Post Graduate Department of Mathematics

Utkal University

Proposed Syllabus

For M.A/M.Sc. Mathematics

Under

Choice Based Credit System

Preamble

M.A./M.Sc Mathematics is a two-year postgraduate course that deals with a deeper knowledge of advanced mathematics through a vast preference of geometry, calculus, algebra, number theory, dynamical systems, differential equations etc. Banks, universities, share markets, space agencies, research centers, etc., offer good job opportunities for the graduates. Since mathematics has a good job scope worldwide, students get placed in reputed firms. This course provides training in different aspects of Pure Mathematics, equipping you with a range of mathematical skills in problem-solving, project work and presentation. You have the opportunity to learn advanced core pure mathematics topics together with a range of more specialised options, and undertake an independent research project in your chosen area.

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 department 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)

Syllabus

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Metric space, Sequences and series of functions, Uniform convergence, Continuity, Integrability, Differentiability, Equicontinous functions, Weirstrass approximation theorem.	**Objectives:** Measure theory provides a foundation for many branches of mathematics such as harmonic analysis, ergodic theory, theory of partial differential equations and probability theory. It is a central, extremely useful part of modern analysis, and many further interesting generalizations of measure theory have been developed. It is also subtle, with surprising, sometimes counter-intuitive, results. The aim of this course is to learn the basic elements of Measure Theory, with related discussions on applications in probability theory. **Expected Outcomes:** After the course the students are expected to be able to: • define and understand basic notions in abstract integration theory, integration theory on topological spaces and the n-dimensional space • describe and apply the notion of measurable functions and sets and use Lebesgue monotone and dominated convergence theorems and Fatous' Lemma • describe the construction of and apply the Lebesgue integral • describe the construction of product measures and use Fubini's theorem • describe the notion of absolute continuity and singularities of measures and apply Lebesgue decomposition and the Radon-Nikodym theorem • apply Hölder's and Minkowski's inequalities and describe Riesz representation
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.	theorem • describe the notion of extended real valued and complex measures

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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	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.	**Objective:** The objective of this course is to introduce the fundamental ideas of the functions of complex variables and developing a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, complex integrals and a range of skills which will allow students to work effectively with the concepts. **Expected Outcomes:** The student should be able to Represent complex numbers algebraically and geometrically, Define and analyze limits and continuity for complex functions as well as consequences of continuity, Apply the concept and consequences of analyticity and the Cauchy-Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra, Analyze sequences and series of analytic functions and types of convergence, Evaluate complex contour integrals directly and by the fundamental theorem, apply the Cauchy integral theorem in its various versions, and the Cauchy integral formula and Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.
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.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)

<table>
<tr><th>Paper-II</th><th>Content</th><th>Objectives and Expected Outcomes</th></tr>
<tr><td>Unit-I</td><td>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.</td><td rowspan="5">Objectives:
This is an introductory course in topology of metric spaces. The objective of this course is to impart knowledge on open sets, closed sets, continuous functions, connectedness and compactness in metric spaces.
• Work with topological definitions and theorems related to the content described.
• Read and evaluate the correctness of topological proofs.
• Produce examples and counterexamples that illustrate why theorem hypotheses are necessary or why a statement is untrue.
• Draw pictures to represent topological ideas.
• Formulate conjectures about topological concepts, and test these conjectures.
• Prove topological statements.
• Use topological ideas (e.g., homeomorphisms, fundamental group) to classify spaces.
• Present mathematical arguments both orally and in writing.

