Prerequisite Knowledge

This is a graduate Engineering class. We will assume that you have the following background from your undergraduate engineering education:

- Basic probability and statistics concepts
  - Axiomatic probability, Random Variables, Distribution functions, expectation (mean, variance, higher moments), independence (correlation, covariance), multivariate functions, Linear regression
  - Discrete and continuous Stochastic (Markov) processes
- Optimization principles
- Engineering Economics
  - cash flow diagrams, Time value of money, Interest Rates, Project evaluation, rate of return, inflation, factors
- Integral and differential calculus/differential equations
Basic Knowledge

- The focus of the course is on the application of analytical tools to financial data.
- Thus, in theory we don’t need to have a deep understanding about how the data was generated as long as we have access to the relevant data.
- However, to get the most benefit from the course we need to understand the basics of the underlying sources of data such as stock, bonds, options and futures markets.
## IEE 512 (19139, 19141)

### Introduction to Financial Engineering

#### Syllabus

<table>
<thead>
<tr>
<th>Lecture Hours</th>
<th>Tuesdays and Thursdays 3:00 PM – 4:15PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom:</td>
<td>BYAC (ARTISAN COURT AT THE BRICKYARD) 210</td>
</tr>
<tr>
<td>Instructor</td>
<td>J. René Villalobos</td>
</tr>
<tr>
<td></td>
<td><a href="mailto:Rene.Villalobos@asu.edu">Rene.Villalobos@asu.edu</a></td>
</tr>
<tr>
<td>Phone(s):</td>
<td>(480) 965-0437, (480) 727-6098</td>
</tr>
<tr>
<td>Office:</td>
<td>BYD 322</td>
</tr>
<tr>
<td>Office Hours:</td>
<td>W, TH, 10:00-11:30 AM or by appointment</td>
</tr>
</tbody>
</table>

**Required Text:** *Investment Science* (First edition) by David G. Luenberger, Oxford Press

**Required Reading:** *All about Investing: The easy way to get started* by Esme Faerber, McGraw Hill

**Reference books:**
- *Investments* by Bodie, Kane and Marcus
- *Financial Engineering* by Lawrence C. Galtiz, Irwin
- *Quantitative Finance* by T.W. Epps

**Additional Reading**
- *Capital Ideas: The Improbable Origins of Modern Wall Street* by Peter Bernstein
- *When Genius Failed: The Raise and Fall of Long-Term Capital Management* by Lowenstein
- A subscription to *Wall Street Journal*

**Prerequisites:** IEE376, IEE300, IEE470 or equivalent or permission of instructor.

**Additional requisites**
- Passing introductory exam with a grade of 80/100 or higher, you will need to bring to class a laptop computer with access to internet.

**Course Description:** This course will be an intensive/exploration/hands on course that will consist of three phases, Phase I will be a preparation phase in which the student will acquire on his/her own all the terminology and financial lingo to be used throughout the semester. Examples of the topics to be covered in this phase include from basics such as principles of corporations, definition of the different types of stocks, options, other derivatives and financial ratios to more advance topics such as assessment of stock volatility. The second Phase will introduce more advanced financial topics such as portfolio formation, assessment and traditional portfolio theory. In the third phase of the course we will explore Financial Engineering topics such as the application of stochastic models to stock and derivatives pricing and risk management.

**Additional notes:**
- There will be three exams: an introductory exam after on the fourth week of the course, a second one after the second phase of the course and a final examination. The introductory exam will cover general terminology and concepts that you will, mostly, learn on your own from readings assigned in class and from reading the book by Faerber. In addition this exam will include concepts of time-value of money and other concepts from Engineering Economy. Those students who do not obtain a grade above 80/100 in this introductory exam will be strongly encouraged to drop the class.
- There will a major project during the semester. The project will include: a proposal for the project, gathering the relevant data, analyzing the data, applying relevant models, giving appropriate recommendations and a final report.

**Course Organization:**
The setting of the class will be a combination of lectures and workshops. During the lectures the instructor will introduce the concepts of theory, during the workshops we will apply those concepts to real data that we will get from different sources (Internet, WSJ, research).

