Master of Science Program in Financial Mathematics

The Department of Mathematics (http://www.math.uchicago.edu/graduate) offers a separate Master of Science in Financial Mathematics degree. Students of the Financial Mathematics Program (http://www-finmath.uchicago.edu) develop a thorough understanding of the theoretical background of pricing models for financial derivatives and the underlying assumptions. Moreover, students learn to critically ascertain the applicability and limitations of these various models.

Faculty members and financial industry professionals work jointly to create a curriculum with relevancy to the field. Professors use a pedagogical approach emphasizing the use of computer simulations to illustrate the material. Through this approach, professors cover more material and students develop a thorough understanding of theory application while navigating the Program.

Professionals from the financial industry instruct a significant number of classes in the Program using methods to explore how models behave in practice under a variety of market conditions as well as to evaluate the validity of underlying assumptions and consequential violations of these assumptions. Students will learn to use these models to set up and evaluate the effectiveness of hedges by simulating various market conditions.

The Program consists of four components: Mathematics (spans three quarters), Probability Theory (spans two quarters), Economics (spans one quarter), and Financial Applications and Simulations (spans three quarters). In addition to these four components, students may be required to complete a Computing for Finance sequence and Introduction to Finance and Markets course if unable to pass the Computing for Finance and Introduction to Finance placement exams.

Full-time students following the five-quarter track complete the Financial Mathematics curriculum in five quarters, or 15 months. Students who qualify for a waiver of the Computing for Finance in C++ sequence and the Introduction to Finance and Markets requirement, as determined by mandatory placement exams, may opt to complete the Program in three quarters, or nine months. Students on the three-quarter track follow a more constrained curriculum with limited options for elective courses and must be enrolled full-time. Part-time students, on average, complete the Program in two to three academic years. The Program must be completed within four academic years from the date of matriculation. For the convenience of our working students, classes meet for three to four hours on weekday evenings.

Various software packages are licensed to the Program and will be provided free of charge including Symantec Endpoint Protection, Microsoft Office Professional, Microsoft Visual Studio, Mathematic, SPLUS, SPSS, Stata, NVivo, and Thinkcell.

The Financial Mathematics Program seeks candidates with a solid background in mathematics developed through majors such as mathematics, statistics, engineering, science, and economics. Additionally, relevant work experience and experience with basic computer programming skills including C++ are strongly taken into consideration by the Admissions Committee. We admit driven individuals that come from diverse educational, social, and geographic backgrounds. Candidates should be able to demonstrate excellence in both academics and leadership.

The courses listed below are subject to change each academic year. The current required courses can be found below:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>FINM 32000</td>
<td>Numerical Methods</td>
<td>100</td>
</tr>
<tr>
<td>FINM 32500</td>
<td>Computing for Finance in Python</td>
<td>100</td>
</tr>
<tr>
<td>FINM 32600</td>
<td>Computing for Finance in C++ *</td>
<td>100</td>
</tr>
<tr>
<td>FINM 32700</td>
<td>Advanced Computing for Finance</td>
<td>100</td>
</tr>
<tr>
<td>FINM 33000</td>
<td>Mathematical Foundations of Option Pricing</td>
<td>100</td>
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<tr>
<td>FINM 33150</td>
<td>Regression Analysis &amp; Quantitative Trading Strategies</td>
<td>100</td>
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<tr>
<td>FINM 33410</td>
<td>Probability for Risk Management</td>
<td>050</td>
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<tr>
<td>FINM 33601</td>
<td>Fixed Income Derivatives</td>
<td>100</td>
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<tr>
<td>FINM 34500</td>
<td>Stochastic Calculus</td>
<td>100</td>
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<tr>
<td>FINM 36700</td>
<td>Portfolio Theory and Risk Management I</td>
<td>050</td>
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<tr>
<td>FINM 36702</td>
<td>Portfolio Theory and Risk Management II</td>
<td>050</td>
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<tr>
<td>FINM 37700</td>
<td>Introduction to Finance and Markets *</td>
<td>050</td>
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<tr>
<td>FINM 37301</td>
<td>Foreign Exchange: Markets, Pricing, and Products</td>
<td>050</td>
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<tr>
<td>Electives</td>
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<td>Total Units</td>
<td></td>
<td>1350</td>
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* May be tested out of through placement exam
Mathematics - Financial Mathematics Courses

