

The Two year PGDM program at MSE offers two specializations, namely Finance, Research and Business Analytics. The programs are divided into six terms with class room instruction, and one term in the summer which consists of an internship in the industry. The detailed curriculum for the two specializations is shown in Tables 1, 2 and 3.

Table 1: Common First Year Courses

Term 1	Term 2	Term 3
111 Financial Mathematics	121 Basics of Financial Instruments	131 Finance I
112 Microeconomics	122 Macroeconomics	132 Corporate Finance
113 Operations Research	123 Marketing Concepts	133 Organizational Behavior
114 Introduction to Accounting and Management	124 Management Information Systems and Data Bases	134 Supply Chain Models
115 Quantitative Methods	125 Stochastic Process	135 Stochastic Calculus
116 Object Oriented Programming and Data Structures	126 Algorithmic Programming Matlab/R/Python	136 Human Resources

Table 2: Finance (Financial Engineering FE) Second Year Courses

Term 4	Term 5	Term 6
241 Financial Markets, Money and Regulatory Mechanisms	251 Financial Time Series Analysis	261 Banking and Financial Services
242 Introduction to Financial Econometrics	252 Game Theory	262 Advanced Topics in Economics and Finance
243F Pricing of Derivatives and Options	253F Fixed Income Models	263F Credit Risk Models
244F Asset Pricing	254F Simulation Techniques in Finance	264F Computational Finance
245FA Advanced Analytical Models for Decision Making 245FB Stochastic Differential Equations in Finance	255FA Machine Learning 255FB Numerical Methods in Finance	265FA Deep Learning 265FB Statistical and Empirical Methods in Finance
246FA Taxation 246FB Topics in Behavioral Finance	256FA Risk Models 256FB Stochastic Control in Finance	266FA Algorithmic and High Frequency Trading 266FB Advanced Topics in Financial Engineering

Table 3: Research and Business Analytics (Data Science DS) Second Year Courses

Term 4	Term 5	Term 6
241 Financial Markets and Regulatory Mechanisms	251 Financial Time Series Analysis	261 Banking and Financial Services
242 Introduction to Financial Econometrics	252 Game Theory	262 Advanced Topics in Economics and Finance
243D Algorithms for Big Data	253D Machine Learning	263D Reinforcement Learning
244D Artificial Intelligence	254D Artificial Neural Networks	264D Deep Learning
245DA Pricing of Derivatives and Options 245DB Cryptography	255DA Simulation Techniques in Finance 255DB Graphical Models	265DA Computational Finance 265DB Mechanism Design
246DA Information Theory 246DB Advanced Analytical Models for Decision Making	256DA Robotics 256DB Bioinformatics	266DA Quantum Computing 266DB Advanced Topics in Data Science

Common First Year Courses

111 Financial Mathematics

1. Probability and Statistics

Sample Space, Conditional Probability and Bayes' Theorem, Random Variables and Distributions, Law of Large Numbers and Central Limit Theorem, Sampling Methods, Estimation, Maximum Likelihood, Bias and Variance Tradeoff, Hypothesis Testing, Type I and Type II errors

2. Basic Financial Calculations

Introduction: financial securities- zero coupon bond, fixed interest, index linked securities etc.; the time value of money; nominal Vs. real interest, deflationary conditions; accumulating factors, force of interest, compound interest functions.

3. Annuities and Equation of Value

Discounting and Accumulation: discrete and continuous cash flows; level annuities, deferred and increasing/decreasing annuities, equation of value and yield on transaction, probability of cash flows, higher discount, loan schedules; consumer credit: flat rate and APRs.

4. Capital Budgeting Techniques and Compound Interest Problems

Introduction to financial statement, assessing financial performance, net present value, internal rate of return, payback period; projects with different lives; money and time weighed rate of return; fixed interest securities, uncertain income securities, equities, valuing a loan with allowance for capital gains and indexation.

5. Arbitrage, Forward Contracts, and Term Structure of Interest

Rationale for no arbitrage assumption; forward contracts, calculating the forward price for a security with known dividend yield; hedging, fixed cash income; Discrete time and continuous time rates; continuous time spot rates and forward rates; instantaneous forward rates; theories of time; term structure of interest rates; yield curve; yields to maturity; convexity and immunization; interest rate risk..

Books:

- Ross, S.M., *An Introduction to Mathematical Finance*, Cambridge University Press, Norton, London, 1999
- Watsham, T.J. and Perramore, K., *Quantitative Methods in Finance*, International Thomson Business Press, 1997
- Hogg R.V., McKean J. and Craig A.T. *Introduction to Mathematical Statistics*, Pearson Education Limited, 2014.

112 Microeconomics

1. Consumer Behaviour and Demand Consumer preferences

Opportunity sets, optimum choices, indirect utility demand functions, income and substitution effects, Slutsky equation, normal versus inferior goods, types of demand functions, elasticity, welfare evaluation, consumer surplus, equivalent variation and compensating variation, revealed preference (weak and strong axioms)

2. Utility Functions and Expected Utility Theorem

Expected utility function, measures of risk aversion, state-preference approach, portfolio theory and pricing of risk, present discounted value approach to investment decisions, adjustments for risk

3. Production and Cost

Production functions, types of production functions (Cobb-Douglas, CES, etc.), marginal products, rate of technical substitution, technical progress, cost functions, average and marginal costs, short run versus long run costs, economies of scale and scope, profit maximization, cost minimization, derivation of input demand

4. Competitive Markets

Assumptions of perfect market, competitive markets – demand and supply, demand and supply curves of individual firms, short-run versus long-run, competitive market equilibrium, tax incidence analysis, price-controls and shortages.

5. Imperfect Competition

Market failure, imperfect markets, sources of monopoly power, monopoly market equilibrium, price discrimination – first, second and third degree, tax incidence, oligopoly, Cournot Model, Stackelberg model, Bertrand Model, Monopolistic Competition.

Reference Books

- Varian, H. R., Microeconomic Analysis, third edition, W.W. Norton and Co., 1992
- Mas-Collel, Whinston and Green, Micro-economic Theory, OUP, 1995
- Gravelle, H and R. Rees: Microeconomics, Pearson Education, 3rd Edition, 2004

113 Operations Research

1. Linear, nonlinear, and integer programming

Linear programming problems – Mathematical formulation, graphical method of solution, simplex method, Duality in linear programming problems, dual simplex method, sensitivity analysis, transportation and assignment problems, Traveling salesman Problem.

2. Dynamic Optimization

Multistage decision processes; principle of optimality. Applications: network problems; inventory problem; resource allocation problem; knapsack problem; stochastic problems.

3. Integer Optimization

Modeling set up costs, batch production, limited number of production methods, Logical constraints, set covering problems; systematic conversion of logical expression to IP constraints. Solution techniques: branch and bound, Gomory pure integer cuts.

4. Game Theory

Optimal strategies in face of uncertainty (minimax and maxmin). Two person zero sum games, dominated strategies, saddle points, non-zero sum games, reaction curves and Nash equilibria, the maxmin-minimax principle, games without saddle points-Mixed Strategies, graphic solution, dominance property. CPM & PERT- project scheduling, critical path calculations, Crashing.

5. Network Programming

Queueing theory -basic structure of queueing systems, roles of the Poisson and exponential distributions, classification of queues basic results of M/M/1: FIFO systems, extension to multi-server queues.

Books

- Taha, Hamdy, Operations Research, 7th edition, (USA: Macmillan Publishing Company), 2003
- Ravindran A, Philips D.T & Solbery.J.J, Operations Research: Principles and practice, John Wiley & Sons, New York, 1987.
- Budnick, Frank S., Richard Mojena, and Thomas E. Vollmann. Principles of operations research for management. Richard D. Irwin, Incorporated, 1977.
- Gillet.B.E., Introduction to Operations Research - A Computer oriented algorithmic approach, McGraw Hill, 1987.
- Joseph.G.Ecker & Michael Kupper Schimd, Introduction to operations Research, John Wiley & Sons, 1988.

114 Introduction to Accounting and Management

1. Financial Statement and Accounting

Over view and Introduction to Financial Statements, Accounting concepts, Principles of Accrual Accounting, Journal Entry and T-account, Accrual accounting process and preparing financial statements.

2. Sales and Revenue Recognition

Sales and Revenue Recognition, Inventory, and COGS

3. Types of Assets, Liabilities and Interest

Long-Lived Assets, Matching Principle for PP & e and Depreciation, Money Assets, Investment and Marketable Securities, Liabilities and Interest, Current Liabilities, and Contingencies, Bonds, Leases, Deferred taxes, Stockholders Equity, consolidation, and business combinations

4. Financial Statement Analysis

Statement of Cash flows, financial statement analysis and current developments.

5. Capital and budgetary control

Capital Expenditure Evaluation – Capital budgeting concept – Methods – Limitations –Capital Expenditure control. Budgetary Control–Nature and Objective of Budgetary Control–Limitations.

Books

- Narayanaswamy, R. *Financial accounting: a managerial perspective*. PHI Learning Pvt. Ltd., 2017.
- Davidson, Sidney, Clyde P. Stickney, and Roman L. Weil. *Financial accounting: an introduction to concepts, methods, and uses*. Dryden Press, 1979.
- Gupta, A., *Financial Accounting for Management: An Analytical Perspective*, 4th Edition, Pearson, 2012.

115 Quantitative Methods

1. Differential Calculus

Introduction to Functions and Real Analysis; Derivatives – partial and total, economic applications, marginal and elasticity concepts, functions of several variables, implicit function theorem, higher order derivatives and Young's theorem, Taylor's approximation, convex sets, convex and concave functions, properties of linear homogenous functions, Euler's theorem

2. Linear Algebra

Vectors, matrices, inverse, simultaneous linear equations, Cramer's rule for solving system of linear equations, input-output model, Hawkin - Simon condition, open and closed models quadratic equation, characteristic (eigen) roots and vectors

3. Classical Optimization and Applications

Introduction to quadratic forms, unconstrained optimization, constrained optimization with equality constraints, Lagrangian method, Hessian and Jacobian matrices, applications – utility maximization, cost minimization, profit – output maximization

4. Linear and Non-linear Optimization

Duality theory, constrained optimization with inequality and non-negativity constraints, Kuhn-Tucker formulation, linear programming – formulation, primal and dual, solutions using graphical and Simplex methods, applications from economics and finance

5. Dynamics

Definite and indefinite integrals, applications – measuring consumer and producer surplus, continuous interest – discount calculations, difference and differential equations, phase diagrams, Cobweb model, multiplier accelerator, Harrod-Domar and Solow model

Books:

- Simon, C. and L. Blume, *Mathematics for Economists*, Norton, London, 1994
- Chiang, A. C., *Fundamental Methods of Mathematical Economics*, McGraw-Hill, 1984
- Ok, E.A., *Real Analysis with Economic Applications*, Princeton University Press, 2007
- Knut Sydsaeter and Peter J. Hammond, *Mathematics for Economic Analysis*, Pearson Education Asia, 1995
- M.D. Intriligator, *Mathematical Optimization and Economic Theory*, Prentice-Hall, 1971

116 Object Oriented Programming and Data Structures

1. Introduction to Object Oriented Programming

Using Objects and defining classes, subclasses, attributes, methods, instances polymorphism, inheritance, examples to illustrate the idea

2. Conditionals and Loops

If-Then-Else Statement, Nested If, Different type of loops, for, while, repeat until, Nested loops, examples

3. Programs and Data

Various types of data, concept of modularity, procedures, functions and passing of parameters, , expressions and assignment, structured data, pointers

4. Compiling and Running Programs

Environments in different object oriented languages, compile and run time errors, Recursion, Interpreter

5. Data Structures

Arrays one and multi-dimensional, Stacks, Queues, Heaps, Linked Lists, Graphs, Trees, various operations on data structures, dynamic and static data structures

Books

- Kathy Sierra and Bert Bates, *Head First Java* O'Reilly, 2005.
- Michael T Goodrich and Roberto Tamassia, *Data Structures and Algorithms in Java* John Wiley & Sons, 2010
- Robert Lafore, *Object Oriented Programming in C++*, SAMS 4th Edition, 2002.

