

Randomized Algorithms
CSCI 4030 / CSCI 6220

4 credit hours
Fall 2026, RPI
MTh 12pm–1:50pm ET, Location TBD

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Office Hours: TBD

Course website: https://cs.rpi.edu/~gittea/old-site/teaching/fall2026/randalg.html
Piazza: https://piazza.com/rpi/fall2026/csci40306220/home
Submitty: https://submitty.cs.rpi.edu/courses/f26/csci40306220

Prerequisites. CSCI 2200 and CSCI 2300. Students are assumed to be comfortable with proofs, counting, discrete structures, basic probability, algorithm analysis, and basic linear algebra.

Course synopsis. This course presents the basic concepts in the design and analysis of randomized algorithms at a level appropriate for advanced undergraduates and beginning graduate students. The goal is to develop the ability to recognize when randomization simplifies an algorithm, improves performance, or provides a proof technique that is hard to replace deterministically.

This course emphasizes reusable tools, canonical examples, and a few modern applications where randomization is especially effective.

Assessment is based on **weekly homeworks, two quizzes, and a final exam**.

Required Text. **Primary text:** Mitzenmacher and Upfal, *Probability and Computing*.
Supplementary: Additional notes or readings may be posted on the course website as needed.

Shared Learning Outcomes. Upon successful completion of this course, each student will be able to:

(S1) Analyze randomized algorithms using expectation, concentration, and tail bounds.
(S2) Distinguish Monte Carlo and Las Vegas algorithms and reason about amplification.
(S3) Design and analyze randomized data structures using hashing and load-balancing ideas.
(S4) Solve streaming and sketching problems using randomized estimators and summaries.
(S5) Apply the probabilistic method and method of conditional expectation.
(S6) Use derandomization and limited-independence ideas in algorithm design.
(S7) Analyze randomized rounding and approximation algorithms.
(S8) Understand randomized linear algebra methods such as Kaczmarz and sketching.
(S9) Analyze basic Markov chains and sampling algorithms.

Additional Graduate Learning Outcomes. Upon successful completion of the graduate version of this course, each student will be able to:

(G1) Prove stronger concentration and martingale-based bounds for dependent randomized processes.
(G2) Analyze more advanced variants of randomized algorithms and compare multiple proof strategies.
(G3) Read and critically evaluate recent randomized algorithms research papers and derive their main arguments.

Course Calendar. The material covered in practice may vary to achieve learning objectives.

Lecture	Topic / Milestones
Lec 1	Course overview; Monte Carlo vs. Las Vegas; amplification.
Lec 2	Probability refresher: indicators, expectation, linearity, union bound.
	Homework 1 assigned.

Lecture	Topic / Milestones (cont.)
Lec 3	Markov, Chebyshev, and expected-time analysis.
Lec 4	Chernoff bounds and concentration.
	Homework 2 assigned.
Lec 5	Hash tables and extreme bucket loads.
	Homework 3 assigned.
Lec 6	The power of two choices.
	Homework 4 assigned; Research topic due.
Lec 7	Universal hashing and limited independence.
	Homework 5 assigned.
Lec 8	Static perfect hashing (FKS).
Lec 9	Cuckoo hashing: dynamic dictionaries through random graphs.
Lec 10	Fingerprints and Bloom filters.
Lec 11	Streaming I: frequency estimation.
	Homework 6 assigned; Quiz 1 scheduled this week.
Lec 12	Streaming II: moment and distinct-count sketches.
	Homework 7 assigned.
Lec 13	Randomized graph algorithms I: Karger min-cut.
	Homework 8 assigned.
Lec 14	Randomized graph algorithms II: graph sparsification.
Lec 15	Probabilistic method I: existence via randomness.
	Research progress report due.
Lec 16	Probabilistic method II: conditional expectation.
	Homework 9 assigned.
Lec 17	Lovász Local Lemma and Moser-Tardos: escaping the union bound.
Lec 18	Derandomization: how little randomness does an algorithm need?
Lec 19	Randomized rounding and approximation.
	Homework 10 assigned.
Lec 20	Martingales and bounded differences (Azuma-style concentration).
	Homework 11 assigned.
Lec 21	Randomized linear algebra I: randomized Kaczmarz.
Lec 22	Randomized linear algebra II: Johnson-Lindenstrauss and subspace embeddings.
Lec 23	Randomized linear algebra III: sketched least squares and leverage scores.
	Homework 12 assigned.
Lec 24	Randomized linear algebra IV: fast Laplacian solvers via spectral sparsification and preconditioned CG.
Lec 25	Markov chains I: stationarity, reversibility, detailed balance, Metropolis-Hastings.
Lec 26	Markov chains II: mixing time, coupling, conductance intuition.
	Quiz 2 scheduled this week; Final project deliverables due.
Lec 27	Research Presentations
Lec 28	Research Presentations