Course Outline

- Financial Terminology and Introduction to Financial Engineering
- Introductory Exam
- Theory of Interest
- Introduction to Fixed Income Securities
- Introduction to statistical models in Financial Engineering
- Mean Variance Portfolio Theory
- The Capital Asset Pricing Model (CAPM)
- Forwards, futures and Swaps
- Midterm Examination
- Financial Engineering: Discrete Models
- Introduction to Financial Stochastic Models
- Advanced Option Pricing
- Real options
- Advanced topics on risk management

Grading

<p>| | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>Introductory Exam</td>
<td>60 pt.</td>
</tr>
<tr>
<td>Mid-term Exam</td>
<td>100 pt.</td>
</tr>
<tr>
<td>Term Project</td>
<td>100 pt.</td>
</tr>
<tr>
<td>Special Assignments</td>
<td>40 pt.</td>
</tr>
<tr>
<td>Final Exam</td>
<td>100 pt.</td>
</tr>
<tr>
<td>Total Points</td>
<td>400 pt.</td>
</tr>
</tbody>
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The “90/80/70/60%” may be applied but the instructor reserves the right to “curve” the final points in order to determine individual grades.

The teaching plan (available in the web site for the course) lists the reading assignment for the semester. The student will be responsible for this material at the date listed in the teaching plan. The student is expected to attend lectures and complete all homework and exercises. The subject matter of this course is not exceedingly difficult; however, is an intensive course with a demanding work schedule. Failure to keep pace with the course will result in a written warning the first time and subsequent violations can result in dismissal from the class with a grade of E. Plan for the workload and do not over commit yourself.

ASU’s Academic Integrity Policy and Student Code of Conduct can be found at: http://www.asu.edu/studentlife/judicial/index.html

You are expected to be familiar with and abide by this policy and code.
Lecture 1
Introduction to the course

IEE 512 Financial Engineering
J. René Villalobos
Dept. of Industrial Engineering
Arizona State University
Agenda

- Overview of Course
- Prerequisites
- Syllabus
- Course Organization
Instructors

Instructor:  **J. Rene Villalobos**
Rene.Villalobos@asu.edu
Phone(s): (480) 965-0437, (480) 727-6098
Office: BYD 322
Office Hours: W, TH, 10:00-11:30 AM or by appointment

TA: Information on the web site of the course
Textbook and readings

- **Reference books:**
  - *Investments* by Bodie, Kane and Marcus
  - *Financial Engineering* by Lawrence C. Galtiz, Irwin
  - *Quantitative Finance* by T.W. Epps
- **Required Reading:** All about Investing: The easy way to get started by Esme Faerber, McGraw Hill
- **Some additional recommended Reading:**
  - Capital Ideas: The Improbable Origins of Modern Wall Street by Peter Bernstein
  - When Genius Failed: The Raise and Fall of Long-Term Capital Management by Lowenstein
  - A subscription to Wall Street Journal.- (student subscription for 15 weeks $34.95)
Course Organization

- This is an **exploratory and intensive** course in introduction to Financial Engineering
- What do we mean by **exploratory**:
  - The focus of the course is on the use of mathematical models on financial instruments → The instructor is not an expert in all financial issues, relevant topics change
  - In some of the topics we might decide to slow down and go deeper into the practical and theoretical implications of the topic → The tentative teaching plan, reading material and hands-on exercises might change from what is advertised in the syllabus
What do we mean by **intensive**:

- In this course we will try to cover a wide variety of areas within financial engineering. The traditional approach is to take a survey approach → our intention is to go beyond this approach by going deeper into some of the concepts and apply these concepts to practical situations and real data.

We will require that you:

- Read the assigned material before coming to class
- Solve the assigned/proposed exercises before coming to class
- Research on your own cases relevant to the class
Expected Attitude

Some of the characteristics of the student we would like to graduate from this Program

- Be able to tackle open ended problems
- Be proactive in the resolution of problems
- To have an analytical mind to be able to solve complex problems
- Be able to work as part of a team
- To have a professional attitude

I expect the students in this course to have each one of the previous characteristics
Some other comments

- The student is expected to attend lectures and complete all homework and classroom exercises, and be ready to take quizzes over the subject material at any time.
- The subject matter of this course is not difficult; however, is a fast-paced course with a demanding work schedule.

- Plan for the workload and do not over commit yourself.
What is Financial Engineering?

