SYLLABUS

M.A. in Mathematics

REGULAR COURSE

UNDER CBCS SYSTEM

(FROM SESSION- 2023-24 & ONWARDS)

AFFILIATED TO

UTKAL UNIVERSITY

VANI VIHAR, BHUBANESWAR

P.G. DEPARTMENT OF MATHEMATICS

GOVINDPUR (DEGREE) COLLEGE

DEVI VIHAR, GOVINDPUR, CUTTACK-754003

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SEMESTER-I

Paper	Course Title	Category	Marks	Credits
MTC101	Real Analysis	Core	100	6
MTC102	Complex Analysis	Core	100	6
MTC103	Topology	Core	100	6
MTC104	Abstract Algebra	Core	100	6
MTC105	Data Processing and Numerical Computing Lab	Core	100	6

TOTAL-30

SEMESTER-II

Paper	Course Title	Category	Marks	Credits
MTC201	Functional Analysis	Core	100	6
MTC202	Differential Equation	Core	100	6
MTC203	Linear Algebra	Core	100	6
MTC204	Numerical Optimization	Core	100	6
MTC205	Data base and C++ Lab	Core	100	6

TOTAL-30

SEMESTER-III

Paper	Course Title	Category	Marks	Credits
MTCE301	Numerical Analysis-I	Core Elective	100	6
MTCE302	Number Theory and Cryptography-I	Core Elective	100	6
MTAE303	Statistical Methods	Allied Elective	100	6
MTFE304	Discrete Mathematics	Free Elective	100	6
MTAE305	Differential Geometry/Computational Fluid Dynamics-I/ Theory of Computation-I	Allied Elective	100	6

TOTAL-30

N:B -The department also offers the following core elective papers:
Theory of Relativity-I, Sequence Spaces-I, Numerical solution of Partial Differential Equations-I, Operator Theory-I, Computational Finance-I, Distribution Theory and Sobolev Spaces-I, Fluid Dynamics-I, Beizer Techniques for Computer Aided Geometric Designs-I, Analytic Number Theory-I, Fourier Analysis-I.

The department also offers the following Allied elective papers:
Fractal Geometry-I, Design and Analysis of Algorithm -I, Wavelet Analysis-I

SEMESTER-IV

Paper	Course Title	Category	Marks	Credits
MTC401	Numerical Analysis-II	Core Elective	100	6
MTC402	Number Theory and Cryptography-II	Core Elective	100	6
MTAE403	Advanced Analysis/ Computational Fluid Dynamics-II/ Theory of Computation-II	Allied Elective	100	6
MTC404	Project	Core	100	6
MTC405	Comprehensive Viva Voce	Core	100	6

TOTAL-30

N.B- The deptartment also offers the following core elective Papers.

Theory of Relativity-II, Sequence Spaces-II, Numerical solution of Partial Differential Equations-II, Operator Theory-II, Computational Finance-II, Distribution Theory and Sobolev Spaces-II, Fluid Dynamics-II, Beizer Techniques for Computer Aided Geometric Designs-II, Analytic Number Theory-II, Fourier Analysis-II.

The department also offers the following Allied Elective papers:

Fractal Geometry-II, Design and Analysis of Algorithm-II, Wavelet Analysis-II

DETAILED SYLLABUS

SEMESTER-I

MTC101 (REAL ANALYSIS)

(Marks: 100)

Unit-1: Metric space, Sequences and series of functions, Uniform convergence, Continuity, Integrability, Differentiability, Equicontinous functions, Weirstrass approximation theorem.

Unit-II.: Measures and integration, Open sets, cantor like sets, Lebesgue outer measure, Measurable sets, regularity, Measurable functions, Borel and Lebesgue measurability.

Unit-III. Integration of non-negative functions, the general integral, Integration of series, Riemann and Lebesgue integrals.

Unit-IV :The four derivatives, Functions of bounded variation, Lebesgue differentiation theorem, Differentiation and integration, the Lebesgue set.

Unit-V :The Lp spaces, Convex functions, Jensen's inequality. The inequalities of Holder and Minkowski,Completeness of Lp(μ), convergence in measure, Almost uniform convergence, Convergence diagrams,Counter examples.

Books Recommended

1. W.Rudin : Principles of Mathematical Analysis, Chapters 2, 7.
2. G.De. Barra : Measure Theory and Integration (Willey Eastern Ltd.). Chapters 1(1.6 & 1.7), 2(excluding 2.6), 3,4(excluding 4.2), 6, 7.

MTC102 (COMPLEX ANALYSIS)

(Marks: 100)

Unit-I :Elementary properties of analytic functions, Power series, analytic functions, Cauchy-Riemann equations, Branches of many valued functions.

Unit-II :Analytic functions as mappings, Mobius transformations, Complex integration.

Unit-III :Power series representation of analytic functions, Zeros of an analytic functions.

Unit-IV :Index of a closed curve, Cauchy's theorem and integral formula, counting zeros, Open mapping theorem, Goursat's theorem.

Unit-V :Singularities and classifications, Laurent series, Residues evaluation of integrals, Argument principle,Rouche's theorem.

Book Recommended

J.B.Conway: Functions of one Complex variable, Springer-Verlag, International Student-Edition, Narosa Publishing House, 1980. Chapters : III, IV(excluding art.6), V.

MTC103 (TOPOLOGY)
(Marks: 100)

Unit-1 :Countable and uncountable sets, Infinite sets and the Axiom of choice, Well-ordered sets. Topological spaces, Basis and subbasis for a topology, The order, Product and subspace topology, Closed sets and limit points.

Unit-II :Continuous functions and homeomorphism, Metric topology, Connected spaces, Connected subspaces of the real line, Components and local connectedness.

Unit-III :Compact spaces, Basic properties of compactness, Compactness and finite intersection property, Compact subspaces of the real line, Compactness in metric spaces, Limit point compactness, Sequential compactness and their equivalence in matric spaces, Local compactness and one point compactification.

Unit-IV :First and second countable spaces, Lindelof space, Seperable spaces, Seperable axims, Hausdorff Regular and normal spaces.

Unit-V :The Urysohn lemma, Completely regular spaces, the Urysohn metrization theorem, Imbedding theorem, Tietu extension theorem, Tychonoff theorem, Stone-Cech campatification.

Book Recommended

J.R.Munkres - Topology, 2nd Edition, Pearson Education, 2000.

Chapters : 1(7,9,10), 2 (excluding section 22), 3, 4(excluding section 36), 5.

Books for Reference

1. K.D.Joshi, Introduction to General Topology, Wiley Eastern Ltd., 1983.
2. W.J.Pervin, Foundation of General Topology, Acadmic Press, 1964.
3. S.Nanda and S.Nanda, General Topology, Macmillan India.

MTC104 (Abstract Algebra)
(Marks-100)

UNIT-I

Groups, Subgroups, Cyclic groups, Normal Subgroups, Quotient groups, Homomorphism, Types of homomorphisms,

UNIT-II

Permutation groups, symmetric groups, cycles and alternating groups, dihedral groups; Isomorphism theorems, Automorphisms, Inner automorphisms, groups of automorphisms and inner automorphisms and their relation with centre of a group

UNIT-III

Group action on a set, Conjugacy, Normalizers and Centralizers, Class equation of a finite group and its applications, Direct products, Finitely generated abelian groups, Sylow's groups and subgroups, Sylow's theorems for a finite group, Applications and examples of p-Sylow subgroups, Solvable groups, Simple groups, Applications and examples of solvable and simple groups.

UNIT-IV

Rings, Some special classes of rings (Integral domain, division ring, field), ideals, quotient rings, ring homomorphisms, isomorphism theorems, prime ideals, maximal ideals, Chinese remainder theorem, Field of fractions, Euclidean Domains, Principal Ideal Domains, Unique Factorization Domains, Polynomial rings, Gauss lemma, irreducibility criteria

UNIT-V

Modules, submodules, quotients modules, examples, module homomorphisms, isomorphism theorems

Book Recommended

Text Book:

1. D. S. Dummit, R. M. Foote, "Abstract Algebra", Wiley-India edition, 2013.

References:

1. I. N. Herstein, "Topics in Algebra", Wiley-India edition, 2013.
2. M. Artin, "Algebra", Prentice-Hall of India, 2007.
3. J. B. Fraleigh-A first Course in Algebra, Pearson, 7th Ed., 2013.
4. J. Gallian - Contemporary Abstract algebra, Brooks/Cole Pub Co; 8 edition, 2012.

