Department of Mathematics

Curriculum of M.Sc (Mathematics)

FIRST SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 401	Abstract Algebra	3-1-0	4
2	MA 403	Linear Algebra	3-1-0	4
3	MA 405	Partial Differential Equations	3-1-0	4
4	MA 407	Metric Spaces	3-1-0	4
5	MA 409	Topology	3-1-0	4
6	MA 471	Object Oriented Programming Practice Lab.	0-0-3	2
7	MA 481	Departmental Seminar - I	0-0-3	2
TOTAL				**24**

SECOND SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 400	Functional Analysis	3-1-0	4
2	MA 402	Measure Theory	3-1-0	4
3	MA 404	Functions of a Complex Variable	3-1-0	4
4		Professional Elective - I	3-1-0	4
5		Professional Elective - II	3-1-0	4
6	MA 470	Operations Research Laboratory	0-0-3	2
7	MA 472	Viva Voce	0-0-3	2
8	MA 480	Departmental Seminar - II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1		Professional Elective - III	3-1-0	4
2		Professional Elective - IV	3-1-0	4
3		Professional Elective - V	3-1-0	4
4		Professional Elective - VI	3-1-0	4
5	MA 571	Statistics Lab.	0-0-3	2
6	MA 591	Research Project I	0-0-6	4
7	MA 593	Seminar and Technical Writing I	0-0-3	2
8	MA 595	Short term Industrial/Research Experience	0-0-3	2
TOTAL				**26**

FOURTH SEMESTER

Sl. No	Sub. Code	Subject	L-T-P	Credit
1		Professional Elective - VII	3-1-0	4
2		Professional Elective - VIII	3-1-0	4
3		Professional Elective - IX	3-1-0	4
4		Professional Elective - X	3-1-0	4
5	MA 572	Lab. Works on Sampling	0-0-3	2
6	MA 592	Research Project II	0-0-9	6
7	MA 594	Seminar and Technical Writing II	0-0-3	2
8	MA 596	Comprehensive Viva Voce	0-0-3	2
TOTAL				**28**

LIST OF PROFESSIONAL ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	MA 510	Calculus of Several Variables	3-1-0	4
2	MA 511	Differential Geometry	3-1-0	4
3	MA 512	Fourier Analysis	3-1-0	4
4	MA 513	Differential Topology	3-1-0	4
5	MA 514	Rings and Modules	3-1-0	4
6	MA 515	Homotopy Theory	3-1-0	4
7	MA 516	Operator Theory	3-1-0	4
8	MA 517	Lie Algebra	3-1-0	4
9	MA 518	Advanced Complex Analysis	3-1-0	4
10	MA 519	Multi-Linear Algebra	3-1-0	4
11	MA 520	Automata Theory	3-1-0	4
12	MA 521	Combinatorics	3-1-0	4
13	MA 522	Operations Research	3-1-0	4
14	MA 523	Discrete Mathematics	3-1-0	4
15	MA 524	Statistical Methods	3-1-0	4
16	MA 525	Ergodic Theory	3-1-0	4
17	MA 527	Fractals	3-1-0	4
18	MA 529	Information Theory	3-1-0	4
19	MA 530	Computational Methods in Boundary Value Problems	3-1-0	4
20	MA 531	Boundary Layer Theory	3-1-0	4
21	MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4
22	MA 534	Geometry of Robotics	3-1-0	4
23	MA 540	Singular Homology Theory	3-1-0	4
24	MA 542	Tensor Analysis	3-1-0	4
25	MA 544	Category Theory	3-1-0	4
26	MA 546	Differentiable Manifolds	3-1-0	4

27	MA 548	Field Theory	3-1-0	4
28	MA 549	Algebraic Geometry	3-1-0	4
29	MA 550	Coding Theory	3-1-0	4
30	MA 551	Numerical Analysis	3-1-0	4
31	MA 552	Fuzzy logic and Set Theory	3-1-0	4
32	MA 553	Optimization Techniques	3-1-0	4
33	MA 554	Graph Theory	3-1-0	4
34	MA 555	Stochastic Processes	3-1-0	4
35	MA 556	Number Theory	3-1-0	4
36	MA 558	Sampling Techniques	3-1-0	4

DEPARTMENT OF MATHEMATICS

SUMMARY OF COURSES

Sub Discipline: Foundation Courses

MA 101	Differential Equations	3-1-0	4
MA 102	Matrix theory, Vector Calculus and Fourier Analysis	3-1-0	4
MA 201	Probability, Statistics and Numerical Methods	3-1-0	4
MA 202	Complex Analysis and Partial Differential Equations	3-1-0	4
MA 400	Functional Analysis	3-1-0	4
MA 401	Abstract Algebra	3-1-0	4
MA 402	Measure Theory	3-1-0	4
MA 403	Linear Algebra	3-1-0	4
MA 404	Functions of a Complex Variable	3-1-0	4
MA 405	Partial Differential Equations	3-1-0	4
MA 407	Metric Spaces	3-1-0	4
MA 409	Topology	3-1-0	4

Sub Discipline: Topology, Analysis and Algebra

MA 311	Linear Algebra	3-1-0	4
MA 312	Real Analysis	3-1-0	4
MA 411	Metric Spaces	3-1-0	4
MA 510	Calculus of Several Variables	3-1-0	4
MA 511	Differential Geometry	3-1-0	4
MA 512	Fourier Analysis	3-1-0	4
MA 513	Differential Topology	3-1-0	4
MA 514	Rings and Modules	3-1-0	4
MA 515	Homotopy Theory	3-1-0	4
MA 516	Operator Theory	3-1-0	4
MA 517	Lie Algebra	3-1-0	4
MA 518	Advanced Complex Analysis	3-1-0	4
MA 519	Multi-Linear Algebra	3-1-0	4
MA 540	Singular Homology Theory	3-1-0	4
MA 542	Tensor Analysis	3-1-0	4
MA 544	Category Theory	3-1-0	4
MA 546	Differentiable Manifolds	3-1-0	4
MA 548	Field Theory	3-1-0	4
MA 549	Algebraic Geometry	3-1-0	4

Sub Discipline: Statistics and Optimization

MA 423	Discrete Mathematics	3-1-0	4
MA 424	Operations Research	3-1-0	4
MA 426	Elementary Stochastic Processes with Applications	3-1-0	4

MA 520	Automata Theory	3-1-0	4
MA 521	Combinatorics	3-1-0	4
MA 522	Operations Research	3-1-0	4
MA 523	Discrete Mathematics	3-1-0	4
MA 524	Statistical Methods	3-1-0	4
MA 525	Ergodic Theory	3-1-0	4
MA 527	Fractals	3-1-0	4
MA 529	Information Theory	3-1-0	4
MA 550	Coding Theory	3-1-0	4
MA 551	Numerical Analysis	3-1-0	4
MA 552	Fuzzy logic and Set Theory	3-1-0	4
MA 553	Optimization Techniques	3-1-0	4
MA 554	Graph Theory	3-1-0	4
MA 555	Stochastic Processes	3-1-0	4
MA 556	Number Theory	3-1-0	4
MA 558	Sampling Techniques	3-1-0	4

Sub Discipline: Fluid Dynamics

MA 530	Computational Methods in Boundary Value Problems	3-1-0	4
MA 531	Boundary Layer Theory	3-1-0	4
MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4
MA 534	Geometry of Robotics	3-1-0	4

Sub Discipline: Laboratory Courses

MA 270	Numerical Methods Laboratory	0-0-3	2
MA 470	Operations Research Lab.	0-0-3	2
MA 471	Object Oriented Programming Practice Lab.	0-0-3	2
MA 472	Viva Voce	0-0-3	2
MA 571	Statistics Lab.	0-0-3	2
MA 572	Lab. Works on Sampling	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

MA 480	Departmental Seminar – II	0-0-3	2
MA 481	Departmental Seminar – I	0-0-3	2
MA 591	Research Project - I	0-0-6	4
MA 592	Research Project - II	0-0-9	6
MA 593	Seminar and Technical Writing – I	0-0-3	2
MA 594	Seminar and Technical Writing – II	0-0-3	2
MA 595	Short term Industrial/Research Experience	0-0-3	2
MA 596	Comprehensive Viva Voce	0-0-3	2

