

# *21-270 Introduction to Mathematical Finance*

## *Syllabus*

*Spring 2018*

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### *Course Description:*

INTRODUCTION TO MATHEMATICAL FINANCE is both a finance course and a mathematics course. We will discuss financial markets and how they operate, the the different types of assets that are traded in those markets. We will also discuss mathematical models of financial markets, engage in abstract reasoning within these models, and prove theorems about these models.

We begin with an introduction to the main asset classes: equities, fixed income, commodities, and an investigation of derivative securities related to each of these classes. We then discuss three fundamental concepts of mathematical finance: arbitrage, the no-arbitrage assumption, and pricing by replication. We apply these concepts to price derivative securities in a simple (binomial) financial model.

Next we discuss fixed income investing, the major types of fixed income assets, and how the no-arbitrage assumption and replication can be applied to determine relationships among the prices of these assets.

We then discuss finite probability spaces, which allows us to introduce another fundamental concept: risk neutral probability measures. Returning to the binomial model discussed earlier we derive the risk neutral pricing formula.

We conclude the semester with a discussion of optimal investing. Here we again use the concepts of finite probability spaces.

THE CLASS WILL MEET three times per week in Lecture sections. The Lecture sections will follow a typical format, with opportunities to ask and answer questions along the way. There are no recitation sections, but TAs will hold frequent office hours.

*Assumed Knowledge:*

The only prerequisite for 21-270 is 21-120 Differential and Integral Calculus. This material is used in a few specific instances, but most of the computations we will encounter are very basic. There are two things that can help the course go more smoothly. One is a familiarity with financial assets and markets. The other is experience with mathematical thinking and writing. Most students in 21-270 will have some experience in at least one of these areas.

A student who feels themselves to be weak in both of these areas would be well advised to discuss their situation with Dr. Handron at the earliest opportunity.

*Learning Resources:*

**TEXTBOOK** There is no “textbook” for 21-270. The course will follow an excellent set of notes written by Profs. Hrusa and Kramkov.

These notes will be distributed via the Canvas site for the course.

**COURSE WEBSITE.** The course website can be found at

[http://www.math.cmu.edu/~handron/21\\_270](http://www.math.cmu.edu/~handron/21_270)

The course website will be the main source of information about scheduling and assignments throughout the semester. Contact information for course instructors and TA’s, and office hours will be posted on the website, as will additional policy details.

**CANVAS.** Canvas is the new Blackboard. There will be a Canvas site for the course which will be used to distribute course materials and record grades.

**LECTURE.** It should go without saying that the Lectures are a vital resource for the course.

**OFFICE HOURS.** Your instructor and TA’s will hold office hours each week. These are an opportunity to get even more personalized and direct help with issues that are of concern to you.

*Learning Objectives:*

- Understand the similarities and differences among the main asset classes: equities, fixed income securities, and commodities.
- Internalize the concept of pricing by replication. Use pricing by replication to determine the value of forward contracts, stock options, and fixed income securities.

- Develop short but rigorous proofs of true mathematical statements about financial models. Construct counter-examples for false statements.
- Understand risk neutral probability measures and the fundamental theorems of asset pricing.

### *Assesment*

**WRITTEN HW** A typical week will have a written homework assignment due on Wednesday. The homework assignments will generally include some computational problems, as well as some more involved problems or problems of a more conceptual nature. The purpose of these assignments will be to (1) deepen your understanding of the mathematical concepts in the course, (2) to practice reasoning abstractly, and (3) to develop concepts that may be used elsewhere in the course.

**MIDTERM EXAMS** There will be three mid-term exams given during the semester. When creating an exam (midterm or final) I try to make sure the every student gets an opportunity to show me what they know, and that every student sees something that challenges them.

**FINAL EXAM** The final exam for the course will be cumulative, covering material from the entire semester. It has been my practice to give a final exam split into two parts, with a short break between the two.

Your cumulative average for the course will be calculated as

$$CumAvg = \frac{15}{100}[HWAvg] + \frac{60}{100}[MidtermAvg] + \frac{25}{100}[Final]$$

where  $HWAvg$  is your average grade on Homework assignments,  $MidtermAvg$  is your average Midterm Exam grade, and  $Final$  is your Final Exam grade.

Grade cutoffs for Homework will be A=85, B=75, C=65, D=50. Grade cutoffs for the exams will be determined individually based on the grade distribution and the difficulty of the exam. Grade cutoffs for your cumulative average will be determined by averaging the cutoffs for each assignment, in the same way that your cumulative average is computed. For example, if the A-cutoffs for the three Midterm Exams are 70, 90, 85, and the A-cutoff for the Final Exam is 75, then the A-cutoff for cumulative averages will be

$$A\text{-cutoff} = \frac{5}{100}[85] + \frac{10}{100}[85] + \frac{60}{100} \left[ \frac{70 + 90 + 85}{3} \right] + \frac{25}{100}[75] = 80.5$$

## *Policies*

**ATTENDANCE** I do not take attendance in Lecture. Attendance does not factor into your final grade. I will, however, assume that announcements made in class have been received by every student.