MTC105 (DATA PROCESSING & NUMERICAL COMPUTING LAB.)
(Marks: 100)

Mid Term- Written test on Part-A(Introduction to Computers): 30 Marks
End Term- Record: 8 Marks, Viva: 12 Marks, Expt: 50 Marks(Part-B: 20 Marks ,Part-C: 30 Marks.)

Part-A: Introduction to Computers -
Application of Information Technology, Computer system and CPU, Input & output, secondary storage, System and application software(Windows & Linux), Communications & multimedia.
Part-B: Use of scientific software package (Maple/ Matlab/ Scilab/ Mathematica).
Part-C: Numerical Computation using C.

(1) Basic elements of C, Control structures, Loops, I/O concepts, Arrays, Functions.
(2) Implementation of the following by using C.
(i) Solution of the equation f(x) = 0 by (a) Fixed point iteration method (b) Newton-Raphson method.
(ii) Solving a tridiagonal system of equations. (iii) Solving a system of linear equations by (a) Matrix
Factorisation Method. (b) Gauss-Seidel Method.
(iv) Finding the inverse of a matrix.
(v) Finding least square polynomial fit to a given data.
(vi) Approximating a definite integral by (a) Newton-Cotes Rules. (b) Gauss-Legender Rules.
(vii) Solution of an initial value problem by Runge-Kutta Method of order 4.
(viii) Determination of eigen values of a matrix by Power method/QR method.

Books Recommended

1. J.H. Mathews: Numerical Methods for Mathematics, Science and Engineering (2nd edition), Prentice-Hall of India Pvt. Ltd., New Delhi.
2. B.W. Kernighan and D.M. Ritchie: Programming in ANSI C, Prentice-Hall of India Pvt. Ltd., New Delhi.

SEMESTER-II

MTC201 (FUNCTIONAL ANALYSIS)
(Marks: 100)

Unit-1 : Normed linear spaces, Continuity of linear maps, Equivalent norms, Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces.
Unit-II : Banach spaces and examples, Quotient spaces, Uniform boundedness theorem and some of its consequences, Open mapping theorem and Closed graph theorems, Bounded inverse theorem.
Unit-III : Spectrum of a bounded linear operator, Duals and transpose, Duals of Lp([a; b]) and C([a;b]).
Unit-IV : Weak and weak* convergence, Reflexive spaces, Weak sequential compactness.
Unit-V : Inner product spaces, Hilbert spaces and examples, Orthonormal sets, Bessel`s inequality, Complete orthonormal sets and Parseval`s identity, Approximation and Optimization, Projection theorem, Riesz-representation theorem.

Book Recommended

B.V. Limaye: Functional Analysis, New Age International Ltd(2nd Edn.),1995.
Chapters:II(Art.5,6,7(except7.12),8),III(Art.9(9.19.3),10,11,12),IV(Art.13,14(14.6,14.7),15,16),VI(Art. 21,22, 23,24).

MTC202. (DIFFERENTIAL EQUATION)
(Marks: 100)

Unit-1 : Existence and Uniqueness of Solutions : Lipschitz condition, Gronwall. inequality, Successive approximations, Picard's theorem, Continuation and dependence on initial conditions, Existence of solutions in the large, Existence and uniqueness of solutions of systems, Fixed point method .Systems of Linear Differential Equations : nth order equation as a first order system, Systems of first order equations, Existence and uniqueness theorem, fundamental matrix, Non-homogeneous linear systems, Linear systems with constant coefficients.
Unit-II : Non-linear Differential Equations : Existence theorem, Extremal solutions, Upper and Lower solutions, Monotone Iterative method and method of quasi linearization. Stability of Linear and Nonlinear Systems : Critical points, Systems of equations with constant coefficients, Linear equations with constant coefficients, Lyapunov stability.
Unit-III : Boundary value problems for ordinary differential equations : Sturm-Liouville problem, Eigen value and eigen functions, Expansion in eigen functions, Green's function, Picard's theorem for boundary value problems. Series solution of Legendre and Bessel equations.
Unit-IV : The Laplaces Equation : Boundary value problem for Laplace's equation, fundamental solution, Integral representation and mean value formula for harmonic functions, Green's function for Laplace's equation, Solution of the dirichlet problem for a ball, solution by seperation of variables, solution of Laplace's equation for a disc.

Unit-V : The wave equation and its solution by the method of separation of variables, D'Alembert's solution of the wave equation, Solution of wave equation by fourier transform method.

Books Recommended

1. S.D.Deo, V.Lakshmikantham and V.Raghavendra: Text Book of Ordinary Differential Equations, 2nd Eidtion, TMH. Chapters : 4(4.1-4.7), 5, 6(6.1-6.5), 7(7.5), 9(9.1-9.5).
2. J.Sinha Roy and S.Padhy: A Course on Ordinary and Partial Differential Equations, Kalyani Publishers: Chapters: 10, 15, 16 and 17

MTC203 (LINEAR ALGEBRA)
(Marks: 100)

UNIT-I

Vector Spaces, Subspaces, Linear independence, bases, Dimension, Projection, Quotient spaces, Isomorphism of vector spaces, Algebra of matrices, Rank and Inverse of matrix, The Algebra of Linear transformation, Kernel, range, matrix representation of a linear transformation, Change of bases, Dual spaces.

UNIT-II

System of Linear equations, Characteristic roots and Vectors, eigen values, eigen vectors, Cayley-Hamilltorn theorem, Canonical Forms: Diagonal forms, triangular forms, Jordan form, Rational Canonical form, Invariants of nilpotent transformation, Primary decomposition theorem Quadratic form, Inner Product spaces.

UNIT-III

Algebric extensions of fields : Irreducible polynomials and Einstein criterion, Adjunction of roots, Algebraic extensions. Algebraically closed fields, Normal separable extensions : Splitting fields, Normal extensions.

UNIT-IV

Normal separable extensions : Multiple roots, Finite fields, Separable extensions. Galois Theory :Automorphisim groups and fixed fields, Fundamental theorem of Galois theory.

UNIT-V

Application of Galois theory to classical problems : Roots of unity and Cyclotomic polynomials, Cyclic extensions, Polynomials solvable by radicals, Symmetric functions, Ruler and compass constructions.

Books Recommended

1. I. N. Herstein, "Topics in Algebra", Wiley-India edition, 2013.
2. M. Artin, "Algebra", Prentice-Hall of India, 2007.
3. J. Rotman, "Galois Theory", Universitext, Springer-Verlag, 1998.
3. I.S. Luthar and I.B.S Passi: Algebra (Vol-3-Modules), Narosa Publishing House.

MTC204 (NUMERICAL OPTIMIZATION)

(Marks-100)

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

Unit-II : Gradient Based Optimization Methods(I): Calculus on Rn, Method of Steepest Descend, Conjugate Gradient Method, The Generalized reduced Gradient Method, Gradient Projection Method.

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

Unit-IV : Linear Programming: Convex Analysis, Simplex Method, Two Phase Simplex Method, Duality Theory, Dual Simplex Method.

Unit-V : Constrained Optimization Methods: Lagrange Multipliers, Kuhn-Tucker Conditions, Convex Optimization, Penality function techniques, method of Multiplier, Linearly Constrained problems-Cutting plane Method.

N.B.-The mid-semester examinations (Marks:30) will be a programming assignment followed by a viva-voce test.

Books Recommended

1. M.C. Joshi and K.M. Moudgalya-Optimization: Theory and Practice, Narosa Publishing House, 2004.
2. J.A. Snyman Practical Mathematical Optimization, Springer Sciences, 2005.

MTC205 (DATABASE & C++ LAB.)

