15.455x Mathematical Methods for Quantitative Finance

Faculty Member(s):	Prof. Paul Mende
Length:	12 Weeks
Related Course(s) at MIT:	15.455 and 15.456
Prerequisites:	Calculus (multivariable), probability and statistics, linear algebra, basic programming skills.

Modern finance is the science of decision making in an uncertain world, and its language is mathematics. As part of the MicroMasters® Program in Finance, this course develops the tools needed to describe financial markets, make predictions in the face of uncertainty, and find optimal solutions to business and investment decisions.

This course will help anyone seeking to confidently model risky or uncertain outcomes. Its topics are essential knowledge for applying the theory of modern finance to real-world settings. Quants, traders, risk managers, investment managers, investment advisors, developers, and engineers will all be able to apply these tools and techniques.

What you'll learn (at a glance)

- Probability distributions in finance
- Time-series models
- Continuous-time stochastic processes
- Monte Carlo simulation
- Linear algebra of asset pricing
- Optimization
- Applied computational techniques

Approximate total time of lecture videos: 15 hours

Grading: 10% graded problem sets, 90% proctored final exam

Software: The course uses R and RStudio for demonstrations of numerical techniques and coding examples, however, you may use your preferred language. R and RStudio are available free from these locations.

- R Project home page: https://www.r-project.org
- R Studio Desktop: https://www.rstudio.com/products/rstudio/#rstudio-desktop

Course Materials

- **Recommended Textbook:** Tsay, *Analysis of Financial Time Series* (3e), Wiley (Tsay)
- **Recommended Textbook:** Capinski and Zastawniak, *Mathematics for Finance*, Springer (CZ)

Course Structure

This course consists of:

- A course introduction (Week 0);

- 9 Lectures, 9 Problem Sets, 9 Recitations demonstrating how to solve problems similar to those contained in the problem sets (Weeks 1–9)
- 10-day review period for final exam; and
- 1 proctored Final Exam (Week 10)

WEEK	TOPIC
Week 0	**Course Introduction and How to Take this Course**
Week 1	**Probability** ▪ Review of basic concepts for random variables ▪ Probability distributions common in finance ▪ Expectation, variance, and covariance ▪ Sums of random variables ▪ Central Limit Theorem **Problem Set 1**
Week 2	**Introduction to discrete-time stochastic processes** ▪ The random walk and generalizations ▪ Structure and solution of linear time series models ▪ Monte Carlo methods, simulation ▪ Testing the Random Walk Hypothesis **Problem Set 2**
Week 3	**Time series models** ▪ Model identification and estimation ▪ Alternatives to the random walk ▪ AR, MA, ARMA, RW generalizations ▪ Order determination ▪ Boundary value problems ▪ Applications: forecasting, gambling, dynamic trading strategies **Problem Set 3**
Week 4	**Introduction to continuous-time stochastic processes** ▪ Limits of discrete-time processes ▪ Scaling behavior ▪ Brownian motion ▪ Itô processes ▪ Itô's lemma **Problem Set 4**

Week 5	**Itô calculus** ▪ Itô processes in finance ▪ Dynamic hedging and risk management ▪ The Black-Scholes-Merton equation **Problem Set 5**
Week 6	**Continuous-time finance** ▪ From SDE to PDE ▪ Solving partial differential equations of finance ▪ Boundary value problems and Green functions ▪ Applications to derivative pricing and credit default risk **Problem Set 6**
Week 7	**Linear algebra of asset pricing** ▪ Review of linear algebra ▪ One-period model: prices, payoffs, and probabilities ▪ Dual spaces and the FTAP ▪ Linear algebra of portfolio space **Problem Set 7**
Week 8	**Optimization** ▪ Review of high-dimension critical points ▪ Lagrange multipliers and constrained optimization ▪ Quadratic programming solutions ▪ Applications to portfolio optimization **Problem Set 8**
Week 9	**Optimal decision making and optimal strategies** ▪ Dynamic programming ▪ Variational methods ▪ Extensions ▪ Applications: optimal execution and trading
Week 10	**Review period for final exam (no course content)**
Week 11	**Final Exam**