121 Basics of Financial Instruments

1. Financial Regulation

Asymmetric information and the rationale for regulation of securities market, financial market fragility, review of regulatory policies in US, UK, Japan and Asian emerging markets.

2. Indian Capital Markets

Structure of primary and secondary markets, dematerialization, depositories, credit rating of financial instruments, financial institutions: development financial institutions, non-banking financial intermediaries, LIC of India and UTI, mutual funds, venture capital, bank-assurance

3. Financial Sector Reforms

Indian capital market integration, foreign institutional investors, impact of exchange rate variability in a liberalized regime, Issues of GDRs, ADRs

4. Banking Regulation

Banking regulation act 1949, financial stability, basics of public debt management issue of government securities conduct of monetary policy- role of gilt market

5. Bank of International Settlement

Capital adequacy regulations Basel accord I & II. accounting standard, disclosure and relationship banking mark-to-market accounting, liquidity risk and contagion market discipline: issues and evidence market discipline in emerging economies: beyond bank fundamentals

Books

- Houthakker, H.S. and Williamson, P.J. *The Economics of Financial Markets*, Oxford University Press, 1996.
- Krugman, P. and Obstfeld, M. *International Economics, Theory and Policy*, sixth edition, Addison - Wesley, 2003.
- Herring, R. and Litan, R.E. *Financial Regulation in the Global Economy*, Brookings Institution Press, 1995.
- Howells, P. and Bain, K. *Financial Markets and Institutions*, Fifth Edition, Pearson Education, 2007

122 Macroeconomics

1. National Income Accounting

Accounting structure, key concepts in accounting for both closed and open economies – gross national product, gross domestic product, net national product, national income, savings and investment, balance of payments, circular flow of income, computational problems – expenditure approach, income approach and value added approach for measurement, input-output tables

2. Keynesian Models

Simple Keynesian Model, assumptions, concepts of involuntary unemployment, liquidity preference, paradox of thrift, investment function, IS-LM model – two sector model, goods and money market equilibrium, multiplier, liquidity trap, complete Keynesian model – three sector model, role of government in terms of monetary and fiscal policy

3. Keynesian Models versus Classical Models

Says Law, quantity theory of money, price flexibility and full employment, Clowers and Patinkin's money demand functions, equilibrium concept in classical model, synthesis between classical models and Keynesian models, interpretation and policy analysis

4. Expectations and Macroeconomic Adjustments

Expectations formations – Adaptive and rational expectations hypothesis, partial adjustment model, Lucas critique, Phillips curve, rules versus discretion, time consistency, inflation targeting, interest rate rules, effects of spending and taxes in models with flexible and sticky prices, perverse effects of fiscal expansion

5. Macroeconomics: Open Economy Aspects

Market for foreign exchange, devaluation and depreciation, real and nominal exchange rate, factors affecting exchange rate, Mundell-Fleming model, fixed versus floating exchange rate, price adjustment, role of fiscal and monetary policies under alternative exchange rate regimes, purchasing power parity concept

Books

- Scarth, W., *Macroeconomics: An Introduction to Advanced Methods*, third edition, Thomson, 2007
- Mankiw, N. G., *Macroeconomics*, fifth edition, Worth Publishers, 2002
- Hall, E. and Taylor, J. B. *Macroeconomics*. W. W. Norton and Company, 1986
- Barro, R.J. *Macroeconomics*, Fifth edition, MIT Press 1997

123 Marketing Concepts

1. Segmentation, targeting, and positioning

How to assess market potential, understand and analyze customer behavior, and focus resources on specific customer segments and against specific competitors.

2. Branding

How to develop, measure, and capitalize on brand equity.

3. Marketing communications

How to develop an effective mix of marketing communication efforts.

4. Distribution channels

How to understand the role of distributors, retailers, and other intermediaries in delivering products, services and information to customers.

5. Pricing

How to set prices that capitalize on value to the customer and capture value for the firm.

Reference Books

- Chernev A., *Strategic Marketing Management*, 8th Edition, Cerebellum Press, 2012
- Kotler, P. and Keller K. L., *Marketing Management*, 13th Edition, Pearson Education, 2013

124 Management Information Systems and Data Bases

1. Introduction to Databases and Transactions

Overview of database system, purpose of database system, view of data, relational databases, database architecture, transaction management.

2. Data Models

The importance of data models, Basic building blocks, Business rules, The evolution of data models, Degrees of data abstraction

3. Database Design, ER-Diagram and Unified Modeling Language

Database design and ER Model:overview, ER-Model, Constraints, ER-Diagrams, ERD Issues, weak entity sets, Codd's rules, Relational Schemas, Introduction to UML Relational database model: Logical view of data, keys, integrity rules. Relational Database design: features of good relational database design, atomic domain and Normalization (1NF, 2NF, 3NF, BCNF)

4. Relational Algebra and Calculus

Relational algebra: introduction, Selection and projection, set operations, renaming, Joins, Division, syntax, semantics, operators, grouping and ungrouping, relational comparison. Calculus: Tuple relational calculus, Domain relational Calculus, calculus vs algebra, computational capabilities

5. Constraints, Views and SQL

What is constraints, types of constrains, Integrity constraints, Views: Introduction to views, data independence, security, updates on views, comparison between tables and views
SQL: data definition, aggregate function, Null Values, nested sub queries, Joined relations. Triggers

Books

- Silberschatz, A., Korth, H., and Sudarshan, S. *Database System and Concepts*, 6th Edition, McGraw-Hill, 2013.
- Rob, P., *Database Systems*, Seventh Edition, Cengage Learning, 2006

125 Stochastic Process

1. Stochastic Process and Simple Markov Processes

Principles of actuarial modeling, stochastic vs. deterministic models; short run and long-run properties; stochastic process and counting process; analyzing the output of a model; sensitivity testing; types of stochastic processes: discrete state spaces with discrete and continuous time changes, continuous state space, sample paths, stationary, increments, Markov property, filtrations, white noise, general random walk, Poisson process and compound Poisson process

2. Markov Chains

Chapman-Kolmogorov equations; time homogeneous Markov chains, time-inhomogeneous Markov chains; Models- no claims discount policy model, NCD model, simple random walk on $Z = \{\dots, -2, -1, 0, 1, 2, \dots\}$ and on $\{0, 1, 2, \dots, b\}$; accident proneness model; long-term distribution and behaviours of a Markov chain, stationary probability distribution, modelling using Markov chains; estimating transition probabilities, assessing the fit and simulation

3. Two-State Markov Model

Assumptions, probabilities, joint density function, ML estimator; alternative approach, applications, two state model of a single decrement and comparison with those of a random lifetime model

4. General Properties of Markov Process

Poisson processes, deriving and solving the Kolmogorov equations for Markov process-time and age dependent and time independent transition intensities; birth and death problems; simple survival models, sickness and marriage models in terms of Markov process and duration dependent Markov process; Kolmogorov's backward differential equations, Markov jump process, the jump chain, simple two decrement model, calculation of total waiting time

5. Time-inhomogeneous Markov Jump Process

Chapman-Kolmogorov equations, transition rates, time inhomogeneous HSD model, Kolmogorov's backward and forward differential equations; a two state survival model; integrated form of Kolmogorov equations, applications-marriage, sickness and death; time homogeneous Poisson process models, time homogeneous and inhomogeneous Markov models

References

- Ross, S.M., *An Introduction to Mathematical Finance*, Cambridge University Press, 2003
- Parzen, E. *Stochastic Processes*, Society for Industrial and Applied Mathematics, 1999.
- Kulkarni, V. *Modeling and Analysis of Stochastic Systems*, G. Thomson Science and Professional, 1995
- Bhat U.N. and G.K. Miller, *Elements of Applied Stochastic Processes*, Wiley, 2002

126 Algorithmic Programming Matlab/R/Python

1. R and Python

Programming in R and Python, Algorithm design concepts illustrated with examples, use of built in libraries and functions

2. Searching and Sorting

Linear Search, Binary Search, Insertion sort, Bubble sort, Heap sort, Quick sort, Radix sort, Merge sort, space and time complexity with different data structures

3. Graph algorithms

Shortest Path algorithms, Depth first search, Breadth first search, Graph coloring, Spanning Tree algorithms, Max Flow Min Cut, Euler circuit algorithm

4. Numerical Algorithms

Round off and Truncation errors, Ill Conditioned Matrices, Gaussian Elimination, Numerical differentiation and integration

5. Intractable Problems

Notion of NP and NP complete, Various complexity classes, SAT problem, Cook's theorem, Reducibility among various NP complete problems

Books

- T.H. Cormen, C.E. Leiserson, R.L. Rivest and C Stein, *Introduction to Algorithms* MIT Press, 3rd Edition 2009
- Stormy Attaway, Matlab, *A Practical Approach to Programming and Problem Solving*, Elsevier 2009
- Michael J Crawley, *The R Book*, John Wiley & Sons, Ltd, 2007
- Allent Downey, *Think Python*, Green Tea Press 2012

131: Finance I

1. Introduction to Financial Markets

Capital markets, consumption and investments with and without capital markets, market places and transaction costs and the breakdown of separation; Fisher separation theorem; the agency problem; maximization of shareholder's wealth

2. Theory of Uncertainty

Axioms of choice under uncertainty; utility functions; expected utility theorem; certainty equivalence, measures of risk-absolute and relative risk aversions;

3. Stochastic dominance

First order, second order and third order; measures of investment risk-variance of return, Mean - Variance as choice criteria.

4. Mean-Variance Portfolio Theory

Measuring portfolio return and risks, effect of diversification, minimum variance portfolio, perfectly correlated assets, minimum variance opportunity set, optimal portfolio choice; mean-variance frontier of risky and risk-free asset, optimum portfolio weights choice.