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits	Page No.
MA 101	Differential Equations	3-1-0	4	
MA 102	Matrix theory, Vector Calculus and Fourier Analysis	3-1-0	4	
MA 201	Probability, Statistics and Numerical Methods	3-1-0	4	
MA 202	Complex Analysis and Partial Differential Equations	3-1-0	4	
MA 270	Numerical Methods Laboratory	0-0-3	2	
MA 311	Linear Algebra	3-1-0	4	
MA 312	Real Analysis	3-1-0	4	
MA 400	Functional Analysis	3-1-0	4	
MA 401	Abstract Algebra	3-1-0	4	
MA 402	Measure Theory	3-1-0	4	
MA 403	Linear Algebra	3-1-0	4	
MA 404	Functions of a Complex Variable	3-1-0	4	
MA 405	Partial Differential Equations	3-1-0	4	
MA 407	Metric Spaces	3-1-0	4	
MA 409	Topology	3-1-0	4	
MA 411	Metric Spaces	3-1-0	4	
MA 423	Discrete Mathematics	3-1-0	4	
MA 424	Operations Research	3-1-0	4	
MA 426	Elementary Stochastic Processes with Applications	3-1-0	4	
MA 470	Operations Research Lab.	0-0-3	2	
MA 471	Object Oriented Programming Practice Lab.	0-0-3	2	
MA 472	Comprehensive Viva Voce	0-0-3	2	
MA 480	Departmental Seminar – II	0-0-3	2	
MA 481	Departmental Seminar – I	0-0-3	2	
MA 510	Calculus of Several Variables	3-1-0	4	
MA 511	Differential Geometry	3-1-0	4	
MA 512	Fourier Analysis	3-1-0	4	
MA 513	Differential Topology	3-1-0	4	
MA 514	Rings and Modules	3-1-0	4	
MA 515	Homotopy Theory	3-1-0	4	
MA 516	Operator Theory	3-1-0	4	
MA 517	Lie Algebra	3-1-0	4	
MA 518	Advanced Complex Analysis	3-1-0	4	
MA 519	Multi-Linear Algebra	3-1-0	4	
MA 520	Automata Theory	3-1-0	4	
MA 521	Combinatorics	3-1-0	4	
MA 522	Operations Research	3-1-0	4	
MA 523	Discrete Mathematics	3-1-0	4	
MA 524	Statistical Methods	3-1-0	4	
MA 525	Ergodic Theory	3-1-0	4	

MA 527	Fractals	3-1-0	4	
MA 529	Information Theory	3-1-0	4	
MA 530	Computational Methods in Boundary Value Problems	3-1-0	4	
MA 531	Boundary Layer Theory	3-1-0	4	
MA 532	Numerical Solutions of Partial Differential Equations	3-1-0	4	
MA 534	Geometry of Robotics	3-1-0	4	
MA 540	Singular Homology Theory	3-1-0	4	
MA 542	Tensor Analysis	3-1-0	4	
MA 544	Category Theory	3-1-0	4	
MA 546	Differentiable Manifolds	3-1-0	4	
MA 548	Field Theory	3-1-0	4	
MA 549	Algebraic Geometry	3-1-0	4	
MA 550	Coding Theory	3-1-0	4	
MA 551	Numerical Analysis	3-1-0	4	
MA 552	Fuzzy logic and Set Theory	3-1-0	4	
MA 553	Optimization Techniques	3-1-0	4	
MA 554	Graph Theory	3-1-0	4	
MA 555	Stochastic Processes	3-1-0	4	
MA 556	Number Theory	3-1-0	4	
MA 558	Sampling Techniques	3-1-0	4	
MA 571	Statistics Lab.	0-0-3	2	
MA 572	Lab. Works on Sampling	0-0-3	2	
MA 591	Research Project - I	0-0-6	4	
MA 592	Research Project - II	0-0-9	6	
MA 593	Seminar and Technical Writing – I	0-0-3	2	
MA 594	Seminar and Technical Writing – II	0-0-3	2	
MA 595	Short term Industrial/Research Experience	0-0-3	2	
MA 596	Comprehensive Viva Voce	0-0-3	2	

MA 101 DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

(a) *Differential equations***:** First-order differential equations: Basic concepts and ideas, Separable equations, Exact equations, Integrating factors, Linear differential equations, Bernoulli equation, Orthogonal trajectories of curves. Applications to physical problems, Linear differential equations of second and higher order: Homogeneous linear equations of second order, Euler-Cauchy equation, Solution by undermined coefficients and variation of parameters, Higher order linear differential equations. Applications to physical problems. **(b)** *Series solutions of differential equations and special functions***:** Power series method, Legendre's equations and functions, Frobenius method, Bessel's equation and functions, Sturm-Liouville problems, Orthogonal functions, Orthogonal eigen-function expansions, Applications to physical problems. (c) *Laplace transforms*: Laplace transform, Inverse Laplace transforms, Solution of differential equations, Differentiation and integration of transforms, Integral equations.

Essential Reading:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007
   Chapters : Chapter 1 (excluding 1.9), 2, 3, 4, 5.

MA 102 MATRIX THEORY, VECTOR CALCULUS AND FOURIER ANALYSIS 4 credits [3-1-0]

(a)*Matrix theory***:** Linear Systems and equations, Gauss elimination, Rank of a matrix, Linear independence, Vector space, Solutions of linear systems, Existence, uniqueness, Cramer's rule, Inverse of a matrix, Gauss-Jordon elimination, Vector spaces, Inner product spaces, Linear transformations. Eigen values, Eigen vectors, Symmetric, skew-symmetric and orthogonal matrices, Complex matrices: Hermitian, skew- Hermitian, and unitary matrices, Similarities of matrices, Basis of eigenvector, Diagonalisation ; **(b)** *Vector calculus***:** Vector differential calculus: Grad, div, curl, Vector algebra in 2-space and 3-space, Inner product (dot product), Vector product (cross product), Vector and scalar functions and fields, Derivatives, Curves, tangents are length, Velocity and acceleration, Curvature and torsion of a curve, Gradient of a scalar field, Directional derivative, Divergence of a vector field, Curl of a vector field. Vector integral calculus: Line integrals, Line integral independent of path, Double Integrals, Green's theorem in the plane, Surfaces and surface integrals, Triple integrals: Divergence theorem of Gauss, Further applications of the divergent theorem, Stoke's theorem ; **(c)** *Fourier Analysis***:** Fourier series, Integrals and transforms: Fourier series, Functions of any period $p = 2L$, Even and odd functions: Half-range expansions, Complex Fourier series, Forced oscillations, Approximation by trigonometric polynomials, Fourier integrals, Fourier cosine and sine transforms, Fourier transform.

Essential Reading :

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007
   Chapters : 6 (6.3 – 6.8), 7, 8, 9, 10.

MA 201 PROBABILITY, STATISTICS AND NUMERICAL METHODS **4 credits [3-1-0]**

(a) *Probability and Statistics***:** Probability theory: Probability, Random variables, Probability distributions, Mean and variance of distributions, Binomial, Poisson and Hypergeometric distributions, Normal distribution, Distributions of several random variables, Mathematical statistics, Random sampling, Estimation of parameters, Confidence intervals, Testing of hypothesis, Decisions, Quality control, Acceptance sampling, χ^2-test for goodness of fit, Nonparametric tests, Regression analysis, Fitting of straight lines, Correlation analysis. **(b)** *Numerical Methods***:** Numerical methods in general: Floating point, Round-off, error, Propagation of error, Interpolation, Splines, Numerical integration and differentiation. Numerical methods in linear algebra: Gauss elimination, LU-Factorization, Matrix inversion, Linear systems: Solution by iteration, Linear systems: Ill-conditioning, Norms, Method of least squares, Matrix eigen value problems, Inclusion of matrix eigen values, Eigen values by iteration (Power method), Tridiagonalization and QR-factorization, Numerical methods for differential equations: Methods for first-order differential equations, Multistep methods, Methods for systems and higher order equations, Methods for elliptic partial differential equations, Methods for parabolic and hyperbolic equations.

Essential Reading :

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007 Chapters: 17, 18,19, 22 (excluding 22.4), 23.

MA 202 COMPLEX ANALYSIS AND PARTIAL DIFFERENTIAL EQUATIONS **4 credits [3-1-0]**

(a) *Complex Analysis***:** Derivative. Analytic function, Cauchy Riemann equations, Laplace's equation, Geometry of analytic functions, Exponential function, Trigonometric functions, Hyperbolic functions, Logarithm, General power, Conformal mapping, Linear fractional transformations. Complex integration, Line integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral Formula, Derivative of Analytic functions, Power series, Taylor series, Sequences, Series, Convergence tests, Functions Given by power series, Taylor series and Maclaurin series, Uniform convergence. Laurent series, Residue integration, Laurent series, Singularities and zeros infinity, Residue integration methods, Evaluation of real integrals. **(b)***Partial Differential Equations***:** Basic concepts, Modeling of vibrating string, Wave equation, Separation of variable, Use of Fourier series, D'Alembert's solution of the wave equation, Heat equation, Solution by Fourier Series, Solution by Fourier integral and transforms, Modeling: Membrane, Two-dimensional wave equation, Rectangular membrane. Use of double Fourier series, Laplacian in polar coordinates, Circular membrane, Use of Fourier–Bessel series, Laplace's equation in cylindrical and spherical coordinates, Potential, Solution by Laplace transforms.

Essential Reading :

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd. 2007 Chapters: 11, 12 (12.3 – 12.9), 13,14, 15.

