INSTITUTE OF MATHEMATICS AND APPLICATIONS

COURSES OF STUDY

M.A./M.Sc. IN MATHEMATICS WITH COMPUTATIONAL FINANCE

(w.e.f. 2024-25)

UTKAL UNIVERSITY

BHUBANESWAR-751004

REVISED COURSE STRUCTURE FOR
M.A./M.Sc. IN MATHEMATICS WITH COMPUTATIONAL FINANCE

In C (T-P-Tu); C stands for number of credits for the paper, T, P and Tu, respectively stand for number of theory, practical and tutorial classes per week.

SEMESTER-I

Paper No.	Course Title	Category	Marks	C (T-P-Tu)
MCF 101	Analysis	Core	100	4 (3-0-1)
MCF 102	Computational Linear Algebra	Core	100	4 (3-2-0)
MCF 103	Probability, Statistics, and Stochastic Processes with Lab (in R)	Core	100	4 (3-2-0)
MCF 104	Programming (Python & C++)	Core	100	4 (3-2-0)
MCF 105	Micro Economic Theory, Corporate Finance, & Accounting	Core	100	4 (3-0-1)
MCF 106	Numerical Optimization with Lab	Core	100	4 (3-2-0)

SEMESTER-II

Paper No.	Course Title	Category	Marks	Credits
MCF 201	Abstract Algebra	Core	100	4 (3-0-1)
MCF 202	Topology	Core	100	4 (3-0-1)
MCF 203	Financial Derivatives with Lab (in C++)	Core	100	4 (3-2-0)
MCF 204	Multivariate Data Exploration and Analysis with Lab (in R)	Core	100	4 (3-2-0)
MCF 205	Machine Learning with Lab (in Python)	Core	100	4 (3-2-0)
MCF 206	Portfolio Theory and Investment Analysis with Lab	Core	100	4 (3-2-0)

---------- SUMMER *INTERNSHIP*----------

SEMESTER-III

Paper No.	Course Title	Category	Marks	Credits
MCF 301	Functional Analysis	Core	100	4 (3-0-1)
MCF 302	Numerical Analysis with Lab	Core	100	4 (3-2-0)
MCF 303	Complex Analysis	Core	100	4 (3-2-0)
MCF 304	Differential and Integral Equations	Core	100	4 (3-0-1)
MCF 305	Stochastic Calculus & Computational Methods for Financial Derivatives	Core	100	4 (3-2-0)
MCF 306	Data Visualization with Lab + Summer Internship Evaluation	Core	100	3 (2-2-0) + 1

SEMESTER-IV

Paper No.	Course Title	Category	Marks	Credits
MCF 401	Fixed Income Security Analysis	Core	100	4 (3-0-1)
MCF 402	Financial Risk Management and Measurement	Core	100	4 (3-0-1)
MCF 403	Principles of Financial Engineering	Core	100	4 (3-0-1)
MCF 404	Elective I (To be chosen from Group A)	Allied Elective	100	4 (3-0-1)/ (3-2-0)
MCF 405	Elective II (To be chosen from Group B)	Allied Elective	100	4 (3-0-1)/ (3-2-0)
MCF 406	Dissertation with Viva-voce	Core	100	4

For the Elective paper a student can choose any one of the following courses from each group depending on the availability

Elective Papers Group-A		Elective Papers Group-B	
A1	Actuarial Science	B1	Advanced Machine Learning with Lab
A2	Artificial Intelligence	B2	Algorithmic Trading
A3	Behavioral Finance	B3	Big Data Analytics with Lab
A4	Credit Derivative Pricing Models	B4	Causal Inference for Finance
A5	Dynamic Asset Management	B5	Cyber Security
A6	Deep Learning and Reinforcement Learning with Lab	B6	High Performance Computing
A7	International Equity and Currency Markets	B7	Object Oriented Software Engineering
A8	Monte Carlo Methods in Finance	B8	Quantitative Risk Management
A9	Numerical Solution of Partial Differential Equations	B9	Soft Computing Methods
A10	Probabilistic Graphical Models	B10	Time Series Analysis and Forecasting

DETAILED SYLLABUS

Semester–I

MCF 101

Analysis	(Marks -100)	Credit 4 (3-0-1)

Unit-I: Review of Calculus, Metric spaces, limit in metric spaces, open sets, closed sets, relative metric, Continuous functions, homeomorphisms, the space of continuous functions, connected sets, totally bounded sets, complete metric spaces, fixed points, completions, compact metric spaces, uniform continuity, the Baire category theorem. **12 Hours**

Unit-II: Sequence of functions, pointwise and uniform convergence of functions, uniform convergence & continuity, uniform convergence & differentiability, uniform convergence & integrability , series of functions, power series, Dini's theorem. Equicontinuity, Arzela-Ascoli theorem, The Stone- Weierstrass theorem. **12 Hours**

Unit-III: Linear transformations, differentiation in R^n, chain rule, partial derivatives,directional derivatives, Inverse function theorem, Implicit function theorem. Fourier series, Trigonometric series, Dirichlet kernel, convergence of Fourier series, Parseval's theorem. **12 Hours**

Unit-IV: Outer measure and its properties, Lebesgue measurable sets and Lebesgue measure, a non-measurable set. Measurable functions, Littlewood's three principles, Egoroff's theorem, Lusin's theorem. **12 Hours**

Unit-V: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem, Lebesgue integral of nonnegative functions, monotone convergence theorem, Fatou's Lemma, the general Lebesgue integral, Lebesgue convergence theorem. L^p -spaces, Holder's inequality and Minkowski's inequality, Completeness of L^p -spaces. **12 Hours**

Text Books:

1. N.L. Carothers: Real Analysis, Cambridge University Press, United Kingdom.
2. W. Rudin, Principles of Mathematical Analysis, Tata McGraw Hill Publishing Company, New Delhi.
3. Elias M.Stein and Rami Shakarchi, Real Analysis: Measure Theory, Integration, and Hilbert Spaces,, Princeton Lectures in Analysis, Princeton University Press.

Reference Books:

4. Richard R. Goldberg: Methods of Real Analysis
5. W. Rudin, Real and Complex Analysis, Tata McGraw Hill Publishing Company, New Delhi.
6. H. L. Royden, Real Analysis, McMillan, New York.
7. P. Halmos, Measure Theory, Van Nostrand, Princeton, New Jersey.

MCF 102

Computational Linear Algebra (Marks-100) Credit 4 (3-2-0)

Unit-I: Matrix Multiplication: Basic algorithm and notations, Structure and efficiency, Block matrices and algorithms, Fast matrix - vector products, Vectorization and locality, Parallel matrix multiplication. Kronecker Product, Triangular systems, Diagonal Dominance and symmetry, Banded systems, Symmetric indefinite systems, Block tridiagonal systems, Vandermonde systems, Visualization of different matrix computations and their Applications in Data Science. **13 Hours**

Unit-II: Vector Space & Subspaces, Solving AX = 0 & AX = b, Linear Independence, Basis and Dimension, The Four Fundamental Subspaces, Linear Transformation, Orthogonal Vectors, Projections to a line, Projections and Least Squares, Orthogonal Bases & Gram-Schmidt. **9 Hours**

Unit-III: Eigenvalues and eigenvectors, Diagonalization of a Matrix, Complex Matrices, Similarity Transformation, Test for positive definiteness, Vector norms, Matrix norms, Singular Value Decomposition.

Errors in Computations, Computing Norm, Inner product and solution of Triangular System, Efficiency and stability of an Algorithm, Conditioning, Perturbation Analysis, Perturbation Analysis of linear system. **13 Hours**

Unit-IV: LU Factorization Methods, Scaling, Effects of the condition number on accuracy, computing and estimating the condition number, Parallel LU, Orthogonalization and Least Square, Householder's matrices and QR factorization, Classical and Modified Gram-Schmidt Algorithm for QR factorization, Solution of AX = b using QR Factorization, Projections Using QR Factorization, SVD and its computation. **12 Hours**

Unit-V: Existence and uniqueness of least square solutions, Pseudoinverse and the least square problem, sensitivity of the least square problem, Computational Methods for Over determined Problems, Computing selected eigenvalues and eigenvectors, Jacobi, Gauss-Seidel and SOR methods.

Functions of Matrices: Eigen value methods, Approximation methods, The matrix exponential, The sign, Square root and Log of a matrix, Tensors. **13 Hours**

Texts:

1. Gene. H. Golub, Charles F. Van Loan, Matrix Computations, Fourth Edition, The Johns Hopkins University Press, Baltimore 2013.
2. G. Strang, Linear Algebra for Everyone, Wellesley-Cambridge Press, 2020.

Reference Books:

1. G. Strang, Linear Algebra and Its Applications, 4th Edition, Cengage Learning, 2006.
2. J. W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997.
3. P. G. Ciarlet, Introduction to numerical linear algebra and optimization
4. William Ford, Numerical linear algebra with applications, AP
5. Richard Bronson, G.B. Costa, Matrix Methods: Applied Linear Algebra, Third Edition, AP.

MCF 103

Probability, Statistics, and Stochastic Processes with Lab (Marks-100) Credit 4 (3-2-0)

Unit – I: Samples and Probability spaces, Properties of probability measures, Conditional probability and Bayes theorem, Continuity of probability measure, Independence, Borel sigma algebras and

random variables, Distribution function, Proability density function and Probability mass function of a random variable.

Unit – II: Independence of events and independence of random variables, Expectation and Variance, Discrete random variables (Bernoulli, Binomial, Poisson, Geometric, Hypergeometric), Continuous random variables (Uniform, Exponential, Normal, Gamma, Beta), Functions of random variables, Joint distributions of discrete, continuous and independent random variables, Conditional distributions, The moment generating function.

Unit – III: Distributions derived from the normal distribution (X^2, *t,* and *F*), The sample mean and the sample variance, Independence weak laws of large numbers, Borel-Cantelli lemma, Strong law of large numbers, Types of convergence of random variables, Characteristic functions, Central limit theorems.

Unit – IV: Parameter estimation (the method of moments, the method of maximum likelyhood, Confidence intervals, Bayesian approach to parameter estimation, Efficiency and sufficiency of an estimator.

Unit – V: Testing of hypothesis**,** The Neyman-Person Paradigm, The duality of confidence intervals and hypothesis test, Generalized likelihood ratio test, Composite hypothesis and the t-test, Two-sample t-test and signed rank test, Rank sum test and permutation tests, Testing multiple hypothesis, The analysis of variance(one-way-layout), chisquare test of homogeneity and independence. Conditional expectation**,** Matringles and the optional stopping time theorem.

