UNIVERSITY
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FACULTY SENATE

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MEMORANDUM

To: Donna E. Shalala, President

From: Tomas A. Salerno
Chair, Faculty Senate

Date: April 30, 2015

Subject: Faculty Senate Legislation #2014-38(B) – College of Arts and Sciences Master of Science in Mathematical Finance

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The Faculty Senate, at its April 22, 2015 meeting, voted unanimously to approve the proposal for a Master of Science program in Mathematical Finance in the College of Arts and Sciences. Geared for students who are B.S. graduates in Mathematics, Engineering, Computer Science or Physics, this program will offer students a professional education in a relatively new and fast-growing field. As noted in the proposal, "the demand for the skilled quantitative financial analysts ("quants") is on the rise both nationally and globally, with financial institutions looking for the qualified professionals to help them to adapt to increasingly fast tempo of financial innovation." The initial enrollment target of 12 students has the potential to grow to approximately 24 students with each entering cohort.

This legislation is now forwarded to you for your action.

TAS/rh

Enclosure

cc: Thomas LeBlanc, Executive Vice President and Provost
Leonidas Bachas, Dean, College of Arts and Sciences
Victor Pestien, Interim Chair, Department of Mathematics
Alexander Dvorsky, Presenter, Department of Mathematics

CAPSULE: Faculty Senate Legislation #2014-38(B) – College of Arts and Sciences Master of Science in Mathematical Finance

APPROVED: [signature] DATE: 5/5/2015
(President's Signature)

OFFICE OR INDIVIDUAL TO IMPLEMENT: DEAN BACHAS

EFFECTIVE DATE OF LEGISLATION: IMMEDIATELY
(if other than June 1 next following)

NOT APPROVED AND REFERRED TO: ____________________

REMARKS (IF NOT APPROVED): ____________________

Master of Science in Mathematical Finance - Executive Summary

Overview . The Master of Science in Mathematical Finance program aims to address the strong and constantly growing demand in the fields of banking and finance for young professionals with advanced quantitative skills and ability to apply them in a constantly evolving financial setting. It is aimed primarily at B.S. graduates with degrees in Mathematics, Physics, Engineering, or Computer Science, who are interested in a focused study of modern mathematical and modeling techniques applicable in the 21st century financial environment.

The program objectives are to provide the students with the diverse skill set, which includes working knowledge of contemporary financial instruments and advanced mathematical tools of finance, as well as sufficient modeling and programming skills demanded by the modern financial workplace.

The target enrollment for the start of the program is 12 students, with the potential of growth to approximately 24 students per entering cohort.

Curriculum. The core of the program consists of six Mathematics courses and two Finance courses (22 credits total). These courses are designed to provide the necessary mathematical and statistical foundations of the degree. In addition, the program requires at least 12 credits of Mathematics, Computer Science and Finance electives. The program is structured to be completed in 3 semesters of study.

Core (MTH 18 credits, FIN 4 credits)

MTH 647 Introduction to Mathematical Finance

MTH 648 Stochastic Calculus with Applications to Finance

MTH 642 Statistical Analysis

MTH 643 Statistical Analysis II with Financial Applications

MTH 645 Optimization Methods

MTH 649 Computational Methods of Finance

FIN 650 Financial Investments (2 credits)

FIN 651 Advanced Topics in Investments (2 credits)

Electives (minimum of 12 credits required):

CSC/ EEN/ MTH Electives (3 to 9 credits). One, two or three of the following courses:

CSC 632 Introduction to Parallel Computing

CSC 645 Introduction to Artificial Intelligence

EEN 548 Machine Learning

EEN 553 Neural Networks

MTH 613 Partial Differential Equations I

MTH 614 Partial Differential Equations II

MTH 620 Numerical Analysis I

MTH 721 Mathematical Probability

FIN electives (2 to 6 credits). One, two or three of the following courses:

FIN 660 International Finance (2 credits)

FIN 670 Corporate Finance (2 credits)

FIN 681 Financial Institutions (2 credits)

FIN 683 Financial Modeling (2 credits)

Other Business Electives (0 to 3 credits). At most one of the following courses:

ACC 602 Analysis of Financial Statements

ECO 442 International Monetary Economics

ECO 444 Game Theory

FIN 425 Business and Security Valuation

FIN 427 Fixed Income Markets and Analysis

FIN 431 International Financial Management

Proposal to Establish a Master of Science in Mathematical Finance

Name of the program for the Diploma:
Master of Science in Mathematical Finance

Name of the program on student transcripts:
Master of Science in Mathematical Finance

Responsible administrative unit for the program:
Department of Mathematics, College of Arts and Sciences, Graduate School

Proposed date for implementation:
Fall of 2016

1. RATIONALE: This program is designed for B.S. graduates in Mathematics, Physics, Engineering or Computer Science, who are interested in an intensive and focused study of modern mathematical, programming and modeling techniques applicable in the 21st century financial environment. It is expected that the program will attract students from different market groups, compared to both conventional M.S. in Mathematics and M.S. in Finance.

The demand for the skilled quantitative financial analysts ("quants") is on the rise both nationally and globally, with financial institutions looking for the qualified professionals to help them to adapt to increasingly fast tempo of financial innovation.

The program is patterned after similar programs at other highly ranked universities, such as the *Master of Arts in Mathematics with specialization in the Mathematics of Finance* offered by the Department of Mathematics at Columbia University, and the *Master of Science in Mathematics - Mathematical Finance* offered by the Department of Mathematics at Rutgers University.

2. RESOURCES: The program entails teaching two or three new classes each semester, in addition to the existing classes. The Department of Mathematics is currently in the process of recruiting for tenure-track positions; once these positions are filled, the department will have the sufficient resources to offer the required core courses of the program. The electives are already offered by the Mathematics and Finance departments on regular basis.

Teaching: One new tenured track position will dedicate 45 % of their effort to the proposed program. A new Assistant Professor, Dr. Hamed Amini, was recruited for this position. His appointment starts in Fall of 2015.

Library: Students enrolled in the proposed program will have access to appropriate collections and other learning resources that support the educational programs at all degree levels. The University of Miami libraries include extensive print and electronic resources and offer facilities for study, research, and discovery, as well as integrated systems to provide access and services.

In addition to the Richter Library, the students will be able to use the Judi Prokop Newman Business Information Resources Center at the School of Business Administration. There the students will be able to access business research databases including Bloomberg, Compustat etc.

