

# STOCHASTIC PERFORMANCE MODELING AND SCHEDULING IN COMPUTER SYSTEMS

Fall 2022

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<b>Instructor:</b> Ben Berg	<b>Time:</b> Monday, Wednesday 9:30 - 10:45
<b>Email:</b> ben@cs.unc.edu	<b>Room:</b> FB 007

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**Course Page:** [https://bsb20.github.io/teaching/790\\_f22](https://bsb20.github.io/teaching/790_f22)

**Office Hours:** Tuesday 10:00-11:30 and Thursday 4:00-5:30, or By Appointment in FB 336

**Description** This course will teach the fundamentals of stochastic performance modeling, and then apply those fundamentals to better understand the state-of-the-art in systems design and scheduling theory.

We will begin by developing an understanding of the stochastic processes used to model modern computer systems, and some methods for analyzing these models. We will see how these tools can be used to answer a variety of practical questions such as: How can we minimize latency or maximize throughput in a system? How many servers do I need to buy to meet my latency/throughput goals? Should I buy one faster server, or two slower servers? How should I balance load across the many servers in my system?

After looking at the basic tools required to answer some of these questions, we will examine recent work in the area of scheduling theory and system design, analyzing this work through the lens of stochastic performance modeling.

**Student Learning Outcomes:** The goals of this class are to:

1. Develop an understanding of the basic tools of stochastic performance modeling
2. Be familiar with how problems in modern computer systems can be modeled and analyzed via stochastic processes
3. Contrast the style of analysis used by the performance modeling community with that of computer science research communities (e.g. the systems community, worst-case theory community)

**Main References:** The main text for the course is *Performance Modeling and Design of Computer Systems* (Harchol-Balter, Cambridge University Press). It is available for free online through the UNC Library.

**Target Audience:** This class is intended for graduate students with an interest in a quantitative approach to building and optimizing computer systems. This might be a student with a strong theory background who is interested in how theoretical ideas can be deployed in modern computer systems. This might also be a systems student who wants to learn about a more formal approach to optimizing system performance. Students should have familiarity with applied probability at an undergraduate level, but a deeper background in stochastic processes is not required.

**Prerequisites:** STOR 435/535 or equivalent. Familiarity with the material in Chapter 3 of the course text book.

**Course Schedule (subject to change)**

Lecture	Date	DoW	Topic	Work Due
1	8/15	M	Chpt 1: Motivating Examples on Queueing Theory.	
2	8/17	W	Chpt 2: Queueing Theory Notation/Vocabulary.	
3	8/22	M	Chpt 4: Simulating Random Variables	HW 1 Due
4	8/24	W	Chpt 5: Convergence of Random Variables and Time Average versus Ensemble Average.	
5	8/29	M	Chpt 6: Operational Laws (Little's Law)	
6	8/31	W	Chpt 7: Modification Analysis	
	9/5	M	LABOR DAY, NO CLASS	
7	9/7	W	Chpt 8: Discrete-time Markov Chains	HW 2 Due
8	9/12	M	Chpt 9: Ergodicity - Finite-state DTMCs	
9	9/14	W	Chpt 11: Exponential Distribution	
10	9/19	M	Chpt 11: Poisson Process	
11	9/21	W	Chpt 12,13: M/M/1	
	9/26	M	NO CLASS	
12	9/28	W	Chpt 14: M/M/k	HW 3 Due
13	10/3	M	Chpt 15: Capacity Provisioning	
14	10/5	W	Chpt 20: Pareto Distribution	
15	10/10	M	Chpt 21: Phase-type distributions + start Chpt23	
	10/12	M	NO CLASS	
16	10/17	W	Chpt 23: M/G/1	
17	10/19	M	SOAP (Scully et al.)	HW 4 Due
18	10/24	W	Towards Optimality in Parallel Job Scheduling (Berg et al.)	
19	10/26	M	Paper Discussions	
20	10/31	W	-	
21	11/2	M	-	
22	11/7	W	-	
23	11/9	M	-	
24	11/14	M	-	
25	11/16	W	-	
26	11/21	M	-	
	11/23	W	THANKSGIVING, NO CLASS	
27	11/28	M	-	
28	11/30	W	-	

**Important Dates:**

- HW1 Due - 8/22
- HW2 Due - 9/7
- HW3 Due - 9/28
- HW4 Due - 10/19
- Paper Presentations - 10/26 to 11/30

**Course Requirements:** This course will consist of lectures, homework problem sets, and paper discussions. The plan is to spend roughly the first half of the course learning the basics of stochastic performance modeling, and then use the second half of the course to read and discuss papers related to the course material.

