MS in Computational Finance

Open Electives:

S. No.	Course Name	Credits
1.	Linear algebra and differential equations using Matlab	3
2.	Advanced Probability and Statistics using R	3
3.	Stochastic Processes & Mathematical foundation for Finance	3
4.	Advanced Numerical Analysis/Methods using Matlab/R	3

Core courses for MS in Computational Finance

S. No.	Course Name	Credits
1.	Introductory Finance	3
2.	Statistics and Financial Data Analysis using R	3

Elective courses for MS in Computational Finance

S. No.	Course Name	Credits
1.	Market Microstructure and Trading	3
2.	Asset Pricing and Inefficiency of Market	3
3.	Quantitative Risk Management	3
4.	Financial Derivatives	3
5.	Exotic Derivatives	3
6.	Stochastic volatility	3
7.	Machine Learning using R	3
8.	Game Theory and General Equilibrium Theory	3
9.	Algorithmic Trading using Python	3
10.	Optimization in Finance	3
11.	Operation Research	3

Open Electives

Linear algebra and differential equations: using Matlab

Linear second order ODEs, General ODEs and their classification. Homogeneous linear ODEs, The Principle of Superposition, Linear second order constant coefficient homogeneous ODEs. Non-homogeneous linear ODE, Linear operators, Solving non-homogeneous linear ODEs, Method of undetermined coefficients, Initial and boundary value problems, Degenerate inhomogeneities, Resonance, Equidimensional equations, solving linear constant coefficient second order IVPs Linear algebraic equations, Systems of linear algebraic equations, Gaussian elimination, Solution of general rectangular systems, Matrix Equations, Linear independence, Rank of a matrix, Fundamental theorem for linear systems, Gauss-Jordan method, Matrix Inversion, Eigenvalues and eigenvectors, Diagonalization Systems of differential equations, Linear second order systems, Linear second order scalar ODEs, Higher order linear ODEs, Solution to linear constant coefficient ODE systems, Solution to general linear ODE systems

Text/ Reference Books:
- Strang, Gilbert *Differential Equations and Linear Algebra* , Brooks/Cole
- Marty Golubitsky, Michael Dellnitz, Linear Algebra and Differential Equations Using MATLAB

Advanced Probability and Statistics using R

Combinatorial probability, Independence of events, Conditional probabilities. Random variables, densities, Expectation, Variance and moments, Standard univariate distributions, Independence of random variables, Moment Generating Functions. Tchebychev's inequality and weak law of large numbers, Central Limit Theorem. Marginal Distribution, Conditional Distribution, Conditional expectation, Regression, Correlation, Bivariate normal distribution, Multivariate normal distribution, Copula Models. Introduction to Statistics with examples of its use: Draw random samples, Descriptive statistics, Graphical statistics: Histogram, scatter diagram, Pie diagram, estimates sample moments, sample mean, sample standard deviation. Sampling distributions based on normal populations - t, chi-square and F distributions. Sufficient and minimal sufficient statistics. Point and Interval Estimation, Consistency, Minimum Variance Unbiased Estimator
(statement only). Theory and Methods of Estimation, method of moments estimators, maximum likelihood estimator, consistency and asymptotic normality of Maximum Likelihood Estimation (statement only). Testing of Hypothesis: one sample and two sample tests based on t, chi-square and F distributions. Error probabilities, statistical power of test, p-values, log-likelihood ratio test.
Order statistics, empirical distribution function, Glivenko-Cantelli Theorem (statement only). Nonparametric confidence intervals for Quantiles and confidence bands the distribution function, Chi-square and Kolmogorov Goodness-of-fit Tests, Sign and Signed Rank Test, Wilcoxon-Mann-Whitney tests, Kruskal-Wallis Test Bayesian Methods: Prior distribution, Posterior Distribution, Conjugate Prior for Binomial, Poisson and Normal Distribution, Introduction to Hierarchical Bayesian Models (only normal models).