Expected Outcomes:
On successful completion of the course students will learn to work with abstract topological spaces. This is a foundation course for all analysis courses in future.</td></tr>
<tr><td>Unit-II</td><td>Continuous functions and homeomorphism, Metric topology, Connected spaces, Connected subspaces of the real line, Components and local connectedness.</td></tr>
<tr><td>Unit-III</td><td>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.</td></tr>
<tr><td>Unit-IV</td><td>First and second countable spaces, Lindelof space, Seperable spaces, Seperable axims, Hausdorff Regular and normal spaces.</td></tr>
<tr><td>Unit-V</td><td>The Urysohn lemma, Completely regular spaces, the Urysohn metrization theorem, Imbedding theorem, Tietu extension theorem, Tychonoff theorem, Stone-Cech campatification.</td></tr>
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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)

Paper-IV	Content	Objectives and Expected Outcomes
Unit-I	Groups, Subgroups, Cyclic groups, Normal Subgroups, Quotient groups, Homomorphism, Types of homomorphisms,	**Objective:** Group theory is one of the building blocks of modern algebra. Objective of this course is to introduce students to basic concepts of group theory and examples of groups and their properties. This course will lead to future basic courses in advanced mathematics, such as Group theory-II and ring theory. **Expected Outcomes:** A student learning this course gets idea on concept and examples of groups and their properties. He understands cyclic groups, permutation groups, normal subgroups and related results. After this course he can opt for courses in ring theory, field theory, commutative algebras, linear classical groups etc. and can be apply this knowledge to problems in physics, computer
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	science, economics and engineering.
Unit-V	Modules, submodules, quotients modules, examples, module homomorphisms, isomorphism theorems	

<u>Book Recommended</u>

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.

<u>Books Recommended</u>

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Normed linear spaces, Continuity of linear maps, Equivalent norms, Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces.	**Objectives:** Learn the fundamental structures of Functional Analysis. Get familiar with the main examples of functional spaces, in particular with the theory of Hilbert spaces and Lebesgue spaces. Get familiar with the basic notions of operator theory. Be able to frame a functional equation in an abstract functional setting. **Expected Outcomes:** • recognize inner product spaces • Identify duals of some normed spaces. • Identify whether a real valued function defined on Cartesian product of a vector space is inner product or not and an inner product space is Hilbert space or not. • explain the normed space which is not an inner product space • identify orthogonal sets • identify orthogonal sets • understand the notion of orthogonal complement and the decomposition of the space • explain total sets
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.	

		• explain main theorems for normed spaces • explain Hahn -Banach teorem • identify open mapping theorem • explain closed gragh 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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	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.	**Objectives:** Differential Equations introduced by Leibnitz in 1676 models almost all Physical, Biological, Chemical systems in nature. The objective of this course is to familiarize the students with various methods of solving differential equations and to have a qualitative applications through models. The students have to solve problems to understand the methods. **Expected Outcomes:** A student completing the course is able to solve differential equations and is able to model problems in nature using Ordinary Differential Equations. This is also prerequisite for studying the course in Partial Differential Equations and models dealing with Partial Differential Equations.
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)

Paper-III	Content	Objectives and Expected Outcomes
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.	**Objectives:** **linear algebra** helps the student understand geometric concepts such as planes, in higher dimensions, and perform mathematical operations on them**. It can be thought of as an extension of algebra into an arbitrary number of dimensions. Rather than working with scalars, it works with matrices and vectors.** **Expected Outcomes**: • analyze the solution set of a system of linear equations. • express some algebraic concepts (such as binary operation, group, field). • do elemantary matrix operations.
Unit-II	System of Linear equations, Characteristic roots and Vectors, eigen values, eigen vectors, Cayley-Hamilltorn	

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<td>theorem, Canonical Forms: Diagonal forms, triangular forms, Jordan form, Rational Canonical form, Invariants of nilpotent transformation, Primary decomposition theorem Quadratic form, Inner Product spaces.</td>
<td rowspan="4">
• express a system of linear equations in a matrix form.
• do the elementary row operations for the matrices and systems of linear equations.
• investigate the solition of a system using Gauss elimination.
• apply Cramer's rule for solving a system of linear equations, if the determinant of the matrix of coefficients of the system is not zero.
• generalize the concepts of a real (complex) vector space to an arbitrary finite-dimensional vector space.
• definite a vector space and subspace of a vector space.
• explain properties of R^n and subspaces of R^n.
• determine whether a subset of a vector space is linear dependent.
• describe the concept of a basis for a vector space.
• investigate properties of vector spaces and subspaces using by linear transformations.
• express linear transformation between vector spaces.
• represent linear transformations by matrices.
• explain what happens to representing matrices when the ordered basis is changed.
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<td>Unit-III</td>
<td>Algebric extensions of fields : Irreducible polynomials and Einstein criterion, Adjunction of roots, Algebraic extensions. Algebraically closed fields, Normal separable extensions: Splitting fields, Normal extensions.
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<tr>
<td>Unit-IV</td>
<td>Normal separable extensions: Multiple roots, Finite fields, Separable extensions. Galois Theory: Automorphisim groups and fixed fields, Fundamental theorem of Galois theory.</td>
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<tr>
<td>Unit-V</td>
<td>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.</td>
</tr>
</table>