MA 271 NUMERICAL METHODS LABORATORY 2 credits [0-0-3]

Experiments to be handled using FORTRAN/C $^{++}$/JAVA

1. Bisection Method
2. Method of False Position and Secant Method
3. Newton-Raphson Method
4. Method of Successive approximation
5. Gaussian Elimination Method
6. Gauss-Seidel Iterative Method
7. Inversion of a Matrix
8. Eigen Values and Eigen Vectors
9. Lagrange's interpolation
10. Newton's forward and backward interpolation
11. Everette's formula
12. Numerical Differentiation
13. Trapezoidal rule of integration
14. Simpson's one-third rule
15. Simpson's three-eighth rule
16. Euler's method
17. Improved Euler's method
18. Runge-Kutta Second and fourth order methods
19. Predictor-Corrector Methods
20. Taylor Series Method

MA 311 Linear Algebra 4 credits [3-1-0]

Systems of linear equations, Vector spaces, Bases and dimensions, Change of bases and change of coordinates, Sums and direct sums, Quotient spaces. Linear transformations, Representation of linear transformations by matrices, The rank and nullity theorem, Dual spaces, Eigenvalues and eigenvectors, Invariant subspaces, Direct-Sum decomposition, Cyclic subspaces and Annihilators, The minimal polynomial, The rational and Jordan canonical forms, Inner product spaces, Orthonormal bases, Gram-Schmidt process. Adjoint operators, Normal, unitary, and self-adjoint operators, Spectral theorem for normal operators.

Essential Reading:

1. K. Hoffman and R. Kunze, *Linear Algebra*, Prentice Hall of India, 1996.

Supplementary Reading:

1. G. Schay, *Introduction to Linear Algebra* , Narosa, 1997.
2. G. C. Cullen, *Linear Algebra with Applications*, Addison Wesley, 1997.

MA 312 REAL ANALYSIS 4 credits [3-1-0]

The real number system : Elementary logic, The field axioms, the axiom of order, geometric representation of real numbers, *Metric sets and limits* : Metric sets, Interior points and boundary points of a set, open sets and closed sets, limit point of a set, sequences, monotonic sequences, Cauchy sequences, limit of a function, *Continuity and Differentiation*: Continuous functions, uniform continuity, mean value theorem for derivatives, the total differential, the directional derivative, *Integration* : Step functions, upper and lower integral of a bounded function, integral of a bounded function, interchange of limits, the fundamental theorem of differential and integral calculus.

Essential Reading :

1. J.M. Howie, *A First Course in real Analysis*, Springer, 2001

MA 411 METRIC SPACES 4 credits [3-1-0]

Schwarz and triangle inequality, Point set topology, countable and uncountable sets, Compact set and Heine-Borel theorem, Perfect sets, Functions on compact sets, connected sets, Mappings between metric spaces, Sequence and series of functions, Uniform convergence, Uniform convergence and continuity, integration and differentiation, A fixed point theorem and its application differential equation, Newton's method, Complete metric spaces, Convex sets and convex functions, Arzela's theorem, Tietze's extension theorem, Approximations and the Stone-Weierstrass theorem.

Essential reading :

1. Mícheál Ó Searcóid, *Metric Spaces*, Springer, 2006.

Supplementary Reading :

1. W. Rudin, *Principles of Mathematical Analysis*, Mc-Graw Hill, 1976.

MA 423 DISCRETE MATHEMATICS 4 credits [3-1-0]

The language of sets: The concept of a set, Operations with sets, Computer operations with sets, The cardinality of a set, Recursively defined sets: *Functions and Matrices*: The concept of a function, Special functions, Properties of functions, The pigeonhole principle, Composition of functions, Matrices. *Induction and algorithms*: The division algorithm, Divisibility properties, Mathematical Induction, Algorithm correctness, The growth of functions, *Recursion*: Recursively defined functions, Solving recurrence relations, Generating functions, Recursive algorithms, *Combinatorics and Discrete probability*: The fundamental counting principles, Permutations, derangements, Combinations, Permutations and combinations with repetitions, The binomial theorem, The generalized inclusion and exclusion principle, Discrete probability. *Relations*: Boolian matrices, Relations and digraphs, Computer representations of relations, Properties of relations, Operations on relations, The connectivity relations, Equivalence relations, Partial and total orderings. *Graphs*: Computer representation of graphs, Paths, cycles and circuits, Eulerian

and Hamiltonian graphs, Planner graphs, graph colouring, Trees: Spanning trees, Binary trees, Binary search trees. *Boolean algebras and combinatorial circuits*: Boolean algebras, Boolean functions, Logic gates, Combinatorial circuits.

Essential Reading :

1. T. Koshy, *Discrete Mathematics with Applications*, Academic Press (An Imprint of Elsevier) First Indian Reprint 2005

MA 424 OPERATIONS RESEARCH 4 credits [3-1-0]

Convex sets, Supporting and separating hyperplanes, Convex polyhedron and polytope, Convex functions, Generalized convexity, Linear programming model, Graphical solution, The simplex method, Artificial variables, The Big-M method, Two phase simplex method, Degeneracy and cycling, Dual of an LPP, Duality theorems, The dual simplex method, Post optimality analysis, *Transportation and assignment Problems*: Balanced transportation problem, Unbalanced transportation problem, Basic feasible solution by north-west corner rule, Row minima and column minima methods, Vogel's approximation method, Solution of TP, Assignment problem, Hungarian method of assignment, *Queuing Theory*: Introduction, Components of a queuing problem, Classification of queues, Steady, Transient and explosive states of a queue, Roles of poisson process and exponential distribution in queuing theory, Queuing models, (M/M/1:∞/FIFO) Model, Distribution of waiting time and time spent by an unit in the system, (M/M/1:N/FIFO) model, (M/M/c:∞/FIFO) model, (M/M/c:N/FIFO) model, ($M/E_k/1:\infty$/FIFO) model, ($M/E_k/1:\infty$/FIFO) model, (M/E_k/1:1/FIFO) model, Real life examples of queuing models.

Essential Reading :

1. H.A. Taha, *Operations Research,* Prentice Hall, 1997

Supplementary Reading :

1. N. S. Kambo*, Mathematical Programming Techniques*, East West Press, 1997.

MA 426 Elementary Stochastic Processes with Applications 4 credits [3-1-0]

(Prerequisite: MA-201)

Definition and examples of stochastic processes, Classifications of stochastic processes, Markov chains, Definition and examples, Transition Probability matrices, Classification of states of a Markov chain, Determination of higher order transition probabilities, stability of a Markov chain, Graph theoretic approach, Markov chains with denumerable number of states, Reducible Markov Chains, Markov chains with continuous state spaces, General pure birth and death processes, Renewal processes, Renewal processes in continuous time, renewal equation, Renewal theorems, Residual and excess lifetime, Renewal reward processes, Regenerative renewal processes, Stochastic processes in queuing, General concepts of queuing systems,

Steady state and transient behavior, Birth and death process in queuing theory, Network of Markovian queuing systems.

Essential Reading :

1. J. Medhi, *Stochastic Processes*, New Age Publishers, Second Edition, 2007

Supplementary Reading :

1. G. R. Grimmett and D. R. Stirzaker, *Probability and Random Processes,* Oxford University Press, 2001.

MA 400 FUNCTIONAL ANALYSIS 4 Credits [3-1-0]

Normed spaces, Banach spaces, Further properties of normed spaces, Finite dimensional normed spaces and subspaces, Compactness and finite dimension, Bounded and continuous linear operators, Linear functionals, Linear operators and functionals on finite dimensional spaces, Normed spaces of operators, Dual spaces, Inner product spaces, Hilbert spaces, Further properties of inner product spaces, Representation of functionals on Hilbert spaces, Hilbert-adjoint operator, Self-adjoint, unitary and normed operators, Fundamental theorems for normed and Banach spaces: Zorn's lemma, Hahn-Banach theorem, Hahn-Banach theorem for complex vector spaces and normed spaces, Adjoint operators, Reflexive spaces.

Essential Reading:

1. Y. Eidelman, V.D. Milman, A. Tsolomitis, Functional *Analysis: An Introduction*, AMS Bookstore, 2004
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Willey, 1978

MA 401 ABSTRACT ALGEBRA 4 Credits [3-1-0]

Groups, Subgroups, Centralizers, Normalizers, Stabilizers, Kernels, Cyclic groups, Subgroups generated by a subset of a group, Quotient groups, Lagrange's theorem, Homomorphisms, Isomorphism theorems, Composition series, Solvable groups, Nilpotent groups, Symmetric group, Alternating group, Group actions, Permutation representations, Automorphisms, p-groups, The Sylow theorems, Simplicity of the Alternating group, Direct products of groups, Fundamental theorem of finitely generated abelian groups, Groups of small orders, Rings, Ring homomorphisms, Ideals, Ring of fractions, The Chinese remainder theorem, Euclidean domains, Principal domains, Unique factorization domains, Matrix rings, Polynomial rings, Irreducible Criteria, Eisenstein's criterion.