- Combining or carving up existing instruments to create new financial products. (http://www.duke.edu/~charvey/Classes/wpg/glossary.htm)

- Financial engineering is the use of financial instruments such as forwards, futures, swaps, options, and related products to restructure or rearrange cash flows in order to achieve particular financial goals, particularly the management of financial risk. (www.stanford.edu/~japrimbs/00-Intro.ppt)

- Financial engineering is the application of mathematical tools commonly used in physics and engineering to financial problems, especially the pricing and hedging of derivative instruments. (from Neil D. Pearson, Assoc. Prof. UIUC)
Financial Engineering and Risk

- A common denominator in most of the definitions of Financial Engineering is risk.
- There are different definitions of risk but one that we can use is the lack of “certain” or “deterministic” outcome to a given investment or decision.
- In the most common scenario we make an investment now and we expect some positive return in the future. The problem is that very often we don’t know the exact value of the investment in the future.
  - A common question is how much return can we expect in the future for a particular investment we make at the present time.
  - Another question is related to what set of investment decisions would maximize the future return.
However there are some other less common questions, for instance:
- What set of investments would minimize the probability of losing money?
- What investments can I make now to face a future debt?
- What is the set of investments that would give me the best return/risk ratio?

All the previous examples include a mix of uncertainty and a desire to make the best investment decisions subject to certain constraints.

In Engineering we deal with uncertainty through statistical and stochastic models.

We deal with decision problems through the use of optimization models.

Some basic samples of the material to be covered in the course and the tools we will use follow.
Bonds (fixed income)

- A bond is a kind of debt in which the issuer of the bond makes periodic payments (usually semiannually) and a final payment (at maturity) equal to the face value of the bond.

- Question: Should we be willing to buy a 5% bond with a face value of $1000 that has exactly 10 years to maturity if its current price is $950?

\[
950 = 25(P/A, i^*, 20) + 1000(P/F, i^*, 20) = 25 \left[ \frac{1 - (1 + i^*)^{-20}}{i^*} \right] + 1000 \left[ \frac{1}{(1 + i^*)^{20}} \right]
\]

- Solving for \( i^* \)
Bonds Example

- **Yield to maturity (semiannual)**

  - The corresponding annual rate is approx. 5.7%
  - Thus, you should be willing to buy this bond if your MARR is 5.7% or less
  - How to determine your MARR?
  - To what average return of a stock is this comparable?
  - Let’s take a look at Yahoo’s stock
Google’s daily adjusted closing price

Yahoo Stock Closing prices
Google’s daily rate of return

Daily ROR

[Line graph showing daily ROR from 4/12/1996 to 4/12/2010]
Frequency Distribution

Frequency

0 100 200 300 400 500 600 700 800

-0.218362283 0.171827043 0.195094693 0.148559423 0.1253291803 0.107851863 0.055488942 0.032221322 0.014313912 0.006954202 0.003751509 0.001826415 0.000916778 0.000469415 0.000234778 0.000117158 0.000058591 0.000029295 0.000014648 0.000007324 0.000003662 0.000001831 0.000000916 0.000000458 0.000000229 0.000000115 0.000000058 0.000000029 0.000000015 0.000000008 0.000000004 0.000000002 0.000000001 0.000000000 More
Google’s Daily return

Average = 0.001516, Standard Deviation = 0.04137062
Average annual return approx. 38% (Std. Dev. 65% approx.)
Some topics in Data analysis

- Expectation
- Conditional probability
- Regression analysis
- Markov decision models
Example of Option Pricing

- Option: A privilege sold by one party to another that offers the buyer the right, but not the obligation, to buy (call) or sell (put) a security (stock) at an agreed-upon price during a certain period of time or on a specific date.
- A European call option can be exercised only at maturity.
- The call option is worth something if the price of the underlying stock is greater than the strike value of the option.
- The value of the option is the difference between the stock price and the strike value. Thus the expected value of the option is:

  \[ E \left[ C_t \right] = E \left[ \max \left( S_T - K, 0 \right) \right] \]

  Where \( K \) is the strike price of the option and \( C_t \) is the value of the call option at maturity.
- We are interested in estimating the value of an option at any given time.
Probability of being in the money

- By using conditional expectation:

\[
\mathbb{E} \left( \mathbb{P}_t \right) = \mathbb{P}_T \geq K \mathbb{E} \left[ \mathbb{P}_T | S_T \geq K \right] - K \mathbb{P}_T \geq K \mathbb{P}_E \left[ S_T \geq K \right] = \mathbb{P}_T \geq K \mathbb{E} \left[ \mathbb{P}_T | S_T \geq K \right] - K \mathbb{P}_E \left[ S_T \geq K \right]
\]

