B.Tech. Curriculum for Mathematics and Computing

SEMESTER-III

Name of the Subject	Type	Subject Code	L-T-P	Credit	Contact Hour
	HSS 2		3-0-0	3	3
Probability and Statistics	DC 2	MA2L011	3-0-0	3	3
Data Structure	DC 3	CS2L004	3-0-0	3	3
Formal Languages and Automata Theory	DC 4	CS2L003	3-1-0	4	4
Simulation	SDC 3	MA2L013	1-0-3	3	4
Probability and Statistics Lab	DC Lab 2	MA2P011	0-0-3	2	3
Data Structure Lab	DC Lab 3	CS2P002	0-0-3	2	3
Total				20	23

SEMESTER-IV

Name of the Subject	Type	Subject Code	L-T-P	Credit	Contact Hour
	HSS 3		3-0-0	3	3
Design and Analysis of Algorithms	DC 5	CS2L002	3-1-0	4	4
Mathematical Analysis	DC 6	MA2L014	3-1-0	4	4
Financial Risk Management	SDC 4	MA2L012	3-0-0	3	3
Design and Analysis of Algorithms Lab	DC Lab 5	CS2P001	0-0-3	2	3
Financial Risk Management	Lab-6	MA2P012	0-0-3	2	3
Introduction to Algebra and Number Theory	OE 1	MA2L015	3-1-0	4	4
Total				22	24

Syllabus for 2nd Year (3rd & 4th Semesters)

Subject Code: MA2L011	Name: Probability and Statistics	L-T-P-C: 3-0-0-3
Prerequisite: None		

Module 1: (Classical and axiomatic definitions) (6 hours)
Classical and axiomatic definitions of probability, addition rule, Conditional probability, Multiplication rule, Bayes' theorem, Independence
Module 2: (Discrete and continuous random variables) (9 hours)
Discrete and Continuous random variables, Standard distributions: Uniform, Binomial, Geometric, Poisson, Exponential, Gamma, Normal
Module 3: (Jointly distributed random variables) (7 hours)
Jointly distributed random variables, Marginal and conditional distributions, Expectation, Moments, Probability generating functions, Moment generating functions
Module 4: (Laws of large numbers) (7 hours)
Chebyshev's inequality, weak and strong laws of large numbers, functions of random variables and their distributions
Module 5: (Central Limit Theorem) (9 hours)
Central Limit Theorem, distributions of sample mean and variance, Chi-square, t and F distributions, point estimation, interval estimation, maximum likelihood estimation
Module 6: (Hypothesis Testing) (4 hours)
Null and alternative hypotheses, critical and acceptance regions, Neyman–Pearson lemma, one-sample and two-sample tests for normal populations

Text Books:

1. Probability and Random Processes by Grimmett G. R. and Stirzaker D. R., Oxford University Press, 2001
2. An Introduction to Probability and Statistics by Vijay K. Rohatgi, A. K. M. E. Saleh, Wiley Series in Probability and Statistics, 2015
3. Introduction to Probability and Statistics for Engineers and Scientists by Ross S. M., Academic Press, 2014

Reference Books:

1. Probability and Statistics in Engineering by Hines W. W., Montgomery D. C., Goldsman D. M., Borror C. M., 4th Edition, John Wiley and Sons, 2002
2. Introduction to Probability by Bertsekas D. P. and Tsitsiklis J. N., Athena Scientific, 2002
3. Probabilistic Methods by Alon N. and Spenser J., 4th Edition, John Wiley and Sons, 2016

Subject Code: CS2L004	Subject Name: Data Structures	L-T-P-C: 3-0-0-3
Pre-requisite(s): Programming in C		

Theory:

Module 1: **Introduction (8 hours)**: Abstract data type, Stacks, Queues (linear queue, circular queue, double-ended queue), Linked Lists (singly linked list, circular linked list, doubly linked list) and their applications.

Module 2: **Priority queues (4 hours)**: Binary heap.

Module 3: **Sorting (7 hours)**: Comparison based sorting (quick sort, heap sort, merge sort); Decision tree model and lower bound on sorting; Sorting in linear time (radix sort, bucket sort, counting sort).