Essential Reading:

1. D. S. Dummit & R. M. Footee, *Abstract Algebra*, Wiley, 2008

Supplementary Reading :

1. I. N. Herstien, *Topics in Algebra*, Wiley, 2008
2. J. J. Rotman, *An Introduction to the Theory of Groups*, Springer, 1999

MA 402 MEASURE THEORY 4 Credits [3-1-0]

Outer measure, Measurable sets and Lebesgue measure, A nonmeasurable set, Measurable functions, Littlewood's three principles, the Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, The integral of a nonnegative function, The general Lebesgue integral, Convergence in measure, Differentiation of monotone functions, Functions of bounded variation, Differentiation of an integral, Absolute continuity, Convex functions, The L^p spaces, The Minkowski and Holder inequalities, Convergence and completeness, Approximation in L^p, Bounded linear functionals on the L^p spaces.

Essential Reading:

1. E. D. Benedetto, *Real Analysis: Foundations and Applications*, Springer, 2002
2. H. L. Royden, *Real Analysis (Third Edition)*, Macmillan Publishing Company, 1988
3. G. De. Barra, *Measure Theory and Integration*, Horwood Publishing Corporation, 2003.

MA 403 LINEAR ALGEBRA 4 credits [3-1-0]

Linear transformations, Linear functionals, Dual spaces, Characteristic roots, Invariant subspaces, Simultaneous diagonalization, Primary decomposition theorem, Canonical forms, Triangular, Rational and Jordan canonical forms, Inner product spaces, Unitary and normal operators, Forms on inner product spaces, Positive forms, Spectral theorem, Bilinear forms, symmetric and skew-symmetric bilinear forms, Groups preserving bilinear forms.

Essential Reading:

1. K. Hoffman and R. Kunze, *Linear Algebra*, PHI, 1971
2. M. Artin, *Algebra*, PHI, 1998
3. N. Herstein, *Topics in Algebra*, Weilly, 1975
4. P. Halmos, *Finite dimensional vector spaces*, Springer-Verlag, UTM, 1987.

MA 404 FUNCTIONS OF A COMPLEX VARIABLE 4 credits [3-1-0]

Spherical representation of extended complex plane, Analytic functions, Branches of multiple-valued functions, Cauchy's theorem, Singularities, The Argument principle, Calculus of residues, Harmonic functions, Poisson's formula, The reflection principle, Conformal mappings, Geometry of Mobius transformations, Open mapping theorem, The Maximum modulus theorem, Schwarz's lemma, Partial fractions and factorization, Stirling's formula, Jensen's formula, Hadamard's theorem.

Essential Reading:

1. L. V. Ahlfors, *Complex Analysis* (Mc-Graw Hill International), 1979
2. J. B. Conway, *Functions of One Complex Variable* (Springer), 1978
3. W. Rudin, *Real and Complex Analysis* (McGraw-Hill), 1986

MA 405 PARTIAL DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

Origin of first order partial differential equations, Cauchy's problem, Linear equations, Integral surfaces passing through a given curve, Surfaces orthogonal to a given system of surfaces, Nonlinear partial differential equations of the first-order, Cauchy's method of characteristics, Compatible systems of first-order equations, Charpit's method, Special types of first-order equations, Solutions satisfying given conditions, Jacobi's method, Origin of second order partial differential equations , Second and higher order equations in physics, Linear partial differential

equations with constant coefficients, Equations with variable coefficients, Characteristic curves of second-order equations, Characteristics of equations in three variables, Solution of linear hyperbolic equations, Separations of variables, Integral transforms method, Nonlinear equations of second-order. Laplace's equation: The occurrence of Laplace's equation in physics, Elementary solutions of Laplace's equations, Family of equipotential surfaces, Boundary value problem, Problems with axial symmetry, Kelvin inversion theorems , theory of green's function for Laplace equation.

Essential Reading:

1. N. Sneddon: *Elements of Partial Differential Equations*, Dover, 2006

MA 407 METRIC SPACES 4 credits [3-1-0]

Schwarz and triangle inequality, Point set topology, countable and uncountable sets, Compact set and Heine-Borel theorem, Perfect sets, Functions on compact sets, connected sets, Mappings between metric spaces, Sequence and series of functions, Uniform convergence, Uniform convergence and continuity, integration and differentiation, A fixed point theorem and its application differential equation, Newton's method, Complete metric spaces, Convex sets and convex functions, Arzela's theorem, Tietze's extension theorem, Approximations and the Stone-Weierstrass theorem.

Essential Reading:

1. M. Ó Searcóid, *Metric Spaces*, Springer 2006

Supplementary Reading:

1. M. H. Protter & C. B. Morrey, *A First Course in real Analysis*, Springer, 1991

MA 409 TOPOLOGY 4 credits [3-1-0]

Topological spaces and continuous functions: Topological spaces, Basis for a topology, Order topology, Product topology, Subspace topology, Closed sets and limit points, Continuous functions, Homeomorphism, Metric topology, Quotient topology, Connectedness and compactness: Hausdorff spaces, Connected spaces, Connected subspaces of the real line, Compactness and local connectedness, Compact spaces, Compact subspaces of the real line, Limit point compactness, Local compactness, Countability and separation axioms: Countability axioms, Separation axioms, Normal spaces, Regular spaces, Completely regular spaces, Urysohn lemma, Urysohn metrization theorem, Tietze extension lemma, The Tychonoff theorem: Compactification, One-point compactification, The Stone-Cech compactification, Metrization theorems and paracompactness, Local finiteness, Complete metric spaces and function spaces: Compactness in metric spaces, Pointwise and compact convergence, Ascoli,s theorem, Baire's spaces and dimension theory, A nowhere differentiable function, Applications of topology in engineering and sciences.

Essential Reading:

1. J. R. Munkres: *Topology*: (Pearson Prentice Hall), 2005

MA 470 OPERATIONS RESEARCH LABORATORY 2 credits [0-0-3]

Computational works are to be done on the following topics.

1. Formulation of OR Problems
2. Graphical solution of LPP
3. Computation of basic and basic feasible solutions
4. Solution of LPP by simplex method
5. Solution of LPP by the big-M method
6. Solution of LPP through its dual
7. Solution of LPP by the dual simplex method
8. Formulation of transportation problem, initial basic feasible solutions by various methods
9. Solution of transportation problem
10. Solution of games by LPP techniques
11. Solution of assignment problem
12. Solution of travelling salesman problem
13. Solution of quadratic problem by Wolf's method
14. Monte-Carlo simulation for binomial distribution
15. Monte-Carlo simulation for Poisson distribution

MA 471 OBJECT ORIENTED PROGRAMMING PRACTICE LABORATORY 2 credits [0-0-3]

Computational works are to be done on the following 12 topics.

1. Finding all topologies from a 4-point set
2. Income tax calculation
3. Calculation of quantiles
4. Drawing all random samples from a given population and finding the unbiased estimate of the population mean and the variance
5. Calculation of central moments
6. Computations of roots of algebraic and transcendental equations by four methods
7. Interpolation by four methods
8. Numerical integration and numerical solution of differential equations
9. Listing all primes and twin primes up to certain number
10. Listing all divisors of certain numbers
11. Finding the determinant and inverse of a matrix
12. Finding eigen values and eigen vectors of a given matrix

MA 510 CALCULUS OF SEVERAL VARIABLES 4 credits [3-1-0]

Euclidean Space: Vector space, Definition of euclidean space, Orthinormal basis, The dual and second dual, Norms in the dual, The space L(E, F), Open sets, Closed sets, Completeness, Borel covering theorem, Equivalence of norms, Connected open sets, Mappings and their duals: Continuous mappings, Definition of differentials, Differentiability implies continuity, Special cases, Function of class C^1, Mappings of class C^1, Composition of differentiable mappings, Higher differentials, Mappings into reals: Taylor's theorem for one variable, Taylor's theorem for n variables, Absolute maxima and minima, Volume of a set, Integral on a closed interval, Condition for integrability, Integral on an open set, Iterated integral, Volume of n-ball, Interchange of order of integration with differentiation, Main theorems on mappings: Regular

elements in L(E, F), Inverse of a mapping, Implicit function theorem, Determinant, Oriented volume, Change of variables in integration.

Essential Reading:

1. S. Salas and G.J. Etgen, *Calculus: Several Variables*, John Wiley, 2003
2. T. P. Dick, C. M. Patton, *Calculus of Several Variables*, PWS Pub. Co., 1995

MA 511 DIFFERENTIAL GEOMETRY 4 credits [3-1-0]

Vector Fields: height of the level set, level curves, Integral curve, smooth vector field, The tangent Space: tangent to the level set, gradient, Surfaces: Hyperplane, Lagrange multiplier, Vector Fields on Surfaces, maximal integral curve, orientation and its consistency, Osculating plane, Serret Frenet formula, Singular points and their classification Gauss, The Gauss map spherical image, one-sheeted hyperboloid, Geodescis: maximal geodesic, great circle, Parallel Transport, covariant derivative and acceleration, Fermi derivative, The Weingarten Map: shape operator, geodesic flow, Curvature of plane curves: center of curvature, radius of curvature, Isometries, Intrinsic differentiation, Gauss-Kronecker curvature, translation, rotation, Fundamental theorem on curves, Riemannin metrics: Hyperbolic metric, Stereographic projection, Poincare metric, affine and Riemannian connection and covariance derivation, Applications of differential geometry in engineering and sciences.