Equipment and Space: The new courses included in the program will require classroom space (for 4 to 6 meetings a week, total). Other courses will be scheduled at times congruent with the same courses for other programs, all of which have sufficient classroom space available.

Other Resources: No additional resources of the College or University are required.

3. CURRICULUM:

Program Prerequisites:

Introduction to Probability and Statistics (MTH 224 or equivalent)

Introduction to Linear Algebra (MTH 210 or equivalent)

Differential Equations (MTH 311 or equivalent)

Proficiency in C/C# or C++ recommended (CSC 322, EEN 218 or equivalent).

The students may be admitted to the program with only one semester of introductory Computer Science. Such students will be required to take *CSC 220: Computer Programming II* or *EEN 218: Data Structures* during their first semester in the program. Students who are not proficient in C, C# or C++ will be required to take *CSC 322: C Programming and UNIX* during their first or second semester in the program. These courses do not count toward the graduation requirements.

Core and Elective Courses: The program has two sets of courses, entailing a total minimum of 34 credit hours. The **core** of the program consists of six Mathematics courses and two Finance courses (22 credit hours total). These courses are designed to provide the necessary mathematical and statistical foundations of the degree. In addition, the program requires at least 12 credits of Mathematics, Computer Science and Finance **electives**.

Core (MTH 18 credits, FIN 4 credits)

MTH 647 Introduction to Mathematical Finance

MTH 648 Stochastic Calculus with Applications to Finance [a]

MTH 642 Statistical Analysis

MTH 643 Statistical Analysis II with Financial Applications [a]

MTH 645 Optimization Methods [a]

[a] New course, see Attachment C

MTH 649 Computational Methods of Finance [a]

FIN 650 Financial Investments (2 credits)

FIN 651 Advanced Topics in Investments (2 credits)

Electives (minimum of 12 credits required):

CSC/ EEN/ MTH Electives (3 to 9 credits). One, two or three of the following courses:

CSC 632 Introduction to Parallel Computing

CSC 645 Introduction to Artificial Intelligence

EEN 548 Machine Learning

EEN 553 Neural Networks

MTH 613 Partial Differential Equations I

MTH 614 Partial Differential Equations II

MTH 620 Numerical Analysis I

MTH 721 Mathematical Probability

Finance Electives (2 to 6 credits). One, two or three of the following courses:

FIN 660 International Finance (2 credits)

FIN 670 Corporate Finance (2 credits)

FIN 681 Financial Institutions (2 credits)

FIN 683 Financial Modeling (2 credits)

Other Business Electives (0 to 3 credits)[b]. At most one of the following courses:

ACC 602 Analysis of Financial Statements

ECO 442 International Monetary Economics

ECO 444 Game Theory

FIN 425 Business and Security Valuation

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[b] The students have an option of taking 3 elective course credits below 500 level. Since the program requires at least 31 credits at the graduate level, the Graduate School guidelines are observed (cf. LEVELS OF GRADUATE STUDY section of the University of Miami Bulletin)

FIN 427 Fixed Income Markets and Analysis

FIN 431 International Financial Management

Program Description:

- Semester 1 (Fall): MTH 642, MTH 647, FIN 650, one elective. Also EEN 218/CSC 220/CSC 322 if required.
- Semester 2 (Spring): MTH 643, MTH 648, FIN 651, one elective. Also CSC 322 if required.
- Summer internship or summer project (optional).
- Semester 3 (Fall): MTH 645, MTH 649, one or two FIN electives. Additional elective course, if needed to complete the program requirements.

An overall GPA of 3.0 must be maintained in courses used to meet the program requirements.

New courses: The program will involve four new 3-credit classes (MTH 643, MTH 645, MTH 648 and MTH 649). Attachment D describes each of these. All these courses have been approved by the Curriculum Committee of the College of Arts and Sciences.

Program Objectives: The program objectives as well as learning outcomes are detailed in Attachments A and B.

Specifically, the program objectives are to:

- Provide future finance professionals with the advanced quantitative skills required to understand, evaluate and price modern financial instruments. Such skills include both analytic techniques of mathematical finance, and computer-based simulation techniques.
- Expose participants to the key statistical methods, and specifics of applying these methods to working with financial data.
- Impart the necessary hands-on software and programming skills to solve various optimization and simulation problems arising in financial setting.

The learning outcomes, as noted in Attachment B are:

<u>Outcome 1</u>: Understand the risk-neutral approach to pricing financial instruments. Master both the discrete and continuous-time frameworks of modern mathematical finance. Develop the understanding of common financial derivatives.

<u>Outcome 2</u>: Master the tools of statistical analysis and statistical software packages, and be able to apply them to various financial datasets. Master the common models of portfolio analysis, as well as the quantitative approach to risk models.

Outcome 3: Develop the working knowledge of software and programming tools to use optimization and simulation techniques in financial setting

Outcome 4: Develop the understanding of real-life financial markets and exchanges, portfolio construction and performance measurement.

4. FACULTY: Full-time faculty will teach the proposed core courses of the program. The Statistical Analysis courses (MTH 642, MTH 643) will be taught by the tenured faculty in the Mathematics department specializing in Probability and Statistics (specifically, Professors Pestien and Ramakrishnan). The Mathematical Finance, Stochastic Calculus and Optimization classes (MTH 647, MTH 648, MTH 645 respectively) will be taught by the faculty in the Mathematics department with prior expertise in these areas (specifically, Professors Amini, Dvorsky, Grigorescu and Kapitanski). The Computational Methods class (MTH 649) can be taught by both Mathematics faculty (Professors Amini and Coomes), as well as faculty in the Computer Science department (Professor Rosenberg).

In addition, non-tenure track faculty with prior expertise in these areas are currently available at the Department of Mathematics, such as Dr. Draghici (MTH 642) and Dr. Bystrik (MTH 645).

The proposed Mathematics, Computer Science and Finance electives are regularly offered within the existing graduate degree programs. The Department of Computer Science and the Department of Finance are supportive of the goals of the proposed program and will accept the M.S. in Mathematical Finance students to their courses.

5. STUDENTS: The program is designed for students with background in quantitative areas (such as mathematics, statistics, computer science or engineering), who are interested in building on their quantitative undergraduate degree to master mathematical, statistical and programming tools of finance. Since the program will have significant computer programming component, we expect the students to either possess the sufficient programming background, or be willing to acquire it during their first semester in the program.

Initially, we anticipate 10 to 12 qualified students, with the potential of growth to approximately 24 students per entering cohort.