Texts:

1. Rick Durret, Probability: Theory & Examples, Fourth Edition, Cambridge University press, 2013.
2. John A Rice, Mathematical Statistics and Data Analysis, Third Edition, CENGAGE Learning, 2007.

References:

1. Vijay K. Rohatgi, A. K. Md. Ehsaries Sabh, An Introduction to Probability and Statistics, Wiley-Interscience, Second Edition, 2001.
2. LA. Wasserman-All of Statistics-Springer Science, 2004.

MCF 104

Programming (Python & C++) **(Marks-100)** **Credit 4(2-4-0)**

Unit I: Introduction to flowchart and algorithm, Basics of Pseudo code. Problem solving using Pseudo code,examples: check for prime number, factorial of a number, GCD of two numbers, count the number of digits of an integers, convert a decimal number to binary, Fibonacci numbers, Armstrong numbers, evaluating of e^x and sin(x) series using their Taylor series expansion, find minimum and maximum among N numbers, linear search. sum and product of of N numbers, evaluation of polynomial. **6 Hours + 6 Labs (2 Hours each)**

Unit II: Getting Started with Python: Introduction, Basic data types, Control Structures: if, if-elif-else, for, while, break, continue. Data Structures: Lists, Tuples, Sets, and Dictionaries. **6 Hours + 6 Labs (2 Hours each)**

Unit III: Functions: Defining functions, Calling functions, Passing arguments, Keyword arguments, Default arguments, Variable-length arguments, Anonymous functions, Function returning values, Scope of the variables in a function - global & local variables, User defined functions.Modules & Packages: Creating modules, Import statement, from import statement, name spacing; Creating user defined packages. **6 Hours + 6 Labs (2 Hours each)**

Unit IV: File Handling: Handling of csv file.Object Oriented Programming: Features, classes and objects, creating class and object, Using a class & its methods; Exception Handling: Errors, Types of exception, try, except and finally, assertion. **6 Hours + 6 Labs (2 Hours each)**

Unit V: Numpy: Introduction, Creating of arrays and matrices;Introduction to Panda: Creating a data frame, Dealing with row & columns, Indexing & selection data, Working with missing data, Iterating over rows and columns; Merging and joining DataFrame objects, Concatenation, Reshaping DataFrame objects, Pivoting, Data transformation, permutation & sampling, Data aggregation and GroupBy operations; Creating data frame from CSV file; Matplotlib: Creating effective visual representations of your data, Avoiding common pitfalls. **6 Hours + 6 Labs (2 Hours each)**

Text Books:

1. Donal.E.Knuth, Art of Computer Programming,Volume-1, Third Edition, 1997

2. R. N. Rao, Core Python Programming, 2nd Edition, Dreamtech Press, 2018.

3. J. V. Guttag, Introduction to Computation and Programming Using Python, with Application to Understanding Data, 2nd Edition, PHI Learning, 2016.

4. W. McKinney, Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, 2nd Edition, O'Reilly Media, 2017.

Reference Books:

1. P. Barry, Head First Python, 2nd Edition, O'Reilly Media, 2010.

2. A. Downey, Think Python : How to Think Like a Computer Scientist, 2nd Edition, Green Tea Press, 2015.

3. J. Zelle, Python Programming : An Introduction To Computer Science, 3rd Edition, Franklin, Beedle & Associates, 2016.

Online Resources:

1. https://nptel.ac.in/courses/106/106/106106182/: By Prof. S. Iyengar, IIT Ropar

2. https://nptel.ac.in/courses/106/106/106106145/: By Prof. M. Mukund, IIT Madras

3. https://nptel.ac.in/courses/106/106/106106212/: By Prof. R. Rengasamy, IIT Madras

4. https://nptel.ac.in/courses/106/107/106107220/: By Prof. A. Ramesh, IIT Roorkee

MCF 105

Micro Economic Theory, Corporate Finance, & Accounting (Marks-100)
Credit 4 (3-0-1)

Unit-I: Demand and supply, elasticity of demand and supply, market price determination, price control-taxes and subsidies –case of open economy.

Theory of consumer behaviour, consumer surplus, the theory of choice-utility theory under uncertainty (axioms of choice under uncertainty, developing utility functions, risk aversion), state preference theory (uncertainty and alternative future states, pure securities, No-arbitrage profit condition, economic determination of security prices)

Unit-II: Theory of production (production function with one or two variable inputs, estimator of production function), cost theory (cost concepts, short and long run cost function), economic profits versus accounting profits, sunk costs, constrained output maximization and cost minimization, profit maximization.

Unit-III: Perfect competition, Derivation of short run and long run supply curves, monopoly, pricing strategies under monopoly, durable goods monopoly, Auctions, Revenue-maximizing monopolist. Theory of oligopoly-Kinked demand curve, Bertrand, cournot as stackelberg models, Nash equilibrium and subgame-perfect equilibrium. Budent differentiation.

Unit-IV: Rational expectation and market efficiency, Basic valuation principles, valuation of debt and equity. Term structure, cost of capital, Mutual fund, portfolio evaluation.

Unit V: Equity research, capital structure, Dividend policy. Cash flow analysis, capital budgeting under certainty, and capital budgeting under uncertainty.
Balance of payments, Determination of Exchange rates, International capital budgeting and investments.

Books Recommended:

1. *A. Sert- Microeconomics Theory and Applications, Oxford University Press*
2. *R. S. Pindyck and D. L. Rubinfeld, P. L. Meheta, Microeconomics, Pearson Education.*
3. *Micro economic Theory-A Mathematical Approach J. M. Herderson and R. E. Quardt, TMH*
4. *T. E. Copland, J. F. Weston, K. Sastri-Financial Theory and corporate policy-Pearson.*
5. *Essentials of Investment, Zvi Bodie*
6. *Finance, Zvi Bodie and Robert C. Merton, Prentice Hall*
7. *Multinational Financial Management, Alan C. Shapiro, Wiley.*
8. *Corporate Finance, Ross Westerfield and Jaffe, Irwin / Mc GrawHill*

MCF 106

Numerical Optimization with Lab (Marks-100) Credit 4 (3-2-0)

Unit-I: One Dimensional Optimization: Function comparison methods, Polynomial interpolation, Iterative methods.

Unit-II: Gradient Based Optimization Methods (I): Calculus on R^n , Method of steepest descend, Stochastic gradient descent, Conjugate gradient method, Conjugate gradient for non quadratic objective function, The generalized reduced gradient method, Gradient projection method.

Unit-III: Gradient Based Optimization Methods (II): Newton type methods(Newton's method, Marquardt's method), The Quasi-Newton method, BFGS, L-BFGS.

UNIT-IV: Convex sets, convex functions, First and second order conditions for convexity, Jensen`s inequality, Convex optimization problems, Characterization of optimal solutions, Necessary optimal conditions for constrained optimization problems(Fritz John and KKT), Lagrange multiplier method.

Unit-V: Sufficient conditions for optimality, KKT sufficient conditions, Constraint qualification, Second order optimality conditions, KKT second order optimality necessary conditions, Penalty function techniques, Primal dual method.

Books Recommended

Texts

1. M. C. Joshi, K. M. Moudgalya, Optimization: Theory and Practice, Narosa Publishing House, 2004.

2. Stephen Boyd, Lieven Vandenberghe, Convex Optimization, Cambridge University Press

References

1. J. A. Snyman, Practical Mathematical Optimization, Springer Sciences, 2005.

2. Nocedal J, Wright S.J., Numerical Optimization, Springer.

3. Convex Optimization Overview, Lecture notes by Zico Kotler, Stanford University.

4. Optimality Conditions for Constrained Optimization Problems, Lecture notes by Robert M. Freund, MIT.

5. Vivek S Borkar: Elementary Convexity with Optimization, Hindustan Book Agency.

Semester-II

MCF 201

Abstract Algebra	(Marks-100)	Credit 4(3-0-1)

Unit-I: Groups: Review of normal subgroups, quotient groups and homomorhism theorems. Group actions with examples, class equations and their applications, Sylow's Theorems and their applications; groups and symmetry. Direct sum and free Abelian groups. **12 Hours**

Unit-II: Commutative rings with unity: examples, ring homomorphisms, ideals, quotients, isomorphism theorems. Prime and maximal ideals, Zorn's Lemma and existence of maximal ideals.Product of rings, ideals in a finite product, Chinese Remainder Theorem. Prime and maximal ideals in a quotient ring and a finite product. **12 Hours**

Unit-III: Field of fractions of an integral domain. Irreducible and prime elements; PID and UFD. Polynomial rings over UFD's, Criteria for irreducibility of polynomials over UFD's. **12 Hours**

Unit-IV: Modules: Basic definitions and examples, Submodules and Direct sums, Quotient modules, Homomorphism and Isomorphism theorems, Cyclic modules, Free modules. **12 Hours**

Unit-V: Fields: Fields and their extensions; algebraic and transcendental extensions; algebraic closure; splitting fields and normal extensions; separable, inseparable and purely inseparable extensions; finite fields. Galois extensions and Galois groups, Fundamental theorem of Galois theory, cyclic extensions, solvability by radicals, constructibility of regular *n*-gons, cyclotomic extensions. **12 Hours**

Text Book:

1. D. S. Summit and R. M. Foote: Abstract Algebra, John Wiley.

Reference Books:

2. P. B. Bhattacharya, S. K. Jain, and S. R. Naipaul: Basic Abstract Algebra, Cambridge University Press.
3. N. Jacoboson: Basic Algebra Vol. I, W.H. Freeman and Co, 1985.
4. I. N. Herstein: Topics in Algebra", John Wiley & Sons (2nd Edition) 1999.
5. J. J. Rotman: An Introduction to the theory of groups, GTM (148), Springer-Verlag, 2002.
6. N. S. Gopalakrishnan: University Algebra, Wiley Eastern, 1986.
7. J. Rotman: Galois theory, Springer-Verlag, 1998.
8. S. Roman: Field Theory, Springer-Verlag, 1995.
9. M. Artin: Algebra, 2nd Edition, Pearson(Indian Edition).

MCF 202

Topology **(Marks-100)** **Credit 4(3-0-1)**

Unit-I: Infinite sets and Axiom of Choice, Well-ordered sets, Well-ordering theorem, Topological Spaces Basis and sub-basis for a topology, Order and product topologies, Closed sets, limit and interior points, Continuous functions. **14 hours**

Unit-II: The metric topology, Connected spaces, Connected subspaces of the real line, Components and local connectedness, Arc wise connectedness, Arc wise connectedness in Euclidean spaces.