FINM 32000. Numerical Methods. 100 Units.
Implementing the theory introduced in Mathematical Foundations of Option Pricing (FINM 33000), this course takes a numerical/computational approach to the pricing and hedging of financial derivatives. Topics include: Trees as diffusion approximations; Finite difference methods for PDE solution; Monte Carlo methods for simulation; Fourier transform methods for pricing. Program requirement.
Instructor(s): R. Lee Terms Offered: Winter

FINM 32500. Computing for Finance in Python. 100 Units.
In FINM 32500, students will learn how to use Python to develop quantitative models in financial math. The course takes students through both the basics of good implementation in Python as well as more advanced topics, all with a focus on best-practices. Program requirement.
Terms Offered: Autumn
Note(s): Counts toward computing requirement.

FINM 32600. Computing for Finance in C++. 100 Units.
No previous programming knowledge is assumed. In Computing for Finance in C++, we will introduce the syntax and semantics of C++ and basics of OO programming. As part of the course work, students will develop an OO option pricer using the Monte Carlo technique. Classes are taught using a combination of lectures and in class hands-on lab sessions. Program requirement.
Instructor(s): C. Liyanaarachchi Terms Offered: Winter
Note(s): Required if student does not pass the Computing for Finance in C++ placement exam. Counts toward computing requirement

FINM 32700. Advanced Computing for Finance. 100 Units.
This course is intended to teach advanced programming concepts and techniques to students desiring to work in the financial sector. It is tailored for students with basic knowledge in C++ programming. At the end of this class, students will have the necessary programming skills to be successful in their daily activities. We will cover the required skills to work as a quantitative researcher: advanced data structures (STL, Boost), parallel programming, inter-process communication, linear algebra comutation, simulation and modeling. We will work on several projects aimed at building a real trading system including the implementation of a trading algorithm, handling the connectivity to an exchange/brokerage house and issues related to performance. Classes are taught using a combination of lectures and in class hands-on lab sessions. Program requirement.
Instructor(s): S. Donadio Terms Offered: Spring
Note(s): Counts toward computing requirement.

FINM 32850. Case Studies in Computing for Finance. 100 Units.
This course will introduce participants to the field of Computational Finance through real-world “end-to-end” case studies. The course will focus on the importance of data analytics and algorithmic processing and it will be centered around a series of examples that are representative of problems that practitioners in finance have to solve. The course is structured to cover two major themes: 1. Intro to Data analysis and Numerical algorithms in Computational Finance, and 2. Case studies of “end-to-end” system implementations. Prerequisites and recommended background: As a prerequisite, students will be required to have successfully completed two of the following courses: Computing for Finance in Python, Computing for Finance in C++ (or passed the placement exam) and Advanced Computing for Finance. The participants should also have basic familiarity with the use of MS Excel spreadsheets & VBA, as well as with the use of a high level programming language such as Python or R.
Instructor(s): C. Doloc Terms Offered: Autumn
Prerequisite(s): Two of the following three courses required: FINM 32500, FINM 32600 (or having passed the Computing for Finance in C++ placement exam), FINM 32700.
Note(s): Program elective.

FINM 32950. Introduction to HPC in Finance. 050 Units.
This short course introduces parallel programming and related concepts using some popular technologies (e.g. Intel's family of parallel models, OpenMP, CUDA etc.) at an introductory level. Application performance improvement using a systematic and structured approach is illustrated. Applications in finance are used to illustrate how to exploit parallelism to solve largescale computing problems. No prior knowledge of parallel computing is assumed. Previous coursework in C++ or Python (FINM 32500 or 32600 or 32700), or passing the FINM computing placement exam is required.
Instructor(s): C. Liyanaarachchi Terms Offered: Summer
Prerequisite(s): 1 of the following 3: FINM 32500, FINM 32600 (or having passed the Computing for Finance in C++ placement exam), FINM 32700.
Note(s): Program elective.