- Where

\[
\mathbb{E} \left( \mathbb{P}_T | S_T \geq K \right) = \mathbb{E} \left[ \ln \left( \frac{S_T}{S_0} \right) \mid \ln \left( \frac{S_T}{S_0} \right) \geq \ln \left( \frac{K}{S_0} \right) \right] = 
\]

\[
= \int_{K}^{\infty} \ln \left( \frac{S_T}{S_0} \right) \geq \ln \left( \frac{K}{S_0} \right) f \left( \ln \left( \frac{S_T}{S_0} \right) \right) d \ln \left( \frac{S_T}{S_0} \right)
\]

- Solving the original equation will lead to the B-S formula for option valuation
Course Organization

- Three phases:
  - Acquiring general knowledge on financial procedures and modeling (stocks, stock markets, Indices, Bonds, etc) → Some information from class notes, most of the information from reading the book by Faerber
  - Acquiring Basic Financial Engineering knowledge (Valuation of bonds, Portfolio theory, Options theory, Optimization models) → Textbook, Lectures, reading
  - Acquiring more advanced knowledge in Financial Engineering, applying the concepts to real case studies (Asset dynamics, Risk management, pricing) → Textbook, Lectures, additional reading and projects
Preliminary Course Outline

- Financial Terminology and Introduction to Financial Engineering
- Introductory Exam (Around session 11)
- Theory of Interest
- Introduction to Fixed Income Securities
- Introduction to statistical modeling in Financial Engineering
- Mean Variance Portfolio Theory
- The Capital Asset Pricing Model (CAPM)
- Forwards, futures and Swaps
- Midterm Examination (Around session 17)
- Pricing: Discrete Models
- Pricing: Stochastic Models
- Advanced Option Pricing
- Real options
- Advanced topics on risk management
- Final Exam (See ASU Finals’ calendar)
Introductory Exam

- There will be three exams: an introductory exam, a mid-term and a final examination.
- The introductory exam will cover general terminology and concepts that you will, mostly, learn on your own from readings assigned in class and from reading the book by Faerber.
- In addition this exam will include concepts of time-value of money and other concepts from Engineering Economy. Those students who do not obtain a grade above 80/100 in this introductory exam will be strongly encouraged to drop the class.
Grading

- Introductory Exam 60 pt.
- Mid-term Exam 100 pt.
- Term Project 100 pt.
- Special Assignment 40 pt.
- Final Exam 100 pt.
- Total Points 400 pt.
Term Project

- As part of the course there will be a term project
- The project will be centered around using technical analysis in a simulator that will run for most of the semester
- As part of the project you will have to:
  - Learn to use the simulator
  - Research technical analysis (TA) techniques
  - Choose a limited number of TA techniques to use in the simulation
  - Apply these techniques to different type of securities
- There will be five reports spread throughout the semester (Check teaching plan for tentative due dates)
Special Project

- There will be a special project to be based on risk management.
- For this project you will have to do some research, collect data and apply the appropriate methodology to determine risk exposure of some investments.
- The due date of the report will be around the last lecture (Check Teaching plan for specific due date).
Course Organization

- We will use my.asu.edu to post the notes, exercises, projects etc.
- Make sure that you have access to it.
- Teaching plan:
  - Topic to be studied
  - Information on chapters of the book (and other material) to read BEFORE coming to class
  - Homework due date (When the results will be posted)
  - Tentative exam dates
- Notes: download the notes before coming to class → lectures and support material
- Check for updates AFTER the lecture
Chapters in Faerber book

- Introduction to investing
- Investment risk and return
- Security markets and how stocks are traded
- Investment companies (mutual funds)
- Money-market securities
- Common stock and preferred stock
- Bonds
- Treasury, government, mortgage-backed securities, corporate and municipal bonds
- Convertible and bonds and zero coupon bonds
- Options
- Futures
- Real Estate, precious metals and collectibles

The introductory exam will be based on the chapters highlighted in red
Other sources of information

- Throughout the semester we will be using different sources to get information on stocks, bonds, options, futures, etc.
- One of the main sources of information will be the internet. Some sources that will be recurrent include:
  - Investopedia ([www.investopedia.com](http://www.investopedia.com))
  - Google Finance ([www.google.com/finance](http://www.google.com/finance))
Investopedia provides some very useful tutorials on financial topics. Recommended reading:

- Investing 101
- Stock Basics
- Basic Financial Concepts
- Bond & Debt Basics
- IPO Basics
- Brokers and Online Trading
- Economics Basics
- Reading Financial Tables
- Understanding the P/E Ratio
Assignments

- Read Chapters 1 and 2 from your textbook
- Read Chapters 1 & 2 from the book by Faerber