10 hours

Unit-III: Compact spaces, Compact subspaces of the real line, Compactness and finite intersection properties, Compactness in metric spaces, Limit point compactness, Sequential compactness and its equivalence in metric spaces,Local compactness and One point compactification. **12 hours**

Unit-IV: Separation and Countability axioms, Topological spaces based on these axioms such as T_0, T_1, T_2 etc., Lindeloff space, Separable space and Normal spaces and their basic properties. **12 hours**

Unit-V: The Uryshon Lemma, The Uryshonmetrization theorem, The Tychonoff theorem, Completely regular spaces. **12 hours**

Prescribed Text Book:

1. James R. Munkres: Topology, Second Edition, Prentice-Hall.

   Relevent topics prescribed above from chapters 1,2,3,4, and 5.

Reference Books:

2. W. J. Pervin: Foundations of General Topology, Academic Press 1964.
3. J. Dugundji: Topology, UBS, 1999.
4. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw-Hill, 1963.
5. M. A. Armstrong: Basic Topology, Springer, 1983.
6. G. E. Bredon: Topology and Geometry, Springer GTM 139, 1995.

MCF 203

Financial Derivatives wit Lab (in C++) **(Marks-100)** **Credit 4(3-2-0)**

Unit-I: Introduction, Mechanics of futures markets, Hedging strategies using futures. Determination of forward and futures prices, Interest rate futures, swaps. Mechanics of options markets, Properties of stock options, Trading Strategies involving options.

Unit-II: Binomial model for pricing options, Hedging strategies using Greeks, Derivative markets in developing countries. Options on stock indices, currencies and futures, volatility smiles.

Unit-III: Random Walk and Ruin Problems: General Orientation, The classical ruin problem, Expected duration of a game connection with diffusion process.

Markov Chain: Definition, Transition probability matrices of a Markov chain, some Markov Chain Models classification of states and basic limit Theorems of Markov Chain.

Unit-IV: Poisson Process: The Poisson distribution and Poisson Process. The law of rare events, Distributions associated with Poisson Process.

Continuous Time Markov Chain: Birth Process, Death Process, Birth and Death process. The limit behavior of Birth and Death process. Birth and Death processes with absorbing states. Finite state continuous time Markov chain, Kolmogorov's Forward and Backward Equations.

Unit-V: Queuing system: Queuing process, Poisson arrivals exponential service times, General Service time distribution variations and extensions. **Renewal phenomena:** Definition of Renewal process and related concepts some examples of Renewal process, Poisson process viewed as a Renewal process. The asymptotic behavior of Renewal process.

Recommended Text Books:

1. *Introduction to Stochastic Modeling H. M. Taylor and S. Karlin Academic Press.*
2. *A first course on Stochastic Process Sheldon Ross, Low Priced Edition.*
3. *Introduction to Probability and its Applications, W. Feller, Vol I, Wielley.*
4. *Options, Futures and other Derivatives: - J. C. Hull, Prentice Hall of India, 7th Edition, [Chapter 1 through 18 excluding 4, 12, 13].*

References:

1. *An Introduction to Derivatives and Risk Management, D. M. Chance, Thomson - SPD- 2004.*

2. *Derivatives - valuation and risk management, D. A. Dubofsky, T. W. Miller Oxford Univ. Press - 2003.*
3. *Mathematics for Finance an introduction to Financial Engineering, M. Capinski, T. Zastanniak, Springer Verlog – 2003.*

MCF 204

Multivariate Data Exploration and Analysis with Lab (Marks-100) Credit 4 (3-2-0)

Data integration, Data transformation and reduction), Graphical methods for data exploration(Histogram, scatter plots, Box plots, Quantile plots, Bag plots, Glyph plots, coplots, Dot charts, Biplots, Plotting Points as curves, Graphs of growth plots). **10 hours**

Unit II: Random vectors and matrices, Mean vectors and co-variant matrices, sample geometry, Random sampling, Expectation of sample mean and co-variance matrix, Generalized variance, Matrix operations for descriptive statistics.

Multivariate normal density and its properties and sampling from multivariate normal distribution, Maximum likelihood estimation. **10 hours**

Unit III: Sampling distribution sample mean and co-variance, Large sample behaviour of sample mean and co-variance, Assessing normality assumption, detecting outliers and transformation to near normality, and data cleaning.

Inferences about a mean vector, Hotelling's T-square, confidence regions for a mean vector, Likelihood ratio test for a mean vector, Inference about mean vector when observation is missing, large sample inference. **10 hours**

Unit IV: Comparing mean vectors from two populations, Comparison of several multivariate means(One-way MANOVA), Simultaneous confidence intervals for treatment effects, Testing equality of co-variance matrices.

Principal component analysis,Population Principal components, Summarizing the sample variable by principal components, Graphing principal components. **10 hours**

Unit V: Factor analysis (orthogonal factor model, Methods of estimation, Factor rotation, prospective and strategy for factor analysis, factor scores, Data example).

Canonical correlation analysis (canonical variables and canonical correlations, Interpreting the population canonical variables, sample canonical variables and sample canonical correlation), Large sample inference. **10 hours**

Lab Work: Implementation of the following using R **10 lab classes**

1. Computing the summary statistics of a Data set.

2. Data Computation and Data Transformation.

3. Plotting the graphs of the various plots and curves mentioned in Unit I.

4. Computation of co-variance and correlation matrices.

5. Computation of multivariate normal density function and bi variate normal.

6. Obtaining the maximum likelihood estimate of the mean μ and co-variance matrix of a multivariate normal distribution.

7. Detecting outliers in the data and cleaning the data.

8. Assessing the normality of a given data set.

9. Constructing large sample simultaneous confidence intervals.

10. Comparing several multivariate population mean vector using MANOVA.

11. Computing the population Principal Components and summarizing sample variation by Principal Components.

12. Finding Sample Principal Components from standardized data and plotting the Principal Components.

13. Performing factor analysis of a given data set.

14. Computing Canonical variates and Canonical correlations for standardized variables.

15. Performing canonical correlation analysis of a given data set.

Books recommended:

Texts:

1. R. A. Johnson and D. W. Wichern, Applied Multivariate Statistical Analysis, Pearson Education, 6th edition, 2015. Chapters :1(1.1-1.4), 2(2.1-2.5), 3(3.5,3.6), 4(4.1-4.8), 5(5.1-5.7), 6(6.3-6.6), 8(8.1-8.4), 9(9.1-9.6), 10(10.1-10.4,10.6).

2. W. L. Martinez, A R Martinez, J. L. Solka, Exploratory data analysis, 2nd edition, CRC Press, 2010. Chapters 1,9,10

Reference Book:

1. T. W. Anderson, An Introduction to Multivariate Statistical Analysis, Wiley, 2003.

2. B.S.Everitt and T.Hothorn, An Introduction to Applied Multivariate Analysis with R, Springer Verlag, 2011.

MCF 205

Machine Learning with Lab (in Python) (Marks-100) Credit 4(3-2-0)

Unit I: Linear Methods for Regression and Classification: Overview of supervised learning, Linear regression models and least squares, Multiple linear regression, The Gauss-Markov theorem, Subset selection, Ridge regression, least angle regression and Lasso, Elastic net, Linear Discriminant Analysis(LDA), Reduced rank LDA, Logistic regression for two or more classes. Comparison of KNN, LDA, and logistic regression.

Unit II: Model Assessment and Selection: Bias,Variance,and model complexity,Bias-variance trade off, Optimism of the training error rate ,Estimate of In-sample prediction error,Effective number of

parameters, Bayesian approach and BIC, Cross-validation ,Boot strap methods,Performance of classification algorithms (confusion matrix, precision and recall, ROC curve).

Unit III: Additive Models,Trees, and Boosting: Generalized additive models**,** Regression and classification trees, Boosting methods-exponential loss and AdaBoost, Numerical Optimization via gradient boosting, Examples (Spam data, California housing, Demographic data), XGboost.

Unit IV: Support Vector Machines(SVM), and K-nearest Neighbor: Basis expansion and regularization, Kernel smoothing methods, SVM for classification, Reproducing Kernels, SVM for regression, K-nearest –Neighbour classifiers (Image Scene Classification)

Unit V: Unsupervised Learning and Random forests: Cluster analysis(similarity and diasimilarity measures, K-means and K-medoids clustering, Hierarchial clustering, DBSCAN, EM algorithm, Gaussian mixture model and its use in clustering and anomaly detection. Random forests and analysis.

Lab work **10 lab classes**

Implementation of following using Python

1. Multiple linear regression,
1. Logistic regression,
2. Linear discriminant analysis,
3. Ridge regression, LASSO,
4. Cross-validation,
5. Boot strap,
6. Fitting classification and regression trees,
7. K-nearest neighbours,
8. SVM for classification,
9. K-means clustering.
10. Gaussian mixture, and
11. Random forest.

Prescribed Text Books

1.Trevor Hastie, Robert Tibshirani,Jerome Friedman , *The Elements of Statistical Learning-Data Mining, Inference,and Prediction*,Second Edition, Springer Verlag, 2009. [relevant topics prescribed above from chapters : 1 to 10, 13, 14, 15.]

2.Simon Haykin, Neural Networks- a comprehensive foundation, Ch.6, Second edition ,Pearson Education, 2001.

3. Stuart Russell and Peter Norving, "Artificial Intelligence: A Modern Approach", Third Edition, 2010, Pearson Education, New Delhi.

Reference Books

1. G. James, D.Witten,T.Hastie, R.Tibshirani- *An introduction to statistical learning with applications in R*, Springer, 2013.

2. C. M. Bishop –Pattern Recognition and Machine Learning, Springer, 2006.

3. M. J. ZAKI, Wagner M,Jr, Data mining and Machine Learning-Fundamental Concepts and Algorithms, Cambridge Univ.Press, second edition,2020

4. Joseph Giarratano and Gary Riley,"*Expert Systems: Principles and Programming*", Fourth Edition, CENGAGE Learning India Pvt. Ltd., New Delhi.

5. Elanie A. Rich and Kevin Knight, "*Artificial Intelligence*", 3rd Edition, 2009, McGraw-Hill Education (India), New Delhi.

6. Nills J. Nilsson, "*Artificial Intelligence: A New Synthesis*" 2nd Edition, 2000,Elsiver India Publications, New Delhi.

