## Revised Course Structure: MTech (MC)

### 1st Semester

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Course Number</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>C</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>MA501</td>
<td>Probability, Statistics &amp; Stochastic Processes</td>
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<th>Course Title</th>
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<td>1</td>
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<td>2</td>
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### 3rd Semester

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### 4th Semester

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**Total Credits=** 37+37+24+24 = 122
MA 501: Probability, Statistics and Stochastic Processes

Algebra of sets, probability spaces, random variables, cumulative distribution functions, mathematical expectations, conditional probability and expectation, moments and inequalities, special discrete and continuous probability distributions, function of a random variable, random vectors and their distributions, convolutions, joint, marginal and conditional distributions, product moments, independence of random variables, bivariate distributions and properties, order statistics and their distributions, sampling distributions, Central Limit Theorem, strong law of large numbers, sequence of random variables, modes of convergence, distributions of the sample mean and the sample variance for a normal population, chi-square, t and F distributions, method of moments and maximum likelihood estimation, concepts of unbiasedness, criteria for choosing estimators, consistency and efficiency of estimates, confidence intervals, pivotal quantities, confidence intervals for proportions, simple and composite hypothesis, null and alternative hypotheses, types of error, level and size of tests, the most powerful test and Neyman - Pearson Fundamental Lemma, tests for one- and two-sample problems for normal populations, tests for proportions, likelihood ratio tests, chi-square test for goodness of fit, discrete and continuous stochastic processes, markov chains, transition probability matrix, state spaces, classification of states, stationary distributions, ergodicity, poisson process, birth and death process.

References:
CS 501 Database Systems & Data Mining

Data models: entity-relationship, relational model. Query languages: relational algebra, relational calculus, SQL. Theory of database design: functional dependencies; normal forms: 1NF, 2NF, 3NF, Boyce-Codd NF; decompositions; normalization; Transaction management, Concurrency control; error recovery; Need for Data Mining Techniques, Data Preprocessing, Mining Frequent Patterns, Classification, Prediction, Clustering, etc Data Mining: Knowledge Representation Using Rules, Association and Classification Rules.

Text Books:

3. Jiawei Han, Micheline Kamber and Jian Pei, Data Mining Concepts and Techniques, Morgan Kaufmann
Random number and generators, algorithms for generation of random variables: Inverse transform method, convolution method, acceptance-rejection method, generation of continuous random variates: uniform, generalized (exponential), gamma, inverse gamma, weibull, gaussian, lognormal, Pareto, inverse gaussian, Burr type distributions, generation of discrete random variates: discrete uniform, binomial, geometric, negative binomial, Poisson, estimation of different measures: mean, variance, quantiles, Real data analysis

References:
(2) Law, A. M. (2008), Simulation Modelling and Analysis, Tata McGraw Hill
MA 502 : Numerical Optimization

Introduction to optimization problems, Convex sets and convex functions, their properties, convex programming problems, Lagranges Multiplier method, Optimality conditions for unconstrained minimization and constrained minimization problems, KKT conditions.

Unimodal functions, Fibonacci search, Linesearch methods, Convergence of generic line search methods, Method of steepest descent, more general descent methods, Conjugate gradient methods, Fletcher Reeves methods for nonlinear functions, Interior point methods for inequality constrained optimization, Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm, perturbed optimality conditions, A practical primal-dual method

Multitobjective programming, Efficient solutions, Dominated cones, Formulation of Goal programming problems and solution methodologies for linear Goal programming problem.

Introduction to Evolutionary methods and global optimization.

Practice of optimization algorithms using software.

Texts/References


Experiments would be designed to provide hands-on experience in programming data structures and algorithms, to learn a few systems programming tools, and scripting.

References:
MA 504 Computational Differential equations

Introduction of system of linear IVP's and BVP's, Accuracy and stability of the numerical solution, Euler's Explicit and Implicit Method, Runge-Kutta Methods, Higher-Order Methods for the IVP, Linear Multistep Methods, Nonlinear Two-Point BVPs, Ansatz Methods for BVPs.