Text/ Reference Books:
- R. Ash: Basic Probability Theory: John Wiley & Sons (1970).
- P. Billingsley: Probability and Measure, Third Edition, John Wiley & Sons (1995).

Stochastic Processes & Mathematical foundation for Finance

Random sequences. Discrete-time martingales. Random walk. Brownian motion. Conditional Expectations. Markov Chains, Transient probabilities, Stationary probabilities. First Passage times and Stopping times, Reflection Principle. Renewal Theory, renewal equation, limit theorems, Wald's equation. Continuous time martingales. Stochastic integral. Ito formula. Stochastic differential equations. Integration by parts. Stochastic Fubini theorem. Girsanov theorem. Feynman-Kac equation. Large Deviations for i.i.d. Random Variables, Large Deviations Theory for Markov Chains .

Text/ Reference Books:

- Sheldon M. Ross: Stochastic Processes, J. Wiley, New York, 1995. Available at Rutgers Bookstore in Newark and at on-line booksellers.
- Sheldon M. Ross: Introduction to Probability Models, Tenth Edition, Elsevier

Advanced Numerical Analysis/Methods using Matlab/R

Basics of numerical analysis: Binomial models. Principles and methods of Monte Carlo simulation, Finite difference methods for PDE/SDE. Curve constructions: interpolation and smoothing techniques. Simulations of Jump-diffusion processes and integro-differential equations.

Text/ Reference Books:

- Kendall E. Atkinson, An Introduction to Numerical Analysis, Second Edition.
- Hirsa, Ali. Computational methods in finance. Chapman & Hall/CRC Financial Mathematics Series. CRC Press

Core courses for MS in Computational Finance

Introductory Finance

Introduction to Primary securities,Bonds and Equity, Risk free rate of interest, Time value of money, Financial Returns, Net Return, Log Return, Compounding, Annuities. Discounting, Zero Coupon Bond and Regular Bond, Fundamentals of Bond Valuation, Spot Rate Curve, Yield Curve, Clean and Dirty Price of Bond, Term Structure, Pricing Yield Curve with Nelson-Siegel Model, Simulate Bond Prices. Mean-variance portfolio theory. Statistical analysis of portfolios. Efficient Frontier, Value-at-risk, expected shortfall and portfolio risk budgeting. Capital asset pricing model (CAPM). Investment performance measurement and analysis. Binomial Asset

Pricing Model (one and multi-period model), No arbitrage, Q-Martingale, Fundamental Theorem of Asset Pricing, Geometric Brownian Motion as limit of Binomial Asset Pricing Model. Introduction to Derivatives, Futures and Option, European and American Options, Risk-Neutral Pricing, Martingale Representation Theorem, Black-Scholes formula for European Options, Non-path-dependent American Derivatives, Stopping Times, General American Derivatives, American Call Options, Evaluating derivatives via Binomial Option Pricing Models.

Text/ Reference Books:
- Steven E. Shreve, "Stochastic Calculus for Finance I: The Binomial Asset Pricing Model", Springer.
- Steven E. Shreve, "Stochastic Calculus for Finance II: Continuous Time Models", Springer.
- Peters, A. O., and Dong, X., "An Introduction to Mathematical Finance with Applications", Springer.

Statistics and Financial Data Analysis: Using R

Financial time series analysis (Daily closing price), logarithmic return, Covariance matrices, Autoregression, Vector autoregression factor models, Linear regression, robust fits, test statistics, model selection, Principal components analysis, out-of-sample back testing. High frequency data analysis and market microstructure. Multivariate analysis of financial returns including pair trading, Kalman Filtering.

