UNIVERSITY OF MANNHEIM

BAS: Mathematics for Social Scientists

Fall 2025

Instructor:	Carlos Gueiros
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Office Hours:	Tu 10-11:30 *(please make an appointment by email, other hours also possible)*
Office:	B301, A5 6, Mannheim
Lecture Times:	Wednesday 15:30-17:00, every week, starting 03.09.2025 until 03.12.2025
Class Room:	C 216 Seminarraum (A 5, 6 Bauteil C)

Course Description

It is increasingly important for modern social scientists to have a level of mathematical literacy, as mathematical research methods such as statistics and formal modeling have entered the main stream. This course is intended to provide an introduction to mathematical logic and rigor, and to some fundamental mathematical concepts that form the foundation of the modern subject. The course covers introductory set and function theory, including analysis of functions, and includes sections on both probability and linear algebra, which together are the basis of data analysis.

Course Objectives

The main objectives of the course are the following:

- To obtain confidence with mathematical language and notation,
- To learn essential mathematical principles and thought,
- To learn or revise specific mathematical concepts that are necessary for quantitative work, such as matrix algebra, differentiation, probability theory,

Course Structure

Weekly 90-minute lectures where material is introduced with worked examples. I will post (optional) problem sets relevant for the exam to help internalize the concepts. Answers will be provided for self-checking[1]. Students are encouraged to ask questions during office hours or after class.

Readings to complement the material will be circulated. Students are expected to read this material as well as the slides before classes.

[1] Solutions comprise final answers only, not full derivations.

Grading Scheme

There are two grades in this course: Pass / Fail. The final exam contributes to 100% of the grade.

Course Outline

The tentative outline is as follows:

- Set Theory
  - Definition and properties, subsets, indexed families, Cartesian product
  - Set relations, binary operations, inverse and neutral elements
  - Propositional logic, truth tables, logical equivalence, implications
- Functions
  - Definition and properties, identity and inverse functions
  - Injective, surjective and bijective functions
  - Function composition
- Analysis
  - Distances and continuity, norms, neighbourhoods
  - Continuity in $\mathbb{R}$ and $\mathbb{R}^n$, limits of functions
  - Polynomials, exponential and logarithmic functions
  - Differentiation: derivatives in $\mathbb{R}$ and $\mathbb{R}^n$; partial derivatives; *chain rule*
  - Unconstrained maxima and minima: critical points; first/second-derivative tests; gradients
  - Integration: indefinite and definite integrals, substitution, integration by parts, applications (e.g., area under a curve, probability densities)
  - Applications: Linear Regression *(If time permits)*
- Linear Algebra
  - Matrices and vectors: definitions, addition, scalar multiplication, transpose
  - Systems of linear equations (SLEs), matrix representation, Gauss algorithm
  - Inverting matrices, diagonal, triangular and symmetric matrices
  - Trace, determinant, eigenvalues and eigenvectors
- Probability Theory
  - Counting rules, permutations and combinations
  - Probabilistic formalism, Law of Total Probability, Conditional probability, Bayes' Law
  - Simpson's Paradox, Independence
  - Random variables, probability distributions, common discrete and continuous distributions
  - Distribution functions, Cumulative Distribution Functions (CDFs)

Schedule

The tentative schedule is as follows:

- Lecture 1, 03.09.2025
  - Introduction
  - Set Theory and Logic
- Lecture 2, 10.09.2025
  - Functions and Mappings
- Lecture 3, 17.09.2025
  - Analysis I: Sequences, Limits and Continuity
- Lecture 4, 24.09.2025
  - Analysis II: Derivatives
- Lecture 5, 01.10.2025
  - Analysis III: (Un)constrained optimization
- Lecture 6, 08.10.2025
  - Analysis IV: Integration Techniques and Applications
- Lecture 7, 15.10.2025
  - Linear Algebra I: Vectors, Matrices, Linear Systems
- Lecture 8, 22.10.2025
  - Linear Algebra II: Matrix Operations, Inverses, Determinants
- Lecture 9, 29.10.2025
  - Linear Algebra III: Eigenvalues and Eigenvectors
- Lecture 10, 05.11.2025
  - Applications: Linear Regression (matrix formulation, least squares)
- Lecture 11, 12.11.2025
  - Probability I: Counting, Probability Axioms, Conditional Probability
- Lecture 12, 19.11.2025
  - Probability II: Bayes' Law, Independence, Simpson's Paradox
- Lecture 13, 26.11.2025
  - Probability III: Random Variables, Distributions, CDFs
- Lecture 14, 03.12.2025
  - Final Q&A and Exam Preparation

1 Readings

Here are some recommended readings. They provide more detailed explanations about the topics and are helpful if you are not familiar with the material or wish to explore further.

- **General**
  - Moore and Siegel (2013), *A Mathematics Course for Political and Social Research*. Introductory and intuitive, includes YouTube video lectures.
  - Gill (2006), *Essential Mathematics for Political and Social Research*. The main reference on which this course material is based.
  - Bonacich and Lu (2012), *Introduction to Mathematical Sociology*. Focused on social science applications with mathematical modeling.
  - Simon and Blume (1994), *Mathematics for Economists*. A comprehensive text for economics students.
  - Sydsaeter and Hammond (2008), *Essential Mathematics for Economic Analysis*. A standard economics-oriented introduction.
  - Hagle (1996), *Basic Math for Social Scientists*.
- **Calculus and Analysis**
  - Spivak (2006), *Calculus*. A classic and rigorous introduction.
  - Protter and Morrey (1991), *A First Course in Real Analysis*. Short, theorem-proof style.
- **Linear Algebra**
  - Strang (2005), *Linear Algebra and Its Applications*. Accompanied by free MIT video lectures.
  - Lay (2011), *Linear Algebra and Its Applications*.
  - Hefferon (2014), *Linear Algebra*. Free, example-rich resource.
  - Axler (2015), *Linear Algebra Done Right*. A more rigorous but intuitive treatment.
  - The Matrix Cookbook. An overview of matrix calculus identities.
- **Probability Theory**
  - Grinstead and Snell (1997), *Introduction to Probability*. Free and well-suited for beginners.
  - DeGroot and Schervish (2011), *Probability and Statistics*. Standard undergraduate text with intuition and rigor.
  - Casella and Berger (2024), *Statistical Inference*. A comprehensive, formal treatment for advanced study.

Additional Resources

- **Text-based Guides**
  - Math Prefresher for Political Scientists (IQSS) – Especially Chapters 1–6
- **Video Lectures**
  - Essence of Calculus (3Blue1Brown)
  - Essence of Linear Algebra (3Blue1Brown)

  - Khan Academy: Linear Algebra
  - David Siegel's Tutorials

- **Learning Tools**
  - Wolfram Alpha – Useful for symbolic math, graphing, derivatives, integrals.