7. Michael Negnevitsky, "*Artificial Intelligence: A Guide to Intelligent Systems*", Second Edition, 2005, Pearson Education, Inc. New Delhi.

8. Dan W. Patterson, "*Introduction to Artificial Intelligence and Expert Systems*", 1st Edition, 1996, PHI Learning Pvt. Ltd., New Delhi.

9. Ben Coppin, "*Artificial Intelligence Illuminated*", 2005, Narosa Publication, New Delhi. ISBN: 978-81-7319-671-3.

Texts 1 and 2 and references 1 and 3 are available on line.

MCF 206

Portfolio Theory and Investment Analysis with Lab (Marks-100) Credit 4(3-2-0)

Unit-I: Risk and risk aversion, Measuring risk and return of a single asset and portfolio. Mean-Variance Portfolio Theory: Diversification, Forming Portfolios with on assets, efficient frontier. The Markowitz model, the two-fund theorem, Inclusion of a risk free asset, the one-fund theorem.

Unit-II: The capital Asset Pricing Model: Market equilibrium, Capital Market line, Pricing Model, Security Market Line, Investment implications use of CAPM for performance evaluation, CAPM as a Pricing formula.

Unit-III: Single and Multifactor models, CAPM as a factor model, Arbitrage pricing theory (APT), APT and CAPM, Estimation of Parameters of mean-variance portfolio theory, CAPM and APT. Tilting away from equilibrium.

Unit-IV: Market Efficiency and behavioral Finance, Empirical Evidence on Security returns, Evaluation of Portfolio Performance, Equity evaluation models, International diversification. The process of portfolio management, the theory of active portfolio management.

Unit V: Lab Work

Recommended Text Books:

1. *D. G. Luenberger- Investment Science, Oxford University Press.*
2. *Z. Bodie- A Kare, A. J. Marcus, P. Mohanty-Investments, 6th Edition, TMH.*
3. *E. J. Elton. M. J Gruber-Modern Portfolio Theory and Investment Analysis- John Wiley, Student Edition.*
4. *T. E. Copeland, J. Fred Weston, K. Shastri, Financial Theory and Corporate Policy-Addison Wesley.*

Semester–III

MDS 301

Functional Analysis **(Marks-100)** **Credit 4(3-0-1)**

spaces. Operator norm, continuity and boundedness of linear maps on a normed linear space. Baire's theorem and its consequence.

Unit-II: Hahn-Banach theorems, uniform boundedness principle, divergence of Fourier series, closed graph theorem, open mapping theorem and some applications.

Unit-III: Duals spaces, weak and weak* convergence, adjoint of an operator.

Unit-IV: Inner product spaces, orthonormal set, Gram-Schmidt ortho-normalization, Bessel's inequality, orthonormal basis, separable Hilbert spaces. Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem.

Unit-V: Adjoint, normal, unitary, self-adjoint operators, compact operators. Spectral theorem for compact self-adjoint operators, statement of the spectral theorem for bounded self-adjoint operators.

Text Book:

1. Rajendra Bhatia: Notes on Functional Analysis, Hindustan Book Agency.

Reference Books:

2. J. B. Conway: A course in functional analysis, Graduate Texts in Mathematics, 96., Springer-Verlag, 1990.
3. Erwin Kreyszig: Introductory functional analysis with applications, Wiley India.
4. Christopher Heil: Metrics, Norms, Inner Products, and Operator Theory, Birkhäuser.
5. W. Rudin: Functional analysis, McGraw-Hill, Inc., 1991.
6. George Bachman and Lawrence Narici: Functional Analysis, Dover Publications.
7. K. Yosida: Functional analysis, Grundlehren der Mathematischen Wissenschaften, Springer-Verlag, 1980.

MCF 302

Numerical Analysis with Lab **(Marks-100)** **Credit 4 (3-2-0)**

Unit I: Solution of Equations in One and Several Variables: Fixed point iteration method, Accelaration of convergence, Zeros of polynomials and Muller's method, Fixed points for functions of several variables, Newton's method for for non-linear system of equations. **7 hours**

Unit II: Interpolation: Hermite interpolation, Cubic spline interpolation, B-spline: interpolation and approximation, Parametric curves- Bazier curves. **7 hours**

Unit III: Least Square Approximation: Discrete least square approximation, Orthogonal polynomials, The Chebyshev polynomials and economization, Rational function approximation (Pade rational approximation, Chebyshev rational approximation) **7 hours**

Unit IV: Numerical Integration: Elements, Composite integration, Romberg integration, The Gauss quadrature. APPROXIMATION OF Multiple Integrals: Product rules, Rules exact for monomials, The Radon formula for integration of integrals in two dimensions. **7 hours**

Unit V: Numerical solution of ordinary differential Equations: Higher order Taylor series method, Runge-Kutta methods, Error control and Runge-Kutta-Fehlberg method, Multistep methods, Variable step size multistep methods-predictor-corrector method, Stability of numerical methods for solving IVP, Shooting and finite difference methods for boundary value problems (BVP) for ODE. Finite difference method for parabolic PDE. **9 hours**

Lab Work **8 lab classes**

Implementation of the following using Python/ Matlab

1. Finding zeros of a polynomial using Muller's method.

2. Solution of a non-linear system of equations using Newton's method.

3. Construction of cubic spline interpolant of a function.

4. Construction of a cubic Bazier corve given in parametric form.

5. Obtaining Pade rational approximation for a given function.

6. Approximate evaluation of a definite integral using (i) Composite Simpson rule (ii) Gaussian quadrature.

7. Approximate evaluation of a double integral using Guassian quadrature.

8. Finding approximate Solution of an IVP using (i) Runge-Kutta 4^{th} order method (ii) Runge-Kutta-Fehlberg method.

9. Obtaining approximate solution of an IVP using Adms 4^{th} order Predictor-corrector method

10. Obtaining approximate solution of a second order BVP using (i) shooting method (ii) finite difference method.

Prescribed Text Book

1. R. L. Burden and J. D. Faires, Numerical Analysis, Cengage Learning, 9^{th} edition, 2011.

Chapters- 2 (2.2, 2.4-2.6), 3(3.4, 3.5, 3.6), 4(4.3, 4.4, 4.5, 4.7, 4.8), 5(5.3-5.7), 8(8.1-8.4), 10(10.1, 10.2),11(11.1-11.4),12(12.2)

Reference Books

1. P. J. Davis and Rabinowiwitz, Methods of Numerical Integration, A. P., Fourth Edition.

2. W.Cheney and D.Kincoid ,Numerical Mathematics and Computing, Cengage Learning,7^{th} edition, 2013.

MCF 303

Complex Analysis **(Marks-100)** **Credit 4(3-0-1)**

Unit-I: Complex plane, topology of complex plane, open connected sets in the complex plane, the Riemann sphere. Holomorphic functions, Cauchy-Riemann Equations, examples of holomorphic functions, power series, radius of convergence, exponential and trigonometric functions.

Unit-II: Complex integration along piecewise smooth curves, Goursat's theorem, Local existence of primitives and Cauchy's theorem in a disc, evaluation of some integrals, Cauchy's integral formulas, Cauchy inequalities, power series expansion of holomorphic functions, Liouville's theorem, Morera's theorem, holomorphic functions defined in terms of integrals.

Unit-III: Zeros of holomorphic functions, Uniqueness theorem, Laurent series, Singularities, poles, residue theorem, Riemann's theorem on removable singularities, Casorati-Weierstrass theorem, meromorphic functions, argument principle, Rouche's theorem, Open Mapping theorem, Maximum modulus principle.

Unit-IV: Homotopies and simply connected domains, the complex logarithm. Jensen's formula, functions of finite order, Infinite products, product formula for the sine function, Weierstrass infinite products, Hadamard's factorization theorem.

Unit-V: Conformal map, conformal equivalence and examples, Schwarz lemma, automorphisms of the disc, upper plane, Riemann sphere and the complex plane. The Riemann mapping theorem and Picard's theorem.

Text Book:

1. Elias M.Stein and Rami Shakarchi: Complex Analysis, Princeton Lectures in Analysis, Princeton University Press.

Reference Books:

2. W. Rudin: Real and Complex Analysis, Tata McGraw-Hill Publishing Company Ltd., New Delhi, Chapters 10, 11, 12, 13, 14, 15 and 16.
3. J. B. Conway: Functions of one complex Variable, Springer International Student Edition, Second Edition.
4. L.V. Ahlfors, Complex Analysis, Third Edition, International Student Edition, McGraw-Hill Kogakusha, Ltd.

MCF 304

Differential and Integral Equations **(Marks-100)** **Credit 4(3-0-1)**

Unit-I: Existence and uniqueness of solutions: Lipschitz condition, Gronwall inequality, successive approximation, Picard's theorem, continuation and dependence on initial conditions, Existence of solutions in the large, Existence and uniqueness of solutions of systems, Fixed point method, Systems of linear differential equations: n^{th} order equation as a first order system, System of first order equations, Existence and uniqueness theorem, fundamental matrix, Non-homogeneous linear systems, Linear equations with constant coefficients

Unit-II: Non-linear Differential Equations: Existence theorem, Extremal solutions, Upper and lower solutions, Monotone iterative method and method of quasi linearization, Stability of Linear and Non-linear systems: Critical points, System of equations with constant coefficients, Linear equations with constant coefficients, Lyapunov stability.

Unit-III: Boundary value problem for ordinary differential equations: Sturm-Liouville problem, Eigenvalue and eigen functions, Expansion in eigen functions, Green's function, Picard's theorem for boundary value problems. Series solution of Legendre and Bessel equations.

Unit-IV: The Laplace equation: Boundary value for Laplace's equation, fundamental solution, Integral representation and mean value formula for harmonic functions, Green's function for Laplace's equation, solution of the Dirichlet problem for a ball, solution by separation of variables,

Unit-V: The wave equation and its solution by method of separation of variables, D'Alembert solution of the wave equation, Solution of wave equation by Fourier transform method. **Linear Integral Equations:** Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigenfunctions, resolvent kernel.