Admission requirements:

- Complete an online application.
- Bachelor's degree from a regionally accredited U.S. institution, or a comparable degree from an international institution, with a minimum 3.0 (on a 4.0 scale) grade point average (GPA) in all coursework attempted in upper-division undergraduate coursework.
- Candidates are expected to have prior coursework in: multivariable calculus, calculus-based probability, differential equations, linear algebra.
- Proficiency in at least one programming language.

- Graduate Record Examination (GRE) scores.
- Test of English as a Foreign Language (TOEFL) score.
- Two letters of Recommendations.
- Anticipated Launch Date: Fall of 2016.

6. ADMINISTRATION: The program will be administered by the Department of Mathematics, College of Arts and Sciences, Graduate School.

7. BUDGET: See Attachment E.

8. COMPARISONS: More than 40 Master's programs in Quantitative Finance are currently active nationwide (under different designations and names, such as Financial Engineering, Financial Mathematics, Computational Finance, Mathematical Finance and Quantitative Finance). Before designing the proposed program, those at several schools were reviewed in order to survey current practices with respect to curriculum and typical student bodies. The reviewed programs included a mix of programs at both public and private universities:

- **Rutgers University**, Master of Science in Mathematics - Mathematical Finance (MSMF)[c], `finmath.rutgers.edu`
- **Columbia University**, Master of Arts in Mathematics with specialization in the Mathematics of Finance (MAFN)[d], `math.columbia.edu/mafn`
- **North Carolina State University**, Master of Financial Mathematics[e], `financial.math.ncsu.edu`
- **Johns Hopkins University** , Financial Mathematics Master's program, offered through the Department of Applied Mathematics and Statistics as a Master's of Science in Engineering (MSE)[f], `engineering.jhu.edu/ams`
- **University of Illinois at Urbana-Champaign**, Master of Science in Financial Engineering (MSFE)[g], `msfe.illinois.edu` .

The selected materials from these programs are presented in Attachment F.

9. TRANSFERS: Students are not allowed to take any courses outside of the Program, and have those courses count towards their degree requirements. No coursework completed prior to entering the Program will be considered towards a student's degree, with the following exception:

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[c] Ranked #15 in 2015 *Financial Engineer* rankings - `thefinancialengineer.net/rankings`, #12 in 2014 *Quantnet* rankings - `quantnet.com/mfe-programs-rankings`
[d] #7 in *Quantnet* rankings
[e] #24 in *Financial Engineer* rankings
[f] #10 in *Financial Engineer* rankings, #19 in *Quantnet* rankings
[g] #9 in *Financial Engineer* rankings, #20 in *Quantnet* rankings

University of Miami undergraduate students who are in good standing may, upon permission from a student advisor, the course instructor, and the Director of the Program, take up to two courses in the Program. If the student successfully completes the course(s), the credits earned may be applied toward the requirements of the Program.

10. Attachments:

Attachment A: Mission Statement/Program Objectives
Attachment B: Learning Assessments and Outcomes
Attachment C: New Courses
Attachment D: Letters of Support for the Program
Attachment E: Budget for the Program
Attachment F: Overview of Existing Mathematical Finance Degree Programs
Attachment G: Letter from the Office of Planning, Institutional Research, and Assessment

Attachment A - Mission Statement/Program Objectives

University of Miami's Mission Statement - The University of Miami's mission is to educate and nurture students, to create knowledge, and to provide service to our community and beyond. Committed to excellence and proud of the diversity of our University family, we strive to develop future leaders of our nation and the world.

College of Arts and Sciences - The College is dedicated to helping students develop analytical and communication skills, creative abilities, and a sense of civic responsibility needed in an increasingly complex society. It strives to provide them with a rigorous grounding in their chosen field, an awareness of the interconnectedness of disciplines, and an exposure to the discovery of new knowledge. The College seeks to create an intellectual environment that enhances individual growth and supports scholarly activities and creative endeavors that augment human knowledge and understanding.

Program Objectives -

- Provide future finance professionals with the advanced quantitative skills required to understand, evaluate and price modern financial instruments. Such skills include both analytic techniques of mathematical finance, and computer-based simulation techniques.
- Expose participants to the key statistical methods, and specifics of applying these methods to working with financial data.
- Impart the necessary hands-on software and programming skills to solve various optimization and simulation problems arising in financial setting.

Attachment B: Learning Assessments and Outcomes

Student Learning Outcome: Understand the risk-neutral approach to pricing financial instruments. Master both the discrete and continuous-time frameworks of modern mathematical finance. Develop the understanding of common financial derivatives.

Assessment Measure (direct) : Comprehensive tests and exams from MTH 647 and MTH 648 (required quantitative finance courses).

Assessment Measure (indirect): Graduating Masters Students Survey (GMSS) questions related to modeling skills and practice of quantitative finance.

Student Learning Outcome: Master the tools of statistical analysis and statistical software packages, and be able to apply them to various financial datasets. Master the common models of portfolio analysis, as well as the quantitative approach to risk models.

Assessment Measure (direct): Comprehensive tests and exams from MTH 642 and MTH 643 (required statistical analysis courses).

Assessment Measure (indirect): GMSS questions related to data management and data analysis.

Student Learning Outcome: Develop the working knowledge of software and programming tools to use optimization and simulation techniques in financial setting.

Assessment Measure (direct): Comprehensive tests and exams from MTH 645 and MTH 649 (required optimization/computational finance courses).

Assessment Measure (direct): Programming projects required in MTH 645 and MTH 649.

Assessment Measure (indirect) : GMSS questions related to gaining programming knowledge and practice.

Student Learning Outcome: Develop the understanding of real-life financial markets and exchanges, portfolio construction and performance measurement.

Assessment Measure (direct): Questions embedded in assignments and exams in FIN 650, 651 (required finance courses) and Finance electives.

Assessment Measure (indirect) : GMSS relevant questions.

Attachment C - New Courses

MTH 643: Statistical Analysis II with Financial Applications, 3 credits

Exploratory data analysis. Designing parametric models and assessing their uncertainty. Techniques for resampling. Using multivariate distributions to model financial data; families of copulas. Analyzing time series, including ARIMA and GARCH models.

Prerequisites: MTH 642 (or MTH 542), some familiarity with R statistical programming language

Text: *David Ruppert, Statistics and Data Analysis for Financial Engineering*, Springer, 2011.