5. Index Models, CAPM & APT

Models of asset returns, single index model, systematic and specific risk, equilibrium models-capital asset pricing model, capital market line, security market line, estimation of beta,; multi index models - arbitrage pricing theory

Books

- Copeland, T. E. and J. F. Weston, *Financial Theory and Corporate Policy*, Addison Wesley, 1992
- Brealey, R. and S. Myers, *Principles of Corporate Finance*, fifth edition, New York, McGraw Hill, 1997.
- Elton, E.J and M.J. Gruber, *Modern Portfolio Theory & Investment Analysis*, (fourth edition) John Wiley & Sons 1991.
- Houthakker, H.S. and P.J. Williamson, *Economics of Financial Markets*, Oxford University Press, 1996

132 Corporate Finance

1. Capital Structure and Dividend

The value of firm with tax, Modigliani-Miller irrelevance hypothesis, choices in financing-debt and equity, the financing mix: trade-offs and theory; signaling hypothesis; effect of agency cost on capital structure, cost of capital, empirical determinants of capital structure choice

2. Dividend Policy

Irrelevance of dividend policy without tax; valuation, growth and dividend policy, dividend policy with taxes; theory of optimal dividend policy; other issues-stock dividends and share repurchase, empirical determinants of optimal dividend policy

3. Market Microstructure

Defining capital market efficiency, relationship between the value of information and efficient capital markets, rational expectations and market efficiency, market efficiency with costly information, efficient capital market theory and empirical models

4. Corporate Governance Mechanisms

Theory of transaction costs, imperfect contract theory, ownership structure, board of directors and executive compensation

5. Special Topics in Corporate Finance

Value at Risk, mergers and acquisitions, empirical methods in corporate finance

Books

- Copeland, T. E. and J. F. Weston, *Financial Theory and Corporate Policy*, Addison Wesley, 1992
- Hull, J. *Options, Futures and other Derivatives*, fifth edition, Prentice Hall, 2002
- Brealey, R. and S. Myers, *Principles of Corporate Finance*, fifth edition, New York, McGraw Hill, 1997.
- Panjer, H.H. *Financial Economics: with applications to Investments, Insurance and Pensions*, Actuarial Foundation, 1998.
- Houthakker, H.S. and P.J. Williamson, *Economics of Financial Markets*, Oxford University Press, 1996

133 Organizational Behavior

1) Basics of Organizational Behavior

Ethical Values and the importance of organizational behavior, study of personality and the reason for individual differences, Study of Employee Work attitudes and the role of job satisfaction

2) Stress and Happiness at Work

Factors influencing personality and its influence on stress, causes and consequences of job related stress, managing stress, Emotions, Organizational programs of wellness and stress management, Job insecurity

3) Group Behavior and Motivation

Organization structure, Groups in organizations and their Influence and motivation, cultural differences in motivation, Promoting Employee productivity, interpersonal skills and communication

4) Leadership and Organizational Control

Leadership styles and Values, Leadership qualities, Leader vs Boss, Power and Politics, Goal Setting, Performance Appraisals and Rewards, Reward Systems

5) Organizational Dynamics

Factors influencing organizational dynamics, Organizational objectives and effectiveness, Deficiencies in the Work place, Team approach to work, Composition and Cohesiveness of Teams, Importance of a Collaborative Culture

References

- Stephen P. Robins, Organisational Behavior, PHI Learning / Pearson Education, 11th edition, 2008.
- Fred Luthans, Organisational Behavior, McGraw Hill, 11th Edition, 2001.
- Champoux, J. (2011) *Organizational Behavior: Integrating Individuals, Groups, and Organizations* (4th edn). New York, NY: Routledge.

134 Supply Chain Management

1. Forecasting, Facility layout and location

Need for forecasting, quantitative methods, Qualitative aspects, quantitative models for layout decisions, Product, process fixed position, group layout, Location decisions-quantitative models.

2. Capacity and aggregate planning, Inventory management

Capacity measurement, Long-term and short term strategies, Various costs in inventory management and need, Deterministic models and discounts, Probabilistic inventory management

3. Scheduling models and applications

Scheduling in MRP system, Sequencing rules and applications, Batch production sequencing and scheduling.

4. Introduction to supply chain, Value of information and supply chain integration

Definition, complexity, key issues, Centralized vs. decentralized systems, Bullwhip effect, Push-based, pull based systems.

5. Outsourcing, Transportation decision

Make or buy decisions, Drivers of the decision, Network design decisions, Cross-docking, transshipment

Books

- Collier D. A, Evans J. R., *Operations Management*, Student Edition, Cengage Learning, 2009
- Janat Shah, *Supply Chain Management*, 2nd Edition, Pearson Education India, 2016
- Chopra, S., Meindl, P., and Kalra, D. V., *Supply Chain Management*, 6th Edition, Pearson, 2016.

135 Stochastic Calculus

1. Stochastic Calculus

Basics of stochastic processes, poisson process Brownian motion process and its varied generalisations, Geometric Brownian motion, Analysis of second order processes, Ito integral and Ito lemma with applications, Kolmogorov equations, Jump process, Calculus for jump processes, change of measure, basics of Levy stochastic calculus.

2. Stochastic Tool-kit for finance

Martingales, Martingale representation theorem, stopping time, stopped process, first passage time, Doob's optimal stopping theorem, Girsanov theory, Arc-sine law, pricing kernel as a Martingale, Risk neutral analysis, sharpe ratio.

3. Valuation of asset prices

Stochastic characterisation of complete and incomplete markets, Forward and future contracts, binomial tree model, Black-Schole's theory and applications, Put-call parity, Implied volatility, Exchange options, Currency options, American options, Sensitivity analysis (Greeks)

4. Interest rate models and derivatives

Mean-reverting processes, O-U process, Square root process, Factor models-the Merton model, The Vasicek model, The Cox Ingersoll-Ross model, Heath-Jarrow-Merton model, Pricing of Bonds, Stochastic interest rate, Rate of return and yield curve.

5. Further option theory

Swaps, Caps, Floors, Swaptions, Forward LIBOR models, Barrier options, Look back option, Calibration, Levy process as stock price model, Stochastic volatility models, Heston model and Wiggins' model, ARCH and GARCH models and their suitable extensions in diffusion.

Books

- Shreve S.E.: Stochastic calculus for finance volume 2-continuous time models, Springer, 2004
- Hull, John C., and Sankarshan Basu. *Options, futures, and other derivatives*. Pearson Education India, 2016.
- Baz, Jamil, and George Chacko. *Financial derivatives: pricing, applications, and mathematics*. Cambridge University Press, 2004.
- Wilmott, Paul, Sam Howison, and Jeff Dewynne. *The mathematics of financial derivatives: a student introduction*. Cambridge University Press, 1995.
- Applebaum, David. *Lévy processes and stochastic calculus*. Cambridge university press, 2009.

136: Human Resources

1. Introduction to Human Resource Management, Human Resource Planning

Introduction, Concept of Human Resource Management, Scope of Human Resource Management, History of Human Resource Management, Function of Human Resource Management, Role of HR Executives, Process of Human Resource Planning, Need for Human Resource Planning, HR Forecasting Techniques, Successful Human Resource Planning

2. Recruitment and Selection, Training and Management Development

Concept of Recruitment, Factors Affecting Recruitment, Sources of Recruitment, Recruitment Policy, Selection, Selection Process, Application Forms, Selection Test, Interviews, Evaluation, Placement, Induction, Meaning of Training, Area of Training, Methods of Training, Concept of Management Development, Management Development Methods, Differences Between Training and Development, Evaluation of Training and Management Development

3. Employee Career Planning and Growth, Performance Appraisal

Concept of Employee Growth, Managing Career Planning, Elements of a Career Planning Programme, Succession Planning, Concept and Need for Performance, Reviews, Overview of Performance Appraisal, Types of Appraisal Methods, 360 degree appraisal, Benefits

4. Compensation Management, Job Evaluation

Wage and Salary Administration, Managing Wages, Concept of Rewards and Incentives, Managing Benefits in Organisations, Concept of Job Evaluation, Objectives, Techniques, Advantages and Limitations, Introduction to Competency

5. Human Resource Information System, Job Analysis and Design

Introduction, Concept, Components, Types, Application, Implementation, Benefits, Impact, Concept of Job Analysis and Design, Process of Job Analysis, Methods of Job Analysis, Job Analysis Information, Concept of Job Design

Books

- Dessler, G., *Human Resource Management*, 13th Edition, Pearson, 2012.
- Robert N. Lussier and John R. Hendon, *Human Resource Management: Functions, Applications, and Skill Development*, 3rd Edition, SAGE, 2018.

Second Year Finance Courses

241: Financial Markets, Money and Regulatory Mechanisms

1. Financial Regulation

Asymmetric information and the rationale for regulation of securities market, financial market fragility, review of regulatory policies in US, UK, Japan and Asian emerging markets.

2. Indian Capital Markets

Structure of primary and secondary markets, dematerialization, depositories, credit rating of financial instruments, financial institutions: development financial institutions, non-banking financial intermediaries, LIC of India and UTI, mutual funds, venture capital, bank-assurance

3. Financial Sector Reforms

Indian capital market integration, foreign institutional investors, impact of exchange rate variability in a liberalized regime, Issues of GDRs, ADRs

4. Banking Regulation

Banking regulation act 1949, financial stability, basics of public debt management issue of government securities conduct of monetary policy- role of gilt market

5. Bank of International Settlement

Capital adequacy regulations Basel accord I & II. accounting standard, disclosure and relationship banking mark-to-market accounting, liquidity risk and contagion market discipline: issues and evidence market discipline in emerging economies: beyond bank fundamentals

Books

- Houthakker, H.S. and Williamson, P.J. *The Economics of Financial Markets*, Oxford University Press, 1996.
- Krugman, P. and Obstfeld, M. *International Economics, Theory and Policy*, sixth edition, Addison - Wesley, 2003.
- Herring, R. and Litan, R.E. *Financial Regulation in the Global Economy*, Brookings Institution Press, 1995.
- Howells, P. and Bain, K. *Financial Markets and Institutions*, Fifth Edition, Pearson Education, 2007

242: Introduction to Financial Econometrics

1. Simple Regression Analysis

Specification of the two variable regression model, Ordinary Least Squares estimation, Assumptions, BLUE property, General and confidence approach to hypothesis testing, partial effects and elasticity, goodness of fit, model evaluation, ANOVA

2. Multiple Regression Analysis

Motivation, Assumptions and OLS estimation, Interpretation of OLS estimation, Goodness of fit, matrix approach to linear regression models, testing of hypothesis for a single parameter, for linear combination of parameters, for multiple linear restrictions. ,

3. Violation of CLRM Assumptions

Detection and remedial measures of multicollinearity, heteroskedasticity (WLS, MLE), and autocorrelation (GLS), Specification error (omitted variable, inclusion of irrelevant variables, measurement error in dependent and independent variables)

4. Extension of Linear Regressions

Choice of function forms: linear, log-linear, log-log, quadratic functional forms, Box-Cox test, models with quadratics and interaction terms.

5. Dummy Variables

Regression on dummy (qualitative) variables with two categories, with more than two categories- intercept shifters, dummy variable trap, interaction of two categorical variables, interaction of categorical and continuous (quantitative) variables- slope shifters, piecewise linear regression model, Chow test for cross-section data and for time-series data (test structural stability of regression models)

Books

- Gujarati and Porter, *Basic Econometrics*, Fifth Edition, McGraw Hill/Irwin, 2009.
- Greene, William H. *Econometric Analysis*. 6th Edition, Prentice Hall. 2008.
- Johnston J. and DiNardo, J. *Econometric Methods*. 4th Ed. McGraw-Hill 1997. Greene

243F: Pricing of Derivatives and Options

1. Pricing of Options

Law of One Price, Concept of Replicating portfolio, Complete and In-complete markets, AD securities

2. Discrete Time Financial Market Model

Binomial Model, Risk Neutral Probability, Martingale Measure, Conditions for no Arbitrage

3. Continuous Time Financial Market Model

Pricing by the probabilistic approach, Feynman Kac Approach, Self Financing Portfolio

4. Black-Scholes (BS) Model

Derivation and Solution of the BS PDE, Hedging, Greeks, Implied Volatility, Pricing European Options, Call, Put

5. American and Exotic Options

Pricing American Options, Path dependent options, Asian Options, Multi-stage Options, Pricing Barrier, Lookback and Exchange options

Books

- Hull J.C., Options, Futures and Other Derivatives, 9th Edition, Pearson, 2015
- Wilmott P., Howison S., and Dewynne J., The Mathematics of Financial Derivatives, Cambridge University Press, 1995

244F: Asset Pricing

1. Asset Pricing Models and the No-Arbitrage Principle

The terminology of financial markets; Bond prices and interest rates under certainty; An example of a simple asset pricing model. Building Blocks of Asset Pricing Models: Review of probability theory and stochastic processes.