Books for reference

1. S. D. Deo, V. Lakshmikantham and V. Raghavendra: Text Book of Ordinary Differential Equations, Second Edition, Tata McGraw-Hill Publishing Company Ltd., New Delhi, Chapters 4(4.1 – 4.7), 5, 6(6.1 – 6.5), 7(7.5), 9(9.1 – 9.5).
2. Earl A. Coddington, Norman Levinson, The Theory of Ordinary Differential Equations
3. J. Sinha Roy, S. Padhy, A Course on Ordinary and Partial Differential Equations, Kalyani Publishers.
4. Tyn Mint-U, Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Birkhauser.
5. Lawrence Evans, Partial Differential Equations, Second Edition, Graduate Studies in Mathematics, AMS.
6. Abdul J. Jerry, Introduction to Integral Equations with Applications, 2nd Ed., Clarkson University Wiley Publishers, 1999.
7. Chambers, Ll. G., Integral Equations: A short Course,International Text Book Company Ltd., 1976.
8. R. P. Kanwal, Linear Integral Equations,2nd Ed., Birkhauser Bosten,1997.
9. Hochstadt Harry, Integral Equations, John Wiley & Sons,1989.

MCF 305

Stochastic Calculus & Computational Methods for Financial Derivatives
(Marks-100) **Credit 4(3-0-1)**

Unit-I: Stochastic processes, Markov chains, Examples of Markov chains with countable state-space (random walk, Birth-and-death chain, M|G|1 queue), Markov property, Continuous time markov processes.

Unit-II: Construction of finite difference schemes for Laplace and heat equation. Solution of Tri diagonal system of linear equations, iterative methods (Jacobi Successive over relaxation) Introduction to stability and convergence of finite difference method, crank Nicholson and ADI methods.

Unit-III: The Black Scholes (B.S.) Model: Derivation of B.S. equation using no arbitrage argument, options dividend paying equities, Derivation of B.S. formula for calls, Puts and simple digitals, obtaining formulae for Greeks and their numerical computation, Finite Difference method for solution of B.S. equation.

Unit-IV: Simple generalization of B. S. model (Dividend payments, time dependent parameters), Early exercise and American options (Perpetual American call and put, general payoff, local solutions), American option problem as free boundary problems, Finite difference method for American options, Monte-Carlo simulation.

Unit-V: Exotic and path dependent options: General introduction, Barrier options, Strongly path dependent options, Asian options, Look back options, Multi Asset options, Numerical implementation. Extensions of B-S. Model: Defects in B-S Models, Discrete hedging, Transaction costs, stochastic volatility. Jump diffusion, Crash modelling.

Books Recommended:

Text: Paul Wilmott: Paul Wilmott on quantitative finance John Wiley – 2006

Reference Books:

1. *Quantitative Methods in Derivative pricing - an introduction to computational Finance, D. A. Tavella , John Wiley – 2002.*
2. *The concepts and practice of mathematical finance, M. S. Joshi, Cambridge Univ. Press - 2003.*
3. *Derivative Securities and Difference Methods, Y. Zhu, X. Wu, F. Chern, Springer Verlag- 2004.*
4. *Numerical Solution of PDE, G.D. Smith, CUP.*
5. *Rick Durret, Probability: Theory & Examples, Fourth Edition, Cambridge University press, 2013.*
6. *John A Rice, Mathematical Statistics and Data Analysis, Third Edition, CENGAGE Learning, 2007.*
7. *Vijay K. Rohatgi, A. K. Md. Ehsaries Sabh, An Introduction to Probability and Statistics, Wiley-Interscience, Second Edition, 2001.*
8. *LA. Wasserman-All of Statistics-Springer Science, 2004.*

MCF 306

Data Visualization with Lab + Summer Internship Evaluation (Marks: 100)
Credit 3 (2-2-0) + 1

Unit-I: What is Visualization? The visualization process, Seven stages of data visualization, Type of data, Perception, Eight visual variables: position, shape, size, brightness, color, orientation, texture, motion.

Unit-II: Visualization techniques for Multivariate data, Tree, Graph, Networks, Text, Documents.

Unit-III: Visualization techniques for Spatial data, Geospatial data, Time-oriented data, Evaluating Visualizations.

Unit-IV: Introduction to D3, Working with data, Data-binding, Data-driven design and interaction, General charting principles, creating an axis, line charts and interpolations, Layouts (Histograms, Pie charts, Stack layout), Visualization with Scalable Vector Graphics (SVG), Drawing, Transformations, Building Charts with SVG.

Unit-V: Visualization libraries in R/Python: Matplotlib (Histograms, Bar charts, Line plots, Pie charts, Box plots, Scatter plots), Seaborn (Box, Violin plots, Regression plots, Heatmaps), Bokeh, ggplot2, Creating Dashboards with Plotly and Dash.

Experiments:

1. Excel: Use Excel charts for presentation of quantitative data.
2. Tableau: Import and prepare data, Perform data cleaning and harmonization.
3. Tableau: Create data visualizations.
4. Tableau: Use advanced data visualization to discover trends in data sets.
5. D3: Creating lines and circles with select and append.
6. D3: Loading data, displaying it as a bar chart and creating a scatterplot.
7. D3: Draw histograms, violin plots, pie charts and ring charts.
8. Matplotlib: Basic plotting with matplotlib library.
9. Seaborn: Create regression plots and heatmap using seaborn library.
10. Bokeh: Create few standalone interactive plots.
11. ggplot: Data visualization with ggplot2.
12. Plotly: Build a dashboard with Plotly and Dash.
13. Power BI: Data visualization with Power BI.

Text Books:

1. M. Ward, G. Grinstein, and D. Keim, *Interactive Data Visualization: Foundations, Techniques, and Applications*, 2nd Edition, CRC Press, 2015.
2. E. Meeks, *D3.js in Action: Data Visualization with JavaScript*, 2nd Edition, Manning Publications, 2018.
3. A. C. Telea, *Data Visualization Principles and Practice*, 2nd Edition, CRC Press, 2015.
4. H. Guerrero, *Excel Data Analysis: Modeling and Simulation*, Springer, 2010.
5. B. Jones, *Communicating Data with Tableau*, O'Reilly Media, 2014.

Books for Reference:

1. B. Fry, *Visualizing Data*, O'Reilly Media, 2007.
2. S. Murray, *Interactive Data Visualization for the Web*, 2nd Edition, O'Reilly Media, 2017.
3. K. Sosulski, *Data Visualization Made Simple: Insights into becoming Visual*, Routledge, 2018.
4. K. Healy, *Data Visualization: A Practical Introduction*, Princeton University Press, 2019.
5. A. Pajankar, *Practical Python Data Visualization: A Fast Track Approach to Learning Data Visualization with Python*, 1st Edition, Apress, 2020.
6. L. Ryan, *Visual Data Storytelling with Tableau*, 1st Edition, Addison-Wesley, 2018.

Online Resources:

1. https://1lib.in/book/2551564/b19e0b
2. https://1lib.in/book/5216746/8f8e9b
3. https://matplotlib.org/stable/tutorials/index.html
4. https://seaborn.pydata.org
5. https://docs.bokeh.org/en/latest/docs/gallery.html
6. https://www.r-graph-gallery.com/ggplot2-package.html

Semester–IV

MCF-401

Fixed Income Security Analysis	**Credit: 4(3-0-1)**

Unit-I: Bond characteristics, Bond Pricing, Bond yields, Bond prices over time.

Unit-II: Term structure of interest rates under certainty, interest rate uncertainty and forward rate, forward rate agreements, theories term structure, measures the term structure.

Unit-III: Interest rate sensitivity, duration, conversity, passive and active bond management.

Unit-IV: Interest rate derivatives (Bond options, interest rate caps and floors, hedging interest, rate derivatives, convexity, timing, and quanto adjustments).
Interest rate derivative models-Modes of short rate, HJM and LMM.

Unit-V: Mortgage- Backed securities, and their analysis.

Books Recommended:

1. *Z. Bodie, A. Kane, A. J. Marchs, P. Mohanty-Investments, 6th Editions, TMH, 2006.*
2. *J. C. Hull- Options, Futures, and other derivatives- 7th Edition- Peason Edition-2009.*
3. *Y.D. Lyuu- financial Engineering and Computation. Cambridge University Press -2002.*

MCF-402

Financial Risk Management and Measurement	**Credit: 4(3-0-1)**

Unit-I: Regulation of financial Institutions, Need of regulation, credit risk and the Basle accord, regulatory frame work in India, UK & US.

Unit-II: Market Risk: key issues, Value at Risk (VaR), Risk grades, capital adequacy and market risk, yield validity and return validity, VaR for exchange rate risk.

Unit-III: VaR: Mapping cash Flows-VaR for equity portfolio, coupon paying bonds, FAR, FRN and Suraps, FX forwards and options, VaR and the single index model. Statistical issues of VaR – parameter estimation, nonparametric measures of portfolio val, validation of forecasts, Monte Carlo simulation, VaR and stress testing.

Unit-IV: Credit Risk: Credit metrics approach, measuring joint credit migration, types of exposure, incentives and RAROC, Hedging and credit derivatives, regulation, credit rating changes, credit risk of a swap, credit risk models (structural approach, reduced from approach and empirical approach.

Unit-V: Firm value and share price-based models pricing equations, solution to pricing equations, Practical implementation, Unobservable firms values and credit grades, advantage and disadvantages.

Books Recommended:

1. *P. J. Schonbucher - Credit derivatives pricing Models-models, pricing and Implementation - John Wiley 2003.*
2. *Paul Wilmott an Quantitative finance, P. Wilmott, John Wiley 2006.*
3. *Cutliberatson and Nitzsoche- Financial Engineering, Derivatives and Risk Management, John Wiley.*
4. *J. C. Hull: Option, Future and other derivatives, Pearson Education.*
5. *G. Chako, A. Sjoman, H. Motolashi, V. Dessaiv- Credit Derivatives and primer on credit risk, modeling and instruments-Wtarton school publication.*

MCF-403

Principles of Financial Engineering — Credit: 4(3-0-1)

Unit-I: Cast flow engineering and forwards contracts, engineering simple interest derivatives.

Unit-II: Introduction to swap engineering, market strategy in financial engineering.

Unit-III: Dynamic replication methods and synthetics, option engineering applications.

Unit-IV: Tools for volatility engineering, volatility swaps and volatility trading, smile effects in engineering.

Unit-V: Credit derivatives in financial engineering, engineering of equity instruments.

Books Recommended:

1. *Text: S. N. Neftci- Principles of financial engineering, Elsevier (2005).*

MCF-404: Elective Papers Group-A

A1. Actuarial Science — Credit: 4(3-0-1)

Unit-I: Principles of premium calculation: Properties of premium principles, Examples of premium principles.