Module 4: **Hashing (3 hours)**: Hash tables, Hash functions (division method, multiplication method, universal hashing), Collision resolution strategies, Open Hashing (linear probing, quadratic probing, double hashing), Chaining.

Module 5: **Trees (14 hours)**: Binary tree, Binary search trees, Threaded Binary Tree, Balanced binary search trees (AVL tree, Red-black tree); Multi-way search tree (2-3 Tree, 2-4 Tree, B-trees).

Module 6: **Advanced Data Structures (6 hours)**: Disjoint sets, Binomial heap, Tries, Compressed tries, Segment tree, Binary Indexed Tree.

Text Books:

1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, “Introduction to Algorithms”, 4^{th} Edition, MIT Press.
2. Ellis Horowitz, Sartaj Sahni, and Susan Anderson Freed, “Fundamentals of Data Structures in C”, 2^{nd} Edition, Universities Press.

Reference Books:

1. Mark Allen Weiss, “Data structures and Algorithm Analysis in C”, 2^{nd} Edition, Pearson.
2. Yedidyah Langsam, Moshe J. Augenstein, and Aaron M. Tenenbaum, “Data Struc-ture Using C and C++”, 2^{nd} Edition, Pearson.
3. Narasimha Karumanchi, “Data Structures And Algorithms Made Easy”, 2^{nd} Edi-tion, Careermonk Publications.
4. Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser, “Data Structures and Algorithms in Java”, 6^{th} Edition, John Wiley & Sons Inc.

Subject Code:CS2L003	Subject Name: Formal Languages and Automata Theory	L-T-P-C: 3-1-0-4
Pre-requisite(s): None		

Theory:

Module 1: **Introduction:** Motivation for studying theory of computation, a quick overview of the subject. Notion of formal language. Language membership problem.

Module 2: **Finite automata and regular expressions:** DFA, NFA (with and without transitions), their equivalence. Proof that for some languages NFAs can be exponentially more succinct than DFAs. Dentition of regular expressions. Proof that FAs recognize, and regular expressions denote the same class of languages (regular languages).

Module 3: **Properties of regular languages:** Pumping lemma and its use to prove non-regularity of a language, closure properties of class of regular languages, decision properties: converting among representations, testing emptiness, etc. Minimization of DFAs, Myhill-Nerode theorem.

Module 4: **Context-free grammars and languages:** Derivation, parse trees. Language generated by a CFG. Eliminating useless symbols, epsilon-productions, unit productions. Chomsky normal form.

Module 5: **Pushdown automata:** Definition, instantaneous description as a snapshot of PDA computation, notion of acceptance for PDAs. Proof that CFGs generate the same class of languages that PDAs accept.

Module 6: **Properties of context-free languages:** Pumping lemma for context-free languages and its use to prove a language to be not context-free. Closure properties of the class of context- free languages. CYK algorithm for CFL membership, testing emptiness of CFLs.

Module 7: **Turing machines:** Informal proofs of undecidability. Dentition of TM, snap-shot of TM computation, notion of acceptance. Model Robustness, Church-Turing hypothesis.

Module 8: **Undecidability:** R.E. and recursive languages. Turing machine codes, diagonalization, Universal language, Reducibility. Rices theorem. Posts correspondence problem.

Intractability: Class P, Classes NP, co-NP. Polynomial time reductions. NP-completeness, NP-hardness. Cook-Levin theorem. Some NP-completeness proofs.

Text Books:

1. Michael Sipser: Introduction to the Theory of Computation, 3rd edition, PWS Publishing Company, 2012.
2. E. Hopcroft, R. Motwani and J. D. Ullman: Introduction to Automata Theory, Languages and Computation. Low priced paperback edition, published by Pearson Education, 2007.

Reference Books:

1. H. R. Lewis and C. H. Papadimitriou. Elements of the Theory of Computation, Eastern economy edition, 1998.

Subject Code: MA2L013	Name: Simulation	L-T-P-C: 1-0-3-3

Prerequisite:

Module 1: (Principles of Monte Carlo) (20 hours)

Principles of Monte Carlo, Sampling discrete and continuous random variables, Box-Muller methods

Module 2: (Simulating sample paths) (16 hours)

Simulating sample paths of stochastic processes such as Brownian motion and Jump-Diffusion processes

Module 3: (Variance reduction techniques) (8 hours)

Variance reduction techniques; Control variates; Stratified, Latin Hypercube sampling.