Essential Reading:

1. J. A. Thorpe, *Elementary Topics in Differential Geometry* (Springer), 2004.

MA 512 FOURIER ANALYSIS 4 credits [3-1-0]

Trigonometric series and Fourier series, Group structure and Fourier series, Convolutions of functions, Homomorphism of convolutions, Dirchlet and Fejer Kernels, Cesaro summability.

Essential Reading:

1. R.E. Edward, *Fourier series: a modern introduction*, (Holt, Rinehart 7 Winsten)

MA 513 DIFFERENTIAL TOPOLOGY 4 credits [3-1-0]

Manifolds and Smooth Maps: Derivatives and tangents, The inverse function theorem and immersions, submersions, transversability, homotopy and stability, Sard's theorem and Morse functions, embedding manifolds into Euclidean spaces, Simplicial surfaces: Simplices, Simplicial complexes, Simplicial surfaces, The Euler characteristic, Proof of the classification of compact and connected surfaces, Smooth surfaces, Tangent and normal vectors, First fundamental forms, Directional derivatives. Coordinates free, Dirtectional derivatives-coordinates, Length and area, Isometries, Transversality and interactions: Manifolds with boundaries, one-manifolds and some consequences, Transversality and interaction theorem mod 2, winding numbers and the Jordan-Brouwer separation theorem, Oriented interaction theorem: Motivation, orientation, oriented interaction number, Lefschetz fixed-point theory, Vector fields and the Poincare-Hopf theorem, The Hopf degree theorem, The Euler characteristic and triangulations, Intergration on manifolds: Introduction, exterior algebra, differential forms, interior of manifolds, exterior derivatives, cohomology with forms, Stokes' theorem, Integration and mappings, the Gauss-Bonnet theorem.

Essential Reading:

1. D. B. Gauld, *Differential Topology: An Introduction*, Dover Publication 2006

MA 514 RINGS AND MODULES 4 credits [3-1-0]

Ring of continuous functions, matrix rings, polynomial rings, power series rings, Laurent rings, Boolean rings, Direct products, local rings, prime fields, Euclidean domains, PID, Unique factorization domains, Eisenstein's criteria, modules, direct sum, free modules, quotient modules, simple modules, homomorphisms, module's over PID's, Artinian modules, Noetherian modules, Artian rings, Noetherian rings, Nil Radicals, Jacobson radicals.

Essential Reading:

1. C. Musili, *Introduction to Rings and Modules*, Narosa,

MA 515 HOMOTOPY THEORY 4 credits [3-1-0]

Brouwer Fixed point theorem, categories, Functors, Natural transformations, Natural equivalence, Homtopy, Convexity, Contrctibility, Mapping cylinder and cones, Paths and path connected spaces, Affine spaces, Affine maps, Homotopy as equivalence relation, Contractible Spaces, Homotopy of maps, Homotopy classes, Homotopically equivalent spaces with examples, Fundamental Groups, Induced maps and homomorphisms, Lifting property, Calculation of first homotopy groups, Function spaces, Group objects and cogroup objects, Loop space and suspension, Exact sequence of homotopy groups, Homotopy lifting propert, Homotopy extension property, Fibrations and cofibrations, CW-complexes and their examples, attaching of maps, Homotopy groups of CW-complexes, The effect on the homotopy groups of a cellular extension, Spaces with prescribed homotopy groups, Weak homotopy equivalences and CW-approximation Homotopy extension and classification theorems, Study of some cases where homotopy theory is applied in electrical engineering.

Essential Reading:

1. J. Rotman, *Algebraic Topology*, Springer-Verlag, 2004

MA 516 OPERATOR THEORY 4 credits [3-1-0]

Banach Spaces: The Banach space of continuous functions, Abstract Banach spaces, The conjugate space of continuous linear functionals, Examples of Banach spaces: c_0, l^1 and l^∞, Weak topologies on Banach spaces, The Alaoglu theorem, The Hahn-Banach theorem, The conjugate space of C([0,1]). The open mapping theorem, The Lebesgue spaces: L^1 an L^∞, The Hardy spaces: H^1 and H^∞, Banach algebras: The Banach algebra of continuous functions, Abstract of Banach algebras, Abstract index in a Banach algebra, The space of multiplicative linear functions, The Gelfand transform, The Gelfand-Mazur theorem, The Gelfand theorem for commutative Banach algebras, The spectral radius formula, The Stone-Weirstrass theorem, The generalized Stone-Weirstrass theorem, The disk algebra, The algebra of functions with absolutely convergent Fourier series, The algebra of bounded measurable functions, Geometry of Hilbert space: Inner product spaces, The Cauchy-Schwarz inequality, The Pythagorian theorem, Hilbert spaces, Examples of Hilbert Spaces: C^n, l^2, L^2, and H^2. The Riesz-Representation Theorem, The existence of orthogonal bases, The dimension of Hilbert spaces, Operators on Hilbert space and C^*-algebras: The adjoint operators, Normal and self-adjoint operators, Projections and subspaces, Multiplication operators and maximal abelian algebras, The bilateral shift operators, C^*-algebras.

Essential Reading:

1. R. G. Douglas: *Banach Algebra Techniques in Operator Theory*, Springer, 1998

MA 517 LIE ALGEBRA 4 credits [3-1-0]

Definitions and example, Solvable and nilpotent Lie algebras, Simple and semi-simple Lie algebras, Levi's theorem, Idealizer and centralizer, Derivation of a Lie algebra, Structure constant, Special linear algebra, Lie groups and Lie algebras, Classical groups and their Lie algebras, Cartan-Killing form, Root-space decomposition of a Semi-simple Lie algebra, Properties of root space, Simple root system and classification of finite dimensional complex Semi-simple Lie algebra, Cartan matrix, root diagrams, Dynkin diagrams, Weyl group of a root system, Weyl reflection, Real forms of Lie algebras and their classification through Satake and Vogan diagram, Applications of Lie groups and Lie algebras to robotics, Genetic coding, Control theory, Computer vision, Particle physics.

Essential Reading:

1. K. Erdmann, M. J. Wildon, *Introduction to Lie Algebras*, Springer 2006

MA 518 ADVANCED COMPLEX ANALYSIS 4 credits [3-1-0]

Compactness and Convergence in the space of analytic functions, Riemann mapping theorem, Reflection principle, Weierstrass factorization theorem, The Reimann zeta function, Runge's theorem, Simple connectedness, Picard's little theorem and Picard's big theorem, Normal families, Equicontinuity, Arzela's theorem, Normality and continuity, Conformal mapping of polygons, The Schwarz-Christiffel formula, Harnock's of harmonic functions, Diridhlet's principle, The Weierstrass P-function, Analytic continuation, The Monodromy theorem, Picard's theorem, Lacunary values.

Essential Reading:

1. L. V. Ahlfors, *Complex Analysis* (Mc-Graw Hill International)

Supplementary Reading:

1. J. B. Conway, *Functions of One Complex Variable* (Narosa)
2. M. Rao & H. Stetkaer, *Complex Analysis: An Invitation* (World Scientific)

MA 519 MULTI LINEAR ALGEBRA 4 credits [3-1-0]

Tensor product: Multilinear mappings of vector spaces, Existence and universal property of the tensor product, Commutativity and associativity of the tensor product, The tensor product in terms of coordinates, Tensor products and spaces of linear mappings, Tensor algebras: Covariant, contravariant and mixed tensors, Classical definition and notation of a tensor in terms of coordinates, Structure tensor of an algebra, Mixed tensor algebra, Universal property of the tensor algebra, symmetry and alteration, Exterior algebra: Exterior powers and p-vectors, Alternation operator, Exterior powers of linear mappings, Exterior algebra, Duality and p-forms, Exterior algebra, duality in exterior algebra, applications to vector space bundles, exterior differentiation, Tensor products and standard algebras: Graded vector spaces, graded algebra, the graded tensor algebras, commutative algebra, the exterior algebra of a finite dimensional vector spaces, Grassman algebras: Alternate k-linear functions, exterior multiplications, homogeneous elements, decomposable elements, Recent developments.

Essential Reading:

1. R. Merris, *Multilinear Algebra*, (CRC Press) 1997

MA 520 AUTOMATA THEORY 4 credits [3-1-0]

Finite Automata, Regular expressions, equivalence of finite automata and expressions, Moore and Mealy Machines, Properties of regular sets: Pumping lemma, closure properties and decision algorithms, Minimizing finite automata, Context-free grammars, Pushdown automata

Essential Reading:

1. J. E. Hopcroft & J. D. Ullman, *Introduction to Automata theory, Languages and computations* (Narosa)

MA 521 COMBINATORICS 4 credits [3-1-0]

Graphs, Trees, Colorings of graphs and Ramsey's theorem, The addressing problem for graphs, The principle of inclusion and exclusion, inversion formulae, Permanents, Elementary counting, Stirling numbers, Recursions and generating functions, Partitions, (0,1)-matrices, Latin squares, Hadamard matrices, 1 Designs, Codes and designs, Strongly regular graphs and partial geometries, Orthogonal Latin squares, Projective and combinatorial geometries, Gaussian numbers and q-analogues, Lattices and Möbius inversion, Combinatorial designs and projective geometries.

