The Two year PGDM program at MSE offers two specializations, namely Finance, Research and Business Analytics. The programs are divided into six terms with classroom 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

<table>
<thead>
<tr>
<th>Term 1</th>
<th>Term 2</th>
<th>Term 3</th>
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</thead>
<tbody>
<tr>
<td>111 Financial Mathematics</td>
<td>121 Basics of Financial Instruments</td>
<td>131 Finance I</td>
</tr>
<tr>
<td>112 Microeconomics</td>
<td>122 Macroeconomics</td>
<td>132 Corporate Finance</td>
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<tr>
<td>113 Operations Research</td>
<td>123 Marketing Concepts</td>
<td>133 Organizational Behavior</td>
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<tr>
<td>114 Introduction to Accounting</td>
<td>124 Management Information Systems and Data Bases</td>
<td>134 Supply Chain Models</td>
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<td>and Management</td>
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<tr>
<td>115 Quantitative Methods</td>
<td>125 Stochastic Process</td>
<td>135 Stochastic Calculus</td>
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<tr>
<td>116 Object Oriented Programming</td>
<td>126 Algorithmic Programming Matlab/R/Python</td>
<td>136 Human Resources</td>
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<td>and Data Structures</td>
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### Table 2: Finance (Financial Engineering FE) Second Year Courses

<table>
<thead>
<tr>
<th>Term 4</th>
<th>Term 5</th>
<th>Term 6</th>
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</thead>
<tbody>
<tr>
<td>242 Introduction to Financial Econometrics</td>
<td>252 Game Theory</td>
<td>262 Advanced Topics in Economics and Finance</td>
</tr>
<tr>
<td>243F Pricing of Derivatives and Options</td>
<td>253F Fixed Income Models</td>
<td>263F Credit Risk Models</td>
</tr>
<tr>
<td>244F Asset Pricing</td>
<td>254F Simulation Techniques in Finance</td>
<td>264F Computational Finance</td>
</tr>
<tr>
<td>246FA Taxation</td>
<td>256FA Risk Models</td>
<td>266FA Algorithmic and High Frequency Trading</td>
</tr>
<tr>
<td>246FB Topics in Behavioral Finance</td>
<td>256FB Stochastic Control in Finance</td>
<td>266FB Advanced Topics in Financial Engineering</td>
</tr>
<tr>
<td>246FA Information Theory</td>
<td>256FA Robotics</td>
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<tr>
<td>246DB Advanced Analytical Models for Decision Making</td>
<td>256DB Bioinformatics</td>
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### Table 3: Research and Business Analytics (Data Science DS) Second Year Courses

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

- Mas-Collel, Whinston and Green, Micro-economic Theory, OUP, 1995
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

1. Financial Statement and Accounting

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

Books
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:
- Chiang, A. C., Fundamental Methods of Mathematical Economics, McGraw-Hill, 1984
- Knut Sydsaeter and Peter J. Hammond, Mathematics for Economic Analysis, Pearson Education Asia, 1995
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
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

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

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

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
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 $Z=\{-2,-1,0,1,2,\ldots\}$ and on $\{0,1,2,\ldots,b\}$; 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’ 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
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**
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
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
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

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

135 Stochastic Calculus

1. 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


5. Further option theory


Books

- Shreve S.E.: Stochastic calculus for finance volume 2-continuous time models, Springer, 2004
136: Human Resources


2. Recruitment and Selection, 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

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
  University Press, 1996.
  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
243F: Pricing of Derivatives and Options

1. Pricing of Options
Law of One Price, Concept of Replicating portfolio, Complete and Incomplete 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
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

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

4. Imperfect marks and liquidity
Limited arbitrage and liquidity supply, liquidity, liquidity risk and expected returns

Books
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
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

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
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 prospective, Allais and Elsberg’s paradoxes, rationality from an economics and evolutionary prospective, 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

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 externals 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
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
• 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 Stackelberg solution, applications

Books
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
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
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)

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
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
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
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
- Pham, Huyen, Continuous-time Stochastic Control and Optimization with Financial Applications, Springer, 2010
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
- 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
Smother 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
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
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
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

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
- 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
• 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
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
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
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
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 steams

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
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**
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


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
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**
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:

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
- 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
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**
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 Propogation**
   Back Propogation, 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**
- Gurney, K., *An Introduction to Neural Networks*, Routledge, 1997
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**
- 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**
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**

256DB: Bioinformatics

1. **Introduction to Molecular Biology**
   DNA, RNA and Proteins, Cell, Basics of Transcription, Translation, Genes, Mitosis, Meosis, 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**
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
- Subramanyam, P. Investment Banking, TATA McGraw-Hill, 2005
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
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**
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**

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**
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
- Paul Glasserman, Monte Carlo Methods in Financial Engineering, Springer, 2004
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  
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
- Yao Wang, Joern Ostermann, and Ya-Qin Zhang, Video Processing and Communications, Prentice Hall, 2002