

PLSC 30600 - Causal Inference (Winter 2026)
Math Section Syllabus

Location: Pick Hall 407
Course Time: Thursday 2:00-3:00

Supplemental Math TA: Sophia Lipkin, slipkin@uchicago.edu
Office Hours: 1/27 and 3/3, 11-1 in Pick 407 or by appointment

Course Overview. Attendance at this supplementary section is entirely optional, but it is designed to support students who would benefit from additional mathematical foundations for causal inference and estimation. We strongly recommend it for doctoral students, as well as for masters students who plan to continue on to Bobby Gulotty's estimation course in the spring.

If you are planning on taking Bobby's class and cannot attend the section, please contact me.

Prerequisites. The course covers Linear Algebra and continuous probability, as well as some multivariate calculus. Because of the limited time frame, I am assuming that students have attended or familiarized themselves with the content of the Math Camp for PhD students run by Ryan Gibbons and Luke Cain in the fall. I will flag what you should review as the course progresses so you don't have to rush to review everything at once.

Resources. There are multitude of resources on the internet to help you learn these concepts, from people who have been thinking about how to teach math for far longer than me, for many different types of learners. I will make available videos, practice problems, and relevant textbook chapters on Mondays before class.

- **Math Camp Slides:** <https://ryankgibbons.com/resources/>

Course text.

- Available on Github:
 - Bretscher, Otto. *Linear Algebra with Applications*. 5th ed. Boston: Pearson Education, 2013, (*solutions manual also available on Github*)
 - Hansen, Bruce. *Probability for Economists*. 2021
- Linear Algebra:
https://www.asherbroberts.com/teaching/2025_fall_linear_algebra/Linear_Algebra_Notes_2025.pdf

- Calculus 1:
https://www.asherbroberts.com/teaching/2025_fall_calculus_i/Calculus_I_Notes_2025.pdf
- Calculus 2:
https://www.asherbroberts.com/teaching/2025_spring_calculus_ii/Calculus_II_Notes_2025.pdf
- Calculus 3 (Multivariate Calculus):
https://www.asherbroberts.com/teaching/2025_fall_calculus_iii/Calculus_III_Notes_2025.pdf

Course resources. There are many great calculators and step-by-step resources to help with your math understanding that are passed down informally among math students. Here are a few. You should use these before checking ChatGPT or another LLM.

- [Matrix Calculator](#) - any sort of computation with matrices
- [Integral Calculator](#)
- [Derivative Calculator](#)
- [Wolfram Alpha](#)
- [Math Stack Exchange](#) - this is what retired math professors do in their free time, it is infinitely better for conceptual questions than Reddit or ChatGPT and your question has probably already been asked

Course outline.

Week 2. Introduction to Proofs

- Proof: Law of Iterated Expectations

Resources:

- https://www.fsb.miamioh.edu/lij14/411_proof.pdf - Proof here
- Video (preview of the class): ALL of linear algebra in 7 minutes.
- Math camp slides review: Days 1 & 2 (set and number theory, functions and operations)

Week 3. Introductory Matrix Algebra

- Matrix notation for systems of linear equations
- Matrix operations: multiplication, addition
- Matrix laws

Resources:

- Video: Linear Algebra 1.1 Introduction to Systems of Linear Equations **, corresponding [textbook chapter](#)
- Video: Linear Algebra 1.3 Matrices and Matrix Operations , corresponding [textbook chapter](#)
- Students may want to review some of the videos from week 6, particularly Chapter 4 (Matrix multiplication as composition), if they are highly visual learners
- Additional review problems:
 - Bretscher: 1.1 (page 5): problems 1-6
 - Bretscher: 1.2 (page 18): problems 1,4,5

Week 4. Sophia in Colombia, no class

- additional office hours Tuesday Jan 27th
- review problems: calculus: solving derivatives and integrals

Resources:

- Math camp slides review:
 - Days 4, 6, and 7 (Derivation, Integrals, Multivariate Calculus)
 - Day 9 (Continuous probability)
- Video: The essence of calculus (don't worry about chapters 11 and 12)
- Video: But what is the Central Limit Theorem?
- Video: Riemann Sums - Left Endpoints and Right Endpoints

Week 5. Linear algebra continued – Matrix Inverses & Determinants

Resources:

- Video: [Linear Algebra 1.4 Inverses; Algebraic Properties of Matrices](#), corresponding textbook chapter
- [Eigenvectors and eigenvalues | Chapter 14, Essence of linear algebra](#)
- Students may want to review the Chapter 6 video from week 6 if they want to understand determinants visually
- Visualizing linear regression through linear algebra: (*this is the essence of the Estimation class, NOT necessary for the content in Causal!*)
 - [Linear Regression in 3 Minutes](#)
 - [Simple Linear Regression Formula, Visualized | Ch.1](#) – watch all videos in this playlist

Week 6. Linear algebra continued – Vectors, projection matrices

- dot product on unit vectors
- span, basis, coordinates
- eigenvalues

Resources:

- This is a very difficult week conceptually, but it is one of the most important things you learn for understanding how we compute regression models. I will add a bunch of additional videos for this.
- Visually understanding everything we did in weeks 3-5
 - ** [Vectors | Chapter 1, Essence of linear algebra](#)
 - [Linear combinations, span, and basis vectors | Chapter 2, Essence of linear algebra](#)
 - [Linear transformations and matrices | Chapter 3, Essence of linear algebra](#)
 - Visual explanation of matrix multiplication:
 - [Matrix multiplication as composition | Chapter 4, Essence of linear algebra](#)
 - [Three-dimensional linear transformations | Chapter 5, Essence of linear algebra](#)
 - [The determinant | Chapter 6, Essence of linear algebra](#)
 - [Dot products and duality | Chapter 9, Essence of linear algebra](#) (MUST WATCH!!)
- **Visually understanding projection matrices:
 - [Projection Matrix Properties - Projection, Part 1](#)
 - [Orthogonal Projection Formulas \(Least Squares\) - Projection, Part 2](#)

Week 7. Continuous random variables

- Continuous probability, integrals and fundamental theorem of calculus
- expectation properties for continuous RVs

Resources:

- Math camp slides review: Day 9 (Continuous probability)

Week 8. Multivariate random variables

- Multivariate functions, partial derivatives
- Marginal densities, conditional distributions
- Gamma integrals
- joint PDFs & CDFs, visualizing in 3D

Week 9. Review, no new content

- additional office hours Tuesday March 3rd