Essential Reading:

1. V. K. Balakrishnan, *Theory and Problems of Combinatorics*, McGraw Hill, 1994
2. J. H. Van Lint and R.M. Wilson, *A Course in Combinatorics*, Cambridge University Press, 2001.

MA 522 OPERATIONS RESEARCH 4 credits [3-1-0]

Convex sets, Supporting and separating hyperplanes, Convex polyhedron and polytope, Convex functions, Generalized convexity, Linear programming model, Formulation of LPP, Graphical solution, The simplex method, Artificial variables, The big-M Method, Two phase simplex method, Degeneracy and cycling, Dual of an LPP, Duality theorems, The dual simplex method, Post optimality analysis, Transportation and assignment problems: Balanced transportation problem, Unbalanced transportation problem, Basic feasible solution by north-west corner rule, Row minima and column minima methods, Vogel's approximation method, Solution of TP, Assignment problem, Hungarian method of assignment, Kuhn-Tucker optimality conditions and convex programming: Kuhn-Tucker first order optimality conditions, Second order optimality conditions, Lagrange's method, Convex programming problem, Sufficiency of Kuhn-Tucker conditions, Lagrangian saddle-point and duality, Duality of convex programs, Queuing theory: Introduction, Components of a queuing problem, Classification of queues, Steady, transient and explosive states of a queue, Roles of Poisson process and exponential distribution in queuing theory, Queuing models, (M/M/1:∞/FIFO) model, Distribution of waiting time and time spent by an unit in the system, (M/M/1:N/FIFO) model, (M/M/c:∞/FIFO) model, (M/M/c:N/FIFO) model, ($M/E_k/1:\infty$/FIFO) model, ($M/E_k/1:\infty$/FIFO) model, ($M/E_k/1:1$/FIFO) model, Examples of queuing models.

Essential Reading:

1. F. S. Hillier & G. J. Lieberman, *Introduction to Operations Research*, Tata McGraw-Hill, 2005

Supplementary Reading:

1. N.S. Kambo: *Mathematical Programming Techniques*, Affiliated East-West Press Ltd, 1984.

MA 523 DISCRETE MATHEMATICS 4 credits [3-1-0]

Functions and matrices: Special functions, Properties of functions, The pigeonhole principle, Composition of functions, Induction and algorithms: The division algorithm, Divisibility properties, Mathematical induction, Algorithm correctness, The growth of functions, Complexities of algorithms. Recursion: Recursively defined functions, Solving recurrence relations, Generating functions, Recursive algorithms, Correctness of recursive algorithms, Complexities of recursive algorithms. Combinatorics and discrete probability: The fundamental counting principles, The generalized inclusion and exclusion principle, Discrete probability. Relations: Boolian matrices, Relations and digraphs, Computer representations of relations, Properties of relations, Operation on relations, The connectivity relations, Equivalence relations, Partial and total orderings. Graphs: Computer representation of graphs, Isomorphic graphs, Paths, cycles and circuits, Eulerian and Hamiltonian graphs, Planner graphs, graph colouring, Trees: Spanning trees, Minimal spanning trees, Rooted trees, Binary trees, Binary search trees. Boolean algebras and combinatorial circuits: Boolean algebras, Boolean functions, Logic gates, Combinatorial circuits, Minimization of combinatorial circuits, Recent developments.

Essential Reading:

1. T. Koshy, *Discrete Mathematics with Applications*, Academic Press (An Imprint of Elsevier) First Indian Reprint 2005

Supplementary Reading:

1. R. Johnsonbaugh, *Discrete Mathematics*, Pearson Prentice Hall, 2008

MA 524 STATISTICAL METHODS 4 credits [3-1-0]

Random variables: Distribution functions, Properties of distribution functions, Discrete random variables and probability mass functions, Continuous random variables and probability density functions, Two dimensional random variables: Joint, marginal and conditional distributions, Independence, Mathematical expectations: Mathematical expectation of function of a random variable, Linearity of mathematical expectation, Expectation in joint distributions, Conditional expectation and conditional variance, Moments, cumulants and their generating functions, Conditional expectations and conditional variance, Theoretical discrete distributions: Binomial, Poisson, hyper-geometric, Negative binomial and multinomial distributions, Recurrence relations for probabilities and moments, Theoretical continuous distributions: Exponential, gamma, beta and normal distributions, Applications of normal distribution, Chi-square distribution: Test for goodness of fit and population variance, t-distribution: Test for single mean and difference of two means, F-distribution: Test for equality of two population variances, Law of large numbers: Chebyshev's inequality, Weak law of large numbers, De-Moivre Laplace theorem, Central limit theorems.

Essential Reading:

1. J. E. Freund, *Mathematical Statistics with Applications*, Miller 2003.

Supplementary Reading:

1. J. Medhi, *Statistical Methods, An Introductory Text*, New Age, 1992
2. K. Knight, *Mathematical Statistics*, CRC Press, 1999

MA 525 ERGODIC THEORY 4 credits [3-1-0]

Measure preserving transformation, Isomorphism and spectral invariants, Measure preserving transformation with pure point spectrum, Entropy.

Essential Reading:

1. P. Walters, *Ergodic Theory*, Springer Verlag, 1981

MA 527 FRACTUALS 4 credits [3-1-0]

Fractal examples: the Traidic Cantor dust, the Sierpinski Gasket, A space of strings, Turfle graphics, Sets defined recursively, number system, Metric topology, Uniform convergence, The Hausdorff metric, Metrics for strings, Topological dimension, Small and large inductive dimension, Two dimensional euclidean space, Other topological dimensions.

Essential Reading:

1. G. A. Edger, *Measure, Topology and fractal Geometry*, Springer-Verlag.
2. M. Barnsley, *Fractals Everywhere*, Morgan Kaufmann, 2000.
3. H. O. Peitgen, *Chaos and Fractals*, New Frontiers of Science, Springer, 2004

MA 529 INFORMATION THEORY 4 credits [3-1-0]

Information Theory and Source Coding: Introduction to information theory, Uncertainty and information, Average mutual information and entropy, Information measures for continuous random variables, Source coding theorem, Huffman coding, The Lempel-Ziv algorithm, Tun length encoding and PCX format, Rate distortion function, Optimum quantizer design, Introduction to image compression, The Jpeg standard for lossless compression, The Jpeg standard for Lossy compression, Channel Capacity and Coding: Channel models, Channel capacity, Channel coding, Information capacity theorem, The Shannon limit, Random selection of codes, Cryptography: Introduction to cryptography, An overview of encryption techniques, Operations used by encryptions algorithm, Symmetric (secret key) cryptography, Data encryption standards (DES), International data encryption algorithm (IDEA), RC ciphers, Assymmetric (public key) algorithms, Way hashing, Other techniques, Secure communication using chaos functions, Cryptanalysis, Politics of cryptography, Recent developments.

Essential Reading:

1. H. S. M. Coxeter, *Elements of Information Theory*, John Wiley, 2005.

Supplementary Reading:

1. R. Bose, *Information Theory Coding and Cryptography*, Tata McGraw-Hill, 2003
2. S. Goldman, *Information Theory*, Dover, 2005

MA 530 COMPUTATIONAL METHODS IN BOUNDARY VALUE PROBLEMS 4 credits [3-1-0]

Method of superposition, Method of Chasing, Ad-joint operator method, Shooting method: Newton's method, parallel shooting, quasi linearization, Finite difference method, Integral equation method

Essential Reading:

1. T.Y. Na, *Computational Methods in Engineering Boundary Value Problems*, (Academic Press).

MA 531 BOUNDARY LAYER THEORY 4 credits [3-1-0]

Outline of viscous flows: Real and perfect fluids, viscosity, Reynolds number, Laminar and turbulent flows, Asymptotic behavior at large Reylonds numbers, Fundamentals of boundary-layer theory: Boundary-layer concept, Laminar boundary-layer on a flat plate at zero incidence, Separation of the boundary-layer. Field equations for flows of Newtonian fluids: Continuity equation, Momentum equation, General stress state of deformation bodies, General state of deformation of flowing fluids, Relation between stresses and rate of deformation, Stokes hypothesis, Navier-Stokes equations, Energy equations, Equations of motion in different coordinate systems. Exact solutions of the Navier-Stokes equations: Couette-Poiseuille flows, Plane stagnation point flow,Flow at a wall suddenly set into motion, Stokes first problem, Flow at an oscillation flow, Stokes second problem, Unsteady plane stagnation-point flow. Boundary-layer equations in plane flow: Setting the boundary-layer equations, Wall friction, separation and displacement, Dimensional representation of the boundary layer equations, Plate boundary-layer. Thermal boundary- layer: Boundary layer equations for the temperature field, Effect of the Prandtl number.

