Mathematical Tools for Theoretical Neuroscience

Spring 2026

Last updated: 1/19/2026.
Precedence: If information here conflicts with any other page (e.g., SSOL, CTN, Vergil), this page takes precedence.

Instructional Staff

Lecturers:

- A. Erdem Sağtekin(as7853@cumc.columbia.edu)
- Abhishek Shah(as5460@columbia.edu)
- Arnav Raha(ar4307@columbia.edu)
- Lenca-Iarina Cuturela(lc3919@columbia.edu)
- Sofiya Garkot(sg4611@columbia.edu)

Faculty Contact: Prof. Ken Miller* (kdm2103@columbia.edu)
**Please contact Prof. Miller to sign add/drop forms and other items which require faculty permission.*

Logistics

Time:
Lectures: TuTh 12:10-1:25pm
Office Hours: By appointment: please email a TA.
Recitations: TBA.

Location: Jerome L. Greene Science Center, 5th floor (large classroom)

Please email Rozanna Yakub (ry2185@cumc.columbia.edu) if you would like to participate in the course but do not have access to the building.

Credits: 3

Description

An introduction to mathematical concepts used in theoretical neuroscience aimed to give a minimal requisite background for *Introduction to Theoretical Neuroscience*. The target audience is students with limited mathematical background who are interested in rapidly acquiring the vocabulary and basic mathematical skills for studying theoretical neuroscience.

Topics include linear algebra, single- and multivariable calculus, probability theory, dynamical systems and signal analysis. Examples and applications are drawn primarily from theoretical and computational neuroscience.

Prerequisites

Basic prior exposure to trigonometry, calculus, and/or vector operations at the high school level.

Registration

- Undergraduate and graduate students taking the course for the credit: Must register on SSOL.
- Audit interest: Please e-mail one of the TAs.

Grading

- 50% Homeworks (approximately bi-weekly)
- 50% Participation (attendance, asking/answering questions, office hours, comments on notes, etc.)
- Extra Credit: +1% on your next homework assignment for finding a typo and +10% for finding an error in the typed lecture notes.
  - Please add comments directly to the posted files.

Schedule

Schedule (Subject to change. Some advanced topics may be dropped if we need more time to cover the basics).*

#	Date	Topic	Notes	HW
1	Tue Jan 20	Basics	Functions, inverses, complex numbers	
2	Thu Jan 22	Linear Algebra	Vectors and matrices	
3	Tue Jan 27	Linear Algebra	Matrix operations	HW1 out
4	Thu Jan 29	Linear Algebra	Vector spaces	
5	Tue Feb 3	Linear Algebra	Basis, matrix of a vector	
6	Thu Feb 5	Linear Algebra	Linear transformations	
7	Tue Feb 10	Linear Algebra	Matrix of a linear transf., change of basis	HW1 due; HW2 out
8	Thu Feb 12	Linear Algebra	Eigenvectors	
9	Tue Feb 17	Calculus	Limits, derivatives	
10	Thu Feb 19	Calculus	Taylor series	
11	Tue Feb 24	Calculus	Partial derivative, gradient	HW2 due, HW3 out
12	Thu Feb 26	Calculus	Change of variables: Chain rule, Jacobian	
13	Tue Mar 3	Calculus	Directional derivatives, Hessian, Min/Max	
14	Thu Mar 5	Calculus	Convex optimization, Lagrange	
15	Tue Mar 10	Calculus	Lagrange Multipliers	HW3 due
Holiday (no class): Thu Mar 12 – Thu Mar 19				
16	Tue Mar 24	Probability	Intro Probability: Discrete/combinatorics, counting	HW4 out
17	Thu Mar 26	Probability	Intro (discrete): Expectation and variance	
18	Tue Mar 31	Probability	Intro Continuous / Distributions	
19	Thu Apr 2	Probability	Conditional probability + Bayes' Rule	
20	Tue Apr 7	Probability	Covariance + Gaussian's	HW5 out
21	Thu Apr 9	Dynamics	ODEs (single variable)	HW4 due
22	Tue Apr 14	Dynamics	Linear systems (matrix) + Eigenvectors	
23	Tue Apr 21	Dynamics	Fixed points, Nullclines	
24	Thu Apr 23	Dynamics	Linearization	
25	Tue Apr 28	Dynamics	Limit cycles, chaos (buffer)	HW5 due
26	Thu Apr 30	Signals & Systems	Convolution + Fourier series	

Questions and Communication

For any questions or concerns regarding the course, please reach out to Prof. Miller (listed above) or visit the CourseWorks webpage. You may also contact the lecturer of the section directly.

Important Policies

- **Academic Integrity:** All students are expected to adhere to University policies of academic honesty.
- **Use of AI:** Mathematics is learned most effectively through active problem solving rather than passive review. You are therefore encouraged to attempt problems independently before seeking assistance. After making a genuine effort, you may consult peers, instructors, or use AI tools as supplementary support. AI should ideally only be used after you have spent sufficient time and effort working through a problem on your own.
- **Attendance:** Regular attendance is highly recommended to succeed in this course. Participation is a significant component of your grade.
- **Late Submissions:** Homework assignments submitted after the deadline may be subject to a grade penalty unless prior arrangements are made. Extensions requested before the due date will be accepted.
- **Accessibility Statement:** We are committed to providing an inclusive and accessible learning environment for all students. If you require accommodations, please contact the Office of Disability Services at disability.services@columbia.edu as early as possible to discuss your needs. All requests for accommodations will be handled confidentially and in accordance with university policies. We value diverse perspectives and strive to create a space where all students feel welcomed and supported. Discrimination or harassment of any kind will not be tolerated. If you encounter any issues related to inclusion, please reach out to the faculty contact.

We look forward to a fun semester exploring the mathematical foundations of theoretical neuroscience!