Unit-II: The collective risk model: Reinsurance, The effect of reinsurance, Recursive calculation of aggregate claims distributions, Extensions of the Panjer recursion formula, The application of recursion formulae, Approximate calculation of aggregate claims distributions.

Unit-III: The individual risk model: De Pril's recursion formula, Kornya's method, Compound Poisson approximation, Numerical illustration.

Unit-IV: Introduction to ruin theory: A discrete time risk model, The probability of ultimate ruin, The probability of ruin in finite time, Lundberg's inequality.

Unit-V: Classical ruin theory: The classical risk process, Poisson and compound Poisson process, Definitions of ruin probability, The adjustment coefficient, Lundberg's inequality, Survival probability, Recursive calculation, Approximate calculation of ruin probabilities.

Books Recommended:

1. *Actuarial Models (The Mathematics of Insurance) by Vladimir I. Rotar, Chapman and Hall (CRC).*
2. *Fundamentals of Actuarial Mathematics by S. David Promislow , Wiley.*
3. *Risk Analysis in Finance and Insurance by Alexandar Melnikov, Chapman and Hall (CRC).*
4. *International Series on Actuarial Science (Insurance Risk and Ruin) by David C. M. Dickson, Cambridge.*

A2. Artificial Intelligence (Marks-100) Credit 4(3-2-0)

Unit I: Artificial Intelligence: Introduction, Intelligent Agents: Agents & Environments, Concept of Rationality, Nature & Structure of Agents.

Unit II: Problem Solving: Solving Problems by Searching, Classical Search, Adversarial Search, Constraint Satisfaction Problems. Knowledge, Reasoning and planning: Logical agents.

Unit III: First order logic, Inference in First order logic. Classical planning, Knowledge Representation: Uncertain Knowledge and Reasoning: Probabilistic Reasoning, Learning from Examples, Knowledge in learning;

Unit IV: Natural Language Processing: Language models, Text Classification, information retrieval, information extraction.

Unit V: Natural Language for Communication: Phrase structure Grammars, Syntactic Analysis, Augmented grammars and semantic interpretation, Machine translation, Speech recognition; Perception; Expert Systems: Introduction, Design of Expert systems.

Prescribed Text Books

1. Stuart Russell and Peter Norving, "Artificial Intelligence: A Modern Approach", Third Edition, 2010, Pearson Education, New Delhi.

Reference Books

1. Elanie A. Rich and Kevin Knight, "*Artificial Intelligence*", 3rd Edition, 2009, McGraw-Hill Education (India), New Delhi.

2. Nills J. Nilsson, "*Artificial Intelligence: A New Synthesis*" 2nd Edition, 2000,Elsiver India Publications, New Delhi.

3. Michael Negnevitsky, "*Artificial Intelligence: A Guide to Intelligent Systems*", Second Edition, 2005, Pearson Education, Inc. New Delhi.

4. Dan W. Patterson, "*Introduction to Artificial Intelligence and Expert Systems*",1st Edition, 1996, PHI Learning Pvt. Ltd., New Delhi.

5. Ben Coppin, "*Artificial Intelligence Illuminated*", 2005, Narosa Publication, New Delhi. ISBN: 978-81-7319-671-3.

A3. Behavioural Finance — Credit: 4(3-0-1)

Unit I: Introduction, Asset Pricing: Efficient Market Hypothesis, Stock Market Puzzles and Anomalies, Nonstandard Beliefs, Nonstandard Preferences, Bounded Rationality, Limits to Arbitrage and Degrees of Freedom Critique, ESG Investing. Corporate Finance: Market Timing, Behavioral Managers:Managerial Biases and Firm Investment, Managerial Biases and M&A, Managerial Biases and Financing Decision & Biases in Corporate Governance.

Unit II: Behavioral finance: Introduction to Behavioral finance – Nature, scope, objectives and application; Investment Decision Cycle: Judgment under Uncertainty: Cognitive information perception - Peculiarities (biases) of quantitative and numerical information perception - Representativeness – Anchoring - Exponential discounting - Hyperbolic discounting.

Unit III: Utility/Preference Functions: Expected Utility Theory [EUT] and Rational Thought: Decision making under risk and uncertainty - Expected utility as a basis for decision-making – Theories based on Expected Utility Concept - Investor rationality and market efficiency.

Unit IV: Behavioral Factors and Financial Markets: The Efficient Markets Hypothesis – Fundamental Information and Financial Markets - Information available for Market Participants and Market Efficiency -Market Predictability –The Concept of limits of Arbitrage Model - Asset management and behavioral factors - Active Portfolio Management: return statistics and sources of systematic under performance. - Fundamental information and technical analysis – the case for psychological influence.

Unit V: Heuristics and behavioral biases of investors: Types of investors- Individual and Institutional - How the human mind works-the two systems; Familiarity and related heuristics; Representativeness and related biases; Anchoring; Irrationality and adaptation; Hyperbolic discounting. Sovereign credit rating - drivers.

References:

1. Shleifer, Andrei (2000). Inefficient Markets: An Introduction to Behavioral Finance. Oxford, UK: Oxford University Press.

2. Kahneman, D. and Tversky, A. (1984). "Choices, Values, and Frames". American Psychologist 39 (4): 341–350.

3. HershShefrin, (2000) Beyond Greed and Fear, Harvard Business School Press.

4. Chandra, P. (2017), Behavioural Finance, Tata Mc Graw Hill Education, Chennai (India).

5. Ackert, Lucy, Richard Deaves (2010), Behavioural Finance; Psychology, Decision Making and Markets, Cengage Learning.

6. Forbes, William (2009), Behavioural Finance, Wiley.

7. Kahneman, D. and Tversky, A. (2000). Choices, values and frames. New York : Cambridge Univ. Press.

8. Shefrin, H. (2002), Beyond Greed and Fear; Understanding Behavioural Finance and Psychology of investing. New York; Oxford University Press.

9. Shleifer, A. (2000). Inefficient markets; An introduction to Behavioural Finance. Oxford Univ. Press.

10. Thaler, R. (1993). Advances in Behavioral Finance. Vol. I. New York, Russell Sage Foundation.

11. Thaler, R. (2005). Advances in Behavioural Finance. Vol. II. New York; Princeton University Press.

12. Behavioral Finance: Insights into Irrational Minds and Markets, by Montier

13. Behavioral Corporate Finance, by Shefrin .

A4. Credit Derivative Pricing Models — Credit: 4(3-2-0)

Unit-I: Credit Derivatives - Overview, hedge based Pricing, exotic credit derivatives, Default correlation products and CDOs, credit linked notes.

Unit-II: Credit spreads and implied default probabilities, Recovery modelling, Building blocks for credit derivatives pricing, pricing with the building blocks, constructing, and calibrating credit spread curves implementation issues.

Unit-III: Advanced credit spread models - Poisson processes, Intromogeneous Poisson Processes, stochastic credit spread, Recovery Modelling.

Unit-IV: Implementation of Intensity - based models - Tractable models of the spot intensity, computation of credit derivatives in the CIR model, Tree models, and Partial differential equation based implementation, Term and structure of credit spreads, Monte Carlo simulation.

Unit-V: Firm value and share price - based models pricing equations, solution to pricing equations, Practical implementation, Unobservable firms values and credit grades, advantages and disadvantages.

Books Recommended Texts:

1. *P. J. Schonbucher - Credit derivatives Pricing Models- models, Pricing and Implementation- John Wiley 2003.*
2. *G. Chacko, A. Sjoman, H. Motohasli, V. Dessain- Credit Derivatives-Wharton School Publishing, 2007.*

References:

1. *Paul Wilmott an Quantitative finance, P. Wilmott , John Wiley 2006.*
2. *Quantitative Risk Management - Concepts, Techniques, Tools, A. J. Meiveils R. Frey, P. Embrelts, Princton Univ. Press – 2005.*
3. *Credit Risk Pricing Models - Theory and Practice, B. Schmid - Springer 2004.*

A5. Dynamic Asset Management — Credit: 4(3-0-1)

Unit-I: Dynamic Asset Pricing – Multi-period mode, Dynamic Proffering approach, Infinite horizon, setting, state prices and martingale measures, portfolio and consumption choice equilibrium.

Unit-II: Managing individual and institutional Investor portfolios, Capital Market expectations.

Unit-III: Asset allocation, fixed income portfolio management, equity portfolio management, Alternative Investments portfolio management.

Unit-IV: Execution of Portfolio Decisions, Monitoring and rebalancing, Evaluating Portfolio performance, Global Investment performance standards.

Books Recommended:

1. *Darrell Deffie-Dynamic Asset Pricing Theory-Princeton University Press, 2001.*
2. *J. L. Maginn, D.L. Tuttle, J.E. Pinto, D. W. Mcleavey- Managing Investment Portfolios-A Dynamic Process, CFA Institute, 2007.*

A6. Deep Learning & Reinforcement Learning with Lab Credit 4 (3-2-0)

Unit I: Exact inference for graphical models, Variational inference,Monte Carlo inference,MCMC inference,Learning undirected Gaussian graphical models

Unit II: Reinforcement learning and control- MDP, Bellman equations,value iterations and policy iteration, Linear quadratic regulation, LQG, Q-learningValue function approximation, Policy search, Reinforce POMDPs.

Unit III: Review of backpropagation. **Regularization for Deep Learning**: Parameter Norm Penalties, Norm Penalties as Constrained Optimization, Regularization and Under-Constrained Problems, Dataset Augmentation, Noise Robustness, Semi-Supervised Learning, Multitask Learning, Early Stopping, Parameter Tying and Parameter Sharing, Sparse Representations, Bagging and Other Ensemble Methods, Dropout, Adversarial Training, Tangent Distance, Tangent Prop and Manifold Tangent Classifier. **Optimization for Training Deep Models**: How Learning Differs from Pure Optimization, Challenges in Neural Network Optimization, Basic Algorithms, Parameter Initialization Strategies, Algorithms with Adaptive Learning Rates, Approximate Second-order Methods, Optimization Strategies and Meta-Algorithms.

Unit IV: Convolutional Networks: The Convolution Operation, Motivation, Pooling, convolution and Pooling as an infinitely strong prior, Variants of the Basic Convolution Function, Structured Outputs, Data Types, Efficient convolution Algorithms, Random or Unsupervised Features, The Neuroscientific Basis for Convolutional Networks, Convolutional Networks and the History of Deep Learning. **Sequence Modeling : Recurrent and Recursive Nets** : Unfolding Computational Graphs, Recurrent Neural Networks, Bidirectional RNNs, Encoder-Decoder Sequence-to-Sequence Architecture, Deep recurrent Networks, Recursive Neural Networks, The Challenge of Long-Term Dependencies, Echo State Networks, Leaky Units and Other Strategies for Multiple Time Scales, The Long Short-Term Memory and Other Gated RNNs, Optimization for Long-Term Dependencies, Explicit Memory.