Instructor: Dr. Victor Pestien

Learning Outcomes: By the end of the course, the student should be able to:

- Use graphical methods to model and estimate distributions.
- Given an empirical distribution, measure such features as kurtosis and skewness and identify appropriate parametric models.
- Assess the uncertainty of a model by using resampling.
- Use copulas to describe dependence within a multivariate distribution.
- Identify features of a time series by examining the plots of the sample autocorrelation function and partial autocorrelation function.
- Formulate and analyze ARIMA (autoregressive integrated moving average) models and GARCH (generalized autoregressive conditional heteroscedastic) models.

Tentative grading format: Midterm examination - 25%, Final examination - 45%, Six take-home assignments - 30%

Course topics:

Week 1: Modeling and estimating distributions by graphical methods: Quantile-quantile plot; kernel density estimator; transformations of data.

Weeks 2, 3 and 4: Designing parametric statistical models: Characterizing the shape of a probability distribution. Location and scale parameters. Skewness, kurtosis; special properties of heavy-tailed distributions; t-distributions; mixture models. Fitting a univariate distribution by maximum-likelihood estimation of parameters; central-limit theorem for the maximum-likelihood estimator. Choosing between models; Akaike information criterion.

Weeks 5 and 6: Assessing the uncertainty of a model. Simulating sampling from an unknown population: using bootstrap methods for estimating bias, finding standard errors, and constructing confidence intervals. **Midterm exam I**

Weeks 7 and 8: Using multivariate distributions to model data from financial markets. Correlation matrices. Using the multivariate normal and multivariate-t distributions and estimating their parameters. Resampling multivariate data.

Week 9: Using copulas to describe the dependence between components of a multivariate distribution. Archimedean copulas. Rank correlation. Choosing among copulas.

Weeks 10, 11, and 12: Analyzing time series: characteristics of stationary processes; the sample autocorrelation function. The white noise process and the Ljung-Box test. Autoregressive models; moving-average models; partial autocorrelation function; duality. ARIMA models; identification, parameter estimation, and diagnostic checking. **Midterm Exam II**

Weeks 13 and 14: Further analysis of times series. Unit root tests for evidence of non-stationarity. Seasonality in time series. Multivariate time series models; cross-correlation function. Modeling non-constant conditional variance via GARCH processes.

Cumulative Final Examination

MTH 645: Optimization Methods, 3 credits.

Linear optimization: simplex method and simplex tableaus, sensitivity analysis. Quadratic optimization and its applications in finance: risk modeling and portfolio construction. Integer programming techniques, branch and bound method. Dynamic programming – deterministic and probabilistic techniques. Software tools of optimization.

Prerequisites: undergraduate Linear Algebra, MTH 647 recommended.

Instructor: Alexander Dvorsky, dvorsky@math.miami.edu

Office: 503 Ungar

Learning Outcomes: By the end of the course, the student should be able to:

- Master setting up optimization problems. Develop the working knowledge of the tools of mathematical programming, in particular AMPL modeling language.
- Select suitable optimization methods for common types of optimization problems.
- Analyze and interpret the solutions to the optimization problems.
- Apply the techniques of linear and nonlinear optimization to various practical challenges, in particular to the problems of mathematical finance.

Course Summary: This course provides the overview of both the mathematical foundations of modern optimization methods and their applications to practical optimization problems. Special attention will be devoted to the applications of optimization techniques in modern finance.

We will introduce and explore linear, nonlinear and dynamic programming models, and study the details of their implementation. The course will extensively use common optimization software platforms and packages, such as Excel SOLVER and AMPL modeling language. The overview of industrial-strength optimizers will be given as well.

Texts:

- *G. Cornuejols & R. Tutuncu – Optimization Methods in Finance, Cambridge 2007* (required).

The text will be supplemented by the examples from

- *H.P. Williams – Model Building in Mathematical Programming, 5th ed., Wiley 2013.*
- The AMPL book (*AMPL: A Modeling Language for Mathematical Programming*) is freely available at http://ampl.com/resources/the-ampl-book/chapter-downloads/

Software:

The student edition of the AMPL command environment is available at http://ampl.com/products/ampl/ampl-for-students/.

Grading: Homework sets (total of 80 points), programming assignments (100 points), midterm exam (80 points), final exam (140 points). The final exam will consist of an in-class portion and a take-home modeling project.

Class schedule:

Weeks 1, 2, 3 – Introduction to Linear Programming. Primal and dual LP problems. Simplex method and dual simplex method. Simplex method tableaus. Sensitivity analysis. Setting up and solving LP problems using SOLVER. LP in finance (cash flow analysis, arbitrage detection etc). Getting started with AMPL.

Weeks 4, 5 – Overview of nonlinear optimization. Univariate optimization and unconstrained optimization. Introduction to Quadratic Programming.

Weeks 6, 7, 8 – Quadratic Programming. Modern portfolio theory and its relation to quadratic optimization. Sharpe ratio and optimal portfolios. QP in risk management and option pricing. Using AMPL and QP packages to set up and solve QP problems. Midterm exam.

Weeks 9, 10 – Integer Programming. Branch and bound methods. Integer programming in SOLVER and AMPL. Designing index funds – IP and LP approaches to tracking portfolios.

Weeks 11, 12 – Dynamic Programming. American option pricing as DP problem. DP and structuring asset-based securities.

Weeks 13, 14 – A survey of further topics in optimization (stochastic programming, Value at Risk , commercial optimization software).

MTH 648: Stochastic Calculus with Applications to Finance, 3 credits.

An introduction to Stochastic Calculus developing the basic probabilistic techniques necessary to study analytic models of financial markets. Brownian motion and the stochastic integral, stochastic differential equations, the Black-Scholes formula, Girsanov's theorem and applications to option pricing.

Prerequisites. MTH647, Introduction to Probability and Statistics (undergraduate) and Introduction to Markov Processes (intermediate) or equivalent.

Instructor. Ilie Grigorescu.

Office: Ungar 525

Learning Outcomes: At the conclusion of this course, students will know how to:

- Manipulate stochastic differential equations (SDE), which will be understood as a generalization of a classical ordinary differential equation (ODE) with added noise (randomness). Understand the pivotal role of Brownian motion via the random walks scaling and the classical Central Limit Theorem.
- Use Ito's formula as the main tool to represent solutions of SDE and relate them to partial differential equations. Be able to use the connection to Markov processes and be able to do mathematical modeling involving financial markets.
- Acquire the framework used in martingales representation and change of measure. Apply it to pricing options in complete and incomplete markets. Be able to calculate concrete solutions of equations starting with the Black - Scholes formula and continuing with other applications, like exotic options, knock-out barrier options and lookback options.

