New York University Tandon School of Engineering

Department of Finance and Risk Engineering
Course Outline FRE 6083 Quantitative Methods In Finance
Fall 2018
Agnes Tourin
Monday 2pm-4:30pm, location: RH216,Wednesday, 2:30pm-5pm, location RH207

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Office hours: Tuesday 10:00am-12:00pm, or by appointment

Course prerequisites: Students are expected to have knowledge in calculus, linear algebra, basic probability and statistics. Those students who do not have this background should take the Probability and Statistics refresher courses.

Course Description: This course focuses on the art and science of building models of processes that occur in business, economics, and finance. These may include models of interest rates, derivative securities, or behavior of asset prices. These models can be solved by using techniques of modern probability and stochastic processes, which constitute the mathematical foundation. We do not attempt to cover the spectrum of model types and modeling methodologies; rather, the focus is on models that can be expressed in equation form, relating variables quantitatively.

Course Objectives: The main goal of this course is to provide the students with a rigorous introduction to quantitative models in Finance. First of all, the students will be taught the basic concepts of stochastic processes that constitute a prerequisite to quantitative modeling and Econometrics. Secondly, they will become familiar a number of specific models and their underlying assumptions. Finally, this course also serves as an introductory course to the area of Computational Finance and prepares the students to pursue coursework in Computational Finance.

Course Structure: This course will be delivered through a series of lectures, followed by a question and answer session and a discussion. Some weeks, problem solving sessions will be incorporated.

Readings: A set of notes will be distributed through NYU classes before the Semester starts. In addition, there are two mandatory textbooks for this course:

1. Steven E. Shreve, *Stochastic Calculus for Finance*, I, Steven E. Shreve, 2004, Springer.

2. Paul Wilmott, Sam Howison, Jeff Dewynne*, Mathematics of Financial derivatives: A student introduction,* Cambridge University Press, 1995.

The textbook is available at the NYU bookstore. It can also be downloaded for free through our NYU online subscription to Springer.

Optional textbooks or references:

1. Dan Stefanica, A Primer for the Mathematics of Financial Engineering, second Edition, 2011, FE Press New York.
2. Rick Durrett, Probability: Theory and Examples, 4th ed., Cambridge University Press, Cambridge, 2010.
3. Stanley, R. Pliska, Introduction to Mathematical Finance, Discrete Time Models, 1997, Blackwell Publishing.
4. Steven E. Shreve, Stochastic Calculus for Finance, II, 2004, Springer.
5. Charles Tapiero, Applied Stochastic Models and Control for Finance and Insurance, 1998, Kluwer Academic Publisher (Out of Print).
6. Jean Jacod and Philip Protter, Probability Essentials, Universitext, Second Printing, Second Edition, 2004, Springer.
7. J.W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Texts in Applied Mathematics, 22, 1995, Springer.
8. Timothy Falcon Crack, Heard on the street: Quantitative Questions from Wall Street Job Interviews, revised 15th Edition, 2014.
9. Dan Stefanica, Rados Radoicic and Tai-Ho Wang, 150 Most Frequently Asked Questions on Quant Interviews, 2013, FE Press New York.
10. Rama Cont, Empirical properties of asset returns: stylized facts and statistical issues, Quantitative Finance, 1 (2001)223–236.
11. Sheldon Ross, *Introduction to Probability Models,* 11th edition, Academic Press, 2014.

Recommended software for the homework:

Students will be required to use a programming language for prototyping, such as Matlab, R (http://www.r-project.org), or Python.

Course requirements: Students will be expected to attend classes, to read materials ahead of course meetings to participate actively in class and also be prepared to discuss assignments in class. There will be a midterm examination, a final examination, and weekly homework assignments.

Midterm examination (on week 7): 30% of final grade.
This examination will be held in the classroom, at the scheduled class time, on week 7. The students will be required to solve four or five problems by using the computational techniques taught during the first 6 weeks.

Final examination (on week 15): 30% of final grade.

This examination will be held in the classroom, at the scheduled class time, on week 15. The students will be required to solve five or six problems, by using the computational techniques taught throughout this course.

Homework assignments, weekly, due on weeks 2,3,4,5,6,9,10,11,12,13 count for 30% of the final grade. There will be two types of homework assignments. The first type will consist of practice exercises designed to help the students assimilate the techniques taught in class and prepare them for the examinations. The second type will consist of implementing some numerical or simulation techniques or use a software to apply statistical techniques to study the features of financial data.