FINM 33000. Mathematical Foundations of Option Pricing. 100 Units.
Introduction to the theory of arbitrage-free pricing and hedging of financial derivatives. Topics include: Arbitrage; Fundamental theorems of asset pricing; Binomial and other discrete models; Black-Scholes and other continuous-time Gaussian models in one-dimensional and multidimensional settings; PDE and martingale methods; Change of numeraire. Program requirement.
Instructor(s): R. Lee Terms Offered: Autumn
FINM 33150. Regression Analysis & Quantitative Trading Strategies. 100 Units.
Quantitative trading strategies, employing investment decisions based on model output, are a major component of business operations in the finance industry worldwide. We will present the major components of these strategies as found in several asset classes (equities, futures, credit, FX, interest rates and energy). A large proportion of the models involved in quantitative strategies are expressible in terms of regressions. We will cover most of the ways they are used, including practical tricks and considerations, and concentrating particularly on achieving trustworthy performance. Mathematically, we will cover the computation of linear regressions with and without weights, in univariate and multivariate cases, having least squares or other objective functions. Of the major computation technologies actively used by the finance industry (C/C++, Matlab, Java, R, VBA/Excel, C#, Python) we have chosen R and Python for numerical computation, with (very) light usage of Excel and with data coming from Quandl and some proprietary sources. Program requirement.
Instructor(s): B. Boonstra Terms Offered: Spring

FINM 33160. Machine Learning in Finance. 100 Units.
The course will focus on two Machine Learning categorization models: Logistic Regression and Support Vector Machines, both binary and multi-category. The course will develop the mathematical foundations for these models and the optimization algorithms for training them on actual data. The algorithms will be implemented in Python. The necessary parts of Python programming will be taught along the way as they are needed. The Machine Learning models will be used to train models for trading stocks based on both fundamental and technical data. The models will be implemented in Python, using several Machine Learning libraries such as Scikit-learn and back-tested using the web service Quantopian. At the end of the course, the students will develop and implement their own trading models and analyze the performance of their models. Program elective.
Instructor(s): N. Nygaard Terms Offered: Autumn
Note(s): Students may apply FINM 37701 or FINM 33160 toward the computing requirement, but not both. If both are taken, the second will count toward the elective requirement.

FINM 33170. Statistics of High-Frequency Financial Data. 100 Units.
This course is an introduction to the econometric analysis of high-frequency financial data. This is where the stochastic models of quantitative finance meet the reality of how the process really evolves. The course is focused on the statistical theory of how to connect the two, but there will also be some data analysis. With some additional statistical background (which can be acquired after the course), the participants will be able to read articles in the area. The statistical theory is longitudinal, and it thus complements cross-sectional calibration methods (implied volatility, etc.). The course also discusses volatility clustering and market microstructure.
Instructor(s): P. Mykland Terms Offered: Winter
Prerequisite(s): STAT 39000/FINM 34500 (may be taken concurrently), also some statistics/econometrics background as in STAT 24400–24500, or FINM 33150 and FINM 33400, or equivalent, or consent of instructor.
Note(s): Not offered in 2016-17
Equivalent Course(s): STAT 33970

FINM 33180. Multivariate Data Analysis via Matrix Decompositions. 100 Units.
This course is about using matrix computations to infer useful information from observed data. One may view it as an "applied" version of Stat 30900 although it is not necessary to have taken Stat 30900; the only prerequisite for this course is basic linear algebra. The data analytic tools that we will study will go beyond linear and multiple regression and often fall under the heading of "Multivariate Analysis" in Statistics. These include factor analysis, correspondence analysis, principal components analysis, multidimensional scaling, linear discriminant analysis, canonical correlation analysis, cluster analysis, etc. Understanding these techniques require some facility with matrices in addition to some basic statistics, both of which the student will acquire during the course. Program elective.
Instructor(s): L. Lim Terms Offered: Autumn
Equivalent Course(s): STAT 32940