Textbook:

- *Stochastic Calculus and Financial Applications*, by J. Michael Steele, Springer (2001).
- *Option Theory with Stochastic Analysis: An Introduction to Mathematical Finance*, by Fred Espen Benth, Springer Universitext (2003).

Further reading:

- *Stochastic Calculus for Finance II: Continuous-Time Models* by Steven Shreve, Springer (2008).
- *Stochastic Differential Equations: An Introduction with Applications*, by Bernt Oksendal, Springer Universitext (2010).
- *The Concepts and Practice of Mathematical Finance*, by Mark S. Joshi, Cambridge University Press, 2nd edition (2008).

Grading policy:

- Semester work will be 60% of the grade: three homework assignments and two tests. The lowest score in both categories will be dropped. The remaining three items will be worth 20% each.

- The Final Exam will be 40% of the grade. In some cases, the exam will have a project and an in-class component.

- Exams are closed book and closed notebook, with the exception of material provided by the instructor in addition to the exam book. Partial credit is granted. Students must show their work in order to obtain full credit. Strict compliance with the UM Academic Honor Code is expected.

Course summary and schedule.

Week 1 - 2. Probability space, random variables, sigma fields. Probability distributions. Change of measure. Expectation. Moment generating functions. Independence. Covariance. -- Homework 1.

Week 3 - 5. Examples of distributions. Conditional expectation. Filtrations. Martingales. Quadratic variation. Poisson and Gaussian processes. Markov processes in continuous time. **-- Test 1.**

Week 6 - 8. Brownian motion. Basic path properties. Reflection principle. Running maximum, gambler's ruin problem revisited. Random walks. Donsker's Invariance Principle. -- Homework 2.

Week 9 - 11. Stochastic differential equations. Forward and backward equations. Examples. Geometric Brownian motion. Volatility. Killed processes. Relation to Partial Differential Equations. **-- Test 2.**

Week 12 - 13. Black - Scholes formula. Feynman-Kac formula. Girsanov's theorem. Risk - Neutral Pricing. Martingale representation theorem. -- Homework 3.

Week 13 - 14. Exotic options. Knock - out Barrier Options, lookback options.

Final. Comprehensive.

MTH 649: Computational Methods of Finance, 3 credits.

Solutions of nonlinear equations, interpolation, Monte Carlo methods, survey of matrix factorizations, numerical integration and differentiation, and introduction to finite difference and finite element methods for PDEs with applications to finance.

Prerequisites: CSC 220, MTH 643, and MTH 648.

Instructor: Brian Coomes, coomes@math.miami.edu

Office: UB 435

Learning Outcomes: By the end of the course, the student should be able to:

- Develop an understanding of the algorithms underlying the numerical solution of various problems arising in Mathematical Finance.
- Understand the nature of solutions of various problems well enough to identify when data errors and/or mistakes in coding are present.
- Identify circumstances where applying certain algorithms may be problematic.
- Choose among the existing software tools specifically oriented toward the problems of Mathematical Finance.

Course Summary: This course introduces students to many of the classical techniques of Scientific Computing. We investigate both the strengths and weaknesses of various algorithms. The algorithms are presented in the context of example problems arising in Mathematical Finance.
Students will develop proficiency with some standard tools such as Matlab.

Texts:
- "A First Course in Numerical Methods" by Uri Ascher and Chen Greif, SIAM, 2011.
- "Implementing Derivatives Models" by Les Clewlow and Chris Strickland, Wiley, 1998.

Supplemental Material:
- "A Workout in Computational Finance" by Michael Aichinger and Andreas Binder, Wiley, 2013.

Software:
Matlab with the Financial Toolbox.

Grading: Grading: Grades will be based on a midterm exam (100 points), programming projects (200 points), the final exam (100 points), and a final project (100 points).

Class schedule:
Weeks 1, 2 – Solutions of nonlinear equations. Examples include computing bond yields.

Weeks 3, 4 – Interpolation. Estimation of the discount curve.

Weeks 5, 6, 7 – Monte Carlo methods. Simulation of Stochastic Differential Equations. Midterm exam.

Weeks 8, 9 – Introduction to matrix factorizations. Examples include multifactor problems arising in Mathematical Finance.

Weeks 10, 11 – Introduction to numerical integration and differentiation.

Weeks 12, 13, 14 – introduction to finite difference and finite element methods for PDEs. Application to the Black-Scholes equation.

Attachment D: Letters of Support for the Program

- Department of Mathematics
- Department of Computer Science
- School of Business Administration
- Department of Electrical & Computer Engineering

UNIVERSITY OF MIAMI
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Department of Mathematics
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math@math.miami.edu

MEMORANDUM

TO: Tomas Salerno, Chair
Faculty Senate

FROM: Victor C. Pestien, Interim Chair
Department of Mathematics

DATE: February 16, 2015

SUBJECT: Letter of Support of the Master of Science in Mathematical Finance Program

I am writing to express my support for the creation of the Master of Science in Mathematical Finance program. This professional program was initiated by the Department of Mathematics, and it has our enthusiastic support.

The program has been approved by the mathematics department faculty on October 15, 2014 and by the Arts and Sciences College Council on January 12, 2015.

Our department will offer the required and elective mathematics courses as needed by this program. The program will also involve courses from Computer Science and Finance.

We anticipate that the program will attract high quality students both locally and internationally.

pc: Jessica M. Reyes, Executive Director, Programs, College of Arts and Sciences

UNIVERSITY OF MIAMI
COLLEGE of
ARTS & SCIENCES

Department of Computer Science
P.O. Box 248154
Coral Gables, Florida 33124-4245
Ph: 305-284-2268
Fax: 305-284-2264

February 13, 2015

To: Chair, Faculty Senate

From: Geoff Sutcliffe, Chair of Department of Computer Science

I am writing to express my support for the Master of Science in Mathematical Finance (MSMF) Program, as approved by the College of Arts and Sciences College Council on 1/12/2015.

The Department of Computer Science offers the required and elective courses for the proposed program. We expect to be able to accommodate all MSMF students in our courses.

cc: Jessica Reyes, Executive Director, Programs, College of Arts and Sciences
Victor Pestien, Interim Chair, Department of Mathematics

UNIVERSITY OF MIAMI
SCHOOL of BUSINESS
ADMINISTRATION

MEMORANDUM

TO: Jessica Reyes, Director of Programs
College of Arts & Sciences

FROM: Anuj Mehrotra, Vice Dean, Graduate Business Programs & Exec. Education

CC: Alok Kumar, Chairman, Department of Finance
Eugene Anderson, Dean, School of Business Administration
Alexander Dvorsky, Department of Mathematics

Subject: MS in Mathematical Finance

Date: February 24, 2015

I am writing in support of the proposal for the Master of Science in Mathematical Finance (MSMF) Program, as approved by the College of Arts and Sciences Faculty on 2/23/2015.