2. Stochastic calculus

One-period, multi-period and continuous time models, No-arbitrage and market completeness, Stochastic discount factors and Arrow-Debreu securities, Risk-neutral probabilities. The Basics of Option pricing: Binomial model and Black & Scholes formula.

2. Estimation and evaluation of asset pricing models

Linear factor models, structural linear factor models, CAPM and ICAPM, Non linear RE models

3. Investor behavior and Heterogeneity

Limited stock participation and consumption risk, belief formation, investor sentiment

4. Imperfect markets and liquidity

Limited arbitrage and liquidity supply, liquidity, liquidity risk and expected returns

Books

- Campbell, J., A. Lo, and A. C. MacKinlay, *The Econometrics of Financial Markets*, Princeton University Press, 1997
- Cochrane, John H., *Asset Pricing*, Princeton, NJ: Princeton University Press 2nd Edition, 2005
- Singleton, Kenneth J, *Empirical Dynamic Asset Pricing*. Princeton NJ: Princeton University Press, 2006

245FA: Advanced Analytical Models for Decision Making

1. Revenue Management and Pricing Models

Overview, Demand Functions, Solving the basic pricing models with capacity constraints. Customer segmentation, Pricing to multiple segments, Pricing under uncertainty, Models for Perishable Assets, Seasonal demand, Mark up/down, Price Trajectory, Dynamic Pricing.

2. Queuing Models

Waiting line analysis, Elements and Characteristics of a waiting line system, Queue discipline, Finite and Infinite source, Single server, Multiple server waiting line, Measures of waiting-line performance, Monte Carlo process, Simulation of a Queuing system

3. Decision Theory

Decision processes, decision making under certainty, uncertainty and risk. Decision criteria (Maximin, Maximax, Laplace, Minimax regret, Hurwicz) Decision tree analysis, Posterior probability, Expected value of perfect information, Sensitivity analysis

4. Transportation Models

Location decisions and models, Gravity location models Transportation model, Assignment model, Transshipment problem, Distribution network design, Network optimization models

5. Applications

Predictive analytics and Decision models for data driven real world applications, Application of Mathematical models for designing strategies, supporting policy making, business decisions and evaluating performance and risk, Analytical case studies in Healthcare, E commerce, Internet, Retail, Airlines, Finance etc.

Books

- Dimitris Bertsimas and Robert Freund, *Data, Models, and Decisions: The fundamentals of Management Science*, South Western College Publishing, 2000
- Robert Phillips, *Pricing and Revenue Optimization*, Stanford University Press, 2004
- D Gross, J.F. Shortle, J.M. Thompson and C.M. Harris, *Fundamentals of Queueing Theory*, 4th Edition, Hoboken, Wiley, 2008
- Averill M. Law and W. David Kelton, *Simulation Modeling and Analysis*, 2nd Edition, McGraw-Hill, 1991

245FB: Stochastic Differential Equations in Finance

1. A brief review of probability

Basic concepts, Random variables and expectations, Representation of information obtained by observations, Conditional expectation and probability, Basic concepts of stochastic processes, The Poisson process and Brownian motion,

2. Stochastic integration

Stieltjes integral, Definition of stochastic integral, Existence of stochastic integral for finite variation processes, Definition and properties of martingales, Existence of stochastic integral for martingales, Ito's formula, Ito equations for diffusion processes, Poisson random measures,

3. Stochastic differential equations

Existence and uniqueness, Approximation theorems, Multidimensional Gaussian distributions. Brownian motion (its construction by means of Haar functions; regularity properties of trajectories); the Wiener measure.

4. Markov processes

The Ito stochastic integral (basic properties; comparison between the stochastic integral and the Riemann-Stieltjes integral), The Ito stochastic integral (basic properties; comparison between the stochastic integral and the Riemann-Stieltjes integral), Markov property of solutions of stochastic differential equations; connections between stochastic differential equations and parabolic Kolmogorov equations

5. Change of measure

Radon-Nikodym theorem, Bayes formula, Martingales under a change of measure, Change of measure for Poisson processes and Brownian motion, The Doob L^p estimates for martingales with continuous paths.

6. Examples and applications

Filtering, Finance, Control, Backward stochastic differential equations, Possible applications of stochastic differential equations to Mathematical Finance and Population Dynamics

Books

- Eckhard Platen and Nicola Bruti-Liberati, *Numerical Solutions of Stochastic Differential Equations with Jumps in Finance*, Springer 2010
- J. Michael Steele, *Stochastic Calculus and Financial Applications*, Springer 2000.
- Martin Baxter, Andrew Rennie, *Financial Calculus: An Introduction to Derivative Pricing*, Cambridge University Press, 1996
- B. Oksendal, *Stochastic Differential Equations*, Springer, 2003
- I. Florescu and C. Tudor, *Handbook of Probability*, 2013

- I. Florescu, *Probability and Stochastic Processes*, 2014
- I. Karatzas and S. E. Shreve, *Brownian Motion and Stochastic Calculus*, Springer-Verlag, New York, Second Edition, 1991
- Arnold, L., *Stochastic Differential Equations, Theory and Applications*, New York. John Wiley & Sons. 1974

246FA: Taxation

1. Tax Incidence

Definition, Partial and General Equilibrium Incidence, Economic vs Statutory Incidence, Partial Equilibrium model, Tax incidence Formula, Parallel Trends assumption, fixed effects

2. Efficiency Cost of Taxation

Introduction, Excess Burden of Taxation, Efficiency cost, Tax policy implications, Marginal excess burden of Tax increase, Government revenue leakage, Excess burden with Taxes on multiple goods, Goulder and Williams formula

3. Optimal Taxation

Commodity Taxation, Ramsey Tax Problem and Model, Government's problem, Ramsey Optimal Tax formula, Perturbation analysis, Optimal Capital Income Tax Rate, Optimal Income Tax with no Behavioral Responses

4. Income Taxation

Labor-Leisure Choice model, Non-Hours Responses, Progressive Taxes and Labor supply, Negative Income tax, Elasticity estimation using varying tax rate, Taxable income elasticities

5. Corporate Taxation

Corporate decisions and Tax policies, Model of Firm behavior, cash rich and cash constrained firms, evidence on dividend taxation, impacts on investment, corporate taxation in an agency model

Books

- Atkinson and J. Stiglitz. Lectures on Public Economics, New York: McGraw Hill, 1980
- B. Salanie. The Economics of Taxation, Cambridge: MIT Press, 2003
- C. Ballard, D. Fullerton, J. Shoven, and J. Whalley, A General Equilibrium Model for Tax Policy Evaluation, Chicago: University of Chicago Press, 1985

246FB: Topics in Behavioral Finance

1. Information Perception and Intertemporal Choice

Cognitive information perception, peculiarities (biases) of quantitative and numerical information perception, Weber law, subjective probability, representativeness, anchoring, asymmetric perception of gains and losses, framing and other behavioral effects

2. Human Preferences and Market efficiency

Decision-making under risk and uncertainty, decision-making in historical perspective, Allais and Ellsberg's paradoxes, rationality from an economics and evolutionary perspective, different ways to define rationality: dependence on time horizon, individual or group rationality, examples from experimental economics: ultimatum and public goods games, experiments in isolated societies, bounded rationality, investor rationality and market efficiency

3. Behavioral Factors and Financial Markets

Fundamental information and financial markets, market predictability, the concept of limits of arbitrage, asset management and behavioral factors, active portfolio management: return statistics and sources of systematic underperformance, technical analysis and behavioral factors

4. External Factors and Investor Behavior

Weather, emotions, and financial markets: sunshine, geomagnetic activity, mechanisms of the external factor connection to human psychophysiology and emotional regulation, misattribution as a mechanism for external factors influence, statistical methodology for capturing the effects of external influence onto stock market returns, emotional content of news articles and their correlation with market dynamics, social trends and market dynamics, active portfolio management: source of the systematic underperformance, fundamental information and technical analysis: case for psychological influence

Books

- Plous, S., *The Psychology of Judgment and Decision Making*, McGraw-Hill, 1993
- Shleifer, A., *Inefficient Markets: An Introduction to Behavioral Finance*, Oxford University Press, 2000
- Shefrin, H., *Beyond Greed and Fear: Understanding Behavioral Finance and the Psychology of Investing*, Oxford University Press, 2006
- Prechter, R. R. (Jr.) and P. M. Kendall, *Pioneering Studies in Socioeconomics*, New Classics Library, 2003

251: Financial Time Series Analysis

1. Univariate Stationary Time-series Models

Introduction to stochastic process, stationary processes, Wold representation theorem, autocovariance functions, autocorrelation and partial autocorrelation, auto regressive and moving average models, conditions for stationary and invertible process, Box-Jenkins approach, forecasting.

2. Univariate Nonstationary processes

Nonstationary process, deterministic and stochastic trends, Integrated process and random walk, random walk with drift, Unit root process-, test for unit root- Dicky Fuller tests, , ARIMA process. Fractional integrated process

3. Modeling volatility clustering

Volatility-Meaning and measurement, Volatility clustering, Econometric models of volatility, ARCH model, GARCH model and its various extensions, testing for ARCH/GARCH effects

4. Multivariate Stationary and Non-stationary processes

Vector autoregressive model, Granger causality, impulse response function, variance decomposition

5. Multivariate Non-stationary processes:

Introduction to cointegration, testing for cointegration: Single-equation approaches: Engle Granger method, Johansen test for cointegration, Vector error correction model

Books

- Brooks, C., *Introductory Econometrics for Finance*, 3rd Edition, Cambridge University Press, 2014.
- Enders, W., *Applied Econometric Time Series*, second edition, John Wiley and Sons, 2006.
- Hamilton, J. D., *Time Series Analysis*, Princeton University Press, 1994.
- Johnston J. and DiNardo, J. *Econometric Methods*. 4th Ed. McGraw-Hill 1997.
- Maddala G.S. and In-Moo Kim, *Unit Roots, Cointegration, and Structural Change*, 1998.

252: Game Theory

1. Games of Complete Information

Static games; solution concept: Nash equilibrium, mixed and pure strategies, maximin principle; extensive forms, backward induction, subgame perfection, repeated games; applications

2. Games of Incomplete Information

Incomplete and imperfect information; static games of incomplete information, solution concepts, Bayes-Nash equilibrium; dynamic games of incomplete information, equilibrium refinements: weak perfect Bayesian equilibrium, sequential equilibrium and trembling hand perfect equilibrium, forward induction; applications

3. Cooperative Games

Elements of cooperative games, transferable utility games, core, Shapley-Value, coalition structure, credibility and core, matching games, examples

4. Bargaining

Bargaining with complete information, bargaining as an extensive game: Rubinstein model, axiomatic bargaining: Nash bargaining solution, relation between strategic and axiomatic models, outside options, inside options, bargaining with incomplete information, one-sided and two-sided uncertainty, private and correlated values, applications

5. Differential Game

Repeated and differential game, commitment and sub-game perfection, solution concept: open and closed loop solutions, Markov-Perfect equilibrium, hierarchical game and Stackleberg solution, applications

Books

- Osborne, M. J., *An Introduction to Game Theory*, Oxford University Press, 2003
- Gibbons, R., *A Primer in Game Theory*, Harvester-Wheatsheaf, 1992
- Fudenberg, D and J. Tirole, *Game Theory*, MIT Press, 1991
- Osborne, M. J. and A. Rubinstein, *A Course in Game Theory*, MIT Press, 1994
- Muthoo, A., *Bargaining Theory with Applications*, Cambridge University Press, 1999

253F: Fixed Income Models

1. Bonds and Interest Rates

Fixed Income markets and products, Zero-coupon bonds, Interest rates, LIBOR rates and ZCB prices, Forward rates, spot rates and short rates, Introduction to continuous time models and arbitrage free pricing of interest rate derivatives

2. Valuation and Numeraire invariance

Numeraire pairs, Change of Numeraire, Forward Prices and forward measure, Interest rate derivatives, coupon-bearing bonds, interest rate swaps and options

3. Term Structure Modelling

Structural relationships, Short rate modeling, Short rate models, Affine short rate models, Calibration of short rate models, multi factor short rate models, Yield Curve models and construction of yield curves

4. Forward Rate Models

Forward rate dynamics under physical measure, Heath Jarrow Morton (HJM) framework, HJM drift condition under different measures, relation to affine yield models

5. Market Models

Black formula compatibility, LIBOR market model, Forward LIBOR and ZCB volatilities, Forward LIBOR term structure model, Implicit forward volatility term structure, implied flat volatility term structure, construction of forward LIBOR processes.