Module 4: (Quasi-Monte Carlo) (12 hours)

Quasi-Monte Carlo, Low-Discrepancy sequences, Randomized QMC

Text Books:

1. Monte Carlo Methods in Financial Engineering, Paul Glasserman, Springer ISBN-13: 978-0387004518, 2003

Reference Books:

1. Tools for Computational Finance, 5th Ed., R. U. Seydel, Springer, 2012, ISBN-13: 978-1447129929, 2012
2. Simulation, 5th edition, Sheldon Ross, Academic Press ISBN-13: 978-0124158252, 2012

Subject Code: MA2P011	Name: Probability and Statistics Lab	L-T-P-C: 0-0-3-2
Prerequisite: Probability and Statistics		

This course will focus on the computational aspects of probability and statistical models studied in the Probability and Statistics course, such as random variables, probability distributions, limit theorems, estimation methods, and hypothesis testing. The implementation will be carried out using MATLAB/C++/R/Python.

Text Books:

1. Probability and Random Processes by Grimmett G. R. and Stirzaker D. R., Oxford University Press, 2001
2. An Introduction to Probability and Statistics by Vijay K. Rohatgi, A. K. M. E. Saleh, Wiley Series in Probability and Statistics, 2015
3. Introduction to Probability and Statistics for Engineers and Scientists by Ross S. M., Academic Press, 2014

Reference Books:

1. Probability and Statistics in Engineering by Hines W. W., Montgomery D. C., Goldsman D. M., Borror C. M., 4th Edition, John Wiley and Sons, 2002
2. Introduction to Probability by Bertsekas D. P. and Tsitsiklis J. N., Athena Scientific, 2002
3. Probabilistic Methods by Alon N. and Spenser J., 4th Edition, John Wiley and Sons, 2016

Subject Code: CS2P002	Subject Name: Data Structures Lab	L-T-P-C: 0-0-3-2
Pre-requisite(s): Programming in C		

Applications of the Data Structures discussed in the class: Two-way Stack, Dequeue, Priority queue, Sorting Algorithms, Dictionary data structures for string handling, Cy-cle detection and removal, Application of BST, AVL Trees, Data structure for big data maintenance, Tree traversal algorithms, efficient insertion and deletion algorithm with variations across different applications, Hashing Techniques, Application of Union- Find Data Structure for set theoretic problems.

Text Books:

1. Thomas H. Cormen, Charles E. Leiserson, R.L. Rivest. Introduction to Algorithms, Prentice Hall of India Publications, 3rd Edition 2015.
2. J. Kleinberg and E. Tardos. Algorithm Design, Pearson, 2006.

Reference Books:

1. Fundamentals of Data Structures in C by Horowitz, Sahni, and Anderson-Freed, Universities Press
2. Algorithm Design: Foundations, Analysis and Internet Examples by Goodrich and Tamassia, John Wiley
3. Computer Algorithms by Baase and Van Gelder, Pearson.
4. Algorithms by Sedgewick and Wayne, Addison Wesley, 2011.

Subject Code: CS2L002	Subject Name: Design and Analysis of Algorithms	L-T-P-C: 3-1-0-4

Pre-requisite(s): Programming in C

Learning Outcome(s):

- To estimate the time and space that an algorithm uses, particularly in terms of the input size, using concepts like asymptotic and amortized analysis.
- To apply algorithm design paradigms like divide and conquer, dynamic program-ming, greedy algorithms, and linear programming for a given problem.
- To model several real-world problems as graphs, and implement graph algorithms to find optimal solutions for the problems.
- To design and implement pattern matching algorithms.
- To identify problems that are unlikely to have efficient (polynomial-time) solutions, meaning that finding a solution takes time that grows exponentially with the input size.

Theory:

Module 1: **Analysis Techniques (8 hours)**: Asymptotic notations and their signifi-cance, complexity analysis of algorithms, worst case and average case, solving recurrences (the substitution method, the recursion-tree method, the master method).