FINM 33400. Statistical Risk Management. 100 Units.
The course starts at a rather introductory level, but the progress is swift. It covers a brief survey of basic probability theory, and provides an introduction to some useful statistical distributions, both univariate and multivariate. A discussion of copulas and various correlation measures. Risk measures and ideas behind a reasonable risk measure. A few elements from Monte Carlo simulation. Statistical estimation, the maximum likelihood method and nonparametric methods. Asymptotic properties of estimators. Goodness of fit tests and model selection. Extreme value theory. Program requirement.
Instructor(s): J. Paulsen Terms Offered: Autumn

FINM 33410. Probability for Risk Management. 050 Units.
The course starts at a rather introductory level, but the progress is swift. It covers a brief survey of basic probability theory, and provides an introduction to some useful statistical distributions, both univariate and multivariate. A discussion of copulas and various correlation measures. Risk measures and ideas behind a reasonable risk measure. A few elements from Monte Carlo simulation. Program requirement.
Instructor(s): J. Paulsen Terms Offered: Autumn

FINM 33420. Statistical Inference for Risk Management. 100 Units.
Instructor(s): J. Paulsen Terms Offered: Autumn
Prerequisite(s): FINM 33410: Probability for Risk Management
Note(s): Cannot be taken for elective credit if 33400 has already been taken.
FINM 33601. Fixed Income Derivatives. 100 Units.
The topics in this course include an introduction to fixed income markets, a detailed review of fixed income derivative instruments, and a general approach to bootstrapping the LIBOR term curve from available market quotes. We also discuss the application of the Black-Scholes-Merton model to pricing European swaptions and caps/floors. Students will study a statistical approach to building a foundation for the Heath-Jarrow-Morton framework of interest rate models. Students should be prepared for the extensive use of Stochastic Calculus. Program requirement.
Instructor(s): Y. Balasanov, L. Doloc, J. Greco Terms Offered: Spring

FINM 33603. Fixed Income Derivatives I. 050 Units.
This is part one of a two-part course on Fixed Income Derivatives. The topics will include an introduction to fixed income markets, a detailed review of fixed income derivative instruments, and a general approach to bootstrapping the LIBOR term curve from available market quotes. We also discuss the application of the Black-Scholes-Merton model to pricing European swaptions and caps/floors. Students will study a statistical approach to building a foundation for the Heath-Jarrow-Morton framework of interest rate models, covered in the second part of the course. This is a 5-week course taught in the second-half of the quarter.
Instructor(s): Y. Balasanov, L. Doloc, J. Greco Terms Offered: Autumn

FINM 34500. Stochastic Calculus. 100 Units.
The course starts with a quick introduction to martingales in discrete time, and then Brownian motion and the Ito integral are defined carefully. The main tools of stochastic calculus (Ito's formula, Feynman-Kac formula, Girsanov theorem, etc.) are developed. The treatment includes discussions of simulation and the relationship with partial differential equations. Some applications are given to option pricing, but much more on this is done in other courses. The course ends with an introduction to jump process (Levy processes) and the corresponding integration theory. Program requirement.
Instructor(s): G. Lawler Terms Offered: Winter
Equivalent Course(s): STAT 39000

FINM 35000. Topics in Economics. 100 Units.
This course explores the economics of asset pricing. Going beyond no-arbitrage valuation, students learn how asset prices can be linked to economic fundamentals. As the recent recession and financial crisis show, there are important links between financial markets and the real economy. This course gives students a systematic way for understanding these links. Several important areas and puzzles of financial economics are presented. Topics in equity pricing include return-predictability, excess volatility, and factor-models. In fixed income, the course covers the empirical evidence of the term structure and how it compares to the Expectations Hypothesis, as well as how these facts fit with classes of common term-structures models. In international finance, the course covers the carry trade, the home-equity bias, and the currency trilemma. Program elective.
Instructor(s): M. Hendricks Terms Offered: Autumn