Classification of PDEs, Initial and Boundary Conditions, Finite Difference Method for PDE, Explicit Implicit Scheme, Consistency, Stability and Convergence, Stability analysis by matrix method and von Neumann method, Lax’s equivalence theorem; FTCS, Backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff Method, Upwind Scheme; CFL Conditions; Finite Element Method for Ordinary Differential Equations - Variational Methods, Method of Weighted Residuals, Finite Element Analysis of One-Dimensional Problems

References/Text

(4) K. E. Atkinson, W. Han, D. Stewart, Numerical solution of ordinary differential equations, John Wiley and Sons, 2009
(6) Tveito, R. Winther, Introduction to partial differential equations: a computational approach, Springer, 2005
(7) G. D. Smith, Numerical solution of partial differential equations: finite difference methods, Oxford University Press, 1985
CS514 Design and Analysis of Algorithms

Data structures: linked list, stack, queue, tree, balanced tree, graph; Complexity analysis: Big O, omega, theta notation, solving recurrence relation, master theorem Sorting and searching: Quick sort, merge sort, heap sort; Sorting in linear time; Ordered statistics;
Problem solving strategies: recursion, dynamic programming, branch and bound, backtracking, greedy, divide conquer,
Graph algorithms: BFS, DFS, Shortest path, MST, Network flow; NP-completeness
Advanced topics: string matching, FFT-DFT, basics of approximation and randomized algorithms;

References:
MA 505 Number Theory & Cryptography

Divisibility in integers, Review of finite fields, Divisibility and Euclidean algorithm in integers, Well Ordering Property in the set of positive integers, Greatest common divisor and least common multiple and algorithms to find them, Primes, Fundamental Theorem of Arithmetic, Infinitude of primes of certain types.

Congruences, Euler’s phi function, Euler-Fermat theorem, Wilson’s theorem. Linear congruence equations, Chinese Remainder theorem, Multiplicativity and expression for \( \varphi(n) \), Congruence equations of higher degree.

Quadratic Residues, Legendre symbols, Gauss’ lemma, Quadratic Reciprocity Law and applications, Jacobi symbol, Tests of primality.

Multiplicative functions, Functions \( \tau \), \( \sigma \), and \( \mu \) and their multiplicativity, Möbius inversion formula and its converse, Diophantine equations: \( ax + by = c \), \( x^2 + y^2 = z^2 \), \( x^4 + y^4 = z^4 \), Sums of squares, Waring’s problem, Binary quadratic forms over integers, Farey sequences.

Cryptosystems (definition illustrations and classical examples), the idea of public key cryptography, RSA Public Cryptosystems, RSA key generation and algorithm, the RSA conjecture, Attack on RSA crypto systems, ElGamal Public Key Cryptosystems and algorithm, Digital signature algorithm (DSA).

Elliptic curves - basic facts, Elliptic curves over \( \mathbb{R}, \mathbb{Q}, \mathbb{F} \), finite fields, Group Law, Elliptic curve cryptosystems, analogue of ElGamal on elliptic curves, Primality testing and factorizations.

Text Books:

References:
MA508 Fuzzy sets and Artificial Intelligence

Basic Concepts of fuzzy sets, Fuzzy logic, Types of membership functions, Structure of algebra of fuzzy sets, Basic concepts (support, singleton, height, $\alpha$-cut projections), Zadeh's extension principle, Operations on fuzzy sets, T- norms and T- conorms, Fuzzy complement, Fuzzy measures, Probability and Possibility measures, Linguistic variables and hedges, Membership function design.

Classical relations, Fuzzy relations, Fuzzy to crisp conversions, Fuzzy inference methodologies, Graphical techniques of inference, Fuzzyifications/Defuzzification, Introducing higher order fuzzy sets.

Fuzzy systems and algorithms, Approximate reasoning, Applications of fuzzy Sets in management, decision making, medicine and computer Science.