Module 2: **Design Techniques (16 hours)**: Divide and Conquer, Greedy Algorithms, Dynamic Programming, Branch and Bound, Backtracking Techniques.

Module 3: **Elementary Graph Algorithms (16 hours)**: DFS, BFS, Topological Sort, Strongly Connected Components, Minimum Spanning Trees, Single source shortest path, All pair shortest path; Network Flows: Ford Fulkerson Algo-rithm for Max Flow-Min Cut; Bipartite Matching.

Module 4: **String matching Algorithms (8 hours)**: The naive string-matching algo-rithm, The Rabin-Karp algorithm, String matching with finite automata, The Knuth-Morris-Pratt algorithm.

Module 5: **Theory of NP-Completeness (8 hours)**: Polynomial-time verification, NP-completeness and reducibility, NP-Completeness proofs, NP-Complete prob-lems.

Text Books:

1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, “Introduction to Algorithms”, 4^{th} Edition, MIT Press.
2. Jon Kleinberg and Eva Tardos. “Algorithm Design”, 1^{st} Edition, Pearson.
3. Sanjoy Dasgupta, Christos H. Papadimitriou and Umesh V. Vazirani, “Algorithms”, 1^{st} Edition, McGraw-Hill.

Reference Books:

1. Michael T. Goodrich and Roberto Tamassia, “Design and Analysis of Algorithms”, 1^{st} Edition, Wiley.
2. U Steven S. Skiena, “The Algorithm Design Manual”, 3^{rd} Edition, Springer.
3. Gilles Brassard and Paul Bratley, “Fundamentals of Algorithmics”, 1^{st} Edition, Pear-son.
4. Sara Baase and Allen Van Gelder, “Computer Algorithms: Introduction to Design & Analysis”, 3^{rd} Edition, Pearson.

Subject Code: MA2L014	Name: Mathematical Analysis	L-T-P-C: 3-1-0-4
Prerequisite: Calculus and ODE, Linear Algebra and Complex Analysis		

Module 1: (Real Numbers, Sequences, Series and Continuity) (17 hours)
Countable and uncountable sets, Real numbers, Least upper bound and Greatest lower bound; Sequences, Convergence, Limit superior and Limit; Cauchy sequences and completeness of R, Series and various tests for convergence (ratio test, root test and other tests); Riemann rearrangement Theorem. Continuity, Uniform continuity, Differentiability. Power series, radius of convergence.

Module 2: (Metric Spaces, Compactness and Connectedness) (14 hours)
Metric spaces, Open sets, Closed sets, Perfect set; Compactness, Connectedness and its connection to continuous maps; Cantor sets and its properties.

Module 3: (Riemann Integration and Improper Integrals) (14 hours)
Riemann integral: Upper and Lower integrals, Existence of the integral, Properties of the integral: Continuity, Differentiation and Integration; Fundamental theorem of calculus, Integration by parts, Improper integrals, Convergence of improper integrals, Beta and Gamma functions.

Module 4: (Sequences and Series of Functions: Uniform Convergence) (11 hours)
Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation.

Text Books:

4. T. M. Apostol, Mathematical Analysis, 2nd Edition, Narosa Publishing House, 2002.
5. W. Rudin, Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 2023.

Reference Books:

1. E. Hewitt and K. Stromberg, Real and Abstract Analysis: A Modern Treatment of the Theory of Functions of a Real Variable, Springer, 1980.
2. K. A. Ross, Elementary Analysis: The Theory of Calculus, Springer International Edition, 2013.
3. H. L. Royden, Real Analysis, 3rd Edition, Prentice Hall of India, 1988.
4. Terence Tao, Analysis I and Analysis II, 2nd Edition, Hindustan Book Agency, 2009.

Subject Code: MA2L012	Name: Financial Risk Management	L-T-P-C: 3-0-0-3
Prerequisite: Probability & Statistics		

Module 1: (Introduction) (12 hours)

History of financial risk management, The role of financial risk management, Basel and Solvency regulations.

Module 2: (Credit risk) (10 hours)

Credit risk: Fundamental of credit risk, firm value and intensity models, default correlation (Bernoulli and Poisson), Credit Risk + KMV, Credit VaR, CVA and DVA, credit derivatives including CDS and CDO.