Marks: 100 (Mid Term- 30, End Term- Viva:12, Record:8, Experiment:50)

Part-A - Use of a RDBMS package(Marks:10)

Part-B - Implementation of algorithms and program studied in units 2,3 and 4 of paper IX.(Marks:40)

SEMESTER-III

MTCE301 (NUMERICAL ANALYSIS-I)

(Marks-100)

Unit-I : Solution of equations in one and two variables: Fixed point iteration method, Accelerate on of convergence, Zeros of polynomials and Muller`s method, fixed points for functions of several variables, Newton's method.

Unit-II : Interpolation : Hermite interpolation, Cubic spline interpolation, parametric curves, Hermite, Bazier and B spline curves.

Unit-III : Least square approximation, Discrete L.S.approximation, Orthogonal polynomials, Chebyshev poly-nomials and economization, rational approximation.

Unit-IV : Numerical integration : Elements, Composite integration, Romberg integration, Gauss quadrature.

Unit-V : Approximation of multiple integrals : Product rules, Rules exact for monomials, Radon formula for approximation of integrals in two dimensions.

Books Recommended

1. Numerical Analysis (7th Edition) by R.L.Burden and J.D.Faires, (Books/Cole, Thomson learning)
2. Methods of Numerical Integration (4th Edition) by P.J.Davis and Rabinowitz (AP).

MTCE302 (NUMBER THEORY and CRYPTOGRAPHY-I)
(Marks-100)

Unit-I : Divisibility and primes, Modular arithmetic. Time estimates for doing arithmetic.
Unit-II : Cryptography : Classical cryptosystem and their vulnerability public key cryptography, RSA scheme.
Unit-III : Primality testing and factoring, Primitive roots, EI gamal system. Signature scheme,Quadratic
congruences and applications.
Unit-IV : Continued fractions, Factoring methods, Diophantine approximations.
Unit-V : Diophantine equations, Arithmetical functions and Dirichlet series, Quadratic reciprocity law.

Book Recommended

1. Ramanujachary Kumanduri and Christina Romero : Number Theory with Computer Applications, Prentice Hall, New Jersy, 1998.
2. Neal Koblitz : A course of Number Theory and Cryptography, Second Edition, Springer Verlag, New York, 1987.

MTAE303 (STATISTICAL METHODS)

(Marks-100)

Unit-I: Review of descriptive statistics-detailed study on the interpretation, analysis and measurements of various numerical characteristics of a frequency distribution.

Unit-II: Concepts of univariate and bivariate distributions, curve fittings, regression and correlation analysis, rank correlation, correlation ratio, intra-class correlation.

Unit-III: Concept of multivariate distribution, multiple regression analysis, partial and multiple correlations and their properties, Random sampling, sampling distribution and standard error, standard errors of moments and functions of moments.

Unit-IV: Exact sampling distributions-t, F and chi-square distributions, sampling from bivariate normal distribution, distribution of sample correlation coefficient (null case) and regression coefficient, tests based on t, F and chi-square distributions.

Unit-V: Theory of attributes: classes, its order, class frequencies, consistency of data, independence and association of attributes, coefficients of association and colligation.

Book Recommended

1. Mukhopadhyaya, P., Mathematical statistics, New central Book Agency, Calcutta.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B., An outline of statistical theory, vol II (4th Edition), World press
3. Kale, B. K., A first course in parametric inference, Narosa publishing house
4. Kingman, J.F.C. and Taylor, S. J., Introduction to measure and probability, Cambridge university press

MTFE304 (DISCRETE MATHEMATICS)
(Marks-100)

Unit-1 :Fundamentals of logic, Logical inferences, Methods of proof of logical inferences, First order logic, Inference for quantified propositions, Order relations, Posets, Lattices, Enumerations, Hasse diagrams, Path and closure, Discrete graphs, and adjacency matrices.

Unit-II :Boolean algebra, Boolean functions, Switching mechanisms, Cannonical forms, Minterms, Minimization of Boolean functions.

Unit-III :Graphs: Basic concepts, Isomorphic graphs, Sub-graphs, Trees and properties, Spanning trees, Directed trees and Binary trees.

Unit-IV :Planar graphs, Euler formula, Multi graphs and Euler Circuits, Hamiltonian graphs, Chromatic numbers.

Unit-V :Network flows: Graphs as models of flow of commodities, flows, Maximal flows, and minimal cuts, Max-flow Min-cut theorem.

Book Recommended

1. J.L. Mott, A. Kendel and T.P. Baker: Discrete mathematics for Computer Scientists and Mathematicians,
Chapters-I(1.5-1.9),IV(4.4-4.7),V(5.1-5.11),VI(6.1-6.5),VII(7.1-7.4).

MTAE305 (DIFFERENTIAL GEOMETRY)
(Marks-100)

Unit-I : Preliminary Comments on Rn, Topological Manifolds, Differentiability for Functions of Several Variables, Differentiability of Mappings and Jacobians, The Space of Tangent Vectors at a point of Rn,
Another definition of Ta(Rn), Vector Fields on Open subsets of Rn, The Inverse Function Theorem.

Unit-II : Definition of a Differential Manifold, Example of Differential Manifolds, Differentiable Functions and Mappings, The Tangent Space at a point of a Manifold, Vector Fields, Tangent Covectors, Covectors on Manifolds, Covector Fields and Mappings, Bilinear Forms, The Riemannian Metric, Riemannian Manifolds as Metric Spaces, Tensors on a Vector Space.

Unit-III : Lie Groups, The Action of a Lie Group on a Manifold, The Action of a Discrete Group on a Manifold, One parameter and local one parameter Groups acting on a Manifold, The Lie Algebra of Vector Fields on a Manifold.

Unit-IV : Tensor Fields, mapping and Covariant Tensors, Symmetrising and Alternating Transformations, Multiplication of Tensors on a Vector Space, Multiplication of Tensor Fields,

Exterior Multiplication of Alternating Tensors, Exterior Algebra on Manifolds, Exterior Differentiation.

Unit-V : Differentiation of Vector Fields along curves in Rn, The Geometry of Space Curves, Differentiation of Vector Fields on Submanifolds of Rn, Formulas for Covariant Derivatives, Differentiation on Riemannian Manifolds, The Curvature Tensor, The Riemannian Connection and Exterior Differential Forms, Basic Properties of Riemannian Curvature Tensor, The Curvature Forms and the equations of Structure.

Book Recommended

William Boothby: An Introduction to Differentiable manifolds and Riemannian Geometry, Academic Press, New York.

OR

MTAE305 (COMPUTATIONAL FLUID DYNAMICS-I)

(Marks-100)

Unit-1: Basic Concepts, Continuum Hypothesis, Viscosity, Strain Analysis, Stress Analysis, Relation between Stress and Rate of Strain, Thermal Conductivity, Law of Heat Conduction.

Unit-2: Equation of Continuity in Vector Form and in Various Coordinate Systems, Boundary Conditions, Navier-Stokes Equations, Energy Equations, Vorticity and Circulation in Viscous Flow.

Unit-3: Dynamical Similarity by Inspection Analysis, Physical Importance of Non-Dimensional Parameters, Important Non-Dimensional Coefficients in the Dynamics of Viscous Fluids. Exact Solution of Navier-Stokes Equations (Flow between Parallel Plates, Circular Pipes -Velocity and Temperature Distribution).

Unit-4: Finite Difference Methods for Parabolic Equation in one Space Variable (Explicit Method and Its Convergence, Fourier Analysis of the Error, Implicit and Weighted Average Methods and Their Convergence). Finite Difference Method for Hyperbolic Equations in one Space Dimension, Characteristics, The CFL Condition, Furior Error Analysis of The Upwind Scheme, The Lax-Wendroff Shceme and its Application to Conservation Laws.

Unit-5: Consistency, Convergence and Stability of Finite Difference Methods, Introduction to Finite Volume Method.

Text Books Recommended:

1. J.L.Bansal - Viscous Fluid Dynamics, Oxford University Press.
2. K.W, Morton & D.F.Mayers - Numerical Solution of Partial Differential Equations, Second Edition, 2005, Cambridge University Press.

Reference

1.P.Wesseling - Principles of Computational Fluid Dynamics, Springer Verlag, 2000.

2.T.Petrila and D.Trif - Basics of fluid Mechanics and Introduction to Computational Fluid Mechanics, Springer Verlag, 2005.