Text/ Reference Books:

- Carmona , René ,Statistical Analysis of Financial Data in R, Springer Publications (2014)
- Ang,Clifford, Analyzing Financial Data and Implementing Financial Models Using R, Springer (2015)

Elective courses for MS in Computational Finance

Market Microstructure and Trading

Introduction to financial markets. Inventory models of trading. Information-based models Models of limit order markets. Empirical market microstructure. The dynamics of financial returns. Market volatility. Technical trading. Arbitrage trading. Back-testing trading. Execution strategies

Text/ Reference Books:

- Bouchaud et al., "How Markets Slowly Digest Changes in Supply and Demand", in Handbook of Financial Markets: Dynamics and Evolution (2009).
- Abergel et al., "Limit Order Books" Cambridge University Press, 2016.

Asset Pricing and Inefficiency of Markets

Preference and utility. Portfolio selection models: expected utility maximization and mean-variance analysis. Capital asset pricing model (CAPM) and arbitrage pricing theory (APT): equilibrium, market portfolio and pricing formula. Introduction to behavioral asset pricing. Forecasting return and risk. Practical portfolio optimization: costs and constraints, robust techniques for estimation and portfolio management.

Text/ Reference Books:
- Cochrane, John, Asset Pricing, Princeton University Press, (2005)
- Shleifer,Andrei, Inefficient Markets: An Introduction to Behavioral Finance, Oxford University Press (2000)

Financial Risk Management

Market Risk, Value-at-Risk, Expected Shortfall, Max Drawdown. Estimating VaR including extreme value theory, copula model and simulation method. Pricing Asian options and Exotic options using Monte Carlo methods. Estimation of Yield-curve and its effect in Bond pricing, Risk in Bond price via interest rate volatility. Credit Risk: Credit Ratings, events of default, default probabilities, Structural and Reduction form models of credit risk, Structural Models: Merton and KMV models, Altman's z-score model, logistic regression and machine learning models for predicting default. Credit derivatives and its limitations. Aggregate risk, Extreme value theory, Operational risk and Insurance analytics, Behavioral Finance and Risk

Text/ Reference Books:
- McNeil, AJ.; Frey, R.; Embrechts, P.: "Quantitative Risk Management: Concepts, Techniques, Tools", Princeton University Press, 2005.
- Mathematics and Statistics for Financial Risk Management, Michael B. Miller (2012)

Financial Derivatives

Diffusion processes, stochastic integration and Ito's formula. Arbitrage theory in continuous time. Black-Scholes equation for pricing of financial instruments. Feynman-Kac's representation formula. Risk neutral valuation and hedging. Complete and incomplete markets. Applications to financial instruments such as options, forwards, futures, swaps, interest rate and currency derivatives.

Text/ Reference Books:
- Kwok, Yue-Kuen, Mathematical Models of Financial Derivatives, Springer (2008)
- W.Kolb,Robert, A. Overdahl,James, Financial Derivatives: Pricing and Risk Management, Wiley Publications (2009)

Exotic Derivatives

Review of standard Black-Scholes theory, change of numeraire techniques. American and Exchange options, Exotic options: Asians, barriers and lookbacks.

Text/ Reference Books:
- Briys,Eric, Bellalah,Mondher, Mai,Huu Minh, de Varenne,François, Options, Futures and Exotic Derivatives: Theory, Application and Practice, Wiley Publications, (1998)
- Bouzoubaa,Mohamed, Osseiran,Adel, Exotic Options and Hybrids: A Guide to Structuring, Pricing and Trading, Wiley Publications (2010)

Stochastic Volatility

Introduction to different notions of volatility: spot, realised and implied volatility; VIX and volatility indices; stylised facts of asset returns; econometric models; deterministic volatility model; local volatility (LV) models and the Dupire equation; stochastic volatility (SV) models: incompleteness and multiplicity of martingale measures, market completion - delta and vega hedging, examples of martingale measures and of SV models, the hedger's perspective and robustness of the BS formula.

Text/ Reference Books:
- J P Fouque, G Papanicolaou and K R Sircar: Derivatives in Financial Markets with Stochastic Volatility, Cambridge University Press 2000.
- J Gatheral: The Volatility Surface: A Practitioner's Guide, Wiley 2006.