Module 3: (Market risk) (9 hours)

Market risk, risk management of bond and equity portfolios, VaR and Expected Shortfall.

Module 4: (Optional risk) (11 hours)

Operational risk, Liquidity risk, Model risk and Leverage.

Text Books:

1. Credit derivatives pricing Models-models, pricing and Implementation by P. J. Schonbucher, John Wiley, 2003
2. A Quantitative finance by Paul Wilmott, John Wiely, 2006
3. Enterprise Risk Management: From incentive to control, second edition by James Lam Wiley Finance, 2014

Reference Books:

1. Financial Engineering, Derivatives and Risk Management by Cutliberatson and Nitzsoche, John Wiley, 2001
2. Credit Derivatives – A primer on credit risk, modeling and instruments by G. Chako, A. Sjoman, H. Motolashi, V. Dessaiv, FT press publication, 2006.
3. Option, Future and other derivatives by J. C. Hull, Pearson Education, 2012
4. Integrated Risk Management: Techniques and Strategies for Managing Corporate Risk by N. Doherty, Englewood cliffs, NJ: Prentice Hall, 2000

Subject Code: CS2P001	Subject Name: Design and Analysis of Algorithms Lab	L-T-P-C: 0-0-3-2
Pre-requisite(s): None		

Implementation of Algorithms covered in Theory Class: Sorting, Matrix Multiplications, Trees, Graph Traversals, Shortest Paths, Network Flows, Algorithms, Network Flows. [This will involve running the algorithms under varying input sets and measuring running times, use of different data structures for the same algorithm (wherever applicable) to see its effect on time and space, comparison of different algorithms for the same problem etc.] Design of Algorithms: This will involve design and implementation of algorithms for prob-lems not covered in class but related to topics covered in class.

[The exact set of algorithms to design and implement is to be decided by the instructor. In addition, there will be at least one significantly large design project involving some real world application. An efficient design of the project should require the use of multiple data structures and a combination of different algorithms/techniques.]

Text Books:

1. Thomas H. Cormen, Charles E. Leiserson, R.L. Rivest. Introduction to Algorithms, Prentice Hall of India Publications, 3rd Edition 2015.
2. J. Kleinberg and E. Tardos. Algorithm Design, Pearson, 2006.

Reference Books:

1. Sara Baase and Allen Van Gelder. Computer Algorithms: Introduction to Design and Analysis, Pearson education (Singapore) Pvt. Ltd, New Delhi 2007.
2. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman. The Design and Analysis of Computer Algorithms, Pearson Education (Singapore) 2006.
3. Algorithmics: Theory and Practice by Brassard and Bratley, Prentice Hall

Subject Code: MA2L016	Name: Financial Mathematics	L-T-P-C: 1-0-3-3
Prerequisite: Probability & Statistics		

Module 1: Financial Assets, Fixed-Income Securities and Interest Rates (14 hours)
Introduction to financial markets and basic financial instruments; time value of money and valuation of future cash flows; risk-free and risky assets; bond valuation, coupon and zero-coupon bonds, yield and yield-to-maturity; duration, convexity and basic immunization; term structure of interest rates, spot rates and forward rates. Laboratory work using MATLAB/C++/R/Python will include cash-flow and bond valuation, computation and visualization of yield, duration and convexity, construction of spot and forward rate curves, and numerical study of interest-rate sensitivity.

Module 2: Risk-Return Analysis, Portfolio Optimization and Asset Pricing (14 hours)
Returns and risk of financial assets; expected return, variance, covariance and correlation; diversification; portfolio risk and return; Markowitz mean-variance portfolio optimization, feasible set, minimum-variance portfolio and efficient frontier; risk-free borrowing and lending; Capital Asset Pricing Model (CAPM), beta and the security market line; introduction to no-arbitrage. Laboratory work will include estimation of returns, volatility and covariance from financial data, portfolio simulation, construction and visualization of the efficient frontier, constrained portfolio optimization, and estimation of CAPM parameters.