FINM 35910. Applied Algorithmic Trading. 050 Units.
Applied Algorithmic Trading will introduce the required background knowledge and processes necessary for the design and implementation of algorithmic trading models within the context of industry requirements. The objective of the course is to bring together the numerous disciplines covered in other Financial Mathematics courses, focused on quantitative trading, and combine them into a workable industry level presentation. This course will walk students through the process of generating trading ideas, quantifying the trading process, risk-based modeling concepts, back-testing and optimization techniques, and key industry metrics used to evaluate algorithmic trading model performance. Lastly, the course will stress the leadership and presentation skills necessary to make a successful pitch in an industry setting. Program elective.
Instructor(s): C. Gersch, B. Jorge Terms Offered: Autumn
Prerequisite(s): FINM 32400, FINM 33150, or consent of instructors

FINM 36000. Project Lab. 050 Units.
Program elective.
Instructor(s): R. Lee Terms Offered: Autumn,Spring,Summer,Winter
Prerequisite(s): Consent of instructor.

FINM 36001. Project Lab 2. 000 Units.
Program elective.
Instructor(s): R. Lee Terms Offered: Autumn,Spring,Summer,Winter
Prerequisite(s): FINM 36000 and consent of instructor.

FINM 36700. Portfolio Theory and Risk Management I. 050 Units.
The course introduces investment analysis, allocation, risk control. The course begins with classic topics such as mean-variance analysis, priced and un-priced risk, hedging, and the efficient frontier of investment opportunities. Factor models are used to understand the relation between risk and expected return. Examples covered in the course include the CAPM, Black-Litterman, and principal component factors. Finally, the course discusses modern risk control, including risks from interest-rates, liquidity, and credit. Value-at-risk, and expected shortfall are discussed. Program requirement.
Instructor(s): M. Hendricks Terms Offered: Autumn
Note(s): This is a 5 week course taught in the second half of the quarter.
FINM 36702. Portfolio Theory and Risk Management II. 050 Units.
This course combines a technical topic with an analysis of situations that produce outsized losses. Students gain familiarity with the credit portfolio loss models that are used to limit trading, allocate costs, and determine required bank capital. They also review the interplay between the technical and human factors that has led to prominent risk control failures. Unique in the Financial Math program, students make in-class presentations that detail the optimal responses of various market participants to unexpected circumstances. *Program requirement.*
Instructor(s): J. Frye Terms Offered: Winter
Prerequisite(s): FINM 36700 Portfolio Theory and Risk Management I
Note(s): This is a five-week course taught in the second-half of the quarter.

FINM 3701. Foreign Exchange: Markets, Pricing, and Products. 050 Units.
This course will examine international currency markets, financial products, and applications of quantitative models with an emphasis on the quantitative methods and derivative products in common use today. Topics will include a) pricing for FX products in theory and in practice, specifically spot, forward, futures, deposits, cross-currency swaps, non-deliverable contracts, and FX options, b) FX markets in practice, exchange rate regimes, international monetary systems, FX modeling and forecasting, and c) practical market applications of FX options, exotic options, and hybrid products. *Program Requirement.*
Instructor(s): A. Capozzoli Terms Offered: Spring
Note(s): This is a five-week course taught in the first-half of the quarter.