Texts:


References:

**Introduction to Direct Methods:** Direct Methods for solving linear systems and Application to BVP, Discritization of PDE's. (06 Lectures)

**Sparse Matrices:** Introduction to sparse matrices, Storage Schemes, Permutations and Reorderings, Sparse Direct Solution Methods. (06 Lectures)

**Basic iterative methods:** Iterative method for solving linear systems: Jacobi, Gauss – Seidel and SOR and their convergence, projection method: general projection method, steepest descent, MR Iteration, RNSD method (6 Lectures)

**Krylov subspace methods:** Introduction to Krylov subspace, Arnoldi’s method, GMRES method, Conjugate gradient algorithm, Lanczos Algorithm, Block Krylov Methods (6 Lectures)

**Preconditioners:** Introduction to preconditioners, ILU preconditioner, preconditioned CG. (6 Lectures)

**Parallel implementation:** Architecture of parallel computers, introduction to MPI & openMP, HPC kernels (BLAS, multicore and GPU computing) (6 Lectures)

**Introduction to domain decomposition and multigrid methods** (6 Lectures)

**Texts / References**

- Yousef Saad; Iterative Methods for Sparse Linear Systems; SIAM 2003
- A. Grama, A. Gupta, G. Karypis, V Kumar; Introduction to Parallel Computing; Pearson Education Limited 2003
MA 539 Mathematical Modeling

System of differential equations; Linear and nonlinear stability; Basic idea of bifurcation; some illustrations with help of computer programming

Introduction to modeling; Elementary mathematical models and General modeling ideas; General utility of Mathematical models, Role of mathematics in problem solving; Concepts of mathematical modeling; System approach; formulation, Analyses of models; Pitfalls in modeling;

Illustrations models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics, Finance, Economics, Management, etc. (The choice and nature of models selected may be changed with mutual interest of lecturer and students.)

Introduction to probabilistic models.

Text & References:

Mathematical Logics, Sets, Relations and Mappings:
Statements, Logical connectives, Truth tables, Equivalence, Inference and deduction, Predicates, Quantifiers. Relations, Equivalence relations, Partial Order relations and lattices, Chains, Antichains, Dilworth’s Theorem, Composition of mappings, one-one and onto mappings, Pigeonhole Principle, Counting techniques, Countable and Uncountable sets.

Semigroups and Monoids:
Semigroups, Monoids, Subsemigroups/monoids, Congruence and quotient semigroups/monoids, Homomorphism, isomorphism and the basic isomorphism theorem.

Graph Theory:
Basic concepts of graphs, directed graphs and trees, Adjacency and incidence matrices, Spanning trees, Matchings and Coverings, Hall’s condition, Graph Coloring, Planar Graphs, Eulerian and Hamiltonian graphs.

Combinatorics:
Permutation, Combination, Principle of inclusion and exclusion, Recurrence relations, Generating functions

Boolean Algebra:
Boolean algebra and their various identities, Homomorphisms and isomorphisms, Atoms and the Stone’s theorem (finite case), Boolean functions, their simplification.

Texts and References:
5. P.R. Halmos, Naive Set Theory, UTM, Springer, 1

Regular graphs, Eigen values of regular graphs, Diameter of regular graphs, Ramanujan graphs. Groups as Groups of Symmetries of a graph, Normal Subgroups, Isomorphism Theorems, Cyclic groups, Dihedral Groups. Permutation groups.

Text and References:

**List of Electives:**

<table>
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<tr>
<th>Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>MA505</td>
<td>Number Theory &amp; Cryptography</td>
</tr>
<tr>
<td>MA508</td>
<td>Fuzzy sets and Artificial Intelligence</td>
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<tr>
<td>MA511</td>
<td>Large Scale Scientific Computation</td>
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<td>MA539</td>
<td>Mathematical Modeling</td>
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<td>MA 503</td>
<td>Discrete Structures</td>
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<td>MA 509</td>
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<td>CS561</td>
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<td>CS503</td>
<td>Advances in Algorithm</td>
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<td>CS504</td>
<td>Advanced Graph Theory</td>
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<td>CS547</td>
<td>Foundation of Computer Security</td>
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<td>CS544</td>
<td>Introduction to Network Science</td>
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<td>CS542</td>
<td>Software Testing</td>
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<td>Formal methods for analysis and verification</td>
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<td>CS743</td>
<td>Advanced topics on Database</td>
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<tr>
<td>CS502</td>
<td>Pattern Recognition</td>
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In addition other relevant courses as decided by the department may be opted.