Unit V: Practical Methodology: Performance Metrics, Default Baseline Models, Determining Whether to Gather More Data, Selecting Hyperparameters, Debugging Strategies, Example-Multi-Digit Number Recognition.

Linear Factor Models: Slow Feature Analysis, Sparse Coding, **Autoencoders**: Undercomplete Autoencoders, Regularized Autoendcoders, Representational Power, Layer Size and Depth, Stochastic Encoders and Decoders, DenoisingAutoencoders, Learning Manifolds with Autoencoders, Contractive Autoencoders, Predictive Sparse Decomposition, Applications of Autoencoders, **Deep Generative Models** : Boltzmann Machines, Restricted Boltzmann Machines, Deep Belief Networks.

Implementaion of the following algorithms:

i. Convolution Neural network (CNN)
ii. Recurrent Neural Network (RNN)

iii. Autoencoder
iv. Deep Belief Network

Books for reference:
1.Ian Goodfellow, YoshuaBengio, and Aaron Courville, Deep Learning, The MIT Press, 2016

2. Kevin P. Murphy, Machine Learning-a probabilistic prospective, MIT Press, 2012

3. Tom Mitchel, Machine Learning, McGraw Hill.

A7. International Equity and Currency Markets — Credit: 4(3-0-1)

Unit I: International Financial Environment, International Financial Transactions, Gold Standards and Paper Currency Standard, Purchasing Power Parity and Paper Currency Standards, Floating Rate System, Currency Basket System.

Unit II: Foreign Exchange Market, Exchange Rate Arithmetics, Understanding Merchant Rates, Foreign Exchange Forward Contracts, VaR and Foreign Exchange Market, International Parity Conditions and Movement of Exchange Rate, Exchange Rate Determination and Forecasting.

Unit III: Development of Foreign Exchange Market in India, Foreign Exchange Exposures and Transaction Exposure, Analysis of transaction exposure, Foreign Exchange Futures Market, Currency Options, Interest rate swaps.

Unit IV: Currency swaps, Operating Exposure Assessment, Operating Exposure Management, International Capital Structure, International Capital Asset Pricing, International Capital Budgeting and FDI, International Equity Market - GDR.

Unit V: World Trade Organisation, International Integration of India's Financial Markets, Forex Reserves Composition and Determinants of Optimum Reserves – A Case for India, Movement of Exchange Rates in India, International Trade Theory, International Bond Market, India's Foreign Trade – Direction and Composition, Financial Stability, Money and Forex Markets interaction, Characteristics of Indian Foreign Exchange Market.

References:

1. International Financial Managemnet by P.G.Apte, TMH Publication, 4th Ed.
2. International Finance Management,Eun & Resnick TMH Publication, 4th Ed.
3. International Finance Management, 2. Jeff Madura, Thomson Publication, 7th Ed.
4. Multinational Business Finance by David K Eiteman,Arthur IStonehill, Michael H Moffett, Alok Pandey ,Pearson Publication, 10th Ed.
5. Multinational Financial Management, by Alan C.Shapiro, Wiley India, 8th Ed.

A8. Monte Carlo Methods in Finance — Credit: 4(3-0-1)

Unit-I: Principles of Monte Carlo, Generating random numbers and random variables: Random number generation, general sampling methods, normal random variables.

Unit-II: Generating Sample paths: Brownian and Geometric Brownian motions; Gaussian start rate methods; Square root diffusions; process with jumps; Forward rate models; simple rates and continuous rates.

Unit-III: Variance Reduction Techniques.

Unit-IV: Discretization methods.

Unit-V: Pricing American Options.

Books recommended:

1. *Monte Carlo Methods in Financial Engineering, By Paul Glasserman, Springer: Applications of Mathematics. 53, 2004.*
2. *Introduction to databases, including simple relational databases, data warehouses and introduction to online analytical data processing.*
3. *Association rules and prediction, data attributes, applications to electronic commerce.*

Books for reference:

1. *Berson, A. and Smith, S.J. (1997). Data Warehousing, Data Mining, and OLAP. (McGraw-Hill).*
2. *Breiman, L., Friedman, J.H., Olshen, R. A. and Stone, C. J. (1984). Classification and Regression Trees. (Wadsworth and Brooks/Cole).*
3. *Han,J. and Kamber, M. (2000). Data Mining; Concepts and Techniques. (Morgan Kaufmann).*
4. *Mitchell, T.M. (1997). Machine Learning. (McGraw-Hill).*
5. *Ripley, B.D. (1996). Pattern Recognition and Neural Networks. (Cambridge University Press).*
6. *S. Koutroumbas, K. Theodoridis, Pattern Recognition, 4th Edition, AP, 2009.*
7. *C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.*
8. *S. Haykin, Neural Networks- A Comprehensive Foundation, Pearso Education, 2001.*
9. *E. Alpaydin, Introduction to Machine Learning, MIT, 2004 (PHI-2006).*

A9. Numerical Solution of Partial Differential Equations Credit: 4(3-0-1)

Unit I: Solution of first order ordinary differential equations Approximate Solution: Picard Iteration Method, Taylor Series method.

Unit II: Numerical Solution: Euler method; Algorithm; Example; analysis.

Unit III: Modified Euler Method: Algorithm; Example; analysis

Unit IV: Runge Kutta methods, Second Order methods

Unit V: Fourth Order Runge Kutta methods, Higher Order Runge Kutta methods

References:

1. Bradie B A Friendly Introduction to Numerical Anaysis Pearson Education,2007

2. Burden RL, Faires J D Numerical Analysis Cengage Learning, 2007

3. Chapra SC, Canale, R P Numerical Methods for Engineers Tata McGraw Hill, 2003

4. Gerald C.F., Wheatley P O Applied Numerical analysis, Addison Wesley, 1998

A10. Probabilistic Graphical Models (Marks100) Credit 4(3-0-1)

Unit I: Introduction, Probability Theory, Bayesian Networks

Unit II: Undirected models, Learning Bayes Nets, Exact Inference; Message Passing

Unit-III: Sampling, MAP Inference; Structured prediction

Unit-IV: Parameter Learning, Bayesian Learning; Structure Learning,

Unit-V: Exponential families; variational inference

Recommended Text Books:
1. Probabilistic Graphical Models: Principles and Techniques by Daphne Koller and Nir Friedman. MIT Press.

References:

1. *Modeling and Reasoning with Bayesian networks* by Adnan Darwiche.
2. *Pattern Recognition and Machine Learning* by Chris Bishop.
3. *Machine Learning: a Probabilistic Perspective* by Kevin P. Murphy.
4. *Information Theory, Inference, and Learning Algorithms* by David J. C. Mackay.
5. *Bayesian Reasoning and Machine Learning* by David Barber.
6. *Graphical models, exponential families, and variational inference* by Martin J. Wainwright and Michael I. Jordan.

MCF-405: Elective Papers Group-B

B1. Advanced Machine Learning with Lab Credit: 4(3-2-0)

Unit-I: Introduction, generative models for discrete data (Bayesian concept learning, Naïve Bayes classifier), Gaussian discriminant analysis, Inference in jointly Gaussian distributions, Bayesian statistics, Bayesian linear and logistic regression.

Unit-II: General linear models and exponential family, Mixture models and EM algorithm, Sparse linear models, Review of SVM, Multiclass SVM, kernels for building generative models, Multiple kernels, kernels for strings, trees, and graphs, Gaussian Processes.

Unit-III: Graphical models- DIRECTED Graphical models (Bayesian networks), Markov and Hidden Markov Models, Markov Random fields, Conditional Random fields.

Unit-IV: Neural Networks-Perceptron, MLP and back propagation , Methods of acceleration of convergence of BPA.

Unit-V: Dimensionality reduction (Factor analysis, Kernel PCA, Independent Component analysis, ISOMAP, LLE), feature Selection, Spectral clustering.

Books for Reference:

1. *Kevin P. Murphy , Machine learning – a Probabilistic Perspective, MIT Press,2012.*
2. *Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2007.*

3. *Simon Haykin, Neural Network – a comprehensive foundation, Pearson Education-1994.*
4. *Tom Mitchel, Machine Learning – McGraw Hill Science, 1997.*

B2. Algorithmic Trading — Credit: 4(3-2-0)

Unit I: Introduction to Algorithmic Trading: Evolution of Algorithmic Trading, What is Algorithmic Trading? Different Trading Methodologies, Trends in Algorithmic Trading: Global and India, Benefits of Algorithmic Trading. Technical analysis and trend determination, Dow Theory, Moving averages, Momentum indicators, Classical price patterns.

Unit II: Order Types: Different Order Types, Execution Trading Strategies, Trading Strategies: Calendar, Spread Cash Future Arbitrage Strategy Index Arbitrage Pair Trading News Based Trading Strategies, Conversion- Reversal.

Unit III: Algorithmic Trading- System Architecture: Market Data, CEP Engine, Order Routing / Order Manager Colocation, Smart Order Routing (SOR) Connectivity, Options. Risk management in Algorithmic Trading: Different Stages involved in Risk Management, Risk Management Specific to High Frequency & Algorithmic Trading.

Unit IV: Advanced time-series regression algorithms: ARMA/ARIMA models, Mean reverting trading strategies with vector error correction models and cointegration, model risk management, back testing, model validation, and stress testing with R

Unit V: Audit and Compliance process: International Organization of Securities Commissions Auditing Process and Requirements (As defined by NSE for member-broker), SEBI Recommendations on Algorithmic Trading, Software Testing and Empanelment, Exchange Audits, Technology and System Audit Compliance Requirements.

Books and references

1. Machine Learning in Finance by M. Dixon, I Halperin, and P. Bilokon, Springer, 1st Edition
2. Advances in Financial Machine Learning, Marcos Lopez, Wiley, 1st Edition
3. Machine Learning for Asset Managers, Marcos Lopez, Cambridge University Press, 1st Edition
4. Machine Learning for Algorithmic Trading, Stefan Jansen, 2nd Edition, Packt
5. Elton & Gruber, "Modern Portfolio Theory", Wiley, 9th Edition
6. Reilly, Frank,K., "Investment Analysis and Portfolio Management," 5th Edition, Dryden.