Books

- Bjork T, Arbitrage Theory in Continuous Time, OUP, 3rd ed. 2009
- Filipovic D, Term-structure models, Springer Finance, Springer-Verlag, Berlin 2009

254F: Simulation Techniques in Finance

1. Generation of Random Variables

Introduction and motivation for simulation, generating random variables with different distributions, review of law of large numbers and central limit theorem, speed of convergence, Inversion, Acceptance Rejection Methods

2. Simulation of Stochastic Processes

Simulation of discrete and continuous time Markov chains, simulating queuing models, Random Walks and Poisson Processes

3. Pricing Options

Simulating sample paths of Brownian and Geometric Brownian Motion and Stochastic Differential Equations driven by Brownian motion

4. Variance Reduction

Antithetic method, Example of expected log return of a portfolio, Control Variates, Stratification, Estimation of derivatives

5. Markov Chain Monte Carlo

Simulating from stationary distribution of Markov Chains, Metropolis Hastings Algorithm, Gibbs Sampling

Books

- Soren Asmussen and Peter Glynn, *Stochastic Simulation: Algorithms and Analysis*, Springer-Verlag New York 2007
- Carl Graham and Denis Talay, *Stochastic Simulation and Monte Carlo Methods*, Springer-Verlag Berlin Heidelberg, 2013

255FA: Machine Learning

1. Mathematical Preliminaries

Review of Probability and Statistics, Linear Algebra and Optimization

2. Supervised Learning

Introduction to Machine Learning, Logistic Regression, Gaussian Discriminant Analysis, Support Vector Machines (SVM)

3. Un-supervised Learning

Clustering Algorithms, K-means, Mixture of Gaussians, Expectation Maximization Algorithm, Principal Components Analysis (PCA)

4. Machine Learning Theory

Bias Variance Trade-off, Regularization, Model fitting and Feature selection, Statistical Bounds, Kernel functions

5. Applications of Machine Learning

Volatility estimation, Construction of Volatility Surface, Clustering of assets, Prediction of credit defaults

Books

- Mitchell T, *Machine Learning*, McGraw Hill 1997
- Bishop C.M., *Pattern Recognition and Machine Learning*, Springer 2006

255FB: Numerical Methods in Finance

1. Numerical Linear Algebra

Condition Number, Eigenvalue Computations, SVD, Direct and Iterative methods, Preconditioning, Conjugate gradient method, Householder transformation, Givens rotation, Complete and Incomplete Markets

2. Numerical Solution of Ordinary Differential Equations

Numerical Differentiation and Integration, Runge Kutta methods, Stability, Predictor corrector methods

3. Numerical Solution of Partial differential equations

Finite Difference Methods, Explicit and Implicit Schemes, Stability, Maximum Principle, Von Neumann Stability Analysis

4. Finite Element and Spectral Methods

Weak formulation, various types of elements, natural boundary conditions, Fast Fourier Transform, Spectral methods, Aliasing

5. Applications to Financial Engineering

Solution of nonlinear equations, implied volatility, Checking for Arbitrage, Numerical solution of Black Scholes equation, Tree methods

Books

- Michael T. Heath, *Scientific Computing: An Introductory Survey*, McGraw-Hill, 2002
- Domingo Tavella and Curt Randall, *Pricing Financial Instruments The Finite Difference Method*, Wiley 2000

256FA: Risk Models

1. Decision Theory and Loss Distributions

Prior and posterior distributions; sequential decision procedure and its risk functions; minimax and Bayes criterion; MGFs of loss distributions: gamma, exponential, Pareto and generalized Pareto, Normal and log Normal, Weibull and Burr; deductibles and retention limits; reinsurance; excess of loss insurance; estimation of parameters of failure time using MLE and MOM

2. Bayesian Statistics and Credibility Theory

Bayes theorem; Posterior Distribution; loss function to derive Bayesian estimates of parameters; credibility theory; Bayesian credibility-Poisson/gamma model; Baye's thermo, a Bayesian approach to the updating of claim frequency rates; no claim discount; the credibility premium

3. Rating Systems

Credit rating for mortgages; experience rating system based on claim frequency; delay triangle techniques, chain ladder method, inflation adjustment, development factors, estimating outstanding claims

4. Construction of Risk Models

Models for short term insurance contracts, calculations of MGFs and moments for risk models: the sum of N independent random variables when N has a binomial, Poisson and geometric distributions; compound binomial, Poisson and negative binomial random variables; aggregate claim distribution for short term insurance contracts

5. Ruin for a Risk Model

Ruin for a risk model, aggregate claim process, probability of ruin in infinite/finite and continuous and discrete time and state; relation between different probabilities of ruin; adjustment coefficients and Lundberg's inequality

Books

- Ross, S.M., *Introduction to Probability Models*, Academic Press, seventh edition, 2000
- Hossack, P. and Zehnirith, *Introductory Statistics with Applications in General Insurance*, Cambridge University Press, Second Edition, 2012
- Hogg, R.V. and S.A. Klugman, *Loss Distributions*, Chichester: John Wiley & Sons Limited, 1984

256FB: Stochastic Control in Finance

1. Dynamic Programming in Finance

Merton's optimal investment problem, Merton's problem with transaction costs, Minimal time problem, Target Reachability problem

2. Super Replication under portfolio and Gamma constraints

Solution by duality, Black-Scholes case, Pure upper bound case, Terminal condition, Double Stochastic Integrals, European Digital option

3. Optimal Stopping Problem

Finite and Infinite Horizon optimal stopping, Regularity of the value function, deterministic and stochastic problems

4. Solution of control problems by verification

Optimal portfolio allocation, law of iterated logarithm for double stochastic integrals, verification argument for optimal stopping problems

5. Stochastic Target Problems

Hedging under portfolio constraints, Quantile hedging in Black Scholes model, dynamic programming for stochastic control problems

Books

- Oksendal, Bernt & Agnes Sulem, *Applied Stochastic Control of Jump Diffusions*, 2nd edn, Springer, 2007
- Pham, Huyen, *Continuous-time Stochastic Control and Optimization with Financial Applications*, Springer, 2010

261: Banking and Financial Services

1. Introduction: Overview of Investment Banking

Corporate debt and underwriting procedures securitization and asset backed debt securities, high yield debt investment bankers as traders and market-makers, private placements

2. Innovation and New Products in Fixed Income Instruments

equity issues; valuing an initial public offering, international equity issues, GDR, ADR, convertible securities, innovation and new equity securities, derivative securities

3. Mergers & Acquisitions

Introduction to valuation of companies; the law of mergers & acquisitions, markets for takeover stocks and risk arbitrageurs restructuring: theory of adding value, LBOS, practice of adding value

4. How Investment Bankers Compete

Developing new business, international business, professional standards and management

5. Structure of the Investment Banking

Structure of banking industry, major developments in India, and in international capital markets 1975-1997: legal basis of corporate finance and investment banking

Books

- Bodie, Z., A Kane and A.J. Marcus, *Investments*, Irwin McGraw-Hill, 2005.
- Sharpe, W.F., J.A. Gordon, and J.V. Bailey, *Investments*, Prentice-Hall, 1999.
- Liaw, T. *The Business of Investment Banking*, John-Wiley, 1999.
- Subramanyam, P. *Investment Banking*, TATA McGraw-Hill, 2005

262: Advanced Topics in Economics and Finance

1. Kalman Filters

Introduction to Kalman filters, local level model, local linear trend model, local level model with explanatory variable and intervention variable, confidence interval, filtering and prediction, forecasting

2. Estimation, Testing and Resampling

Smoother and simulation smoother techniques, linear Gaussian state space model, choice of simulation method, Wavelet estimation, goodness of fit tests, tests for cycles, re-sampling in state space models, Bayesian parameter estimation, applications

3. Bootstrap

Introduction, estimation of standard error, parametric bootstraps, number of bootstrap replications, application of bootstrap in regression models, bootstrap pairs, bootstrap residuals, examples, confidence intervals based on bootstrap

4. Hypothesis Testing and Bootstrap Computation

Testing hypothesis with bootstrap, two sample problems, testing multimodality, cross validation, post sampling adjustment, bootstrap bias, bootstrap variance, applications of bootstrap computations

5. Bootstrap Bioequivalence

Confidence intervals, power calculations, Fieller's interval

Books

- Harvey, A., S.J. Koopman, and N. Shephard, *State Space and Unobserved Components Model, Theory and Applications*, Cambridge University Press, 2004
- Efron, B., and R. Tibshirani, *An Introduction to Bootstrap*, Chapman Hall, 1993
- Mooney, C. and R. D. Duval, *Bootstrapping: A Nonparametric Approach to Statistical Inference*, Sage, 1993
- Friedman, J., T. Hastie, and R. Tibshirani, *Additive Logistic Regression- A Statistical View of Boosting*, Annals of Statistics, 2000

263F: Credit Risk Models

1. Liabilities as Contingent Claims

Merton Model with Stochastic interest rates, jumps, Discrete Coupons, Default Barriers, Continuous Coupons and Perpetual Debt

2. Default Boundaries

Leland's Model, Models with Maturity Structure and Debt Service, Credit Scoring using logistic regression and Discriminant Analysis, Survival Analysis methods, Hazard Regression

3. Intensity Modeling

Cox process construction of single jump time, Recovery of Market value, Risk premiums in Intensity models, Interacting intensities, Role of Incomplete information

4. Rating Based Term Structure Models

Markovian Model, Fractional Recovery of Market Value, Class Dependent Recovery, Trouble of using Ratings to Price

5. Credit Risk and Interest Rate Swaps

LIBOR, Valuation with Counterparty Risk, Nonlinearity of Cash flows, Swap Spread versus the Corporate Bond, Pricing the Default Swap, Bond Spreads, Modeling dependent defaults, Asset value correlation and Intensity Correlation

Books

- David Lando, *Credit Risk Modeling Theory and Applications*, Princeton University Press, 2004
- Christian Bluhm, Ludger Overbeck, Christoph Wagner, *An Introduction to Credit Risk Modeling*, Chapman & Hall/CRC 2003
- Bishop C.M., *Pattern Recognition and Machine Learning*, Springer 2006

264F: Computational Finance

1. Estimation of Volatility

ARCH, GARCH modeling approaches, Value at Risk (VAR), Volatility estimators

2. Optimization Methods

Mean Variance Risk Adjusted Utility Formulation, Robust Sharpe Ratio problem, Portfolio Optimization, Risk Budget problem, Optimization Algorithms, KKT conditions