Machine Learning in Finance

Introduction to Machine Learning, Assessing Model accuracy, Simple Linear Regression, Multiple Linear Regression, Classification, Logistic Regression, Logistic Regression, Linear Discriminant Analysis, Quadratic Discriminant Analysis, and k-Nearest Neighbours, Cross-Validation and the Bootstrap, Dimension Reduction, Tree-Based Methods, Support Vector Machines, Unsupervised Learning,

Text/ Reference Books:
- Gareth,James, Witten,Daniela, Hastie,Trevor, Tibshirani,Robert, Introduction to Statistical Learning with Applications in R, Springer(2009)
- Shai,Shalev-Shwartz, ,Ben-David,Shai Understanding Machine Learning, Cambridge University Press (2014)

Game Theory

Introduction to Game Theory, Simultaneous Games, The Prisoner's' Dilemma, Iterated Elimination, Nash Equilibrium, Mixed Strategies, Evolutionary Stability, Sequential Games, Backwards Induction, Subgame Perfect Equilibrium, Alternating Offer Bargaining, Sequential Rationality, Repeated Games, Games with Incomplete Information, Bayesian Games, Auctions, The Buyer-Seller Problem, Agreeing to Disagree, Strategic Voting, Bad Reputation, Modeling Irrationality

Text/ Reference Books:
- The Art of Strategy by A. Dixit and B. Nalebuff. Norton 2010.

Algorithmic trading: Using Python

Basic terms, concepts related to orders and data management. System Architecture and Risk Management in Algorithmic Trading – complexities involved Order Flow Management, Pegging, Discretion, VWAP strategies. Statistical arbitrage, market microstructure, trend following, momentum based, market making, machine learning. Introduction to coding in Python. Introduction to automated trading platforms based on Python, Object Oriented Programming and Useful Packages in Python for trading.

Text/ Reference Books:
- Chan, Ernest, Algorithmic Trading, Wiley Publications (2013)

Optimization in Finance

Introduction to optimization models. Elements of convex analysis. Linear programming models. Optimality. Duality in linear programming. Application to asset pricing. Nonlinear programming models. Optimality. Duality in nonlinear programming. Economic interpretation of Lagrange multipliers. The portfolio selection problem. Two-fund and one-fund theorems. Value at risk. Theory of mean-risk optimization models. Average value at Risk. Coherent measures of risk. Stochastic dominance. Optimization with stochastic dominance constraints. Introduction to multistage models. Information on professional optimization software.

Text/ Reference Books:
- D.G. Luenberger, Investment Science, Oxford University Press, New York 1998.
- A. Ruszczynski, Nonlinear Optimization, Princeton University Press, 2006.

Operations Research

Introduction to Operations Research (OR), Linear Programming (LP), LP and allocation of resources, Maximization and Minimization problems, Graphical LP Minimization solution, Introduction, Simplex method definition, formulating the Simplex model. Linear Programming – Simplex Method for Maximizing, Simplex maximizing example for similar limitations, Mixed limitations, Example containing mixed constraints, Minimization example for similar limitations, Sensitivity Analysis: Changes in Objective Function, Changes in RHS, The Transportation Model, Basic Assumptions. Solution Methods: Feasible Solution: The Northwest Method, The Lowest Cost Method; Optimal Solution: The Stepping Stone Method, Modified Distribution (MODI) Method. The Assignment Model: - Basic Assumptions, Solution Methods:-Different Combinations Method, Short-Cut Method (Hungarian Method), MSPT:- The Dijkestra algorithm, and Floyd's Algorithm (Shortest Route Algorithm).

Text/ Reference Books:
- D.G. Luenberger, Investment Science, Oxford University Press, New York 1998.
- A. Ruszczynski, Nonlinear Optimization, Princeton University Press, 2006.