Essential Reading:

1. H. Schlichting and K. Gersten, *Boundary-Layer Theory*, Springer, 2003.

MA 532 NUMERICAL SOLUTIONS OF PARTIAL DIFFERENTIAL EQUATIONS 4 credits [3-1-0]

Parabolic equations in one space dimension, Explicit and implicit formula, Convergence and stability, Derivative boundary conditions, Parabolic equations in three dimensions, Explicit methods and their stability, Alternating direction implicit methods, nonlinear equations, Elliptic equations in two dimensions, Laplace equation in a square, the Nuemann problem, Mixed boundary conditions, Non-rectangular regions, Alternative method for constructing difference formula, Properties of difference formula, The solution of elliptic difference equations, Direct factorization methods, Successive over relaxation, A.D.I methods, Conjugate gradient and related methods, First order hyperbolic equations, Explicit and implicit schemes and their stability.

Essential Reading:

1. A.R. Mitchel & D.F. Griffllts: *The Finite Difference Methods in Partial Differential Equations*, Willey, 1980

MA 534 GEOMETRY OF ROBOTICS 4 credits [3-1-0]

Robotics: An introduction, Theoretical robotics, Mathematical ingredients: Lie groups, subgroups, the Proper Euclidean group, Chasle's theorem, SE(3), Reuleaux's lower pairs, Lie algebras, Commutators, Exponential mapping, Robots Jacobian and Derivatives, Robot

Kinematics: Inverse kinematics for 3-R wrists, 3-R Robots and planar motion, Planar 4-bar, Line geometry, Plucker coordinates, Inverse robots Jacobian, Representation SO(3), Screw systems, Clifford algebra, Dual quarternions, Euclidean geometry, Pieper's theorem, the T3 Robot, the PUMA, Statics: Gripping, Friction, Dynamics: Lagrangian and Hamiltonian Dynamics of Robots. Robot equation of motion, Constrained dynamics, trees and stars, Serial robot with end effector constraints, Biped walking, Differential geometry, Controlling of Robots, Hybrid control, Non linear control and Lie brackets.

Essential Reading:

J.M. Seling, *Geometric fundamentals of Robotics*, Springer (2005)

Supplementary Reading:

1. R M Murray, S. Sastry, Li Z, *A mathematical introduction to robotic manipulation*, CRC press, Boca Raton, Florida

MA 540 SINGULAR HOMOLOGY THEORY 4 credits [3-1-0]

General Homology Theory: Axioms of homology theory, Singular homology theory, Affinely independent, Ordered simplex: Standard n-simplex, Singular n-simplex, singular n-chain, Free abelian group, Singular chain complex, nth singular homology group of a topological space, boundary operator, Induced homomorphism of singular homology groups, Connecting homomorphism, Brouwer fixed point theorem: Brouwer degree, Jordan-Brouwer separation theorem, Brouwer theorem on the invariance domain, Inverse system and direct system of abelian groups, Attaching spaces with maps, Singular homology groups of standard projective spaces: Excision theorem, Reduced singular homology groups, Strong deformation retract, Relative homeomorphim theorem, Verification Eilenberg-Steenrod axioms, Calculation of singular homology groups using Eilenberg-Steenrod axioms, Products: Kunneth formula, Acyclic model Theorem, Homology external product, Alexander-Whitney diagonal approxi-mation, Homology theory of CW-complxes, Some cases application of singular homology groups in electrical engineering.

Essential Reading:

1. J. Rotman: *An Introduction to Algebraic Topology* (Springer-Verlag) 2004

MA 542 TENSOR ANALYSIS 4 credits [3-1-0]

Tensor analysis: Transformation of coordinates, The summation convention, Contravariant vectors, Invariants, Covariant vectors, Tensors, The Christofell 3-index symbols and their relations, Riemann symbols and the Riemann tensor, The Ricci tensor, Quadratic differential forms, The equivalence of symmetric quadratic differential forms, Covariant differentiation with respect to a tensor g_{ij}, Introduction to a metric: Definition of a metric, N-tuply orthogonal systems of hypersurfaces in a V_n, Metric properties of a space V_n immersed in a V_m, Geodesics, Riemannian, Normal and geodesic coordinates, Geodesic form of the linear element, Finite equations of geodesics, Curvature of a curve, Parallel displacement and the Riemann tensor, Fields of parallel vectors, Associate directions, Curvature of V_n at appoint, The Bianchi identity, The theorem of Schur, Isometric correspondence of spaces of constant curvature, Conformal spaces, Spaces conformal to flat space, Orthogonal ennuples: The Frenet formulas Principal directions determined by a symmetric covariant tensor of the second order, The Ricci principal tensors, Condition that a congruence of an orthogonal ennuple be normal, N-tuply orthogonal systems of hypersurfaces, N-tuply orthogonal systems of hypersurfaces in a space conformal to a flat space, Congruence canonical with respect to a given congruence, Recent developments.

Essential Reading:

1. L.P. Lebedev: *Tensor Analysis* (World Scientific) 2003.

MA 544 CATEGORY THEORY 4 credits [3-1-0]

Categories and Functors: The definition of a category, Covariant and contravariant functors, Natural transformations, Natural equivalence, Examples from from different topics of engineering and sciences, The duality principle, The construct of small categories, Reflective subcategories, Coma category, Full and faithful functors, Limits and colimits: Products and coproducts, Limits, colimits, equalizer, coequaliser, pullback, pushout, Universal and couniversal properties, Equivalence of equalizer and pullback in presence of products, Equivalence of coequalizer and pushout in presence coproducts, Limits in terms of products and equalizers, Limits in terms of products and pullback, Colimits in terms of coproducts and coequalizers, Colimits in terms of coproducts and pushout, Adjoint functors: Left adjoint, Right adjoint, Adjoint functor theorem, Preservation of limits by adjoint functors, Representable functors, Representing objects, Tensor products of categories.

Essential Reading:

1. S. Awodey: *Category Theory* (Oxford University Press) 2006

MA 546 DIFFERENTIABLE MANIFOLDS 4 credits [3-1-0]

Differentiable Manifolds: Topological manifolds, Chart, Atlas, Maximal atlas, Differentiable structures, Differentiable functions, Diffeomorphisms, Germs of local smooth functions, Algebra of smooth germs, Derivation, Tangent and cotangent spaces, Differential of smooth map, Immersion, Vector bundles, Examples of smooth vector bundles, Differential forms: Alternate k-linear functions, Grassmann algebras, Universal property of exterior algebra, Differential forms, Differential k-forms, Exterior multiplication, Exterior differentiation, De Rham cohomolgy groups, Induced transformations, Poincare's lemma, Riemannian manifolds: Innerproducts, Riemannian structures, Riemannian metric, Riemannian connection, Geodesics, Convex neighborhoods, De Rahm's theorem: Singular homology groups, Real singular cohomology groups, De Rham's theorem.

Essential Reading:

1. L. Conlon: *Differentiable Manifolds* (Springer-Verlag): 2001

MA 548 FIELD THEORY 4 credits [3-1-0]

Algebraic Extensions, Algebraic closed fields, Splitting fields, Normal extensions, Multiple Roots, Finite fields, Separable extensions, Galois theory: Automorphism groups and fixed firelds, Fundamental theorem of Galois theory, Fundamental theorem of algebra, Applications: Roots of unity and cyclotomic polynomials, cyclic extensions, Polynomoals solvable by radicals, Symmetric functions, Ruler and compass construction

Essential Reading:

1. S. Lang: *Algebra* (Addison-Wesley)
2. T. W. Hungerford: *Algebra* (Springer)

MA 549 ALGEBRAIC GEOMETRY 4 credits [3-1-0]

Regular Functions and Maps: The Zariski topology, Regular functions on an affine variety, Projective varieties, Regular maps, The Veronese map, Determinantal representation of Veronese varieties, Subvarieties of Veronese varieties, The Segre maps, Subvarieties of Segre varieties, Products of varieties, Graphs, Fiber products, Combinations of Veronese and Segre maps, Cones, Projections and More about Products: Cones, Quadrics, Projections, More cones, More projections, Constructible sets, Families and parameter spaces: Families of varieties, The universal hyperplane, The universal hyper section, Parameter spaces of hypersurfaces, Universal families of hypersurfaces, A family of lines, Rational functions and rational maps: Rational functions, Rational Maps, Graphs of Rational Maps, Birational Isomorphism, The Quadric Surface, Hypersurfaces, Degree of a rational map, Blow-ups, Blowing up points, Blowing up subvarieties, The quadric surface again, The cubic scroll in $\mathbb{P}^4$, Unirationality.

Essential Reading :

1. J. Harris, *Algebraic Geometry A First Course*, Springer, 1992

MA 550 CODING THEORY 4 credits [3-1-0]

Block codes, Linear codes, Hamming codes, Weight enumerators, Binary Golay code, Ternary Golay code, Constructing codes from other codes, Ree-Muller codes, Cyclic codes: Generator matrix and check polynomial, Zeros of a cyclic code, BCH codes, Reed-Solomon codes, Binary cyclic codes of length 2n (n odd).