1. Z.U.A.Warsi - Fluid Dynamics - Theoretical and Computational Approach, CRC Press.
2. M.D.Raisinghania - Fluid Dynamics, S.Chand and Company.
3.

OR

MTAE305 (THEORY OF COMPUTATION-I)

(Marks-100)

Unit-I : Introduction to Automata & Computability theory, Mathematical preliminaries.
Unit-II : Finite automata and Non-determinism.
Unit-III : Regular expressions, Pumping lemma for regular languages.
Unit-IV : Context-Free Grammars and Pumping lemma for Context free languages.
Unit-V : Pushdown automata.

Books Recommended

1. Michael Sipser: Introduction to the Theory of Computation, PWS Publishing Company, 1997,First Reprint 2001 by thomson Asia Pvt. Ltd.
2. J.E. Hopcroft, Rajeev Motwani, J.D. Ullman: Introduction to Automata Theory, Languages & Computation,Pearson Education, Inc. 2001.
3. Peter Linz: An Introduction to Formal Languages & Automata, Narosa Publishing House, 1998.

The Dept. also offers the following Core Elective Papers

Theory of Relativity-I
(Marks-100)

Unit-I : Foundations of Special Relativity.
Unit-II : Electromagnetic field.
Unit-III : Accelerated observers and incompatibility with special relativity.
Unit-IV : Geodesic deviation and spacetime curvature.
Unit-V : Riemannian Geometry: Metric as foundation of all.

Book Recommended

Gravitation by C.W. Misner, K.S. Thorne, J.A. Wheeler(W.H. Freeman).
Chapters:2(Unit-1),3(Unit-2),6.1 & 7(Unit-3),11(Unit-4),13(Unit-5).

Sequences Spaces-I

(Marks-100)

Unit-I : Matrix and linear transformations.
Unit-II : Algebra of matrices, Summability, Tauberian theorems.
Unit-III : Limitation methods, Example of Limitation method.
Unit-IV : Norlund and Riesz means, Consistence of matrix methods.
Unit-V : The Norlund mean, Cesaro and Holder matrices, Hausdroff methods.

Books Recommended

1. I.J. Maddox: Elements of Functional Analysis, Cambridge Univ. Press, 1970. Chapter: 7 only.
2. G.M. Peterson: Regular Matrix Transformation, McGraw Hill. Chapter: 2(2.1-2.3).

Numerical Solution of Partial Differential Equations-I
(Marks-100)

Unit-I : Introduction to finite difierences (finite difference approximation of partial differential equations (PDE), derivation of difference equations), convergence and consistency of difference schemes for Intial-Value problems and initial-boundary value problems.
Unit-II : Stability of difference schemes for initial-value-problems and initial-boundary value problems, The lax theory, Implicit schemes, Analysis of stability, Finite fourier series and stability, Computational considerations.
Unit-III : Parabolic Equations : Difference schemes for two dimensional parabolic equation, Convergence, Consistency and Stability. Alternating direction implicit schemes (Peaceman-Rachford scheme, Stability consistency and implementation; douglas-Rachford scheme and its stability), Difference schems in polar cordinates..
Unit-IV : Hyperbolic equations : Initial-value problems, Explict & implicit difference schemes for IVP(one sided, centred, lax-windroff and crank-Nicolson schems), Initial-Boundary-value problem and their difference schemes, Two dimensional hyperbolic equations and difference schemes, CFL conditions, Computational considerations.
Unit-V : Rieview of classical iterative methods (Gauss-Jacobi, Gause-Seidel, SOR, Gradient methods, Conjugate gradient and the minimal residual method, Pre-conditioning, Multigrid methods, Convergence of multigrid methods, Computation of starting values using multigrid method, non-linear multigrid method.

Books Recommended

1. J.W.Thomas: Numerical Partial Differential Equations (Fintie Difference Methods), Springer Verlag, 1995. Chapters : 1,2,3,4,5.
2. D.Braess: Finite Elements, Cambridge University Press, 1997. Chapters : IV, V.

Books References

1. K.W.Morton and D.F.Mayers: Numerical Solution of Partial Differential Equations, Cambridge University Press, 1994.
2. J.C.Strikwerda: Finite Difference Scheemes and Partial Differential Equations, Wadsworth and Books, 1889.
3. W.Hackbusoh: Interative Solution of Large Sparse System of Equations, Springer-Verlag, 1994.

Operator Theory-I
(Marks-100)

Unit-I : Introduction, Complex homomorphisms.
Unit-II : Basic properties of spectrum, Symbolic calculus.
Unit-III : Differentiation, the groups of invertible elements, Commutative Banach algebra.
Unit-IV : Ideals and homomorphisms, Gelfand transform.
Unit-V : Involutions, Application to non-commutive algebra, Positive functionals.

Book Recommended
W.Rudin : Functional Analysis (TMH), Chapter: 10, 11.

Computational Finance-I
(Marks-100)

Unit-I : Basic concepts of financial derivatives (forwards and futures, stock options, speculation, hedging), Putcall parity, Principle of non-arbitrage pricing, Black-Scholes Option Pricing formula and the 'Greeks', Implied volatility Hedging strategies, American option pricing modele.
Unit-II : Stochastic processes, Markov processes, Random walks, Arithmetic Brownian motion, Geometric Brawnian motion, Martingles.
Unit-III : Stochastic integrals, Ito integral, Ito's lemma, Mean-reverting processes, Derivation of Black-Scholes differential equation, Kolmogorov equations.
Unit-IV : Finite difference methods for partical differential equations - finite difference approximation to
derivatives, Local truncation error, Convergence, Consistency and stability, Explicit implicit and ADI schemes for parabolic equations, Finite difference method for elliplic equations, Solution of sparse system of linear equations.
Unit-V : Numerical schemes for pricing options. Binomial pricing models and extensions, Explicit and implicit finite difference methods for Europian and American options, Monte Carlo simulation.
Note: The midterm test shall be on computer implementation of algorithms and methods studied.

Book Recommended
1. J.Bax and G.Chacko-Financial Derivatives : Pricing, Applications and Mathematics-Cambridge Univ. Press, 2004.
2. Steven Shreve-Stochastic Calculus and Finance, Vol.I and II-Springer Verlag.
3. P.Wilmott-Paul Willmott on Quanktative Finance-John Wiley, 2000.
4. Y.K.Kwok-Mathematical Models of Financial Derivatives-Springer Verlag.
5. G.Evans, J.Blackledge and P.Yardly-Numerical Methods for Partial Differential Equations-Springer Verlag, 2000.
6. Y.D.Lyuń-Financial Engineering and Computation : Principles, Mathematics and Algorithms-Cambridge Univ. Press, 2002.
7. J.C.Hull-Options, Futures and other Derivatives-Prentice Hall of India, 2003.

Distribution Theory and Sobolev Spaces-I

(Marks-100)

Unit-I : Test functions and distributions, Operation with distributions.
Unit-II : Supprots and singular supports of distributions, Convolution of functions and distributions.
Unit-III : Fundamental solutions, Fourier transform, Schwartz space, Fourier inversion formula, Tempered distributions.
Unit-IV : Definitions and basic properties of Sobolev spaces.
Unit-V : Approximation of elements of a Sobolev space by smooth functions.

Book Recommended

S.Kesavan : Topics in Functional analysis and Application, Willey Eastern Ltd. Chapter: 1, 2(2.1-2.2).

Fluid Dyanamics-I
(Marks-100)

Unit-I : Basic concepts, Continum hypothesis, Stress in a fluid at rest and in motion, Relation between stress and rate of strain components, Thermal conductivity, Law of heat conduction.
Unit-II : Methods of describing fluid motion, Velocity and acceleration of a fluid particle, Equation of continuity, Boundary conditions, Stream lines and Path lines, Velocity potential.
Unit-III : Navier-Stokes equations, Energy equations, Vorticity and circulation in viscous flow, Bernoulli's equation.
Unit-IV : Dimensional similarity and analysis, Reynold's law,PAI- theorem, Physical importance of non-dimensional parameters, important non-dimensional parameters, Method of finding out π product,
important non-dimensional coefficients in the Dynamics of viscous fluids.
Unit-V : Exact solution of Navier-Stokes equations: Flow between parallel plates and flSow in circular pipes(Velocity and temperature distribution).