The School of Business Administration will strive to accommodate MSMF students in the required and elective courses offered by SBA as listed in the proposal.

It will be my pleasure to provide any additional information in this regard.

UNIVERSITY OF MIAMI
COLLEGE of ENGINEERING

Electrical and Computer Engineering Department
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March 23, 2015

Chair, Faculty Senate,

I am writing to express the Department's support for the Master of Science in Mathematical Finance (MSMF) Program.

The Department of Electrical and Computer Engineering will accommodate MSMF students in the elective courses, EEN548 and EEN553.

Sincerely,

M Saeed

Dr. Mohamed Abdel-Mottaleb,
Professor and Chairman
Dept. of Electrical & Computer Engineering

cc: Jessica Reyes, Executive Director of Programs, College of Arts and Sciences

MSMF 4 YEAR FINANCIAL PROJECTION

Budget Information Redacted.

Attachment F - Overview of Existing Mathematical Finance Degree Programs

RUTGERS UNIVERSITY. Master of Science in Mathematics (Mathematical Finance)

Prospective students with any undergraduate major are welcome to apply if they will have completed the minimum prerequisites prior to entering the program, which include **individual one-semester courses** on

- Multivariable calculus
- Linear algebra
- Ordinary differential equations
- Partial differential equations
- Probability (calculus-based)
- Computer programming

Degree Requirements

The program requires completion of ten (10) three-credit courses (6 required and 4 elective) taken in residence at Rutgers, as described in the table of courses, a practical training experience within the first year, seminar in mathematical finance (3 semesters, 1/2 credit per semester), and a master's degree essay prior to graduation.

Unit	Course	Title	Semesters	Prerequisites	Comments
Four (4) required courses					
Math	16:642:621	Mathematical Finance I	Fall		Required
Math	16:642:622	Mathematical Finance II	Spring	Math 621	Required
Econ	16:220:507	Econometrics I (pdf)	Fall		Required. No credit with Stat 563
Econ	16:220:508	Econometrics II (pdf)	Spring	Econ 507	No credit with Stat 565 or ISE 530
Select two (2) of the following three required courses					
Math	16:642:573	Numerical Analysis I	Fall		Required
Math	16:642:574	Numerical Analysis II	Spring		Required
Math	16:642:575	Numerical Solution of Partial Differential Equations	Spring	Math 573 or 574	Required.
Strongly recommended elective					
ECE	16:332:503	Programming Methodology for Numerical Computing and Finance (C++)	Fall		Strongly recommended
Select one (1) or more of the following electives					
Math	16:642:623	Computational Finance	Spring	Math 573, 621,	Strongly

				ECE 503 Corequisites: Math 622 & 575	recommended
Math	16:642:624	Credit Risk Modeling	Fall (odd years)	Math 573, 621 Corequisite: Math 622	Recommended
Math	16:642:625	Portfolio Theory and Applications	Fall	Math 621, Econ 507. *Co-requisite:*Econ 508	Recommended.
If additional electives needed to complete program, select from our Mathematics and Statistics courses ...					

COLUMBIA UNIVERSITY. Master of Arts in Mathematics with specialization in the Mathematics of Finance

The Department of Mathematics at Columbia University offers a Master of Arts program in Mathematics with specialization in the Mathematics of Finance (MAFN). It is co-sponsored by the Department of Statistics, and it draws on the diverse strengths of the university in mathematics, statistics, stochastic processes, numerical methods, and financial applications.

The program attracts students whose academic background is in quantitative areas such as mathematics, statistics, physics, economics, computer science, or engineering. Many have previous work experience in finance.

Six mandatory courses and 12 points of elective courses are required for graduation.

The elective courses can consist in 4 elective courses of 3 points, or any number of elective courses that add up to a total of at least 12 points. In the Fall of 2013, we had 137 registered students, of which 94 were full-time and 43 were part-time. They took on average 1.5 elective courses each, to a total of 200 electives.
Mandatory MAFN Courses

Fall

STAT G6501 Stochastic Processes
Basics of continuous-time stochastic processes. Wiener processes. Stochastic integrals. Ito's formula, stochastic calculus. Stochastic exponentials and Girsanov's theorem. Gaussian processes. Stochastic differential equations. Additional topics as time permits.

MATH W4071 Introduction to the Mathematics of Finance
Prerequisites: MATH V1202, V3027, STAT W4150, SEIOW4150, or their equivalents. The mathematics of finance, principally the problem of pricing of derivative securities, developed using only calculus and basic probability. Topics include mathematical models for financial instruments, Brownian motion, normal and lognormal distributions, the Black-Scholes formula, and binomial models.

STAT G6503 Statistical Inference / Time-Series Modeling
Prerequisites: W4105 and W4107 or the equivalent. Available to SSP, SMP. Modeling and inference for random processes, from natural sciences to finance and economics. ARMA, ARCH, GARCH and nonlinear models, parameter estimation, prediction and filtering.

Spring

STAT G6505 Stochastic Methods in Finance
Prerequisites: Statistics G6501 or the equivalent. Available to SSP, SMP. Mathematical theory and probabilistic tools for modeling and analyzing security markets are developed. Pricing options in complete and incomplete markets, equivalent martingale measures, utility maximization, term structure of interest rates.

MATH G6071 Numerical Methods in Finance
Prerequisites: Some familiarity with the basic principles of partial differential equations, probability and

stochastic processes, and of mathematical finance as provided, e.g., in Mathematics W4071. Review of the basic numerical methods for partial differential equations, variational inequalities and free-boundary problems. Numerical methods for solving stochastic differential equations; random number generation, Monte Carlo techniques for evaluating path-integrals, numerical techniques for the valuation of American, path-dependent and barrier options.

MATH G8210 Practitioners' Seminar

Prerequisites: MATH 4071 or knowledge of J. Hull's book Options, futures. Seminar consists of presentations and mini-courses by leading industry specialists in quantitative finance. Topics include portfolio optimization, exotic derivatives, high frequency analysis of data and numerical methods. While most talks require knowledge of mathematical methods in finance, some talks are accessible to general audience.