		• describe the concepts of eigenvalue, eigenvector and characteristc polynomial. • determine whether a linear transformation is diagonalizable or not.

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	One Dimensional Optimization: Introduction, Function comparison methods, Polynomial Interpolation, Iterative methods	**Objectives:** • find acceptable approximate solutions when exact solutions are either impossible or so arduous and time-consuming as to be impractical; • devise alternate methods of solution better suited to the capabilities of computers; • formulate problems in their fields of research as optimization problems by defining the underlying independent variables, the proper cost function, and the governing constraint functions. **Expected Outcomes:** • understand how to assess and check the feasiblity and optimality of a particular solution to a general constrained optimization problem; • use the optimality conditions to search for a local or global solution from a starting point; • formulate the dual problem of some general optimization types and assess their duality gap using concepts of strong and weak duality; • understand the computational details behind the numerical methods discussed in class, when they apply, and what their convergence rates are.
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.	• master the main numerical methods; • understand the bases of linear programming, unconstrained optimization, constrained optimization; • be able to analyze the behaviour of these numerical methods and in particular to be able to discuss their stability, their order of convergence and their conditions of application; • be able to apply these methods to academic and simple practical instances; • demonstrate the abilities to – apply knowledge of mathematics and computing to the design and analysis of optimization methods, – analyze a problem and identify the computing requirements appropriate for its solution, – design and conduct experiments and numerical tests of optimization methods, and to analyze and interpret their results.

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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives:** To provide the numerical methods of solving the non-linear equations, interpolation, differentiation, and integration. To improve the student's skills in numerical methods by using the numerical analysis software and computer facilities. **Expected Outcomes:** Apply numerical methods to find our solution of algebraic equations using different methods under different conditions, and numerical solution of system of algebraic equations.Apply various interpolation methods and finite difference concepts. Work out numerical differentiation and integration whenever and wherever routine methods are not applicable. Work numerically on the ordinary differential equations using different methods through the theory of finite differences. Work numerically on the partial differential equations using different methods through the theory of finite differences.
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Divisibility and primes, Modular arithmetic. Time estimates for doing arithmetic.	**Objective**: The main objective of this course is to build up the basic theory of the integers, prime numbers and their primitive roots, the theory of congruence, quadratic reciprocity law and number theoretic functions, Fermat's last theorem, to acquire knowledge in cryptography specially in RSA encryption and decryption. **Expected Outcomes**: Upon successful completion of this course students will able to know the basic definitions and theorems in number theory, to identify order of an integer, primitive roots, Euler's criterion, the Legendre symbol, Jacobi symbol and their properties, to understand modular arithmetic number-theoretic functions and apply them to cryptography.
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Review of descriptive statistics-detailed study on the interpretation, analysis and measurements of various numerical characteristics of a frequency distribution.	**Objectives:** 1. Students should be familiar with the terminology and special notation of statistical analysis. The terminology consists of the following: a. Statistical Terms i. Population ii. Sample
Unit-II	Concepts of univariate and bivariate distributions, curve fittings, regression and correlation analysis, rank correlation, correlation ratio, intra-class correlation.	iii. Parameter iv. Statistic v. Descriptive Statistics vi. Inferential Statistics vii. Sampling Error b. Measurement Terms i. Operational definition
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.	ii. Nominal iii. Ordinal iv. Interval v. Ratio vi. Discrete variable vii. Continuous variable viii. Real limits
Unit-IV	Exact sampling distributions-t, F and chi-square distributions, sampling from bivariate normal distribution,	c. Research Terms i. Correlation method

