New York University Tandon School of Engineering
Department of Finance and Risk Engineering
Course Outline FRE 6083 Quantitative Methods In Finance
3.00 credits
Fall 2021

Instructor: Agnes Tourin

Class times: Monday 2:00pm-4:30pm, Wednesday 11:00am-1:30pm, in person
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Office hours: Wednesday 2:30pm-4:30pm, or by appointment

Course prerequisites:

Students are expected to have knowledge in univariate and multivariate calculus, linear algebra, basic probability and statistics.

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 students with a rigorous introduction to quantitative models in Finance. It also constitutes a foundation that more advanced and specialized courses will build on, in the areas of portfolio management, computational finance, algorithmic trading, and machine learning.

Course Structure:

This course will be delivered in person. The lessons, composed of pre-recorded videos and typed notes will be available online. Additional material that will complement lessons, including data animations and exercises with solutions, will be available online on the ARPM website. The instructor and students will meet at the designated class times. In class, the instructor will review the material, answer students' questions, and will hold problem solving sessions.

Readings:

Students should view the videos, read the class notes and go over the additional material on the ARPM platform.

Recommended software:

The online Matlab course offered by Mathworks is integrated into this course. Furthermore, the course content on the ARPM website uses Python, Matlab, and R (http://www.r-project.org). Students will be required to write codes in some of the homework assignments.

Course requirements:

Students will be expected to attend classes, and come prepared to ask questions.

There will be midterm and final examinations on week 7 and week 15 respectively: students will be required to solve five or six problems, by using the computational techniques taught throughout this course.

Finally, there will be weekly homework assignments.

Weekly homework assignments: 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 numerical, simulation or statistical techniques.

Grading of Assignments:

The grade for this course will be determined according to the following formula:

Assignments/Activities	% of Final Grade
Online participation (as recorded on NYU Brightspace under *content progress)*	10%
Average weekly homework assignment grade (the lowest grade will be dropped)	30%
Midterm exam	30%
Final Exam	30%

Letter Grades

Letter grades for the entire course will be assigned as follows:

Letter Grade	**Points**	**Percent**
A	4.00	95% and higher
A-	3.67	90.0 – 94.99%
B+	3.33	87% - 89.99%
B	3.00	83% - 86.99%
B-	2.67	80% - 82.49%
C+	2.33	77% - 79.99%
C	2.00	70.0% - 76.99%
F	.00	69.99% and lower

Syllabus

Module 1 (week 1): Sequences of random variables, random sums, example of the symmetric random walk, example: An insurance aggregate loss model.

- Lecture notes and videos
- Matlab self-paced course
- ARPM Lab: sections About the ARPM Lab, About quantitative finance: P and Q , Notation, Random variables,

Module 2 (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 and videos
- Continue taking the Matlab self-paced course
- ARPM Lab: sections Historical, Maximum likelihood and Notable multivariate distributions
- First assignment is due (problem set)

Module 3 (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 and videos
- Matlab self-paced course
- ARPM Lab: sections Quest for invariance: Mean-reversion (discrete state) (Markov chains, structural model credit risk drivers)
- Second assignment is due.

Module 4 (week 4): A Markov Chain in continuous time: the Poisson process

- Lecture notes and videos
- Matlab self-paced course (end)
- ARPM Lab: sections Efficiency: Lévy processes and Continuous time processes: Mean-reversion (discrete state)
- Assignment 3 is due.

Module 5 (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 and videos
- ARPM Lab: sections Fundamental axioms, Fundamental theorem of asset pricing
- Assignment 4 is due

Module 6 (week 6): Introduction to stochastic processes:

- Lecture notes and videos
- Additional reading: Empirical properties of asset returns: stylized facts and statistical issues, Rama Cont, Quantitative Finance, 1 (2001)223–236

- ARPM Lab: sections Efficiency: random walk, Fixed-income: Yield to maturity and Quest for invariance
- Assignment 5 is due.

Week 7 Midterm examination

Module 8 (week 8): the continuous-time limit of the random walk

- Lecture notes and videos
- ARPM Lab: section Simple tests
- Assignment 6 is due

Module 9 (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 and videos
- ARPM Lab: sections Stochastic processes primer: Main definitions, Relationships among processes, and Pitfalls
- 7th assignment is due

Module 10 (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 the Vasicek interest rate model.

- Lecture notes and videos
- 8th assignment is due

Module 11 (week 11): Black-Scholes lognormal model via formal integration Monte Carlo simulation and option value

- Lecture notes and videos
- ARPM Lab: section Mean-reversion (continuous state): ARMA
- 9th assignment is due

Module 12 (week 12): The Black-Scholes Partial Differential Equation Finite Difference approximation method

- Lectures notes and videos
- ARPM Lab: section Option based portfolio insurance
- 10th assignment is due

Module 13 (week 13): One period investment models

- Lecture notes and videos
- ARPM Lab: chapter Optimization primer, in particular section Integer ¯n-choose-k selection

- 11th assignment is due (implementation of a Finite Difference method to compute the price of a European option).

Module 14 (week 14): Complements in option pricing

- Lectures notes
- ARPM Lab: sections Taylor approximations: equities and Taylor approximations: fixed income

Week 15: Final examination

Accommodations for students with disabilities

If you are a 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.

Inclusion Statement

The NYU Tandon School values an inclusive and equitable environment for all our students. I hope to foster a sense of community in this class and consider it a place where individuals of all backgrounds, beliefs, ethnicities, national origins, gender identities, sexual orientations, religious and political affiliations, and abilities will be treated with respect. It is my intent that all students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. If this standard is not being upheld, please feel free to speak with me.