# MATH-577: Monte Carlo Methods

# Spring 2026

## Instructor Information

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## Course Description

Monte Carlo methods are numerical algorithms that use random sampling to generate statistical estimates of (usually) deterministic quantities. They are often more efficient than their deterministic counterparts, especially for higher-dimensional problems, and are widely used in scientific, engineering, and statistical computing. This introductory course is aimed at graduate students in mathematics, statistics, computer science, engineering, physical sciences, quantitative biology, or really any field where Monte Carlo methods are used. The goal is to equip students with knowledge of basic algorithms and relevant theory so they can design and implement Monte Carlo solutions to scientific problems and perform basic statistical analysis on the output. As such, the course tries to balance between discussion of practical algorithms and their mathematical analysis.

## Course Prerequisites or Co-requisites

Students should know probability at the advanced undergraduate level, e.g., MATH 464 or equivalent, as well as linear algebra (e.g., MATH 410 or equivalent). I plan to briefly review some of this, and cover any additional material (e.g., Markov chains) as needed. Students are expected to carry out both pencil-and-paper analysis and computer experiments. Interested students unsure about their background are encouraged to see the instructor prior to registering for the course.

## Course Format and Teaching Methods

The course is scheduled to be in-person. Lectures will be recorded and/or streamed as needed.

## Course Objectives

To equip students with basic principles of the design, analysis, and implementation of Monte Carlo methods.

## Expected Learning Outcomes

Upon successfully completing this course, students should be able to design and analyze Monte Carlo methods to solve practical problems in scientific and engineering computing.

## Required Texts and Materials

There is no required text, and I do not plan to follow any particular text closely. I do plan to assign reading from some of the books and lecture notes listed below, in addition to course notes and papers to be posted later in the term. All these are either downloadable for free from the UA Library (just follow the links below from a computer on the campus network, or use VPN), or available from the authors.

The following standard textbooks on Monte Carlo are intended as primary references. Of these, [O] is perhaps closest in spirit and level to this course.

- [KW] Monte Carlo Methods by MH Kalos and PA Whitlock
- [Liu] Monte Carlo Strategies in Scientific Computing by JS Liu

- [O] Monte Carlo theory, methods and examples by AB Owen
- [RK] Simulation and the Monte Carlo Method, Third Edition by RY Rubinstein and DP Kroese

Additional general references:

- [AG] Stochastic Simulation: Algorithms and Analysis by S Asmussen and PW Glynn
- [HH] Monte Carlo Methods by JM Hammersley and DC Handscomb

[AG] provides a more advanced mathematical treatment of a range of topics. [HH], a classic, touches on many central ideas of modern Monte Carlo.

In addition to the books above, there are two sets of lecture notes you may find useful:

- [M] Introduction to Monte Carlo Methods by DJC MacKay
- [S] Monte Carlo Methods in Statistical Mechanics: Foundations and New Algorithms by A Sokal, in Functional Integration: Basics and Applications, C DeWitt-Morette, P Cartier, and A Folacci, eds. NATO ASI Series (Series B: Physics) 361, Springer, 1997

[M] provides a very readable introduction to some of the things we'll cover, and [S] gives a clear, concise exposition of some key ideas in Markov chain Monte Carlo, with a focus on statistical physics problems.

Finally, for Markov chain theory:

- [D] Essentials of Stochastic Processes by Durrett
- [HPS] Introduction to Stochastic Processes by Hoel, Port, and Stone

## Schedule of Topics and Activities

See course web page.

## Assessments

Grading will be based on a small number of problem sets and an individual term project. The breakdown is

- 40% project paper
- 40% project presentation
- 10% homework
- 10% participation

There are no exams in this course.

## Final Project

Students will consult the instructor to choose a suitable project topic; projects related to students' own research are especially encouraged. Project results will be presented to the class *and* summarized in a term paper, to be published on the course web page after the end of semester. Because term papers will be published, you should be careful not to include new work that you plan to publish later.

## Grading Scale and Policies

Students receiving [90,100]% of the maximum number of points are guaranteed an A,[80,90)% at least a B, [70,80)% at least a C, [60,70)% at least aa D.

## Safety on Campus and in the Classroom

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview

Also watch the video available at https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy000000000003560

## Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

## University Policies

All university policies related to a syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies. By placing this link in your syllabus, you no longer need to have each individual policy included in your syllabus.

## Subject to Change Notice

Information contained in the course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.