The first half of the course will therefore consist of lectures which will be accompanied by problem sets. Problem sets will account for 40% of your course grade.

In the second half of the course, each student will lead 2 paper presentations. One of the papers you present should be closely related to the course material and should come from the performance modeling research community. The second paper can be a little further afield if you want — something closer to your own research, or from a related community like the real-time scheduling community. However, your job for both paper presentations is to explain the contents of the paper and relate it to the course material. For example, if you choose a systems paper, explain how you might formally model the problem addressed in the paper and explain why this is a hard theory problem. Alternately, if you choose a scheduling paper from the worst-case or real-time scheduling communities, compare the model being used to an analogous stochastic model, and explain how the differences between the models might change the results of the paper. Each paper presentation will count for 25% of your course grade.

Throughout the course, but particularly during the paper discussions, participation is critical and therefore will count for 10% of your course grade.

**Grading:** To Recap:

- Homework: 40%
- Paper Presentation 1: 25%
- Paper Presentation 2: 25%
- Participation: 10%

**Collaboration Policy and Other Rules:** Collaboration on homework with current classmates is allowed. This includes any discussion that occurs in office hours. However, everyone must turn in their own version of each assignment. Please document your collaborators at the top of each assignment.

In addition to all UNC policies (below), everyone must adhere to the [reasonable person principle](#).

**University of North Carolina at Chapel Hill**  
**Information for Undergraduate Classes**  
**Summer & Fall 2022**

**Syllabus Changes**

The professor reserves the right to make changes to the syllabus including project due dates and test dates. These changes will be announced as early as possible.

**Attendance Policy**

**University Policy:** As stated in the University's [Class Attendance Policy](#), no right or privilege exists that permits a student to be absent from any class meetings, except for these University Approved Absences:

1. Authorized University activities
2. Disability/religious observance/pregnancy, as required by law and approved by [Accessibility Resources and Service](#) and/or the [Equal Opportunity and Compliance Office](#) (EOC)
3. Significant health condition and/or personal/family emergency as approved by the [Office of the Dean of Students](#), [Gender Violence Service Coordinators](#), and/or the [Equal Opportunity and Compliance Office](#) (EOC).

**Class Policy:** Instructors may work with students to meet attendance needs that do not fall within University approved absences. For situations when an absence is not University approved (e.g., a job interview or club activity), instructors determine their own approach to missed classes and make-up assessment and assignments.

**University Approved Absence Office (UAAO):** The [UAAO](#) website provides information and FAQs for students and faculty related to University Approved Absences.

**Note:** Instructors have the authority to make academic adjustments without official notice from the UAAO. In other words, it is not required for instructors to receive a University Approved Absence notification in order to work with a student. In fact, instructors are encouraged to work directly with students when possible.

**Honor Code**

All students are expected to follow the guidelines of the UNC Honor Code. In particular, students are expected to refrain from "lying, cheating, or stealing" in the academic context. If you are unsure about which actions violate the Honor Code, please see me or consult [studentconduct.unc.edu](http://studentconduct.unc.edu).

**Optional Mask Use Statement**

UNC-Chapel Hill is committed to the well-being of our community – not just physically, but emotionally. The indoor mask requirement was lifted for most of campus on March 7, 2022. If you feel more comfortable wearing a mask, you are free to do so. There are many reasons why a person may decide to continue to wear a mask, and we respect that choice.

**Acceptable Use Policy**

By attending the University of North Carolina at Chapel Hill, you agree to abide by the University of North Carolina at Chapel Hill policies related to the acceptable use of IT systems and services. The Acceptable Use Policy (AUP) sets the expectation that you will use the University's technology resources responsibly, consistent with the University's mission. In the context of a class, it's quite likely you will participate in online activities that could include personal information about you or your peers, and the AUP addresses your obligations to protect the privacy of class participants. In addition, the AUP addresses matters of others' intellectual property, including copyright. These are only a couple of typical examples, so you should consult the full [Information Technology Acceptable Use Policy](#), which covers topics related to using digital resources, such as privacy, confidentiality, and intellectual property.

Additionally, consult the University website "[Safe Computing at UNC](#)" for information about the data security policies, updates, and tips on keeping your identity, information, and devices safe.

