NPRE 441: Principles of Radiation Protection

Spring 2024

Course Description

This course provides a comprehensive coverage of the principles and methodologies for radiation protection and radiation health physics. The major topics covered by this course include sources of ionizing radiation, the interactions of ionizing radiation with matter, essential tools and techniques for dosimetry measurements, counting statistics, principles of radiation dosimetry, biological effects of ionizing radiation, methods for deriving the radiation dose from internal and external radiation sources, and practical approaches for shielding design and radiation protection.

Prerequisite

NPRE446

Textbook

Primary: J. Turner, "Atoms, Radiation, and Radiation Protection", Third Edition, Wiley-VHC, Inc. (2007).

Reference books:

[1] H. Cember - "Introduction to Health Physics", 4th Edition, McGraw-Hill (2010)
[2] J. K. Shultis and R. E. Faw, "Radiation Shielding," American Nuclear Society (2000)
[3] R. E. Faw and J. K. Shultis, "Radiological Assessment: Sources and Doses, American Nuclear Society (1999)
[4] E. L. Alpen, "Radiation Biophysics," Academic Press (1998)
[5] G. F. Knoll, Radiation Detection and Measurements, Third Edition, John Wiley & Sons, 1999.

Lecture Topics

Introduction

Chapter 1: The Nucleus and Nuclear Radiation

- Nuclear structure and nuclear binding energies
- Alpha decay, beta decay, and companion ionizing radiation
- Transformation kinetics and serial transformation
- Naturally occurring radioactivity

Chapter 2: Interaction of Radiation with Matter

- Interaction heavy charged particles and phenomena associated with charged particle tracks
- Interaction of beta particles with matter
- Interaction of photons I – Interaction mechanisms
- Interaction of photons II – attenuation coefficients, calculation of energy absorption and energy transfer
- Interactions of neutrons

Chapter 3: Methods for Radiation Detection

(Note: this chapter will not be taught in NPRE441, but the conceptual understanding of basic radiation detection and measurement techniques would be needed for Chapters 4 and 5)

- Gas-filled detectors, ionization process, charge migration, ionization counters, and proportional counters.
- Scintillation detectors
- Semiconductor detectors
- Neutron detection techniques

Chapter 4: Counting Statistics

- Statistical models for radioactive decay processes, Bernoulli processes, binomial, Poisson and Gaussian distributions
- Counting statistics, error, and error propagation
- False-positive and false-negative errors and delectability limits
- A brief introduction to Monte Carlo techniques

Chapter 5: Radiation Dosimetry

- Units, dose, exposure, and dose-exposure relationship
- Measurement of exposure and absorbed dose from X-rays, gamma-rays, and charged particles
- Dose calculations associated with X-ray, gamma-ray, charged particles, and neutrons
- Internally deposited radioisotopes and the MIRD method

Chapter 6: Biological Effects of Radiation

- The time frame for radiation effects
- Physical, pre-chemical, and chemical changes in irradiated water
- Basic concepts of cell biology and irradiation of cells
- Types of radiation damage
- Therapeutic ratio and the 5 Rs of radiobiology
- Factors affecting dose responses
- The acute radiation syndrome and delayed somatic effects

Chapter 7: Radiation Protection Criteria and Exposure Limits

- The objective of radiation protection
- NCRP and ICRP dosimetric quantities.

Chapter 8: External Radiation Protection

- Basic principles for external radiation protection
- Gamma-ray shielding considerations
- Shielding in X-ray installations
- Protection from beta
- Neutron shielding

Chapter 9: Internal Dosimetry and Radiation Protection

- Objectives

- ICRP dosimetry models (for the respiratory system and gastrointestinal tract)
- Specific absorbed fraction, specific effective energy, and evaluation of committed quantities