NORTH CAROLINA STATE UNIVERSITY. Master of Financial Mathematics

NC State's Financial Mathematics Program is known for rigorous training in the core areas of probability, statistics, modeling, investment theory, stochastic processes, and economics. The depth of understanding prepares students to respond to today's rapidly evolving, world-wide economic and financial landscape. During the 18 month program, students are encouraged to build on the core with a focus in areas such as business management, statistics, mathematics, or risk management.

These are the program objectives:

1. Students develop successful professional skills related to career-track job searches and interactions in the private-sector workplace.
2. Students obtain highly competitive positions in the financial industry and related industries.
3. Students calculate the fair price of options, futures and other financial derivatives using the no-arbitrage principle and methods from stochastic calculus.
4. Use Monte Carlo (MC) methods for option pricing, hedging and risk management. Implementation the methods and visualize results using languages such as Matlab, SAS, and R.
5. Apply topics in probability such as discrete and continuous distributions, expected values, transformations of random variables, sampling distributions.
6. Use statistical inference including methods of construction and evaluation of estimators, hypothesis tests, interval estimators, and maximum likelihood.

We seek highly qualified students with strong backgrounds in mathematics and computing and an interest in working within the financial community. We do not look for specific majors and do not have a single ideal candidate; rather we look for well rounded students with a definite plan to work in the financial community after graduation. Accepted students in past years have had majors as diverse as Mathematics, Economics, Finance, Computer Science, Physics and Engineering. In addition we have accepted PhD's and MBA's.

In the fall, a new class of full-time students numbers about 30. But our courses are also attended by part-time and non-degree students who work full-time in the financial industry as well as PhD students in Mathematics, Computer Science, Physics, and other sciences for whom quantitative finance is an attractive career option.

Semester One Core Requirements (Fall)

- Capital Investment Economic Analysis (ISE 711)
- Statistical Theory I (ST 501)*
- Asset Pricing (ECG 528)

Semester Two Core Requirements (Spring)

- Financial Mathematics (MA 547)
- Statistical Theory II (ST 502)
- Monte Carlo Methods for Financial Mathematics (FIM/MA 548).

Semester Three Core Requirement (Fall)

- Computational Methods in Economics and Finance (ECG 766)

Three elective courses must be taken . Course substitutions are encouraged (with advisor approval). Students are suggested to include electives that strengthen computing skills, such as SAS, SQL, VBA, C, C++, and Java.

JOHNS HOPKINS UNIVERSITY. Master of Science in Engineering (Financial Mathematics program)

The **financial mathematics master's program** at Johns Hopkins is offered through the Department of Applied Mathematics and Statistics as a Master's of Science in Engineering (MSE) degree. The program takes three semesters to complete, with students starting in the late summer and finishing in mid-December.

At Johns Hopkins, Financial Mathematics continues a rich engineering tradition whereby the strengths of the faculty in research, education and leadership are applied to expand knowledge and apply new knowledge for the benefit of humanity by addressing the complex problems of modern society. Understanding and navigating today's rapidly evolving, world-wide economic and financial landscape presents one of society's most challenging, modern problems.

Learning Objectives for Financial Mathematics Master's students:

1. Gain knowledge of financial markets and asset classes, how markets are regulated, how they are structured and operate
2. Gain knowledge of investments, portfolios, asset allocation, risk management
3. Gain knowledge of how financial derivatives are modeled and valued
4. Gain an ability for areas of applied mathematics that are most useful in real financial application (statistical analysis, time series analysis, optimization, Monte-Carlo methods, stochastic processes)
5. Develop communications skills
6. Develop computational skills
7. Gain insight as to how this knowledge and these skills integrate in the workplace environment

Core financial mathematics requirements (4 courses)
550.442 Investment Science
550.444 Introduction to Financial Derivatives
550.445 Interest Rate and Credit Derivatives
550.448 Financial Engineering and Structured Products or 550.446 Risk Measurement/Management in Financial Markets

- **Core applied mathematics requirements (5 courses)**

550.427 Stochastic Processes and Applications to Finance
550.433 Monte Carlo Methods
550.413 Applied Statistics and Data Analysis
550.439 Time Series Analysis
550.461 Optimization in Finance

- Electives (3 courses)

One course in Applied Mathematics and Statistics
One course in Financial Mathematics
One additional course with prior program approval

- **Financial Mathematics Masters Seminar**

- **Computing requirement** (includes the Topics in Financial Computing Workshop)

- **Communication skills requirement** (includes the Intersession Communications Practicum and Fall/Spring Professional Communications courses as applicable)

- **Summer Internship**

Every student must complete training on the responsible and ethical conduct of research, if applicable. (Please see WSE Policy on the Responsible Conduct of Research.)
Every student must complete training on academic ethics.

An overall GPA of 3.0 must be maintained in courses used to meet the program requirements. At most two course grades of C or C+ are allowed to be used, and the rest of the course grades must be B- or better.

Substitutions and exceptions are permitted at the discretion of the Department Chair.

UNIVERSITY of ILLINOIS at URBANA-CHAMPAIGN. Master of Science in Financial Engineering.

The University of Illinois MSFE degree is a three-semester program (fall, spring, summer internship, fall) offered by the Departments of Finance an Industrial and Enterprise Systems Engineering at the Urbana-Champaign campus. The curriculum is drawn from topics in stochastic modeling optimization, computing and computational methods, finance, and an applied practicum experience, and is taught by internationally recognized engineering and finance faculty. The program provides an opportunity to study with an international peer group at one of the premier research universities in the world.

Program Objectives

As a field Financial Engineering has emerged because of the growing complexity required in describing and solving advanced business problems. Financial Engineers use fundamental economic principles and finance theory coupled with state-of-the-art mathematical methods, computational tools, and computer programming expertise.

Combining deep intellectual appeal and practical importance, Financial Engineering has become a flourishing sub-field over the past two decades; indeed, several recent Nobel prizes in economics have been awarded for work that constitutes the foundation of Financial Engineering. Much current research in finance, operations research, and mathematics studies the many emerging issues associated with new financial instruments, risk assessment, risk measurement and optimization.

The growth of Financial Engineering has been fueled by an active corporate community asset management companies (including mutual funds and hedge funds), insurance companies, and some advanced corporate treasury departments. Long-term outlooks in the financial services industry suggest a trend toward ever more quantitative analysis and methods.

The Illinois Master of Science in Financial Engineering degree is both technical and pragmatic. Students receive training in the most advanced techniques, providing them the grounding and tools to advance quickly in the field. The program features practice-based learning opportunities which assure the curriculum is always demanding and contemporary. Further, the featured Practicum in the third semester of the program serves as a bridge with industry focusing on real world financial modeling problems.