### **Accessibility Resources and Service**

The University of North Carolina at Chapel Hill facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, including mental health disorders, chronic medical conditions, a temporary disability or pregnancy complications resulting in barriers to fully accessing University courses, programs and activities.

Accommodations are determined through the Office of Accessibility Resources and Service (ARS) for individuals with documented qualifying disabilities in accordance with applicable state and federal laws. See the ARS Website for contact information: <https://ars.unc.edu> or email [ars@unc.edu](mailto:ars@unc.edu).

### **Counseling and Psychological Services**

UNC-Chapel Hill is strongly committed to addressing the mental health needs of a diverse student body. The [Heels Care Network](#) website is a place to access the many mental resources at Carolina. CAPS is the primary mental health provider for students, offering timely access to consultation and connection to clinically appropriate services. Go to their website <https://caps.unc.edu/> or visit their facilities on the third floor of the Campus Health building for an initial evaluation to learn more. Students can also call CAPS 24/7 at 919-966-3658 for immediate assistance.

### **Title IX Resources**

Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Reports can be made online to the EOC at <https://eoc.unc.edu/report-an-incident/>. Please contact the University's Title IX Coordinator (Elizabeth Hall, [titleixcoordinator@unc.edu](mailto:titleixcoordinator@unc.edu)), Report and Response Coordinators in the Equal Opportunity and Compliance Office ([reportandresponse@unc.edu](mailto:reportandresponse@unc.edu)), Counseling and Psychological Services (confidential), or the Gender Violence Services Coordinators ([gvsc@unc.edu](mailto:gvsc@unc.edu); confidential) to discuss your specific needs. Additional resources are available at [safe.unc.edu](http://safe.unc.edu).

### **Policy on Non-Discrimination**

The University is committed to providing an inclusive and welcoming environment for all members of our community and to ensuring that educational and employment decisions are based on individuals' abilities and qualifications. Consistent with this principle and applicable laws, the University's [Policy](#)

[Statement on Non-Discrimination](#) offers access to its educational programs and activities as well as employment terms and conditions without respect to race, color, gender, national origin, age, religion, genetic information, disability, veteran's status, sexual orientation, gender identity or gender expression. Such a policy ensures that only relevant factors are considered and that equitable and consistent standards of conduct and performance are applied.

If you are experiencing harassment or discrimination, you can seek assistance and file a report through the Report and Response Coordinators (see contact info at [safe.unc.edu](http://safe.unc.edu)) or the [Equal Opportunity and Compliance Office](#), or online to the EOC at <https://eoc.unc.edu/report-an-incident/>.

### **Diversity Statement**

I value the perspectives of individuals from all backgrounds reflecting the diversity of our students. I broadly define diversity to include race, gender identity, national origin, ethnicity, religion, social class, age, sexual orientation, political background, and physical and learning ability. I strive to make this classroom an inclusive space for all students. Please let me know if there is anything I can do to improve. I appreciate suggestions.

### **Undergraduate Testing Center**

The College of Arts and Sciences provides a secure, proctored environment in which exams can be taken. The center works with instructors to proctor exams for their undergraduate students who are not registered with ARS and who do not need testing accommodations as provided by ARS. In other words, the Center provides a proctored testing environment for students who are unable to take an exam at the normally scheduled time (with pre-arrangement by your instructor). For more information, visit <http://testingcenter.web.unc.edu/>.

### **Learning Center**

Want to get the most out of this course or others this semester? Visit UNC's Learning Center at <http://learningcenter.unc.edu> to make an appointment or register for an event. Their free, popular programs will help you optimize your academic performance. Try academic coaching, peer tutoring, STEM support, ADHD/LD services, workshops and study camps, or review tips and tools available on the website.

### **Writing Center**

For free feedback on any course writing projects, check out UNC's Writing Center. Writing Center coaches can assist with any writing project, including multimedia projects and application essays, at any stage of the writing process. You don't even need a draft to come visit. To schedule a 45-minute appointment, review quick tips, or request written feedback online, visit <http://writingcenter.unc.edu>.

### **Grade Appeal Process**

If you feel you have been awarded an incorrect grade, please discuss with me. If we cannot resolve the issue, you may talk to our departmental director of undergraduate studies or appeal the grade through a formal university process based on arithmetic/clerical error, arbitrariness, discrimination, harassment, or personal malice. To learn more, go to the [Academic Advising Program](#) website.