Essential Reading :

1. J. H. van Lint, *Introduction to Coding Theory*, Springer.
2. F. Blake & R. C. Mullin, *An introduction to Algebraic and Combinatorial Coding theory,* Academic press.

MA 551 NUMERICAL ANALYSIS 4 credits [3-1-0]

Sources of errors, Propagation of errors, Stability in numerical analysis, Root finding of nonlinear for equations: Aitken extrapolation for linearly convergent sequences, Error tests, The numerical evaluation of multiple roots, Brent's root finding algorithm, Hermite interpolation, Piecewise polynomial interpolation, The minimax and near minimax approximations, The Remes algorithms, Numerical integration: Patterson's method, Asymptotic error formulas and their applications, Adaptive numerical integration, Singular integrals, Umerical methods for differential equations: Multistep method, Derivation of higher-order multistep methods, Numerical solutions of system of linear equations: The residual correction method, Error prediction and acceleration, The numerical solution of Poisson's equation.

Essential Reading :

1. K. E. Atkinsan, *An Introduction to Numerical Analysis*, Willey, 1978
2. E. Süli, D. F. Mayers, *An Introduction to Numerical Analysis*, Cambrige University Press, 2003

MA 552 FUZZY LOGIC AND SET THEORY 4 credits [3-1-0]

Fuzzy sets, Support, Membership function, Fuzzy union and intersection, Fuzzy product, Fuzzy topological spaces, Fuzzy continuity, Fuzzy compactness, Fuzzy connectedness, Fuzzy groups, Fuzzy normal Subgroups, Fuzzy ideals, Fuzzy maximal ideals.

Essential Reading :

1. H. J. Zimmermann, *Fuzzy Set Theory and Its Applications*, Kluwer Academic Publishers

MA 553 OPTIMIZATION TECHNIQUES 4 credits [3-1-0]

Dynamic programming: Introduction, The recursive equation approach, Computational procedure in dynamic programming, Solution of LPP by dynamic programming, Application of dynamic programming to a minimum path problem, Goal programming: Goal programming problem, Generalized goal programming models, Chebyshev norm model, Network optimization problem: The shortest-path problem, The mimimun spanning tree problem, Maximum flow problem, Minimum cost flow problem, Network simplex method, Simulation: Various Methods of Sample Collection, Simulated sampling (Monte-Carlo method), Definition of simulation, Steps in simulation procedure, Simulation model, Application of simulation method, Simulations here Monte-Carlo methods are useful, General procedure of Monte Carlo methods, Advantages and disadvantages of Monte Carlo methods, Problem of Replacement: Replacement models and their solutions, Concept of present value, Replacement of items whose efficiency deteriorates with time, Replacement of items whose maintenance cost increases with time and the value of money remains the same, Replacement of items when value of money also changes, Replacement of items that fail completely, Group replacement method, Inventory control: Economic lot size models, EOQ with uniform rate of demand, Economic lot size with different rates of demand in different cycles, Determination of buffer stock, ABC analysis of inventory, Game theory: Solving simple games, Games with mixed strategies, Graphical solution procedure, Solution by linear programming.

Essential Reading :

1. F. S. Hillier & G. J. Lieberman, *Introduction to Operations Research*, Tata McGraw-Hill, 2005

Supplementary Reading :

1. N.S. Kambo, Mathematical Programming Techniques, Affiliated East-West Press Ltd, 1984.

MA 554 GRAPH THEORY 4 credits [3-1-0]

Path and circuits, Trees and fundamental circuits, Cut sets and cut vertices, Planner and dual graphs, Vector spaces of a graph, Directed graphs.

Essential Reading :

1. N. Deo, *Graph Theory with Applications to Engineering and Computer Science,* PHI, 1974

MA 555 STOCHASTIC PROCESSES 4 credits [3-1-0]

Stochastic Processes: Definition and examples of stochastic processes, Classifications of stochastic processes, Markov chains: Definition and examples, Transition Probability matrices, Classification of states of a Markov chain, Determination of higher order transition probabilities, Stability of a Markov chain, Graph theoretic approach, Markov chains with denumerable number of states, Reducible Markov chains, Markov Chains with continuous state spaces, Non-homogeneous Markov Chains, Markov chains in continuous time: General pure birth and death processes, Birth and death processes with absorbing states, Renewal processes: Renewal processes in continuous time, renewal equation, Renewal theorems, Residual and excess lifetime, Renewal reward processes, Regenerative renewal processes, Regenerative inventory systems, Generalization of the classical renewal theory, Stochastic processes in queuing and reliability: General concepts of queuing systems, Steady state and transient behavior, Birth and death process in queuing theory, Network of Markovian queuing systems, Reliability, Introduction to Brownian motion: Wiener processes, Differential equations for a Wiener process, Kalmogrov's equations, The first passage time distribution for a Wiener process. Recent developments.

Essential Reading :

1. J. Medhi, *Stochastic Processes*, New Age Publishers, Second Edition, Reprint 2007

Supplementary Reading :

1. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, Academic Press, 1975

MA 556 NUMBER THEORY 4 credits [3-1-0]

Basis representation: Principles of mathematical induction, The basis representation theorem, The fundamental theorem of arithmetic: Euclid's division lemma, Divisibility, The linear Diophantine equation, The fundamental theorem of arithmetic, Combinatorial and computational number theory: Fermat's little theorem, Wilson's theorem, Generating functions, The use of computers in number theory, Fundamentals of congruences: Basic properties of congruences, Residue systems, Riffling, Solving congruences: Linear congruences, The theorems of Fermat and Wilson revisited, The Chinese remainder theorem, Polynomial congruences, Arithmatic functions: Combinatorial study of $\varphi(n)$, Formulae for d(n) and $\sigma(n)$, Multiplicative arithmetic functions, The Mobius inversion formula, Primitive roots: Properties of reduced residue systems, Primitive root modulo p.

Essential Reading :

1. G. E. Andrews, *Number Theory*, Courier Dover Publications, 1994.

MA 558 SAMPLING TECHNIQUES 4 credits [3-1-0]

Basic concept of sample surveys: Census and sample surveys, Advantages and disadvantages, Probability and non-probability sampling, Sampling unit, Sampling frame, Sampling and non-sampling error, Simple random sampling and Stratified random sampling: Procedure for selecting a random sample, Estimation of population parameters, Estimation of population Proportion, Confidence limits, Estimation of sample size, Principle of stratification, Advantages of stratification, Estimation of population mean and variance, Allocation of sample size in different strata, Relative precision of stratified random sampling over simple random sampling, Estimation of gain in precision due to stratification, Systematic random sampling:

Sample selection procedure, Advantages and disadvantages, Estimation mean and its sampling variance, Comparison of simple random sampling with stratified random sampling in some specified populations, Cluster sampling: Equal cluster sampling, Estimator of mean and its variance, Relative efficiency of cluster sampling, Optimum cluster size, Cluster sampling for proportions.

Essential Reading :

1. R.K.Som, *Practical Sampling Techniques*, CRC Press, 1995

Supplementary Reading :

1. S.K. Thompson, *Sampling*, John Wiley, 1992.

MA 571 STATISTICS LABORATORY 2 credits [0-0-3]

Computational works are to be done on the following topics.

1. Calculation of A.M., G.M., H.M., median and mode
2. Calculation of quartiles, deciles and percentiles
3. Calculation of range, quartile deviation, mean deviation, standard deviation and root mean square deviations
4. Calculation of central moments from raw moments, calculation of skewness and kurtosis
5. Calculation of raw moments from central moments, calculation of moments about one point from moments about another point
6. Flitting of binomial distribution
7. Flitting of Poisson distribution
8. Flitting of normal distribution
9. Tasting of hypothesis based on normal distribution
10. Tests based on chi-square distribution
11. Tests based on t-distribution
12. Tests based on F-distribution

MA 572 LABORATORY WORKS ON SAMPLING 2 credits [0-0-3]

Computational works are to be done on the following topics.

1. Use of random number tables, generating pseudo-random numbers by a computer
2. Methods of choosing a random sample
3. Simple Random Sampling: Estimation of population mean and variance, Variance of the sample mean
4. Simple Random Sampling: Estimation of sample size
5. Stratified Random Sampling: Proportion allocation: Estimation of sample size, population mean and variance, Variance of the sample mean, Comparison of efficiency with mean per unit estimate
6. Stratified Random Sampling: Equal allocation: Estimation of sample size, population mean and variance, Variance of the sample mean, Comparison of efficiency with mean per unit estimate
7. Stratified Random Sampling: Optimum Allocation: Estimation of sample size, population mean and variance, Variance of the sample mean, Comparison of efficiency with mean per unit estimate

8. Stratified Random Sampling: Optimum-type Allocation: Estimation of sample size, population mean and variance, Variance of the sample mean, Comparison of efficiency with mean per unit estimate
9. Systematic Sampling: The method of drawing a sample, Estimation of sample size, population mean and variance, Variance of the sample mean, Comparison of efficiency with mean per unit estimate
10. Cluster Sampling: The method of drawing a cluster sample, Estimation of population mean and variance