing. Audience: Graduate

5. Understand dose algorithms used in radiation therapy (including but not limited to: convolution superposition, Monte Carlo, pencil beam.) Audience: Graduate

MED PHYS 775 — ADVANCED ULTRASOUND PHYSICS
3 credits.

Mathematical and physical foundations of the application of acoustics in diagnostic ultrasound. Derivation of wave equations for mechanical waves in fluids and solids from a continuum mechanics perspective. Diffraction theory and methods for acoustic field calculation (analytic, angular spectrum, simulations). Review of interactions of acoustic waves with biological tissue and methods to measure their acoustic properties. In-depth discussion of methods for structural image formation including ray-line scanning, plane wave compounding, synthetic aperture, coded excitation, and spatial coherent imaging. Introduction to novel functional imaging approach, including ultrafast Doppler, molecular ultrasound, functional ultrasound, and super-resolution imaging. Application of the acquired knowledge to perform a systematic literature review of the state-of-the-art of the field for the solution of a relevant clinical problem.
Requisites: B M E/MED PHYS 573 and 578
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2013
Learning Outcomes: 1. Provide detailed physical explanations, based on advanced mathematical grounds, of (a) the basic principles of the propagation and interactions of mechanical waves in tissues, and (b) several ultrasound-based structural and functional imaging techniques Audience: Graduate

2. Critically assess recent technological developments in medical ultrasound imaging by appraising the motivation, strengths, and limitations of published research in this area Audience: Graduate

3. Based on a critical review of the state of the art of biomedical ultrasound, define the goal and specific aims of a research proposal focused on addressing a knowledge gap in the field and/or solving a relevant clinical problem using advanced concepts of ultrasound image acquisition, formation, and processing Audience: Graduate

MED PHYS 777 — PRINCIPLES OF X-RAY COMPUTED TOMOGRAPHY
3 credits.

Understand the basic principles of x-ray computed tomography (CT), and how to think when a technical problem arises in CT. Accomplished through a review of the history of CT developments and key components of CT systems, lectures on various CT reconstruction algorithms, image quality, and radiation dose, origin and correction methods of various CT artifacts.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Understand the basic principles of x-ray CT imaging systems Audience: Graduate

2. Understand the mathematical foundation of basic CT reconstruction algorithms Audience: Graduate

3. Be able to implement filtered backprojection (FBP) reconstruction algorithms for various CT geometries Audience: Graduate

4. Understand CT image quality metrics and their dependence on CT system properties Audience: Graduate

5. Understand the physical origin of common CT image artifacts and the corresponding correction methods Audience: Graduate

MED PHYS/B M E/E C E 778 — MACHINE LEARNING IN ULTRASOUND IMAGING
3 credits.

Concepts and machine learning techniques for ultrasound beamforming for image formation and reconstruction to image analysis and interpretation will be presented. Key machine learning and deep learning concepts applied to beamforming, compressed sampling, speckle reduction, segmentation, photoacoustics, and elasticity imaging will be evaluated utilizing current peer-reviewed publications.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Critically read and evaluate peer-reviewed journal papers describing machine learning applications in ultrasound imaging. Audience: Graduate

2. Apply, implement and expand upon ideas from these publications to applications in ultrasound imaging. Audience: Graduate

3. Present the results of their critical evaluation and implementation to the class. Audience: Graduate

4. Write a research paper based on their findings suitable for publication. Audience: Graduate

MED PHYS 780 — PHARMACOKINETIC MODELING IN BIOMEDICAL IMAGING
2 credits.

Concepts and techniques of pharmacokinetic modeling will be presented in the context of biomedical imaging. Examine applications in various specialties, e.g. neurology and oncology, using different imaging tools, e.g. positron emission tomography (PET) and magnetic resonance imaging (MRI).
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2020
Learning Outcomes: 1. Understand fundamental principles of pharmacokinetic modeling within the context of biomedical imaging Audience: Graduate

2. Implement appropriate mathematical models for given biological tracer systems Audience: Graduate

3. Apply these skills to biomedical research questions Audience: Graduate

4. Analyze biomedical imaging data to investigate pharmacokinetic properties Audience: Graduate

5. Create a publication quality research paper Audience: Graduate

MED PHYS 900 — JOURNAL CLUB AND SEMINAR
1 credit.

Provides medical physics graduate students with the opportunity to critically evaluate and report on published research and/or research seminar presentations by speakers, from both within the university and from the larger scientific community.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. Understand the various areas of Medical Physics given in seminars Audience: Graduate

2. Explore the subject of a seminar and understand medical terms Audience: Graduate

MED PHYS 990 – RESEARCH
1-12 credits.

Provides graduate students with mentorship to support their development of independent research goals and methods needed to address specific scientific problems that will result in a comprehensive dissertation.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. Conduct independent and focused research using a variety of approaches. Audience: Graduate

2. Analyze and think critically to address research challenges. Audience: Graduate

3. Exhibit and foster professional and ethical conduct in their research. Audience: Graduate

4. Collaborate with other investigators within or outside their lab. Audience: Graduate