	distribution of sample correlation coefficient (null case) and regression coefficient, tests based on t, F and chi-square distributions.	ii. Experimental method iii. Independent variable iv. Dependent variable v. Non-experimental method vi. Quasi-independent variable 2. Students should learn how statistical techniques fit into the general process of science 3. Students should learn the notation, particularly summation notation. 4. Students should understand the concept of a frequency distribution as an organized display showing where all of the individual scores are located on the scale of measurement. 5. Students should be able to organize data into a regular or a grouped frequency distribution table, and understand data that are presented in a table. **Expected Outcomes:** Students should be able to: • Distinguish types of studies and their limitations and strengths, • Describe a data set including both categorical and quantitative variables to support or refute a statement, • Apply laws of probability to concrete problems, • Perform statistical inference in several circumstances and interpret the results in an applied context, • Use mathematical tools, including calculus and linear algebra, to study probability and mathematical statistics and in the description and development of statistical procedures, • Use a statistical software package for computations with data, • Use a computer for the purpose of simulation in probability and statistical inference, and • Communicate concepts in probability and statistics using both technical and non-technical language
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	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.	**Objectives:** This is a preliminary course for the basic courses in mathematics and all its applications. The objective is to acquaint students with basic counting principles, set theory and logic, matrix theory and graph theory. **Expected Outcomes:** The acquired knowledge will help students in simple mathematical modeling. They can study advance courses in mathematical modeling, computer science, statistics, physics, chemistry etc.
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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives:** • To get introduced to the concept of a regular parameterized curve in n • To Understand the concept of curvature of a space curve and signed curvature of a plane curve. • To be able to understand the fundamental theorem for plane curves. • To get introduced to the notion of Serret-Frenet frame for space curves and the involutes and evolutes of space curves with the help of examples. • To be able to compute the curvature and torsion of space curves. • To be able to understand the fundamental theorem for space curves. • To get introduced to the concept of a parameterized surface with the help of examples. • To Understand the idea of orientable/non-orientable surfaces. • To get introduced to the idea of first fundamental form/metric of a surface. • To Understand the normal curvature of a surface, its connection with the first and second fundamental form and Euler's theorem • To Understand the Weingarton Equations, mean curvature and Gaussian curvature. • To understand surfaces of revolution with constant negative and positive Gaussian curvature. • To understand the isometry between two surfaces and characterization of local isometry between them.
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.	

<table>
<tr>
<td>Unit-IV</td>
<td>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.</td>
<td rowspan="2">• To be introduced to Christoffel symbols and their expression in terms of metric coefficients and their derivatives.

• To prove Theorema Egregium of Gauss.

• To Discuss the fundamental Theorem for regular surfaces. • To get introduced to geodesics on a surface and their characterization.

• To understand geodesics as distance minimizing curves on surfaces.

• To find geodesics on various surfaces.

• To Discuss Gauss Bonnet theorem and its implication for a geodesic triangle

Expected Outcomes:

Students should be able to:

• define the equivalance of two curves.
    • find the derivative map of an isometry.
    • analyse the equivalence of two curves by applying some theorems.
• defines surfaces and their properties
    • express definition and parametrization of surfaces.
    • express tangent spaces of surfaces.
    • explain differential maps between surfaces and find derivatives of such maps.
    • integrate differential forms on surfaces.
• list topological aspects of surfaces.
    • define the concept of manifolds.
    • give examples of manifolds and investigate their properties.</td>
</tr>
<tr>
<td>Unit-V</td>
<td>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.</td>
</tr>
</table>

Book Recommended

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

OR

MTAE305 (COMPUTATIONAL FLUID DYNAMICS-I)