**ACADEMIC INTEGRITY** Work that you turn in for grading should be “your own work.” What does that mean? I encourage you to work together to solve problems, and you may use outside resources as learning aids (but *not* solutions to the problems that you may find elsewhere). When you write up the final draft of your assignment, you should not need to consult other students work (their assignment, or notes) or use notes that have also been used by other students. You should feel that, if required to do so, you could recreate your paper with nothing other than your textbook and notes.

When taking exams, no collaboration is permitted, and outside books, notes, or papers are prohibited.

The course website has more information about academic integrity as it relates to this course.

**LATE WORK** I accept late Homework assignments. There is no penalty for the first late assignment. Subsequent late assignments will be subject to increasing penalties. Late submission must be made before the solutions are posted on the Canvas site. Typically, this will mean late assignments should be submitted by class time on the Friday following the Wednesday due date.

A makeup date/time will be set for each Exam. For Midterm Exams, this will typically be on the class day following the original exam. The Final Exam Makeup will be given on May 15, the University scheduled makeup exam day. Students may request a makeup for a Midterm Exam if they have (1) three exams scheduled that day, or (2) a University sponsored trip, or (3) a documented medical excuse. Students may request a makeup for the Final exam if they have (1) three final exams scheduled to begin within a 25 hour period, or (2) two final exams scheduled at the same time, or (3) a University sponsored trip, or (4) a documented medical excuse.

Student who miss an exam for other reasons may also take the makeup exam, but will be subject to a 15% penalty to their grade.

**ACCOMMODATIONS** If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your needs with me as early in the semester as possible.

I will work with you to ensure that accommodations are provided as appropriate.

If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at [access@andrew.cmu.edu](mailto:access@andrew.cmu.edu).

**RE-GRADING** If you have a concern about the grading of an Exam, I will be happy to discuss the matter with you. You may request that an exam be re-graded by submitting the exam to your instructor with a brief written description of your concern (it can be a note on the cover sheet). When you do so, *the entire exam will be reviewed* with special attention paid to your highlighted concern. Changes up or down in the grade may be made. Requests for re-grading of Midterm Exams must be made within one week of the date on which the exams are returned.

Concerns about the grading of homework assignments should be brought to the attention of one of the TA's. If you are not satisfied with the result of that conversation, you (or your TA) may bring the matter to me.

**MOBILE DEVICES** The use of laptops, tablets, phones and such are a distraction to those seated behind you, and also a distraction to me. Some students prefer to take notes on these devices, and that is fine. Having sat in the back of a few classrooms, though, that seems not to be the dominant use. If you would like to use these devices in my classroom, I ask that you sit in the back row to minimize the disruption.

**RECORDING** I have adopted the following sample policy from the Eberly Center:

“Classroom activities may be recorded by a student for the personal, educational use of that student or for students presently enrolled in the class only, and may not be further copied, distributed, published or otherwise used for any other purpose without the express written consent of David Handron. All students are advised that classroom activities may be taped by students for this purpose.”

If you choose to record the class, I would ask that you let me know. If you have any concerns about recordings being made by other students, please feel free to discuss those concerns with me.

**WELLNESS** I have adopted the following sample statement from the Eberly Center:

“Universities are in general vibrant communities, places of tremendous vitality and richness that offer abundant opportunities for meaningful work and play. This abundance brings with it the challenge of maintaining a healthy, balanced life — a life characterized by productive tension among such competing needs as work and play, sleep and wakefulness, solitude and sociability. All members of university communities — students, staff, and faculty — have the responsibility to promote balance in their lives by making thoughtful choices.

“Balanced choices flow from an understanding that human flourishing requires the fulfillment of very real physical, emotional, spiritual, and social needs.

“Balanced choices flow from an understanding that failure is part of the road to success in all endeavors, whether academic, extracurricular, or social. The diligent pursuit of success in the long term will not preclude failures in the short term. Conversely, unrealistic expectations of success in the short term can compromise both health and long-term success if basic human needs are neglected.

“Balanced decision-making flows from an understanding that short-term imbalances are inevitable. Short-term decisions must respond to immediate context, but those decisions are forming longer-term patterns of healthfulness. Balance requires an ability to discern how long an imbalance may safely persist.

“Balance results from two skills: avoiding imbalance through careful planning, and managing and containing imbalance when it occurs.”

To that, I would like to add the following: You will likely find yourself in a situation where you feel overwhelmed, that everyone around you has everything together, and you are floundering. *Everybody* feels like that from time to time. In those situations, the most important thing is to ask for help. Trying to pretend that you understand something you don't or that you are comfortable in a situation where you are not doesn't help anyone.

Your friends, classmates, and instructors are a valuable resource — use them. Another resource for you or anyone you know who experiences academic stress, difficult life events, or feelings of anxiety or depression, is Counseling and Psychological Services (CaPS): call 412-268-2922 and visit their website at

<http://www.cmu.edu/counseling/>.

Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.