Attendance count for 10%

Week 1: Sequences of random variables, random sums, example of the symmetric random walk, example: An insurance aggregate loss model

- Lecture notes for week 1

Week 2: Convergence concepts for random variables, law of large numbers, central limit theorem, Markov sequences, martingale property for sequences of random variables

- Lecture notes for week 2
- First assignment is due (problem set)

Week 3: Discrete Markov chains and applications: basic concepts, long-run distribution, the gambler's ruin problem, examples of applications to Insurance, credit risk, credit ratings

- Lecture notes for week 3
- Second assignment is due.

Week 4: Introduction to Stochastic Processes: independence of increments, random walk, Poisson process, aggregate loss model in insurance.

- Lecture notes for week 4
- Assignment 3 is due (problem set including a code)

Week 5: The Binomial tree model for option pricing: definition of an arbitrage opportunity, no arbitrage pricing theory, the risk-neutral probability measure, hedging portfolio, risk-neutral pricing formula, examples of the European and the lookback options.

- Lecture notes for week 5
- Textbook by Shreve
- Assignment 4 is due

Week 6: Introduction to stochastic processes, part II: stationarity, issues in statistical estimation, review session.

- Lecture notes for week 6
- Empirical properties of asset returns: stylized facts and statistical issues, Rama Cont, Quantitative Finance, 1 (2001)223–236
- Assignment 5 is due (problem set).

Week 7 Midterm examination

Week 8: Arithmetic random walk with and without drift, geometric random walk with and without drift. Passing to the continuous-time limit: from the arithmetic random walk to the Brownian motion and from the geometric random walk to the geometric Brownian motion

- Lecture notes for week 8

Week 9: Brownian Motion, definition and properties, quadratic variation, First hitting Time, maximum up to date, the gambler's ruin model in continuous time.

- Lecture notes for week 9
- 6th assignment is due (problem set).

Week 10: Stochastic integration and mean squares convergence, stochastic differentiation, Ito Processes and Ito's formula, application to the Geometric Brownian Motion model for asset prices, and to theVasicek interest rate model.

- Lecture notes for week 10
- 7th assignment is due (problem set)

Week 11: Black-Scholes lognormal model via formal integration Monte Carlo simulation and option value

- Lecture notes for week 11.
- 8th assignment is due (problem set and implementation of Monte Carlo Simulations to compute the price of a European Option).

Week 12: The Black-Scholes Partial Differential Equation Finite Difference approximation method

- Lectures notes for week 12
- 9th assignment is due (implementation of a Finite Difference method to compute the price of a European option).

Week 13: The Black Scholes framework: sensitivity analysis, the Greeks

- Lecture notes for week 13
- 10th assignment is due

Week 14: Problem solving session

- Prepare the last two Semesters' final examinations before coming to class

Week 15: Final examination

If you are student with a disability who is requesting accommodations, please contact New York University's Moses Center for Students with Disabilities (CSD) at 212-998-4980 or mosescsd@nyu.edu. You must be registered with CSD to receive accommodations. Information about the Moses Center can be found at www.nyu.edu/csd. The Moses Center is located at 726 Broadway on the 2nd floor.

NYU School of Engineering Policies and Procedures on Academic Misconduct
(from the School of Engineering Student Code of Conduct)

A. Introduction: The School of Engineering encourages academic excellence in an environment that promotes honesty, integrity, and fairness, and students at the School of Engineering are expected to exhibit those qualities in their academic work. It is through the process of submitting their own work and receiving honest feedback on that work that students may progress academically. Any act of academic dishonesty is seen as an attack upon the School and will not be tolerated. Furthermore, those who breach the School's rules on academic integrity will be sanctioned under this Policy. Students are responsible for familiarizing themselves with the School's Policy on Academic Misconduct.

B. Definition: Academic dishonesty may include misrepresentation, deception, dishonesty, or any act of falsification committed by a student to influence a grade or other academic evaluation. Academic dishonesty also includes intentionally damaging the academic work of others or assisting other students in acts of dishonesty. Common examples of academically dishonest behavior include, but are not limited to, the following:

    1. Cheating: intentionally using or attempting to use unauthorized notes, books, electronic media, or electronic communications in an exam; talking with fellow students or looking at another person's work during an exam; submitting work prepared in advance for an in-class examination; having someone take an exam for you or taking an exam for someone else; violating other rules governing the administration of examinations.

2. Fabrication: including but not limited to, falsifying experimental data and/or citations.
3. Plagiarism: intentionally or knowingly representing the words or ideas of another as one's own in any academic exercise; failure to attribute direct quotations, paraphrases, or borrowed facts or information.
4. Unauthorized collaboration: working together on work that was meant to be done individually.
5. Duplicating work: presenting for grading the same work for more than one project or in more than one class, unless express and prior permission has been received from the course instructor(s) or research adviser involved.
6. Forgery: altering any academic document, including, but not limited to, academic records, admissions materials, or medical excuses.