Module 3: Derivative Pricing and Computational Finance (14 hours)
Introduction to financial derivatives; forwards and futures; European call and put options, payoff structures and elementary option strategies; no-arbitrage valuation and put-call parity; binomial pricing model; stochastic modelling of asset prices; Black-Scholes option pricing; risk-neutral and martingale-based pricing principles; basic option sensitivities and their financial interpretation. Laboratory work will include implementation of binomial trees and Black-Scholes pricing, Monte Carlo simulation of asset-price paths and option prices, and visualization of option values and sensitivities with respect to model parameters.

Module 4: Financial Risk Management and Data-Driven Risk Analysis (14 hours)
Introduction to financial risk management; market risk, credit risk and model risk; volatility and loss distributions; Value-at-Risk (VaR) and Expected Shortfall; historical, parametric and simulation-based risk measurement; basic credit-risk concepts including probability of default, loss given default and credit exposure; model uncertainty, parameter sensitivity and basic model validation. Laboratory work will include estimation and visualization of risk measures from real or realistic financial datasets, Monte Carlo analysis of market and credit losses, sensitivity analysis, and comparison of alternative risk models.

Course Focus: This course focuses on the computational, numerical and data-driven aspects of Financial Mathematics, combining fundamental concepts of financial engineering with quantitative methods for financial risk management. Students will use MATLAB/C++/R/Python to implement models and algorithms for asset valuation, portfolio optimization, derivative pricing and risk measurement. Emphasis will be placed on numerical computation, Monte Carlo simulation, statistical modelling, optimization, visualization, and the analysis of real or realistic financial datasets, enabling students to connect mathematical models with practical financial applications.

Text Books:

4. David G. Luenberger, Investment Science, 2nd ed., Oxford University Press, 2014.
5. John C. Hull, Options, Futures, and Other Derivatives, 11th ed., Pearson, 2022.
6. David Ruppert and David S. Matteson, Statistics and Data Analysis for Financial Engineering: With R Examples, 2nd ed., Springer, 2015.

Reference Books:

5. Alexander J. McNeil, Rüdiger Frey and Paul Embrechts, Quantitative Risk Management: Concepts, Techniques and Tools, 2nd ed., Princeton University Press, 2015.
6. Paul Glasserman, Monte Carlo Methods in Financial Engineering, Springer, 2003.
7. Steven E. Shreve, Stochastic Calculus for Finance II: Continuous-Time Models, Springer, 2004.

Subject Code: MA2L015	Name: Introduction to Algebra and Number Theory	L-T-P-C: 3-1-0-4

Prerequisite: Basic knowledge of linear algebra

Module 1: (Number Theory) (15+5 hours)
Division algorithm, GCD and LCM, Euclidean algorithm, linear Diophantine equation, Primes, the fundamental theorem of arithmetic, Properties of congruences, linear congruences, Chinese remainder theorem, Fermat's Little Theorem, Wilson's Theorem, and Euler's Theorem, Arithmetic functions; Euler's phi function, Mobius functions, and divisors functions.

Module 2: (Group Theory) (15+5 hours)
Groups and their properties, Subgroups, Cyclic groups, Group of integers and its properties, Cayley's theorem, cosets and Lagrange's theorem, normal subgroups, quotient groups, homomorphisms and isomorphism theorems.

Module 3: (Basics of Ring Theory) (12+4 hours)
Ring and its properties, Characteristic of a ring, Ideals and Quotient Ring, Homomorphism, Integral Domain, Polynomial ring, factorization in polynomial rings, fields, characteristic of a field, and construction of a finite field.

Text Books:

1. I. N. Herstein, Topics in Algebra, John Wiley & Sons, 2005.
2. D. Burton, Elementary Number Theory, McGraw-Hill Education, 2017.
3. Thomas Koshy, Elementary Number Theory with Application, Academic Press, Inc., 2007.
4. J. A. Gallian, Contemporary Abstract Algebra, Brooks/Cole, 2013.

Reference Books:

1. M. Artin, Algebra, Prentice Hall of India/Pearson Education, 2nd Ed., 2024.
2. I. Niven, H. S. Zuckerman, and H. L. Montgomery, An Introduction to the Theory of Numbers, John Wiley & Sons, 2019.
3. D. S. Dummit and R.M. Foote, Abstract Algebra, John Wiley & Sons, 2011.