Curriculum

First Semester (Fall) -		**17 hours**
FIN 500	Introduction to Finance	4 hours
FIN 501	Financial Economics	4 hours
IE 522	Statistical Methods in Finance	4 hours
IE 523	Financial Computing	4 hours
IE 598	Professional Development	1 hour
Second Semester (Spring) -		**17 hours**
IE 525	Numerical Methods in Finance	4 hours
FIN 512	Financial Derivatives	4 hours
FIN 580	Risk Measures and Management	4 hours

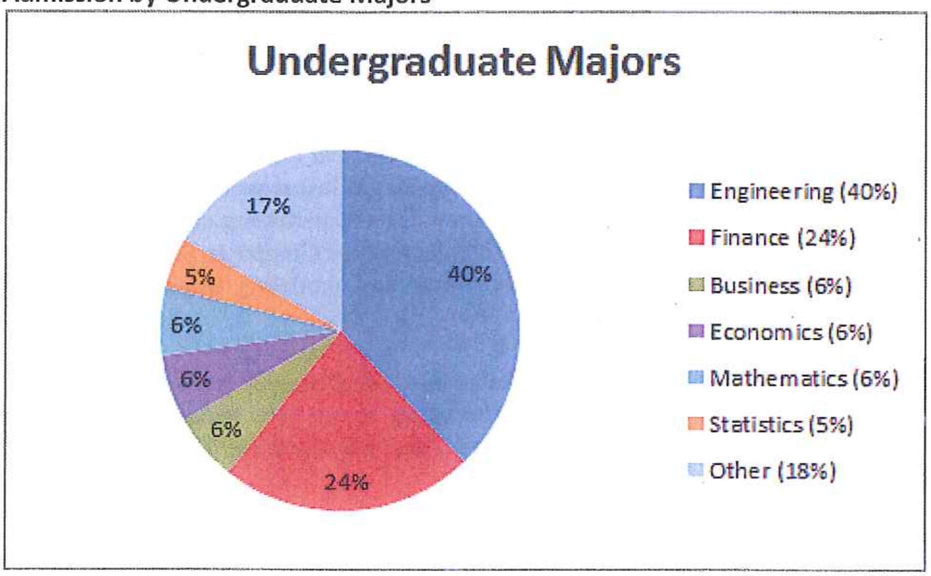
IE 526	Stochastic Calculus in Finance	4 hours
IE 598	Professional Development	1 hour

Summer Internship

Third Semester (Fall) - **16 hours**

IE 524 or IE 598	Optimization in Finance or Clustering and Approximation Methods	4 hours
FIN 516 or FIN 580	Term Structure Models or Market MicroStructure	4 hours
IE 597/FIN 590	Financial Engineering Project	4 hours
	Electives	4 hours

Admission by Undergraduate Majors



UNIVERSITY OF MIAMI

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MEMORANDUM

DATE: March 12, 2015

TO: Jessica Reyes, Executive Director of Programs
College of Arts and Sciences

FROM: David E. Wiles, Executive Director
Assessment and Accreditation

SUBJECT: Master of Science in Mathematical Finance

On February 27, 2015, the College of Arts and Sciences submitted a proposal notifying our office of its intent to launch a new Master of Science degree program in Mathematical Finance, effective fall 2016. The proposed 34-credit graduate degree program will prepare graduates with advanced quantitative skills for careers in banking and finance. The program will be of particular interest to students with baccalaureate degrees in Mathematics, Physics, Engineering, or Computer Science, and who are interested in a focused study of modern mathematical and modeling techniques applicable in the 21st century financial environment.

The program will be comprised mostly of existing courses in the areas of Mathematics Accounting, Finance, Engineering and Computer Science, but will require the hiring of one new tenure-track faculty member who specializes in Mathematical Finance/Network Theory to teach the following two new mathematics courses:

- MTH 645 – Optimization Methods
- MTH 649 – Computational Methods of Finance

In addition, the following two courses will also be added but will not require the hiring of additional faculty or infrastructure resources:

- MTH 643 – Statistical Analysis II with Financial Applications
- MTH 648 – Stochastic Calculus with Applications to Finance

Because the Department of Mathematics already offers closely related master's and doctoral degrees, and the proposed M.S. in Mathematical Finance will not require a significant number of new courses, new faculty, or other resources, the proposal is not considered substantive in nature; however, a letter of notification will need to be submitted to the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC). Please allow at least three months for a formal review by SACSCOC.

Please feel free to contact our office should you have any questions or need additional guidance (305) 284-9431.

cc: Faculty Senate
Dr. Brian Blake, Vice Provost and Graduate School Dean
Dr. Leonidas Bachas, Dean, College of Arts and Sciences
Dr. Victor Pestien, Interim Chair, Department of Mathematics
Ms. Rose-Ketlie Glemaud, Executive Assistant, College of Arts and Sciences

UNIVERSITY OF MIAMI
COLLEGE of
ARTS & SCIENCES

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TO: Tomas Salerno
Chair, Faculty Senate

FROM: Leonidas Bachas
Dean

SUBJECT: Master of Science in Mathematical Finance

DATE: March 23, 2015

At the College Faculty meeting on February 23, 2015, the faculty voted unanimously in favor for a Master of Science in Mathematical Finance in the Department of Mathematics. I am now forwarding the proposal to the Senate for action.

A copy of the proposal is attached for your convenience. Should you have any questions or require additional information, please feel free to contact me.

LGB/jmr

UNIVERSITY OF MIAMI
GRADUATE SCHOOL

M. Brian Blake, Ph.D.
Vice Provost for Academic Affairs
& Dean of the Graduate School

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MEMORANDUM

DATE: March 31, 2015

TO: Tomas Salerno
Chair, Faculty Senate

FROM: M. Brian Blake
Dean, The Graduate School

SUBJECT: New Master of Science in Mathematical Finance

The College of Arts and Sciences submitted a proposal for a Master of Science in Mathematical Finance. The proposal for the new degree program was discussed at the meeting of the Graduate Council on Tuesday, March 17, 2015, and was unanimously approved. The second reading was waived.

cc: Leonidas Bachas, Dean, College of Arts and Sciences
Charles Mallery, Associate Dean, College of Arts and Sciences
Victor Pestien, Interim Chair, Department of Mathematics
Alexander Dvorsky, Department of Mathematics
Jessica Reyes, Executive Director, Program, College of Arts and Sciences
Office of Planning, Institutional Research and Assessment