3. Computational Statistics

Splines and Polynomial Basis, Normality Testing and Weighted Regression, Autocorrelation models

4. Rare Event Simulation

Motivation and Challenges, Importance Sampling, Likelihood Ratio for Stochastic Models, Efficiency for rare event simulation, Applications

5. Fractals

Definition and motivation of Fractals, Notion of Scaling and Self-similarity, Fractal dimension, Julia and Mandelbrot sets

Books

- Bjork T, *Arbitrage Theory in Continuous Time*, OUP, 3rd ed. 2009
- Gianluco Fusai and Andrea Roncoroni, *Implementing Models in Quantitative Finance: Methods and Cases*, Springer Finance, 2008
- Paul Glasserman, *Monte Carlo Methods in Financial Engineering*, Springer, 2004
- Benoit B. Mandelbrot, *The Fractal Geometry of Nature*, Freeman and Company, 1983

265FA: Deep Learning

1. Mathematics for Deep Learning

Linear Algebra, Numerical Methods, Probability and Statistics

2. Neural Networks

Multi layer neural networks, Introduction to the Feed forward and Back propagation algorithm

3. Deep Learning Basics

Deep Feedforward Networks, Regularized Deep learning, Training Deep networks, convolutional networks, recurrent and recursive nets, Tensor flow

4. Advanced methods in Deep learning

Linear Factor Models, Autoencoders, probabilistic models for deep learning, Partition function, Approximate inference, deep generative models

5. Applications

Deep learning applications in image and video processing, biological data, text data, medicine, Natural language processing

Books

- Ian Goodfellow, Yoshua Bengio and Aaron Courville. *Deep Learning*, MIT press, 2016
- Michael A. Nielsen, *Neural Network and Deep Learning*, Determination Press, 2015

265FB: Statistical and Empirical Methods in Finance

1. The Random Character of Stock Market Prices

Unconditional distributions, conditional distributions, conditional means - mean reversion, conditional means - instrumental variable, conditional variances, relationship between means and variances, stock prices and volume

2. Efficient Markets Hypothesis

Various approaches to efficient market hypothesis, variance bounds tests, anomalies, cross-asset relationships, over-reaction hypothesis

3. Event Study Methodology

Various approaches to event study methodologies, measurement abnormal returns and test statistics

4. Pricing Options, Futures and Other Derivative Assets

Option pricing models, Black and Scholes model, real option pricing, futures and forward prices, pricing of other derivatives, numerical solution for derivative pricing.

5. Fixed Income Securities

Portfolio performance evaluation, term structure of interest rates, pricing debt with default risk, immunization strategies.

Books

- Campbell, J. Y. Lo, A. W. and Mackinlay, A. C. *The Econometrics of Financial Markets*, Princeton University Press, 1997
- Brooks, C. *Introductory Econometrics for Finance*, Cambridge University Press, 2002.
- Joel Hasbrouck, *Empirical Market Microstructure*, Oxford University Press, 2007

266FA: Algorithmic and High Frequency Trading

1. Algorithmic Trading

Example of Algorithmic trading. Exchanges, Quote and Order driven markets, Evolution of markets, Limit order Book, Order Imbalance, High frequency data

2. Optimal Betting and Execution Strategies

Optimal Execution and Liquidation and their impact, Optimal acquisition with temporary impact, inventory path formulation, Permanent price, Quantitative investment and trading framework

3. Order Flow

Temporary and Permanent Impact, Parameters of the market impact model, concept of value function, Weightage average price, volume traded, Optimal liquidation speed and its interpretation, Strategy performance,

4. Dark Pools

Full Execution in Dark Pools, Riccati ODE and its solution, Optimal liquidation and inventory model, simulations and back-testing strategies, Performance measurement

5. Market Making

Mathematical formulation of Market Maker's control problem, Symmetric fill probability, Optimal postings, Mean reversion in inventory, Market Making with no terminal penalty

Books

- Cartea A, Jaimungal S and Penalva J *Algorithmic and High-Frequency Trading*, Cambridge University Press 2015
- Chan E *Algorithmic Trading: Winning Strategies and Their Rationale*, Wiley Trading 2013

266FB: Advanced Topics in Financial Engineering

The topics of this course vary from year to year and are given by visiting experts from industry or abroad. The topics are of current interest in industry or academia. They could, for example range from computational problems in financial engineering or they could be more mathematical involving techniques from measure theory, large deviations and advanced statistics

1. Measure Theory

Applications of Measure Theory to problems in Finance

2. Large Deviations

Varadhan's, Sanov's Theorems, Extreme Value Theory Application to Finance

3. Interest Rate Models

Various Stochastic techniques to model Interest rates

4. Advanced Stochastic Processes

Infinitely Divisible Distributions, Heavy Tailed Processes, Levy Processes, Markov Chains in General State Space

5. Advanced Scientific Computing

Algorithms for large sparse matrices, Perturbation Techniques, Spectral Methods, Inverse Problems

Books

- Amir Dembo and O. Zeitouni, Large deviations techniques and applications, Springer, 1998
- Patrick Billingsley, Probability and measure, third edition, John Wiley and Sons, 1995
- E. L. Lehmann, Testing Statistical Hypothesis, 2nd Edition Springer, 1997
- René Carmona and Mike Tehranchi, Interest Rate Models: an Infinite Dimensional Stochastic Analysis Perspective. Springer Finance (2006)

Second Year Research and Business Analytics Courses

241: Financial Markets, Money and Regulatory Mechanisms

1. Financial Regulation

Asymmetric information and the rationale for regulation of securities market, financial market fragility, review of regulatory policies in US, UK, Japan and Asian emerging markets.

2. Indian Capital Markets

Structure of primary and secondary markets, dematerialization, depositories, credit rating of financial instruments, financial institutions: development financial institutions, non-banking financial intermediaries, LIC of India and UTI, mutual funds, venture capital, bank-assurance

3. Financial Sector Reforms

Indian capital market integration, foreign institutional investors, impact of exchange rate variability in a liberalized regime, Issues of GDRs, ADRs

4. Banking Regulation

Banking regulation act 1949, financial stability, basics of public debt management issue of government securities conduct of monetary policy- role of gilt market

5. Bank of International Settlement

Capital adequacy regulations Basel accord I & II. accounting standard, disclosure and relationship banking mark-to-market accounting, liquidity risk and contagion market discipline: issues and evidence market discipline in emerging economies: beyond bank fundamentals

Books

- Houthakker, H.S. and Williamson, P.J. *The Economics of Financial Markets*, Oxford University Press, 1996.
- Krugman, P. and Obstfeld, M. *International Economics, Theory and Policy*, sixth edition, Addison - Wesley, 2003.
- Herring, R. and Litan, R.E. *Financial Regulation in the Global Economy*, Brookings Institution Press, 1995.
- Howells, P. and Bain, K. *Financial Markets and Institutions*, Fifth Edition, Pearson Education, 2007

242: Introduction to Financial Econometrics

1. Simple Regression Analysis

Specification of the two variable regression model, Ordinary Least Squares estimation, Assumptions, BLUE property, General and confidence approach to hypothesis testing, partial effects and elasticity, goodness of fit, model evaluation, ANOVA

2. Multiple Regression Analysis

Motivation, Assumptions and OLS estimation, Interpretation of OLS estimation, Goodness of fit, matrix approach to linear regression models, testing of hypothesis for a single parameter, for linear combination of parameters, for multiple linear restrictions. ,

3. Violation of CLRM Assumptions

Detection and remedial measures of multicollinearity, heteroskedasticity (WLS, MLE), and autocorrelation (GLS), Specification error (omitted variable, inclusion of irrelevant variables, measurement error in dependent and independent variables)

4. Extension of Linear Regressions

Choice of function forms: linear, log-linear, log-log, quadratic functional forms, Box-Cox test, models with quadratics and interaction terms.

5. Dummy Variables

Regression on dummy (qualitative) variables with two categories, with more than two categories- intercept shifters, dummy variable trap, interaction of two categorical variables, interaction of categorical and continuous (quantitative) variables- slope shifters, piecewise linear regression model, Chow test for cross-section data and for time-series data (test structural stability of regression models)

Books

- Gujarati and Porter, *Basic Econometrics*, Fifth Edition, McGraw Hill/Irwin, 2009.
- Greene, William H. *Econometric Analysis*. 6th Edition, Prentice Hall. 2008.
- Johnston J. and DiNardo, J. *Econometric Methods*. 4th Ed. McGraw-Hill 1997. Greene

243D : Algorithms for Big Data

1. Algorithms for Matrices

Approximate Matrix Multiplication, Randomized Least square Approximation, Low Rank Matrix Approximation

2. Large Data Set Algorithms

Introduction to MapReduce, Association rules, Frequent itemset, Nearest Neighbor search, mining data streams

3. Dimensionality Reduction

Singular Value Decomposition, CUR matrix approximation, Clustering Algorithms, Recommendation Systems

4. Page Rank

Stationary Distribution of Markov Chain, Perron Frobenius Theorem, Google's page rank algorithm, Hubs and Authorities

5. Information Retrieval

Index construction and compression, term frequency and weighting, vector space model, Probabilistic information retrieval, Boolean retrieval

Books

- C. Manning, P. Raghavan and H. Schütze, *Introduction to Information Retrieval*, Cambridge University Press, 2008
- Jure Leskovec, Anand Rajaraman and Jeff Ullman, *Mining of Massive Datasets*, 2nd Edition, Cambridge University Press, 2014
- Michael Mahoney, *Randomized Algorithms for Matrices and Data, Foundations and Trends in Machine Learning*, Vol. 3, No. 2, pages 123-224, 2011

244D: Artificial Intelligence

1. Problem Solving by Searching

Searching for problem solutions, Heuristic Search, Alpha-Beta Pruning, MIN-MAX strategies, A* Algorithm

2. Propositional Logic

Introduction to Propositional Logic, Theorem proving using propositional logic, Agents, Model Checking

3. First Order Logic

Syntax and Semantics of First Order Logic, Knowledge Representation, Comparing Propositional vs First Order logic, Inference, Resolution Incompleteness theorems, Unification

4. Constraint Satisfaction Problem

Introduction to Constraint Satisfaction Problem (CSP), Inference in CSP, Backtracking search for CSP, Search domain reduction, visual object recognition

5. Applications

Planning in Nondeterministic domains, Knowledge Representation, Acting under Uncertainty, HMMs, Natural Language Processing, Complex Decision Making

Books

- Stuart Russell and Peter Norvig, *Artificial Intelligence A Modern Approach*, Prentice hall series in Artificial Intelligence, 3rd Edition 2010
- Nils J Nilsson, *The quest for Artificial Intelligence: A history of Ideas and Achievements*, Cambridge University Press 2009

245DA: Pricing of Derivatives and Options

1. Pricing of Options

Law of One Price, Concept of Replicating portfolio, Complete and In-complete markets, AD securities

2. Discrete Time Financial Market Model

Binomial Model, Risk Neutral Probability, Martingale Measure, Conditions for no Arbitrage

3. Continuous Time Financial Market Model

Pricing by the probabilistic approach, Feynman Kac Approach, Self Financing Portfolio

4. Black-Scholes (BS) Model

Derivation and Solution of the BS PDE, Hedging, Greeks, Implied Volatility, Pricing European Options, Call, Put

5. American and Exotic Options

Pricing American Options, Path dependent options, Asian Options, Multi-stage Options, Pricing Barrier, Lookback and Exchange options

Books

- Hull, J. *Options, futures, and other derivatives*. Upper Saddle River, N.J: Pearson/Prentice Hall. 2006.
- Paul Wilmott, Sam Howison, Jeff Dewynne *The Mathematics of Financial Derivatives*; Cambridge University Press, 1995.