Books Recommended

1. J.L. Bansal- Viscous Fluid Dyanamics, IBH Publication. Chapters: 1, 2, 3(3.1-3.9), 4,(4.1-4.4).
2. M.D. Raisinghania- Fluid Dynamics, S. Chand and co., Chapters: 2(2.1-2.11, 2.17-2.26), 4(4.1-4.3).

Bezier techniques for Computer Aided Geometric Design-I
(Marks-100)

Theory - Marks 60

Unit-I : Affine maps, Barycentric coordinates, Linear and piecewise linear interpolation, Hat functions,
C1functions. Curves and surfaces in Euclidean spaces, Parametric curves and arc length. Frenet frame,
Osculating circle.
Unit-II : Bezier curves, The de Casteljau algorithm, Properties of Bezier curves, the Blossom, Bernstein forms of Bezier curves, Subdivision, Blossom and polar.
Unit-III : Degree elevation, Variation diminishing property, Degree reduction, Non-parametric curves, Cross plots, Different interpolation by polynomial curves, Aitken's algorithm, Lagrange interpolation, Cubic and quintic Hermite interpolation.

Unit-IV : Spline curve in Bezier form, Smoothness conditions, C1 and C2 continuity conditions, C1-quadratic and C2-cubic B-spline curves, Pamamentrization, C1 piecewise cubic interpolation.
Unit-V : cubic spline interpolation, Hermite form, end conditions and curvature plots, Minimum property.

Practical - Marks-40

1. Constructing Bezier curves using de Casteljau algorithm and Bernstein form.
2. Repeated degree elevation and convergence of control polygons to the Bezier curve.
3. Numerical verification of Weierstrass approximation theorem.
4. To construct cubic and quintic Hermite interpolants.
5. To construct C1 and C2 spline curves.
6. To construct the C1-piecewise cubic interpolant for prescribed data.
7. To draw a curve close to given figure by designing first an appropriate control polygon and then the spline.curve of desired shape.
8. To construct the C1-piecewise cubic spline interpolant for prescribed data.

Book Recommended
G.Frain: Curves and Surfaces for Computer Aided Geometric Design, Academic Press, Third Edition,1993.

Analytic Number Theory-I
(Marks-100)

Unit-I :The unique factorization theorem, congruences.
Unit-II :Rational approximation of irrationals & Hurwitz's theorem, Quadratic residues & the representation of a number as a sum of four squares.
Unit-III :Arithmetical functions & Lattice points.
Unit-IV :Chebyshev theorem on the distribution of prime numbers.
Unit-V :Weyl's theorems on uniform distribution & Kronecker's theorem.
Book Recommended
K. Chandrasekharan : Introduction to Analytic Number Theory, Springer-Verlag, 1968.
Chapters: 1,2,3,4,6,7,8.

(Fourier Analysis-I)
(Marks-100)

Unit-I : Trigonmetric series and fourier series.
Unit-II : Group structure and fourier series.
Unit-III : Convolution of functions.
Unit-IV : Homomorphism of convolutions.
Unit-V : The dirchlet and fejer kernels, Cesaro summability.
Book Recommended
R.E.Edward, Fourier Series: A Modern Introduction, Holt, Rinehart 7 winsten.
Chapters: 1,2,3,4,5.

Allied Electives

Fractals Geometry-I
(Marks-100)

Unit-I : Fractals examples : The triadic cantor dust, the sierpinski gasket, A space of strings.
Unit-II : Fractal examples : Ture graphics, Sets defined recursively, Number system.
Unit-III : Metric topology : Uniform convergence, The Hausdorff metric, Matrices for strings.
Unit-IV : Topological dimension : Small and large inductive dimension.
Unit-V : Two dimensional Euclidean space, other topological dimensions.

Book Recommended

G.A.Edger : Measure, Topology, Fractal Geometry, Springer-Verlag.
Chapter: 1, 2(2.3-2.5), 3.

Design and Analysis of Algorithms-I
(Marks-100)

(Correctness proof of algorithms along with their design and performance analysis are to be studied)

Unit-I : Design and analyis Techniques(i) : Introduction growth of function, Recurrence, Divide and Conquer
(Heap sort, Quick sort), Lower bounds of sorting, counting sort.
Unit-II : Design and Analysis Techniques(II) : randomization (Randomized quick sort, Dynamic programming (Logest common subsequence), Greedy Method (Single source shortest path algorithms, Matroids, Task Scheduling).
Unit-III : Analysis of Data Strucutre : Hash tables, Balanced Trees, Binomial Heap, Amortised analysis,Disjoint sets.
Unit-IV : Number-Theoretic Algorithms : Moduler-Exponentiation, the RSA Public-key Crypto system, Primality testing, Integer factorization.
Unit-V : Geometric Algorithms : Determining line segment intersection, Finding Convex Hull, finding closestpair of points, Vornoi Diagram..

Note : Midterm test shall comprise of (i) a written examination (weightage 15%) and (ii) a test on computer implementation of some algorithms assigned by the teacher (weightage 15%)

Book Recommended

1. T.H.Corman, C.E.Leiserson and R.L.Rivest, Introduction to Algorithms, Prentice Hall of India, 2001.
2. Aho, Hoperoft and Ullman, The Design and Analysis of Computer Algorithms, AWL, 1998.
3. M.A.Weiss, Data Structure and Algorithm Analysis in C-Addison, Wesley Longmans, 1999.
4. M.de.Btrg, M.Vankreveld, M.Overmars and O.Schwrekopf, Computational geometry - Algorithms and Applications, Springer Verlag, 2000.

Wavelet Analysis-I
(Marks-100)

Unit-I : Bounded functions, Square Integrable L2 Functions, Differentiable Cn Functions, Numerical Convergence, Pointwise Convergence, Uniform Convergence, Mean Convergence, Mean square Convergence,
Interchange of Limits and Integrals, Trigonometric Series, Approximate Identities, Generalized Fourier
Series.

Unit-II : The Fourier Transform-:Motivation and Definition, Basic Properties of the Fourier Transform, Fourier Inversion, Convolution, Plancherel's Formula, The Fourier Transform for L2 Functions, Smoothness versus Decay, Dilation, Translation and Modulation, Bandlimited Functions and the Sampling formula, Signals, Systems, Periodic Signals and the Discrete Fourier transform, The Fast Fourier transform, L2 Fourier series.

Unit-III : Dyadic Step Functions, The Haar System, Haar Bases on [0; 1]; Comparison of Haar Series with Fourier Series, Haar Bases on R; The Discrete Haar Transform(DHT), The DHT in two Dimensions, Image Analysis with DHT.

Unit-IV : Orthonormal Systems of Translates, Multiresolution Analysis- Definition and Some Basic Properties of MRAs, Examples of Multiresolution Analysis, Construction and Examples of Orthonormal Wavelet Bases, Necessary Properties of the Scaling Function, General Spline Wavelets.

Unit-V : Motivation-From MRA to a Discrete Transform, The Quadrature Mirror Filter Conditions, The
Discrete Wavelet Transform(DWT), Scaling Functions from Scaling Sequences.

Book Recommended

An introduction to Wavelet Analysis, David F. Walnut, Birkhauser, 2002.
Ch-I, II, III(7.1-8.4).

Data Science-I
(Marks-100)

UNIT-I

Linear Methods for Regression and Classification: Overview of supervised learning, Linear regression models and least squares, Multiple regression, Subset selection , Ridge regression, least angle regression andLasso , Linear Discriminant Analysis , Logistic regression .