Assessment and Grading

Grading components

CSCI 4030	CSCI 6220
Weekly homeworks (12 total) - 25%	Weekly homeworks (12 total) - 15%
Quiz 1 - 25%	Quiz 1 - 20%
Quiz 2 - 25%	Quiz 2 - 20%
Final Exam - 25%	Final Exam - 20%
	Research Presentation - 25%

Quizzes and exams: Quizzes and exams are closed book, with a single hand-written notes page to be submitted with the exam, and no electronic assistance. For the graduate students, additional problems may be used to assess the graduate-level learning outcomes. Make-up assessments are only granted for documented excused absences or institute-approved accommodations.

Homeworks: Homeworks are assigned weekly; the due dates will be announced on the course website and Submitty. Homework is due by the deadline posted unless arranged with the instructor at least two days before the due date.

Problems may be a mix of proof and algorithm design and implementation questions. For the graduate students, additional problems may ask for sharper bounds, alternate proofs, or analyses based on short readings. Submissions should be typed unless otherwise specified. Any collaborators and any external sources used (including AI) must be acknowledged clearly, with a clear explanation of their role in your submission.

Research presentations (CSCI 6220 only, 25% of course grade): Graduate students will complete a research project individually or in pairs. The project consists of four graded components: topic selection (10%), a progress report (30%), final deliverables (25%), and an in-class presentation (35%); these percentages are of the research component, not the total course grade. Detailed descriptions are posted on the course website.

Grade Thresholds:

CSCI 6220: A $\geq$ 90, B+ $\geq$ 85, B $\geq$ 80, C+ $\geq$ 75, C $\geq$ 70, F $<$70
CSCI 4030: A $\geq$ 90, B+ $\geq$ 85, B $\geq$ 80, C+ $\geq$ 75, C $\geq$ 70, D+ $\geq$ 65, D $\geq$ 60, F $<$60

Course Mechanics and Policies.

Regrade requests: Regrade requests must be submitted via email to the instructor within one week of the return of the assignment or exam. The entire problem set or exam may be reconsidered.

Attendance: Attendance is expected and strongly encouraged. Students are responsible for material covered in lecture and for all announcements posted on the course website or Submitty.

Collaboration: Discussion with classmates is encouraged at the level of ideas and approaches. Calculations, detailed proofs, and final write-ups must be your own work.

Oral spot-checks and individual explanations may be required to verify authorship. When significant gaps are observed between the understanding exhibited in person and that in submitted work, penalties may include reduction of the score on the assignment up to a failing grade in the course.

Academic integrity: Students are expected to complete all work honestly and independently unless collaboration is explicitly allowed for a particular homework. Any external sources used in written work must be cited clearly. Unauthorized use of AI tools, copying, or submission of uncredited material is not permitted. See the Student Conduct Code, available in the RPI Handbook of Student Rights & Responsibilities, for the institute-wide standards on academic integrity:

`https://info.rpi.edu/dean-students/student-rights-responsibilities-and-judicial-affairs/`.

Academic Accommodations: RPI is committed to equal access for students with disabilities. Students needing academic accommodations should contact the Office of Disability Services for Students (dss@rpi.edu; 518-276-8197) to establish accommodations and notify the instructor as early as possible so that accommodations can be implemented in a timely manner.