(Marks-100)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Basic Concepts, Continuum Hypothesis, Viscosity, Strain Analysis, Stress Analysis, Relation between Stress and Rate of Strain, Thermal Conductivity, Law of Heat Conduction.	**Objectives:** A tool that allows the student to visualize complex flow phenomena in a virtual environment can significantly enhance the learning experience. Such a visualization tool allows the student to perform open-ended analyses and explore cause-effect relationships. Computational fluid dynamics (CFD) brings these benefits into the learning environment for fluid mechanics. **Expected Outcomes** • solve hydrostatic problems. • describe the physical properties of a fluid. • calculate the pressure distribution for incompressible fluids. • calculate the hydrostatic pressure and force on plane and curved surfaces. • demonstrate the application point of hydrostatic forces on plane and curved surfaces. • formulate the problems on buoyancy and solve them. • describe the motion of fluids.
Unit-II	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-III	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-IV	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.	- describe the principles of motion for fluids. - describe the areas of velocity and acceleration. - formulate the motion of fluid element. - identify derivation of basic equations of fluid mechanics and apply - identify how to derive basic equations and know the related assumptions. - apply the equation of the conservation of mass. - apply the equation of the conservation of momentum - apply the equation of the conservation of energy. - make dimensional analysis and similitude. - use the dimensional analysis and derive the dimensionless numbers - apply the similitude concept and set up the relation between a model and a prototype.
Unit-V	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.

OR

MTAE305 (THEORY OF COMPUTATION-I)

(Marks-100)

Paper-I	**Content**	**Objectives and Expected Outcomes**
Unit-I	Introduction to Automata & Computability theory, Mathematical preliminaries.	**Objectives:** To understand the concept of machines: finite automata, pushdown automata, linear bounded automata, and Turing machines. To understand the formal languages and grammars: regular grammar and regular languages, context-free languages and context-free grammar; and introduction to context-sensitive language and context-free grammar, and unrestricted grammar and languages. To understand the relation between these formal languages, grammars, and machines. To understand the complexity or difficulty level of problems when solved using these machines. To understand the concept of algorithm. To compare the complexity of problems. **Expected Outcomes**: • Demonstrate advanced knowledge of formal computation and its relationship to languages
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.	• Distinguish different computing languages and classify their respective types • Recognise and comprehend formal reasoning about languages • Show a competent understanding of the basic concepts of complexity theory

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Foundations of Special Relativity.	**Objectives :** • Understand the motivation for developing the Theory of Special Relativity. • Understand Einstein’s postulates and their consequences. • Understand how to apply Einstein’s postulates to describe simultaneity. • Understand how to model length contraction and time dilation. • Understand how to apply Lorentz transformations and make space-time diagrams. • Understand how to model the energy and momentum of a relativistic object. **Expected Outcomes:** 1. Describe the basic concepts of the theory of relativity. 2. Differentiate facts from wrong general public ideas about the theory of relativity. 3. Discuss postulates of the special theory of relativity and their consequences. 4. Explain the twin paradox. 5. Explain the concept of invariance. 6. Explain the concept of space-time.
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.	

		7. Discuss the equivalence principle. 8. Describe gravity as space-time curvature. 9. Describe the basic characteristics of black holes and gravity waves. 10. Describe general theory of relativity as mathematical basis of physical cosmology.

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Foundations of Special Relativity.	**Objectives :** To know • Sequence spaces and their topological and geometric properties • Special summability methods in the space of functions • Positive linear operators and approximation methods • Korovkin's type approximation • Measures of noncompactness and their applications in characterizing compact matrix operators • Applications to differential, integral, functional integral and integro-differential equations in sequence spaces and function spaces **Expected Outcomes:** • understand the Euclidean distance function on R^n and appreciate its properties, and state and use the Triangle and Reverse Triangle Inequalities for the Euclidean distance function on R^n • explain the definition of continuity for functions from R^n to R^m and determine whether a given function from R^n to R^m is continuous • explain the geometric meaning of each of the metric space properties (M1) – (M3) and be able to verify whether a given distance function is a metric • distinguish between open and closed balls in a metric space and be able to determine them for given metric spaces
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.	

		• define convergence for sequences in a metric space and determine whether a given sequence in a metric space converges • state the definition of continuity of a function between two metric spaces.