UNIT-II

Model Assesment and Selection :Bias, Variance,and model complexity, Bias-variance trade off, Optimisim of the training error rate, Esimate of In-sample prediction error, Effective number of parameters, Bayesian approach and B. IC, Cross-validation, Boot strap methods, conditional or expected test error. Dimensionality reduction (Factor analysis, PCA, Kernel PCA, Independent Component analysis, ISOMAP, LLE, feature Selection)

UNIT-III

Additive Models, Trees, and Boosting: Generalized additive models, Regression and classification trees, Boosting methods-exponential loss and AdaBoost, Numerical Optimization via gradient boosting, Examples (Spam data, California housing, New Zealand fish, Demographic data)

UNIT-IV

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

UNIT-V

Unsupervised Learning and Random forests: Cluster analysis (k-means, Hierarchical clustering, spectral clustering), Gaussian mixtures and EM algorithm, Random forests and analysis.

Lab work

Implementation of following methods using PYTHON

Simple and multiple linear regression, Logistic regression, Linear discreminant analysis, Ridge regression, Cross-validation and boot strap, Fitting classification and regression trees, K-nearest neighbours, Principal component analysis , K-means clustering.

Recommended Texts

1. Trevor Hastie, Robert Tibshirani, Jerome Friedman, *The Elements of Statistical Learning-Data Mining, Inference, and Prediction*, Second Edition , Springer Verlag, 2009.
2. G. James, D.Witten, T. Hastie, R. Tibshirani -*An introduction to statistical learning with applications in R*, Springer, 2013.

Refeerences

1. C. M. Bishop - Pattern Recognition and Machine Learning, Springer, 2006
2. L. Wasserman - All of statistics

Texts 1 and 2 and reference 2 are available on line.

SEMESTER-IV

MTCE401 (NUMERICAL ANALYSIS-II)

(Marks-100)

Unit-I : Solution of Linear system of equations, Direct methods, Gauss elimination method, Pivoting strategy, Matrix factorization techniques crout, Dolittle and Cholesky's method

Unit-II : Interative techniques for linear systems, GaussJacobi and Gauss-Seidel techniques, Approximating eigen values - Gerschgovin Circle Theorem, Power method.
Unit-III : Numerical solution of i.v.p. : - Euler method, Taylor method Runge-Kutta methods, Control of
error in R.K.Methods.
Unit-IV : Multti step methods, Adam Moulton and Adam-Bash for the methods, Variable step size methods, Stability.
Unit-V : BVP for ODE : The shooting method, Finite difference methods.

Books Recommended

1. Numerical Analysis by R.L.Burden and J.D.Faires
2. Introduction to Numerical Analysis by A.Z.Aitkanson, Mc-Graw Hill.

MTCE402 (NUMBER THEORY AND CRYPTOGRAPHY-II)

(Marks-100)

Unit-I : Finite fields and Quadratic residues, Knapsack problem in public key cryptography, Zero knowledge protocols.
Unit-II : Primality and factoring: Factoring by continued fractions, Quadratic sieves .
Unit-III : Distribution of primes, Binary quadratic forms.
Unit-IV : Discrete Logarithms ,ElGamal Cryptosystem, Algorithm for Discrete Logarithm Problem, Security of ElGamal System, Schnorr signature scheme, The ElGamal signature scheme, The digital signature algorithm, Provable secure signature schemes.
Unit-V : Elliptic curves over the reals, Elliptic curves modulo a prime, Properties of Elliptic curves, Point compression and ECIes, Computing point multiples on Elliptic curves, Elliptic curve digital signature algorithm, Elliptic curve factorization, Elliptic curve primality test. .

Books Recommended

1. Ramanujachary Kumanduri & Christna Romero: Number Theory with Computer Applications, Prentice Hall, New Jersey 1998.
2. Neal Koblitz: A Course of Number Theory and Cryptography(2nd Edn.), Springer-Verlag, New York, 1987.
3. I.P. Blake, G. Seroussi and N.P. Smart: Elliptic Curves in Cryptography, Cambridge Univ. Press, Cambridge,1999.
4. Douglas R. Stinson: Cryptography: Theory and Practice (3rd Edn.), Chapman Hall/CRC, 2006.

MTAE403 (ADVANCED ANALYSIS)

(Marks-100)

Unit-I : Signed measure, Hahn decomposition theorem, mutually singular measures, Raydon-Nikodim theorem, Lebesgue decomposition , Riesz representation theorem, Extension theorem(Caratheodary).
Unit-II : Completion of a measure, Lebesgue-Stieltjes measure, Absolutely continuous functions, Integration by parts, Product measures, Fubini's theorem.

Unit-III : Spaces of analytic functions, Montel's theorem, Weierstrass factorization theorem, Gamma function
and its properties,Riemann Zeta function.
Unit-IV : Schwarz reection principle, Monodromy theorem, Harmonic functions on a disc, Harnack's inequality and theorem, Dirichlet problem, Green's function.
Unit-V : Canonical products, Jensen's formula, Pisson-Jensen formula, Hadamard three circle's theorem, Order of an entire function, Exponent of convergence, Borel's theorem, Hadamard's factorization theorem, The range of an analytic function, Bloch's theorem, The Little Picard's theorem, Schottky's theorem, Montel caratheodary and the Great Picard theorem. .

Books Recommended

1.G.de Barra: Measure Theory and Integration, Wiley Eastern Ltd.,1981.
2.J.B. Conway: Functions of one Complex Variable, Springer-Verlag, International Student-Edition, Narosa Publishing House,1990.

OR

MTAE403 (COMPUTATIONAL FLUID DYNAMICS-II)

(Marks-100)

Unit-I: **Exact solutions of Navier-Stokes' Equations**: Flow in the types of uniform cross-sections, circular-cross section, annular cross-section, elliptic cross-section, equilateral triangular cross-section, rectangular cross-section. Flow between two concentric rotating cylinders (courtly flow): velocity distribution temperature distribution.

Unit-II: **Stagnation point flows**: Stagnation in two dimensional flows (Hiemenz flow), rotationally symmetrical flow with stagnation point (Hamann flow), flow due to a rotating disc (Kärmän flow), steady incompressible flow with variable viscosity plane poiscuille flow, unsteady incompressible flow with constant fluid properties, flow due to a plane wall suddenly set in motion, flow due to an oscillating plane wall, starting flow in a pipe, plane coquette flow with transpiration cooling. **Two**

Unit-III: **Two Dimensional parabolic equations**: Neumann boundary conditions, convergence, consistency, stability (stability of initial value schemes, stability of initial boundary value schemes). Alternating direction implicit schemes, Peaceman, Richford Scheme, Initial-value problems, two dimensional hyperbolic equations, Lax-wendroff scheme, crank. Nocdson scheme, Stability analysis of two dimensional hyperbolic equations:

Unit-IV : The finite volume method for diffusion problems, Finite volume method for one-dimensional steady state diffusion, the finite volume method for convection-diffusion problems, steady one-dimensional convection and diffusion, the central differencing scheme, properties of discrimination scheme, conservativeness, boundless, transportiveness.

Unit-V : Finite element method for elliptic model problems, finite element method for the model problem with piecewise linear functions, an error estimate for finite element method for the model problem, finite element method for the poisson equation.

References:

1.An Introduction to Computational Fluid Dynamics, The finite volume method by H.K.Versteeg and W.MaLa Lasakera.

2. Numerical Methods for Partial Differential Equations by G.Evans, J.Blackledge and P.Yardley. Springer Publication.

OR

MTAE403 (THEORY OF COMPUTATION-II)

(Marks-100)

Unit-I : Turing Machine, Variants of Turing Machine.
Unit-II : Definition of Algorithm, Hilbert's problem, Decidable Languages.
Unit-III : Halting problem and Undecidable problems from Language theory.
Unit-IV : Post Correspondence problem, Mapping Reducibility.
Unit-V : Measuring Complexity, The class P and the class NP.

Books Recommended

1. Michael Sipser: Introduction to the Theory of Computation, PWS Publishing Company, 1997,First Reprint 2001 by Thomson Asia Pvt. Ltd.
2. J.E. Hopcrof, Rajeev Motwani, J.D. Ullman: Introduction to Automata Theory, Languages & Computation, Pearson Education, Inc. 2001.
3. Peter Linz: An Introduction to Formal Languages & Automata, Narosa Publishing House, 1998.