B3. Big Data Analytics with Lab — Credit: 4(3-2-0)

Unit-I: Evolution of data management, Introduction to Big data, Introduction to Databases, Relational Model, and SQL, Data exploration and reproducibility, Data quality.

Unit-II: Introduction to map reduce , Map reduce algorithm patterns and relations, Parallel data bases vs Map Reduce, Storage solutions, Introductions to Spark, Hadoop, Hive, Pig-Latin.

Unit-III: Big Data Algorithms/Mining techniques- 1(Finding similar items and spark, exploring spatio-temporal data, mining association rules, EM algorithm for text processing).

Unit-IV: Big Data Algorithms/Mining techniques-2(Page Rank and K-means in Pig and Spark, Efficient regularized SGD, Hash kernels for logistic regression, Matrix factorization, Matrix factorization with SGD, DGMs for naive Bayes, Fast sampling for LDA.

Unit-V: Large scale graph processing –Pregel, Large-Scale visualisation.

Books for Reference:

1. Mining Massive Datasets, Anand Rajaraman, J. Leskovec, and Jeff Ullman- http://www.mmds.org
2. Data-Intensive Text Processing with nMapReduce, J. Lin and C. Dyer, http://lintool.github.com/MapReduceAlgorithms/index.html

B3. Causal Inference for Finance — Credit: 4(3-2-0)

Unit I: Introduction, Statistics and probability review, Introduction to Causation, Ignorability and unconfoundedness, Randomized Experiments,Randomization Inference.

Unit II: Randomized Experiments and contextual covariates: Treatment Effect Heterogeneity, Blocking and Stratification.

Unit III: Observational inference: Introduction to Observational Inference, Directed acyclic graphs, Weighting Methods The Propensity Score, Introduction to Matching, Matching Methods.

Unit IV: Regression: Regression Adjustment,Causal Inference with grouped data,Difference in differences, Instrumental Variables: assumptions and motivation Instrumental Variables Estimators.

Unit V: Regression Discontinuity Designs: Introduction to RDD and Examples, RDD: Estimators and Inference, Sensitivity Analysis, Causal Inference and Machine Learning, Causal Inference and Ethics.

References Text:

1. Mastering' Metrics: The Path From Cause to Effect. Princeton University Press, 2014. Joshua D. Angrist and Jörn-Steffen Pischke.

B5. Cyber Security (Marks: 100) Credit 4(3-2-0)

Unit I: Introduction - Introduction to cyber security, Confidentiality, integrity, and availability. Foundations - Fundamental concepts, CIA, CIA triangle, data breach at target.Security management, Governance, risk, and compliance (GRC)- GRC framework, security standards.

Unit II: Contingency planning - Incidence response, Disaster Recovery, BCP. Cyber security policy - ESSP, ISSP, SYSSP. Risk Management - Cyber Risk Identification, Assessment, and Control.

Unit III: Cyber security: Industry perspective - Defense Technologies, Attack, Exploits. Cyber security technologies - Access control, Encryption, Standards. Foundations of privacy - Information privacy, Measurement, Theories.

Unit IV: Privacy regulation - Privacy, Anonymity, Regulation, Data Breach. Privacy regulation in Europe, Privacy: The Indian Way - Data Protection, GDPR, DPDP, Aadhar.

Unit V: Information privacy: Economics and strategy, Economic value of privacy, privacy valuation, WTA and WTC, Business strategy and privacy, espionage, Privacy vs safety.

References Text:

1. Michael E. Whitman, Herbert J. Mattord, (2018). Principles of Information Security, 6th edition, Cenage Learning, N. Delhi.
2. Darktrace, "Technology" https://www.darktrace.com/en/technology/#machine-learning, accessed November 2018.
3. Van Kessel, P. Is cyber security about more than protection? EY Global Information Security Survey 2018-2019.
4. Johnston, A.C. and Warkentin, M. Fear appeals and information security behaviors: An empirical study. MIS Quarterly, 2010.
5. Arce I. et al. Avoiding the top 10 software security design flaws. IEEE Computer Society Center for Secure Design (CSD), 2014.
6. Smith, H. J., Dinev, T., & Xu, H. Information privacy research: an interdisciplinary review. MIS Quarterly, 2011.
7. Subramanian R. Security, privacy and politics in India: a historical review. Journal of Information Systems Security (JISSec), 2010.
8. Acquisti, A., John, L. K., & Loewenstein, G. What is privacy worth? The Journal of Legal Studies, 2013.
9. Xu H., Luo X.R., Carroll J.M., Rosson M.B. The personalization privacy paradox: An exploratory study of decision making process for location-aware marketing. Decision Support Systems, 2011.

B6. High Performance Computing — Credit: 4(3-2-0)

Unit I: Program execution: Program, Compilation, Object files, Function call and return, Address space, Data and its representation.

Unit II: Computer organization: Memory, Registers, Instruction set architecture, Instruction processing

Unit III: Pipelined processors: Pipelining, Structural, data and control hazards, Impact on programming. Virtual memory: Use of memory by programs, Address translation, Paging, Cache memory: Organization, impact on programming, virtual caches.

Unit IV: Operating systems: Processes and system calls, Process management, Program profiling. File systems: Disk management, Name management, Protection.

Unit V: Parallel architecture: Inter-process communication, Synchronization, Mutual exclusion, Basics of parallel architecture, Parallel programming with message passing using MPI.

References Text:

1. J. L. Hennessy and D. A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann.

2. A. Silberschatz, P. B. Galvin, G. Gagne, Operating System Concepts, John Wiley.

3. R. E. Bryant and D. R. O'Hallaron, Computer Systems: A Programmer's Perspective, Prentice Hall.

B7. Object Oriented Software Engineering — Credit: 4(3-2-0)

Unit-I: Introduction, Software life cycle modules, Requirements Analysis and specification, software design, Function oriented software design.

Unit-II: Coding and Testing, Software reliability and quality management, Computer Aided Software Engineering, Software maintenance.

Unit-III: Introduction to object oriented Analysis and Design, Iterative Development and the unified process, case study-The next-Gen POS, Inception, Understanding Requirements, Use case Model, Identifying other requirements.

Unit-IV: Elaboration, Use case Model, Drawing system sequence diagrams, Visualizing concepts, Adding Associations, adding attributes, adding details with operation contracts, interaction diagram notation.

Unit-V: PATTERNS, GRASP, Creating design class diagrams, GOF Design pattern Planning and project queues comments on iterative development and the UP, Rational Unified Process.

Recommended Text Books:

1. *Crag Larman: Applying UML and Patterns-An introduction OOAP & D and the Unified process, Pearson Education Asia.*
2. *Rajib Mail: Fundamentals of Software Engineering, PHI.*

B8. Quantitative Risk Management — Credit: 4(3-0-1)

Unit-I: Basic concepts in risk management, Multivariate Models (Basic of multivariate modeling, Normal mixture distributions, and Dimension reduction techniques), volatility models and risk estimation, fundamentals of multivariable time series, multivariate GRACH Process.

Unit-II: Copulas and dependence (Copulas, Dependence measures, Normal mixture copulas, flitting copulas to data), Aggregate risk (coherent measures of risk, bounds for aggregate risk capital allocation).

Unit-III: Extreme value theory (Maxima, Tails of specific, Models, Point process models, Multivariate maxima), Operational risk and Insurance analysis (Operational risk in perspective, Elements of insurance analytics).

Unit-IV: Credit risk management, (credit risk modeling threat hold, mixture Monte Carlo Models, Dynamic credit risk models (mathematical tools, financial and Actuarial pricing of credit risk, pricing with doubly stochastic default time, conditionally independent defaults).

Book Recommended:

A. J. Mc Neil, R. Frey, and P. Embrechts- Quantitative Risk Management –Concept, techniques, Tools. Princeton University Press, 2005.

B9. Soft Computing Methods — Credit: 4 (3-2-0)

Unit-I: Neural Network topologies, activation functions and learning methods, perception training algorithm, The multilayer perception (MLP), Back Propagation learning algorithm, financial applications.

Unit-II: Self-organization maps, Support vector machine for classification and regression, application to finance.

Unit-III: Genetic algorithm (GA), MLP-GA, SVM-GA hybrid methods and financial applications.

Unit-IV: Elements of fuzzy set theory, Fuzzy logic and approximate reasoning, Neuro-fuzzy and Fuzzy –GA hybrid methods, Rough set theory financial applications.

Unit-V: The particle swarm optimization algorithm, Discrete PSO, MLP-Swarm Hybrids, Ant colony optimization methods, financial applications.

Recommended Text Books:

1. *S. Haykin-Neural Networks: A Comprehensive Foundation, Pearson Education, 2001.*
2. *Brabazan, M.O' Neill-Biologically Inspired Algorithm for Financial Modelling-Springer-2006.*
3. *R. A. Aliev, B. Fazlollahi, R.R. Aliev-Soft Computing and its Applications in Bussines and Economic, Springer Verlag, 2004.*
4. *Relevant research papers an use of soft computing methods for financial problems.*

B10. Time Series Analysis and Forecasting (Marks: 100) Credit 4(3-2-0)

Unit-I: Linear Time Series Analysis and its Applications: Stationary, Correlation and Autocorrelation Function. White Noise and Linear Time Series, Simple Autoregressive Models, Simple Autoregressive Models.

Unit-II: Conditional Hoteroscedastic Models: Characteristic of Volatility, Structure of a Model, Model Building, The Arch MODEL, The GARCH Model, The Integrated GARCH Model, The GARCH-M Model, The Exponential GARCH Model, The threshold GARCH Model, The CHARAM Model, Random Coefficient Autoregressive Models, The stochastic Volatility Model, Application.

Unit-III: Nonlinear Models and Their Applications: Nonlinear Models, Nonlinearity Tests, Modelling, Forecasting, Applications.

Unit-IV: High- Frequency Data Analysis and Market Microstructure: Nonsynchronous Trading, Bid-Ask Spread, Empirical Characteristics of Transactions Data, Models for price changes, Duration Models, Nonlinear Duration Models, Bivariate Models for Price Change and Duration.

Unit-V: Principle Component Analysis and Factor Models: A Factor Model, Macro econometric Factor Models, Fundamental Factor Models, Principal Component Analysis, Statistical Factor Analysis, Asymptotic Principal Component Analysis.
Recommended Book:

Analysis of Financial Time Series, by Ruey S. Tsay, Wiley Series in Probability and Statistics.

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Dissertation with Viva-voce — Credit: 4