**In the name of God**

# Guide to Principles and foundations of Monte Carlo simulation and its application in medicine

**instructor/instructors:** Dr. Mikaeil Molazadeh – Dr. Asra Sadat Talebi

**Prerequisite or concurrent unit:** None

**Number of units:** 2 Unit **type:** 1 theoretical unit and 1 practical units **Level:** PhD's degree

**Number of sessions:** 17

**Start and end dates of sessions:** According to the educational calendar

**Time of sessions per week:** According to the educational calendar

**Location of in-person sessions:** Theoretical & Practical (Faculty of Medicine)

**General Objective and Introduction to the Course Unit**:

**General Objective:** Introduction to the concepts of Monte Carlo simulation and computer modeling in medical physics.

**Specific Objectives:** Outline of theoretical and practical topics that learners are expected to be able to explain after completing this course:

1. Introduction to the application of Monte Carlo methods in medical physics
2. Probability and mathematical foundations of Monte Carlo
3. Sampling methods of random variables
4. Random number generation methods
5. Principles of computer simulation with Monte Carlo methods
6. Introduction to the transport of photons, charged particles and light in materials with the Monte Carlo method
7. Variance reduction methods
8. Introduction to the types of phantoms used in Monte Carlo simulation

## Educational objectives of the course unit

**After completing this course, learners are expected to be able to:**

| Session | Lesson Topic | Table of Contents |
|---|---|---|
| **1** | Probability and Mathematical Foundations of Monte Carlo - Methods for Sampling Random Variables in Monte Carlo | Introduction to the Monte Carlo method, calculating the area under the graph of various curves using mathematical and Monte Carlo methods (solving a practical example in class), the basis of the Monte Carlo method, how to generate random samples, sampling methods in Monte Carlo, introducing and explaining various types of mathematical functions and distributions in Monte Carlo: uniform distribution, normal distribution, log-normal distribution, beta distribution, gamma distribution |
| **2** | Random Number Generation Methods<br>Convergence, Accuracy, and Computational Error of the Monte Carlo Method | Generating random numbers based on a specific distribution function, generating random numbers using $CDF^{-1}$, generating random numbers using the beta distribution function, generating random numbers in Excel, the accept-reject method, using the inverse of the $cpdf^{-1}$ cumulative distribution function, using existing library functions, the Monte Carlo sampling method (solving a practical example in class), determining the number of samples required for Monte Carlo simulation in sufficient numbers (convergence of the Monte Carlo method) along with solving practical examples in class, determining the accuracy and computational error of the Monte Carlo method |
| **3** | Introduction to Monte Carlo Simulation, Introduction to the types of phantoms used in Monte Carlo Simulation | Simulation and Monte Carlo: Simulation, basics and principles, Monte Carlo simulation, Monte Carlo codes used in medical physics<br>Types of anthropomorphic phantoms, MCNP4C-based CT X-ray simulator, future applications of Monte Carlo… |
| **4** | Basics of the Monte Carlo Method | What is Monte Carlo? Basic probability theory, Random number generators, Sampling theory, Principles of computer simulation with Monte Carlo methods, Introductory introduction to the transport of photons, charged particles, and light in materials, Modeling reactions |
| **5** | Introduction to MCNP | MCNP4C code features, MCNP site introduction, introduction to MCNP features, history, MCNPX, user input file to code, MCNP input structure, input file format, MCNP geometry, MCNP surfaces, surface sense, surface direction, cell meaning, cell cards, geometry definition, cells defined by intersection of regions, cells defined by union of regions, cells defined by complement operator, cell definition examples, surface cards, reversible-periodic and white surfaces, main data cards, mode card, sample input file, MCNP execution, execution options, geometry drawing commands, material specifications, cross-section, data class |

| | | |
|---|---|---|
| **6** | Source specifications in MCNP | Source commands, general cards, source specifications, general source card (SDEF), SDEF variables and their defaults, simple examples, material card, source information card, source probability card, examples, energy spectrum, examples, spatial distribution (shape), examples, directional distribution, temporal distribution, biasing, miscellaneous examples |
| **7** | MC Practical Class (1) | Solving various examples by coding in Monte Carlo MCNP code (including defining geometry and cells, defining types of sources, solving real examples of human body simulation, tube and X-ray spectrum, debugging student-written codes) |
| **8** | MC Practical Class (2) | Solving various examples by coding in Monte Carlo MCNP code (including defining geometry and cells, defining types of sources, solving real examples of human body simulation, tube and X-ray spectrum, debugging student-written codes) |
| **9** | | |
| **10** | | |
| **11** | | |
| **12** | | |
| **13** | | |
| **14** | | |
| **15** | | |
| **16** | | |
| **17** | End of semester exam | End of semester exam |

## Method of providing training

■ Speech ■ Slide ■ Questions and Answers ■ Problem-based learning ■ Practical training

## Student evaluation method

Class participation in teaching sessions 5%, practical assignment 15%, end-of-semester written exam in the form of an essay/short answer/limited answer 80%

**Minimum passing score for this course:** According to the curriculum.

**Number of hours of absence allowed for this course unit:** According to the approved educational regulations.

## Educational resources

1. Xie George Xu. Handbook of Anatomical Models for Radiation Dosimetry. CRC Press; Last edition.

2. Michael Ljungberg. Monte Carlo Calculations in Nuclear Medicine: Applications in Diagnostic Imaging. CRC Press; Last edition.

3. H. Zaidi. Therapeutic Applications of Monte Carlo Calculations in Nuclear Medicine. IOP; Last edition.

4. Pedro Andreo. Monte Carlo techniques in medical radiation physics. Physics in Medicine and Biology. 1991 Phys. Med. Biol. 36 861

## Educational resources for further study

Related resources from the Internet and university web pages

## Learning opportunities

Holding limited conferences in each session, managed by the teacher and presented by the student

## Contact information

**Course Instructor/Instructors (Phone, Email, etc.)**:

**Dr. Mikaeil Molazadeh:** **04133364660 – molazadeh91@gmail.com**

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