245DB: Cryptography

1. Introduction to Cryptography

History of Cryptography, stream cipher, one time pad, Attacks, , Secure ciphers, PRG and Semantic security

2. Block Ciphers

Basics of block ciphers, the data encryption standard, attacks on block ciphers, AES block cipher, PRP and PRF, one time key, many time key

3. Message Integrity

Introduction to message integrity, CBC-MAC, Collision resistant Hashing, Merkle-Damgard, SHA, HMAC, Authenticated encryption, Session set up using a key distribution center

4. Public key Cryptography

Arithmetic modulo primes, Key exchange protocols, Diffie-Hellman, Discrete log problem, ElGamal encryption, Trapdoor permutations, RSA

5. Digital Signatures

Signing using RSA, Hash based signatures, certificates, password protocols, salts, authenticated key exchange SSL/TLS session setup

Books

- J Katz and Y Lindell, *Introduction to Modern Cryptography*, Chapman & Hall/CRC Press, 2nd Edition 2014
- Carmit Hazay and Yehuda Lindell, *Efficient Secure Two-Party Protocols : Techniques and Constructions*, Springer-Verlag 2010

246DA: Information Theory

1. Entropy

Introduction to Entropy, Examples where it appears, Joint Entropy, Conditional entropy, Mutual information, Chain rule, KL divergence

2. Lossless Data Compression

Asymptotic Equipartition property, Data Compression, Entropy of Stationary Markov Chains, Codes, Kraft's Inequality

3. Data Communication

Communication over noisy channels and channel capacity, coding theorem, Gaussian Channel and information measures

4. Lossy Compression

Introduction to lossy compression and Rate distortion theory, Joint Typicality Lemma, Geometric interpretation and examples, joint source channel coding, Channel separation theorem

5. Method of Types

Sanov's theorem, Shannon Games, HMMs, Maximum entropy principle and Maximum conditional entropy, Applications to Statistics and Machine learning

Books

- T.M. Cover and J.A. Thomas, *Elements of Information Theory*, John Wiley, 1991
- R.B. Ash, *Information Theory*, Dover, 1990

246DB: Advanced Analytical Models for Decision Making

1. Revenue Management and Pricing Models

Overview, Demand Functions, Solving the basic pricing models with capacity constraints. Customer segmentation, Pricing to multiple segments, Pricing under uncertainty, Models for Perishable Assets, Seasonal demand, Mark up/down, Price Trajectory, Dynamic Pricing.

2. Queuing Models

Waiting line analysis, Elements and Characteristics of a waiting line system, Queue discipline, Finite and Infinite source, Single server, Multiple server waiting line, Measures of waiting-line performance, Monte Carlo process, Simulation of a Queuing system

3. Decision Theory

Decision processes, decision making under certainty, uncertainty and risk. Decision criteria (Maximin, Maximax, Laplace, Minimax regret, Hurwicz) Decision tree analysis, Posterior probability, Expected value of perfect information, Sensitivity analysis

4. Transportation Models

Location decisions and models, Gravity location models Transportation model, Assignment model, Transshipment problem, Distribution network design, Network optimization models

5. Applications

Predictive analytics and Decision models for data driven real world applications, Application of Mathematical models for designing strategies, supporting policy making, business decisions and evaluating performance and risk, Analytical case studies in Healthcare, E commerce, Internet, Retail, Airlines, Finance etc.

Books:

- Dimitris Bertsimas and Robert Freund, *Data, Models, and Decisions: The fundamentals of Management Science*, South Western College Publishing, 2000
- Robert Phillips, *Pricing and Revenue Optimization*, Stanford University Press, 2004
- D Gross, J.F. Shortle, J.M. Thompson and C.M. Harris, *Fundamentals of Queueing Theory*, 4th Edition, Hoboken, Wiley, 2008
- Averill M. Law and W. David Kelton, *Simulation Modeling and Analysis*, 2nd Edition, McGraw-Hill, 1991

251: Financial Time Series Analysis

1. Univariate Stationary Time-series Models

Introduction to stochastic process, stationary processes, Wold representation theorem, autocovariance functions, autocorrelation and partial autocorrelation, autoregressive and moving average models, conditions for stationary and invertible process, Box-Jenkins approach, forecasting.

2. Univariate Nonstationary processes

Nonstationary process, deterministic and stochastic trends, Integrated process and random walk, random walk with drift, Unit root process-, test for unit root- Dicky Fuller tests, , ARIMA process. Fractional integrated process

3. Modeling volatility clustering

Volatility-Meaning and measurement, Volatility clustering, Econometric models of volatility, ARCH model, GARCH model and its various extensions, testing for ARCH/GARCH effects

4. Multivariate Stationary and Non-stationary processes

Vector autoregressive model, Granger causality, impulse response function, variance decomposition

5. Multivariate Non-stationary processes:

Introduction to cointegration, testing for cointegration: Single-equation approaches: Engle Granger method, Johansen test for cointegration, Vector error correction model

Books

- Brooks, C., *Introductory Econometrics for Finance*, 3rd Edition, Cambridge University Press, 2014.
- Enders, W., *Applied Econometric Time Series*, second edition, John Wiley and Sons, 2006.
- Hamilton, J. D., *Time Series Analysis*, Princeton University Press, 1994.
- Johnston J. and DiNardo, J. *Econometric Methods*. 4th Ed. McGraw-Hill 1997.
- Maddala G.S. and In-Moo Kim, *Unit Roots, Cointegration, and Structural Change*, 1998.

252: Game Theory

1. Games of Complete Information

Static games; solution concept: Nash equilibrium, mixed and pure strategies, maximin principle; extensive forms, backward induction, subgame perfection, repeated games; applications

2. Games of Incomplete Information

Incomplete and imperfect information; static games of incomplete information, solution concepts, Bayes-Nash equilibrium; dynamic games of incomplete information, equilibrium refinements: weak perfect Bayesian equilibrium, sequential equilibrium and trembling hand perfect equilibrium, forward induction; applications

3. Cooperative Games

Elements of cooperative games, transferable utility games, core, Shapley-Value, coalition structure, credibility and core, matching games, examples

4. Bargaining

Bargaining with complete information, bargaining as an extensive game: Rubinstein model, axiomatic bargaining: Nash bargaining solution, relation between strategic and axiomatic models, outside options, inside options, bargaining with incomplete information, one-sided and two-sided uncertainty, private and correlated values, applications

5. Differential Game

Repeated and differential game, commitment and sub-game perfection, solution concept: open and closed loop solutions, Markov-Perfect equilibrium, hierarchical game and Stackleberg solution, applications

Books

- Osborne, M. J., *An Introduction to Game Theory*, Oxford University Press, 2003
- Gibbons, R., *A Primer in Game Theory*, Harvester-Wheatsheaf, 1992
- Fudenberg, D and J. Tirole, *Game Theory*, MIT Press, 1991
- Osborne, M. J. and A. Rubinstein, *A Course in Game Theory*, MIT Press, 1994
- Muthoo, A., *Bargaining Theory with Applications*, Cambridge University Press, 1999

253D: Machine Learning

1. Mathematical Preliminaries

Review of Probability and Statistics, Linear Algebra and Optimization

2. Supervised Learning

Introduction to Machine Learning, Logistic Regression, Gaussian Discriminant Analysis, Support Vector Machines (SVM)

3. Un-supervised Learning

Clustering Algorithms, K-means, Mixture of Gaussians, Expectation Maximization Algorithm, Principal Components Analysis (PCA)

4. Machine Learning Theory

Bias Variance Trade-off, Regularization, Model fitting and Feature selection, Statistical Bounds, Kernel functions

5. Applications of Machine Learning

Volatility estimation, Construction of Volatility Surface, Clustering of assets, Prediction of credit defaults

Books

- Mitchell T, *Machine Learning*, McGraw Hill 1997
- Bishop C.M., *Pattern Recognition and Machine Learning*, Springer 2006

254D: Artificial Neural Networks

1. Architecture

Introduction to Neural Networks and their History, Biological Neurons and Neural Networks, Artificial neurons, Networks of Artificial Neurons

2. Data Processing

Hebbian Learning, Gradient Descent Learning, Generalized Delta Rule, Practical Considerations

3. Back Propagation

Back Propagation, Learning in Multi-Layer Perceptrons, Learning with Momentum, Conjugate Gradient Learning

4. Performance Management

Bias and Variance, under-Fitting and Over-Fitting, improving generalisation

5. Applications

Practical applications of neural networks in analytics

Books

- Smith, M., *Neural Networks for Statistical Modeling*, Van Nostrand Reinhold, 1993
- Gurney, K., *An Introduction to Neural Networks*, Routledge, 1997
- McNelis, P.D., *Neural Networks in Finance*, Academic Press, 2005
- Rothman, P., *Nonlinear Time Series Analysis of Economic and Financial Data*, Kluwer Academic Publishers, 1999

255DA: Simulation Techniques in Finance

- **Generation of Random Variables**
Introduction and motivation for simulation, generating random variables with different distributions, review of law of large numbers and central limit theorem, speed of convergence, Inversion, Acceptance Rejection Methods
- 2. **Simulation of Stochastic Processes**
Simulation of discrete and continuous time Markov chains, simulating queuing models, Random Walks and Poisson Processes,
- 3. **Pricing Options**
Simulating sample paths of Brownian and Geometric Brownian Motion and Stochastic Differential Equations driven by Brownian motion
- 4. **Variance Reduction**
Antithetic method, Example of expected log return of a portfolio, Control Variates, Stratification, Estimation of derivatives
- 5. **Markov Chain Monte Carlo**
Simulating from stationary distribution of Markov Chains, Metropolis Hastings Algorithm, Gibbs Sampling

Books

- Soren Asmussen and Peter Glynn., *Stochastic Simulation*, Springer-Verlag 2007
- Carl Graham and Denis Talay., *Simulation and Monte Carlo Methods*, Springer-Verlag 2013

255DB: Graphical Models

1. Over View of Graphical Models

Review of conditional probability, Bayesian Networks, Distributions, Factors, Semantics and Factorization, flow of probabilistic influence, conditional independence,

2. Different Models

Template and Temporal models, HMM. Plate models, computing on data, control statement, Vectorization, Structured CPD's, Causal influence

3. Markov Networks

HMM's, Pairwise Markov Networks, Gibbs distribution, Conditional Random fields, concept of independence in Markov networks, I-maps and perfect maps

4. Knowledge Engineering

Introduction to conditional probability queries, MAP inference, variable elimination algorithm and its complexity, Graph theoretic perspective

5. Belief Propagation

Cluster graphs, Clique Tree algorithm, Max Sum message passing, sampling graphical models, Markov chain Monte-Carlo, Regularization, Model selection, Maximum Likelihood estimation for Bayesian Networks

Books

- Daphne Koller and Nir Friedman, *Probabilistic Graphical Models : Principles and Techniques*, MIT Press, 2010
- Adnan Darwiche, *Modeling and Reasoning with Bayesian Networks*, Cambridge University Press, 2009
- David Barber, *Bayesian Reasoning and Machine Learning*, Cambridge University Press, 2012

256DA: Robotics

1. Kinematics and Dynamics

Introduction to velocity, acceleration, force, frames of reference, work and energy, equations of motion and conservation laws, Rotation, torque, Euler Angles