MTC404 (PROJECT)

(Marks-100)

The Dept. also offers the following Core Elective Papers

Theory of Relativity-II
(Marks-100)

Unit-I : Equivalence principle and measurement of the gravitational field, How mass energy generated curvature.
Unit-II : Weak Gravitational Field.
Unit-III : Spherical stars.
Unit-IV : Motion in Schwarzchild Geometry.
Unit-V : Gravitational aspect of black holes.

Book Recommended

Gravitation by C.W.Misner, K.S.Thorne, J.A.Wheeler, W.H.Freeman.
Chapters : 16.2 and 17(Unit-6), 18(Unit-7), 23(Unit-8), 25(Unit-9), 32.1-32.4 and 35 (Unit-10).

Sequence Spaces-II
(Marks-100)

Unit-I : Abel's method, Tauberian theorem.
Unit-II : Banach limits, Strongly regular matrices, Counting functions.
Unit-III : Some matrices of a special type, a universal tauberian theorem.
Unit-IV : Bounded sequences, Uniformly limitable sequences, Intersection of bounded convergence fields.
Unit-V : Sets of matrices, Bounds of limits of sequences, Matrix norms, Pairs of consistent matrices.

Book Recommended

G.M.Paterson : Regular matrix transformation (McGraw Hill)
Chapters : 2(2.4-2.5), 3, 4.

Numerical Solution of Partial Differential Equations-II
(Marks-100)

Unit-I : Sobolev spaces, Variational formulation of Elliptic boundary value problems of second order, The Neumann boundary-value problem, The Ritz Galerkin method, Standard finite elements, Computational considerations.
Unit-II : Approximation properties of finite element approximations, Error bounds for elliptic problems of second order, Abstract lemmas and boundary approximation, Isoparametric elements, Negative norms and adjoint operators, Abstract existence and convergence theorems.
Unit-III : Saddle point problems, Mixed finite element methods,The stokes equation, finite element method for the stokes equation, A posteriori error estimates..
Unit-IV : Finite element method for parabolic equations - One-dimensional problem, Semi-discretization in space, Discretization in space and time, Error estimate for fully discrete approximation, Non-linear parabolic problem, The incampressible Euler equation.
Unit-V : Domain Decomposition Method- One level algorithms: Alternating Schwarz method, Approximate Solvers, Many subdomains, Convergence behaviour, Implementation issues.
Two level algorithms, Simple two level method, General two level methods, Coarse grid corrections, Convergence behaviour, Implentation issues, Multi method Schwarz methods.

Book Recommended

1. D.Braess: Finite Elements, Cambridge University Press, 1997. Chapters : II, III.
2. C.Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Cambridge University Press, 1990. Chapter : 8.
3. B.smith, P.Bjorstad and W.Gropp: Domain Decomposition - Parallel Multilevel Methods for elliptic Partial Differential Equations, Cambridge Unviersity Press, 1996. Chapters : 1,2.

Books Reference

1. S.C.Brenner and L.R.Scoh: The Mathematical Theory of Finite Element Methods, Springer Verlag, 1994.
2. W.Hackbusch: Iterative Solution of Large Sparse Systems of Equations, Springer Verlag, 1994.

Operator Theory-II
(Marks-100)

Unit-I : Basic facts, bounded operators, a commutative theorem.
Unit-II : Resolution of identity, the spectral theorem, Eigen values of normal operators.
Unit-III : Positive operators and square roots, the group of invertible operators, a characterization of B-
algebras, Unbounded operators.
Unit-IV : Introduction, Graphs and symmetric operators, The Caley transform.
Unit-V : Resolution of the identities, the spectral theorem, semigroups of operators.

Book Recommended

W.Rudin: Functional Analysis (TMH). Chapters : 12, 13.

Computational Finance-II
(Marks-100)

Unit-I : Exotic and Path Dependent Options (Introduction, Barrier Options, Asian Options, Lookback Options, Computational Schemes), Options on stock indices, Currencies and futures.
Unit-II : Extensions of Black-Scholes Model Limitation of Black-Scholes Model, Discrete Hedging, Transactioncosts, Volatility smiles, Stochastic volatility, Jump difusion, Dividend modelling, Pricing models for multi-asset options.
Unit-III : Interest rates and their derivation Fixed-income products and analysis (yield, duration and convexity), Swaps, One-factor and multifactor interest rate models, Interest rate derivatives, Health-Jarrow Merton model.
Unit-IV : Riskmeasurement and Management Portfolio management, Value at risk, Credit risk, Credit derivatives, risk metrics and credit metrics.
Unit-V :Finite element methods for ordinarry differential equations (Galarkin method, Variational formulation,Finite elements), Finite element methods for partial differential equation (variational methods, Finite elements and assembly, Variational principle), Applications to finance.
Note - The midterm test shall be on computer implementation of the methods studied.

Book Recommended

1.J.Bax & G.Chacko-Financial Derivatives : Pricing, Applications and Mathematics-Cambridge Univ. Press, 2004.
2. Steven Shreve-Stochastic Calculus & Finance, Vol.I & II-Springer Verlag.
3. P.Wilmott-Paul Willmott on Quanktative Finance-John Wiley, 2000.
4. Y.K.Kwok-Mathematical Models of Financial Derivatives-Springer Verlag.
5. G.Evans, J.Blackledge & P.Yardly-Numerical Methods for Partial Differential Equations-Springer Verlag, 2000.
6. Y.D.Lyun-Financial Engineering and Computation : Principles, Mathematics and Algorithms-Cambridge Univ. Press, 2002.
7. J.C.Hull-Options, Futures & other Derivatives-Prentice Hall of India, 2003.

Distribution Theory and Sobolev Spaces-II
(Marks-100)

Unit-I : Extensions and imbedding theorems in Soboleve space.
Unit-II : Compactness theorems.
Unit-III : dual spaces, Fractional order spaces and frace theore.
Unit-IV : Abstract variational problem : Theroem of stampacchia, Lax-milgram and Babuska-Brezz.
Unit-V : Weak solutions of elliptic boundary value problem : the 2nd order Dirchlet's problem and Neumann problem, Regulation of week solutions.

Book Recommended

S.Kesavan: Topics in Functional Analysis and Applications (Wiley Eastern Ltd.)
Chapters : 2(2.3-2.), 3(3.1. 3.2.1, 3.2.2., 3.3).

Fluid Dynamics-II
(Marks-100)

Unit-I : Flow in the tubes of uniform cross section, flow between two concentric rotating cylinders.
Unit-II : Hiemarz flow, Hamman flow, Karman flow, Flow due to suddenly accelerated plate, Oscilating plane wall, starting flow in aplane couette motion, Staring flow in a pipe, Plane coutee flow with transpiration colling.
Unit-III : Theory of very slow motions, Stokes equation, Oseen's equations, flow past a sphere, Lubrication theory.
Unit-IV : Theory of laminar boundary layers, Two dimensional boundary layer equations for flow . over a plane wall, Blasious-Topfer solutions.
Unit-V : Flow past porous flat plate and porous circular cylinder, Karman Karman - Pohlausen method, Energy integral equation.

Books Recommended

1. Viscous fluid dynamics by J.L.Bansal (IBM Publication).
Chapters : 4(4.5-4.12, 4.15-4.17), 5(5.1-5.4, 5.6), 6(6.1-6.3), 7(7.1-7.4, 7.6).
2. Meeredith f.W and Friffith : A.A.Paper in AARC2315, 1955, R.A.E. Report No.8.
3. Lew, H.G., Problems in J.Aero/Space Science, Vol.23, p.276, 1956.

Bezier Technique for Computer Aided Geometric Design-II(Marks-100)
Theory : Marks-60

Unit-I : The space of spline functions of arbitrary degree n.B-splines, Knot insertion algorithm, The de Boor algorithm, B-spline basis, Recursion formulas, respested knot insertion B-spline blossom.
Unit-II : Geometric continutiy, a characterization of G2-curves, Nu-splines, C2-piecewise Bezier curves and direct G2 cubic splines, γ and β splines, Local basis function for G2-splines.
Unit-III : Rational Bezier curves, The de Casteljau algorithm, Derivatives, Reparametrization and degree elevation, Rational cubic B-spline curves, Interpolation with rational cubics, Rational B-spline of aribitrary degree.