FINM 3701. Mathematical Market Microstructure: An Optimization Approach. 100 Units.
Mathematical Market Microstructure: An Optimization Approach for Dynamic Inventory Management and Market Maker Quoting. This course is an introduction to mathematical theory of market microstructure, with key applications in solving optimal execution problems with inventory management. We will start from discussions of market design, global market structure, algorithmic trading and market making practices. We will then present traditional market microstructure theory in the context of dealer inventory management and information-based quoting and pricing. Latest literature about realized volatility calculations and intraday implied volatility surface modeling using high-frequency data will be reviewed. The subject of order book dynamics research with applications to market impact modeling will be discussed as well. Finally, a review on continuous-time stochastic control theory will be provided and a discussion will be given on execution algorithm development and market making strategy design using stochastic programming techniques. The main goal of this course is to provide a clear discussion on key mathematical treatments and their practical applications of market microstructure problems, in particular relating to price discovery and utility optimization for certain transaction processes with non-trivial transaction cost present. *Program elective.*
Instructor(s): H. Chou Terms Offered: Autumn
Note(s): This is a five-week course taught in the first half of the quarter.

FINM 3702. Mathematical Market Microstructure w/o Rationality Assumptions. 050 Units.
Just like the view on micro world made us rethink our theories about the laws of physics previously based on macro world experience, algorithmic trading at extremely low latency exposes us to new phenomena and demands new mathematical models for their analysis. Objectives of this course are: introducing students to some models that have become important for analysis of market microstructure in recent years and show how they can be applied to low latency trading and risk management. We start with a review of the main features of the market behavior at ultra-low latency, explain why we prefer to look at the market events with “frog’s eye” and concentrate on mathematical models consistent with Principle of Ma. During the course we study stochastic processes that describe market behavior at the microstructure level. Among them are Poisson, Cox, Ammeter, Hawkes and other processes. Students will learn how to simulate each of the processes, fit it to market data and interpret the results. We will relate these processes to common approaches to modeling market price formation and limit order book behavior. Demonstrations and applications will be implemented in R. Students will work with some real market data examples. Classes consist of lecture part and in-class workshop. Students are required to have some background in probability theory, statistical methods and statistical data analysis with R is recommended.
Instructor(s): Y. Balasanov Terms Offered: Autumn
Note(s): This is a five-week course taught in the second half of the quarter.

FINM 37700. Introduction to Finance and Markets. 050 Units.
This course is an introduction to the basics of finance and financial markets. It assumes minimal finance/markets background with the option for experienced students to test out during a placement exam in the first week. Topics include: financial systems, financial returns, capital markets, and financial management. *Program requirement.*
Instructor(s): P. Hirschbein, Terms Offered: Autumn
Note(s): Required if student does not pass the Introduction to Finance and Markets placement exam. This is a five-week course taught in the first half of the quarter.

FINM 38000. Financial Mathematics Practicum. 050 Units.
Program elective.
Terms Offered: Autumn, Spring, Summer, Winter

FINM 38500. Career Seminar. 000 Units.
Presentations/workshops/networking events related to career development in quantitative finance. *Program requirement.*
Instructor(s): Career Development Office Terms Offered: Autumn
FINM 39000. Regulatory & Compliance Requirements for Financial Institution. 050 Units.
The course introduces students to the key regulatory and compliance requirements for bank and non-bank financial institutions under the Dodd-Frank Act. Students first learn the basics of the regulatory framework governing the U.S. capital markets and financial institutions, and are given an overview of the financial crisis of 2008-09 that led to the Dodd-Frank legislation. Next, we examine the primary areas under the Act that a risk-management system must address. Topics include: a) regulation of systemic risk, including stress testing of large depository and systemically important non-depository institutions, b) Basel III's capital adequacy requirements issued by the Federal Reserve Board for such institutions and the SEC's net capital rules for broker-dealers, and c) the regulation of the derivatives market and counterparty risk. The course covers the Act's basic modeling requirements relating to these regulations. Students learn the primary components of a financial institution compliance program pertaining to corporate governance, supervision, internal controls, management of conflicts of interest, and gain an understanding of a risk management system optimally designed to achieve compliance with the Dodd-Frank Act. Case studies illustrate both compliance breakdowns and best practices. Program elective.
Instructor(s): A. Dill Terms Offered: Autumn
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

- Times was used instead of Trajan.
- Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.