2. Spatial Descriptions

Positions, Orientations and Frames, Changing descriptions from frame to frame, Rotation matrix, Operators for translation and rotation

3. Manipulator Kinematics

Link connection description, convention for fixing frames to links, concept of the actuator and joint space, DH parameters

4. Inverse Manipulator Kinematics and Jacobians

Notion of manipulator subspace, Algebraic and Peper's solution, examples of inverse manipulator kinematics, Time varying position and orientation, Angular Velocity, Velocity propagation from link to link, Jacobians and singularities, computational aspects

5. Dynamics of the Manipulator and Trajectory generation

Newton's and Euler's equation, Mass distribution, Inertia Tensor, Lagrangian formulation of manipulator dynamics, joint space schemes and geometric problems with Cartesian paths

Books

- John. J. Craig, *Introduction to Robotics Mechanics and Control*, 3rd Edition, Pearson Prentice Hall, 2005
- R. Paul, *Robotic Manipulators*, MIT Press, 1981

256DB: Bioinformatics

1. Introduction to Molecular Biology

DNA, RNA and Proteins, Cell, Basics of Transcription, Translation, Genes, Mitosis, Meiosis, Codons, Amino Acids, Genomes, Protein Structure

2. Genomics

Alignment algorithms for sequence alignment, Local Alignment Blast algorithm and its statistics, Global alignment for protein sequences PAM and BLOSUM matrices, comparative genomics

3. Genome Sequencing

Short read alignment and mapping, DNA-Protein interactions, gene regulation, identification of sequence motifs using Gibbs sampling, Hidden Markov Models to identify genes, CpG islands and other genomic signatures

4. RNA and Proteins

RNA sequence analysis and secondary structure prediction, primary, secondary, tertiary and quaternary structure of proteins, various algorithms to predict protein structure

5. Biological Networks and Computational Genetics

Modeling Metabolic Networks, Flux Balance analysis, Gene regulatory networks, protein interaction networks, SNP's and Haplotypes

Books

- Uri Alon, *An introduction to Systems Biology: Design principles of Biological Circuits*, Chapman and Hall 2013
- Dan Gusfield, *Algorithms on Strings, Trees and Sequences*, Cambridge University Press, 1997

261: Banking and Financial Services

1. Introduction: Overview of Investment Banking

Corporate debt and underwriting procedures securitization and asset backed debt securities, high yield debt investment bankers as traders and market-makers, private placements

2. Innovation and New Products in Fixed Income Instruments

equity issues; valuing an initial public offering, international equity issues, GDR, ADR, convertible securities, innovation and new equity securities, derivative securities

3. Mergers & Acquisitions

Introduction to valuation of companies; the law of mergers & acquisitions, markets for takeover stocks and risk arbitrageurs restructuring: theory of adding value, LBOS, practice of adding value

4. How Investment Bankers Compete

Developing new business, international business, professional standards and management

5. Structure of the Investment Banking

Structure of banking industry, major developments in India, and in international capital markets 1975-1997: legal basis of corporate finance and investment banking

Books

- Bodie, Z., A Kane and A.J. Marcus, *Investments*, Irwin McGraw-Hill, 2005.
- Sharpe, W.F., J.A. Gordon, and J.V. Bailey, *Investments*, Prentice-Hall, 1999.
- Liaw, T. *The Business of Investment Banking*, John-Wiley, 1999.
- Subramanyam, P. *Investment Banking*, TATA McGraw-Hill, 2005

262: Advanced Topics in Economics and Finance

1. Kalman Filters

Introduction to Kalman filters, local level model, local linear trend model, local level model with explanatory variable and intervention variable, confidence interval, filtering and prediction, forecasting

2. Estimation, Testing and Resampling

Smoother and simulation smoother techniques, linear Gaussian state space model, choice of simulation method, Wavelet estimation, goodness of fit tests, tests for cycles, re-sampling in state space models, Bayesian parameter estimation, applications

3. Bootstrap

Introduction, estimation of standard error, parametric bootstraps, number of bootstrap replications, application of bootstrap in regression models, bootstrap pairs, bootstrap residuals, examples, confidence intervals based on bootstrap

4. Hypothesis Testing and Bootstrap Computation

Testing hypothesis with bootstrap, two sample problems, testing multimodality, cross validation, post sampling adjustment, bootstrap bias, bootstrap variance, applications of bootstrap computations

5. Bootstrap Bioequivalence

Confidence intervals, power calculations, Fieller's interval

Books

- Harvey, A., S.J. Koopman, and N. Shephard, *State Space and Unobserved Components Model, Theory and Applications*, Cambridge University Press, 2004
- Efron, B., and R. Tibshirani, *An Introduction to Bootstrap*, Chapman Hall, 1993
- Mooney, C. and R. D. Duval, *Bootstrapping: A Nonparametric Approach to Statistical Inference*, Sage, 1993
- Friedman, J., T. Hastie, and R. Tibshirani, *Additive Logistic Regression- A Statistical View of Boosting*, Annals of Statistics, 2000

263D: Reinforcement Learning

1. Motivation and Introduction

Examples and History of Reinforcement Learning

2. Markov Decision Process

Review of Markov Chains, State Space, Actions, Goals, Rewards and Returns, Policy and Value functions

3. Dynamic Programming

Bellman's principle of Optimality, Policy prediction and Improvement, Policy and Value Iteration, Examples and Applications

4. Monte Carlo Methods

Monte Carlo Prediction and estimation of Action Values, Monte Carlo Control, Importance Sampling to predict policy

5. Approximate Methods

Value function approximation, Stochastic Gradient Methods, Feature construction for linear methods, least squares

Books

- Richard S Sutton and Andrew G Barto, *Reinforcement Learning: An Introduction*, MIT Press 2nd edition 2017
- Csaba Szepesvari, *Algorithms for Reinforcement Learning*, Morgan and Claypool Publishers

264D: Deep Learning

1. Mathematics for Deep Learning

Linear Algebra, Numerical Methods, Probability and Statistics

2. Neural Networks

Multi layer neural networks, Introduction to the Feed forward and Back propagation algorithm

3. Deep Learning Basics

Deep Feedforward Networks, Regularized Deep learning, Training Deep networks, convolutional networks, recurrent and recursive nets, Tensor flow

4. Advanced methods in Deep learning

Linear Factor Models, Autoencoders, probabilistic models for deep learning, Partition function, Approximate inference, deep generative models

5. Applications

Deep learning applications in image and video processing, biological data, text data, medicine, Natural language processing

Books

- Ian Goodfellow, Yoshua Bengio and Aaron Courville. *Deep Learning*, MIT press, 2016
- Michael A. Nielsen, *Neural Network and Deep Learning*, Determination Press, 2015

265DA: Computational Finance

1. Estimation of Volatility

ARCH, GARCH modeling approaches, Value at Risk (VAR), Volatility estimators

2. Optimization Methods

Mean Variance Risk Adjusted Utility Formulation, Robust Sharpe Ratio problem, Portfolio Optimization, Risk Budget problem, Optimization Algorithms, KKT conditions

3. Computational Statistics

Splines and Polynomial Basis, Normality Testing and Weighted Regression, Autocorrelation models

4. Rare Event Simulation

Motivation and Challenges, Importance Sampling, Likelihood Ratio for Stochastic Models, Efficiency for rare event simulation, Applications

5. Fractals

Definition and motivation of Fractals, Notion of Scaling and Self-similarity, Fractal dimension, Julia and Mandelbrot sets

Books

- Bjork T, *Arbitrage Theory in Continuous Time*, OUP, 3rd ed. 2009
- Gianluco Fusai and Andrea Roncoroni, *Implementing Models in Quantitative Finance: Methods and Cases*, Springer Finance, 2008
- Paul Glasserman, *Monte Carlo Methods in Financial Engineering*, Springer, 2004
- Benoit B. Mandelbrot, *The Fractal Geometry of Nature*, Freeman and Company, 1983

265DB: Mechanism Design

1. **Mechanism design introduction**
Social Choice, Mechanisms with money, Revelation principle, transferable utility, implementation of mechanism design as an optimization problem
2. **Auctions**
Ascending auctions, Clinching auctions, Vickery auction, sealed bid first price auction, The All pay auction, English and Dutch auction
3. **Learning and Equilibria**
Information model, Regret minimization and game theory, convergence of regret minimizing strategies in routing games
4. **Valuations**
Unit demand valuations, Gross substitutes, Submodular valuations, Revenue maximization
5. **Profit Maximization and various algorithms**
Bayesian optimal mechanism design, prior free optimal mechanism design, distributed algorithmic mechanism design, interdomain routing, online mechanisms and Bayesian implementations

Books

- Jason D Hartline, *Mechanism Design and Approximation*, 2014
- Tilman Borgers, *An Introduction to the theory of Mechanism Design*, Oxford University Press, 2014
- Noam Nisan, Tim Roughgarden, Eva Tardos and Vijay V Vazirani, *Algorithmic Game Theory*, Cambridge University Press, 2007

266DA: Quantum Computing

1. Classical Computation

Turing Machine, Church-Turing Thesis, Circuit model of Computation, Computational Complexity, Energy and Information

2. Quantum Mechanics

Stern Gerlach and Young's Double slit experiments, Linear Vector space, postulates of quantum mechanics, matrix formulation, Entanglement, EPR paradox, Bell's Inequalities

3. Quantum Computation

The Qbit, Bloch sphere, measurement of state of qbit, Bell basis, rotations of Bloch Sphere, circuit model of quantum computation, Function evaluation, Quantum adder

4. Quantum Algorithms

Deutsch-Jozsa algorithm, Quantum Search algorithms, Grover's algorithm, Quantum Fourier Transform, Shor's algorithm

5. Adiabatic Quantum Computing

Challenges of Quantum Computing, Noise and Decoherence, Quantum Adiabatic Optimization

Books

- Michael A. Nielsen and Isaac L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2010
- P Kok and B Lovett, *Introduction to Optical Quantum Information Processing*, Cambridge University Press, 2010
- Scott Aaronson, *Quantum Computing since Democritus*, Cambridge University Press, 2013

266DB: Advanced Topics in Data Science

The topics of this course vary from year to year and are given by visiting experts from industry or abroad. The topics are of current interest in industry or academia. They could, for example range from computational advertising, static analysis of programs, applications of deep learning in medicine, image and video processing, natural language processing, new algorithms to handle big data, advances in cryptography and data privacy.

1. Static Analysis of Programs

Logic, Proving Invariants, Karr's Analysis, Polyhedral Analysis

2. Cryptography and Data Privacy

Elliptic Curve Cryptography, Differential Privacy

3. Image Processing

Image Representation, Pixels, Detection and Feature Extraction, Enhancement, Transforms, Image Compression

4. Video Processing

Frames, Sampling, Motion Analysis, Video Compression

5. Natural Language Processing

Word Vectors, Dependency Parsing, Application of Deep Learning to Natural Language Processing

Books

- Aaron R. Bradley and Zohar Manna, The Calculus of Computation: Decision Procedures with Applications to Verification, Springer 2007
- William K. Pratt, Introduction to Digital Image Processing, CRC Press, 2013
- Yao Wang, Joern Ostermann, and Ya-Qin Zhang, Video Processing and Communications, Prentice Hall, 2002
- Jurafsky, David, and James H. Martin. Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition. Upper Saddle River, NJ: Prentice-Hall, 2000
- Manning, Christopher D., and Hinrich Schütze. Foundations of Statistical Natural Language Processing. Cambridge, MA: MIT Press, 1999
- L.C. Washington, Elliptic Curves : Number Theory and Cryptography, 2 nd Edition, CRC Press, 2008