Unit-IV : Tensor product Bezier curvs, De Casteljau algorithm and degree elevation for surfaces, Composite surfaces and spline interpolation, Sommothness subdivision, biobic B-spline surfaces, Tensor product interpellants.
Unit-V : (Bivariate surfaces) Bezier triangles, Barycentric coordinate and linear interpolation, Bernstein polynomials, Derivtives, Subdivision, Degree elevation, Non-parametric patches.

Practical : Marks-40

1. Curvature plots of spline interpellants with different and conditions.
2. To evaluate n-th degree B-spline at a parameter value using knot insertion algorithm and de Boor algorithm.
3. To verify that by repeated knot insertion, the control polygons P' converge to the B-spline curve that they define.
4. Chaikin's algorithm.
5. To construct G1 and G2 spline curves and Beta-spline curves for a polygon. Presise refinement in shaptes achieved by verying the parametric values involved.
6. To construct rational cubic B-spline curve for a given control polygon.
7. Tensor product Bezier surfaces and Bezier triangles.
8. To verify the degree elevation process and subdivision for tensor product Bezier surface and Bezier triagle.

Book Recommended

G.Frain: Curves and surfaces for Computer Aided Geometric Design, Academic Press, Third Edition, 1993.

Analytic Number Theory-II
(Marks-100)

Unit-I : Minkowski's theorem on lattice points on convex sets.
Unit-II : Dirchlet's theorem on primes in an arithmetical progression, the prime number theorem.
Unit-III : Quadratic residue and the quadratic reciprocity law.
Unit-IV : Primitive roots.
Unit-V : Partitions.

Books Recommended

1. K.Chandrasekharan : Introduction to Analytic Number Theory, Springer Verlag, 1968.
Chapters : 9. 10, 11.
2. Tom. M.Apostal : Introduction to Analytic Number Theory, Springer International, 1980.
Chapters - 9(9.1-9.8), 10(10.1-10.9), 14.

Fourier Analysis-II
(Marks-100)

Unit-I : Cesaro summability of fourier series and its consequences.
Unit-II : Some special series and their application.
Unit-III : Fourier series in L2.
Unit-IV : Positive definite functions and Boolinear theorem.
Unit-V : Pointwise convergence of fourier series.

Book Recommended

R.E.Edward : Fourier series, A modern introduction. Chapters : 6,7,8,9,10.

Data Science II

(Marks-100)

UNIT-I

Graphical models - Directed Graphical models (Bayesian networks), Markov and Hidden Markov Models, Markov Random fields, Conditional Random fields, Exact inference for graphical models, Learning undirected Gaussian graphical models

UNIT-II

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

UNIT-III

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

UNIT-IV

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

State Networks, Leaky Units and Other Strategies for Multiple Time Scales, The Long Short-Term Memory and Other Gated RNNs, Optimization for Long-Term Dependencies, Explicit Memory.

UNIT-V

Practical Methodology: Performance Metrics, Default Baseline Models, Determining Whether to Gather More Data, Selecting Hyperparameters, Debugging Strategies, Example-Multi-Digit Number Recognition. **Linear Factor Models**: Slow Feature Analysis, Sparse Coding, **Autoencoders** : UndercompleteAutoencoders, Regularized Autoendcoders, Representational Power, Layer Size and Depth, Stochastic Encoders and Decoders, DenoisingAutoencoders, Learning Manifolds with Autoencoders, Contractive Autoencoders, Predictive Sparse Decomposition, Applications of Autoencoders, **Deep Generative Models** : Boltzmann Machines, Restricted Boltzmann Machines, Deep Belief Networks.

Implementaion of the following algorithms:

i. Convolution Neural network (CNN)
ii. Recurrent Neural Network (RNN)
iii. Autoencoder
iv. Deep Belief Network

TextBooks

1. Deep Learning, Ian Goodfellow, YoshuaBengio, and Aaron courville, The MIT Press, 2016

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

3. Machine Learning, Tom Mitchel, McGrawhill.

Allied Electives

Fractals Geometry-II
(Marks-100)

Unit-I : Self similarity : Ratio lists, String models, Graph self similarity.
Unit-II : Measures for strings, Hausdorff measure, Examples, Self similarity.
Unit-III : Graph self similarity, Other fractional dimensions.
Unit-IV : A three demensional dragon overlap.
Unit-V : Self affine sets, Other examples.

Book Recommended

G.A.Edger : Measure, Topology, Fractaral Geometry (Springer-Verlag).
Chapters : 4, 5(5.5), 6, 7.
Note : Students are requred to write Turbo C++ programs for each of the fractal example discussed.

Design and Analysis of Algorithms-II
(Marks-100)

Unit-I : Discrete Logarithms, ElGamal Cryptosystem, Algorithm for Discrete Logarithm Problem, Security of ElGamal System, Schnorr signature scheme, The ElGamal signature scheme, The digital signature algorithm, Provable secure signature schemes. Fast Fourier transform & Application to finding product of large integers.

Unit-II : Elliptic curves over the reals, Elliptic curves modulo a prime, Properties of Elliptic curves, Point compression and ECIes, Computing point multiples on Elliptic curves, Elliptic curve digital signature algorithm, Elliptic curve factorization, Elliptic curve primality test.

Unit-III : NP-Completeness : Polynomial time, Polynomial-time veri_cation, NP-completeness and reducibility, NP-completeness proofs, NP-complete problems. Approximation Algorithms : The vertex-cover problem, The travelling salesman problem.

Unit-IV: Parallel Algorithms (I) : Introduction to parallel computing, Performance metrics for parallel systems, Brents theorem and work efficiency, Bass parallel algorithm design techniques (Balanced trees, pointer jumping, Divide and conquers), Introduction to MPI.

Unit-V : Parallel Algorithms (II) : Parallel Algorithm for : Matrix-Vector multiplication, Matrix-Matrix mul-
tiplication, solving a system of linear equations by Gaussian Ellimination, Iterative and conjugate gradient methods.

Note : Midterm test shall comprise of (i) a written examination (weightage 15%) and (ii) a test on computer implementation of some algorithms assigned by the teacher (weightage 15%)

Book Recommended

1. T.H.Corman, C.E.Leiserson, R.L.Rivest and C.Stein, Introduction to Algorithms, Prentice Hall of India, 2001.
2. J.Jaja, An Introduction to Parallel Algorithms, Addison Wesley, 1992.
3. A.Grama, A.Gupta, G.Karypis and V.Kumar, Introduction to Parallel Computing, Pearson Education, 2003.
4. M.J.Quinn, Parallel Programming in C with MPI, Tata MagrawHill, 2003.
5. M.T.Goodrich and R.Tamassia, Algorithm Design : Foundation, analysis and internet examples.

Wavelet Analysis-II
(Marks-100)

Unit-I : Vanishing Moments, Equivalent Conditions for Vanishing Moments, The Daubechies Wavelets, Image Analysis with Smooth Wavelets.

Unit-II : Linear Independence and Biorthogonality, Riesz Bases and Frame Condition, Riesz Bases of Translates, Generalized Multiresolution Analysis(GMRA), Riesz Bases Orthogonal Across Scales, A Discrete Transform for Biothrogonal Wavelets, Compactly Supported Biorthogonal Wavelets.

Unit-III : Motivation- Completing the Wavelet Tree, Localization of Wavelet Packets, Orthogonality and Completeness properties of Wavelet Packets, The Discrete Wavelet Packet Transform(DWPT), The Best-Basis Algorithm.

Unit-IV : The Transform Step, The Quantization Step, The Coding Step, The Binary Huffman Code, A Model Wavelet Transform Image Coder.

Unit-V : Examples of Integral Operators, Sturm-Liouville Boundary Value Problems, The Hilbert Transform, The Radon Transform, The BCR Algorithm, The Scale j Approximation to T, Description of the Algorithm.

Book Recommended

1. An introduction to Wavelet Analysis, David F. Walnut, Birkhauser, 2002.
   CH-III(9.1-9.3), IV, V.

2. C. Chui, ed., Wavelets: A Tutorial in Theory and Applications, Academic Press (1992).
3. M. Frazer, Introduction to Wavelets through Linear Algebra, Springer-Verlang (1999).