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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives:** To provide the numerical methods of solving the non-linear equations, interpolation, differentiation, and integration. To improve the student's skills in numerical methods by using the numerical analysis software and computer facilities. A major advantage of numerical method is that a numerical solution can be obtained for problems, where an analytical solution does not exist. An additional advantage is, that a numerical method only uses evaluation of standard functions and the operations: addition, subtraction, multiplication and division. **Expected Outcomes**: 1. Apply a range of techniques to find solutions of standard Partial Differential Equations (PDE) 2. Understand basic properties of standard PDE's. 3. Demonstrate accurate and efficient use of Fourier analysis techniques and their applications in the theory of PDE's.
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	
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.	4. Demonstrate capacity to model physical phenomena using PDE's (in particular using the heat and wave equations). 5. Apply problem-solving using concepts and techniques from PDE's and Fourier analysis applied to diverse situations in physics, engineering, financial mathematics and in other mathematical contexts.

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Introduction, Complex homomorphisms.	**Objectives :** To study linear operators on function spaces, beginning with differential operators and integral operators. The operators may be presented abstractly by their characteristics, such as bounded linear operators or closed operators, and consideration may be given to nonlinear operators. The study, which depends heavily on the topology of function spaces, is a branch of functional analysis. **Expected Outcomes**: • Prove the continuity of concrete linear operators between topological vector spaces. • Given a linear operator, understand whether or not it is compact. • Find the essential spectra of linear operators. • Find the maximal spectra of concrete commutative Banach algebras.
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	• Describe the functional calculi and the spectral decompositions of concrete selfadjoint operators

Book Recommended

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

Computational Finance-I
(Marks-100)

<table>
<tr><th>Paper-I</th><th>Content</th><th>Objectives and Expected Outcomes</th></tr>
<tr><td>Unit-I</td><td>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.</td><td rowspan="5">Objectives :

To provide the students with a strong mathematical background with the skills necessary to apply their expertise to the solution of problems. You will develop skills to formulate mathematical problems that are based on the needs of the financial industry. You will carry out relevant mathematical and financial analysis, develop and implement appropriate tools to present and interpret model results.

Expected Outcomes:

▪ Analyze and simulate time series data using a stochastic process.
▪ Implement a portfolio optimization algorithm based on Modern Portfolio Theory.
▪ Demonstrate an in-depth knowledge of:
• Bond Valuation Models.
• Stock Valuation Models.
• Options Valuation Models.</td></tr>
<tr><td>Unit-II</td><td>Stochastic processes, Markov processes, Random walks, Arithmetic Brownian motion, Geometric Brawnian motion, Martingles.</td></tr>
<tr><td>Unit-III</td><td>Stochastic integrals, Ito integral, Ito's lemma, Mean-reverting processes, Derivation of Black-Scholes differential equation, Kolmogorov equations</td></tr>
<tr><td>Unit-IV</td><td>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.</td></tr>
<tr><td>Unit-V</td><td>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.</td></tr>
</table>

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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.Lyun-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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Test functions and distributions, Operation with distributions.	**Objectives :** To study Sobolev spaces and their applications in the elliptic boundary value problems and their finite element approximations are presented. Also many additional topics of interests for specific applied disciplines and engineering, for example, elementary solutions, derivatives of discontinuous functions of several variables, delta-convergent sequences of functions, Fourier series of distributions, convolution system of equations etc. have been included along with many interesting examples.
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.	**Expected Outcomes**: Student will develop i. Capability of demonstrating comprehensive knowledge of mathematics and understanding of one or more disciplines of mathematics.
Unit-IV	Definitions and basic properties of Sobolev spaces.	**ii.** Ability to communicate various concepts of mathematics effectively using examples and their geometrical visualizations.
Unit-V	Approximation of elements of a Sobolev space by smooth functions.	**iii.** Ability to use mathematics as a precise language of communication in other branches of human knowledge. **iv.** iv. Ability to employ critical thinking in understanding the

		concepts in every area of mathematics. **v.** Ability to analyze the results and apply them in various problems appearing in different branches of mathematics. **vi.** Ability to provide new solutions using the domain knowledge of mathematics by framing appropriate questions relating to the concepts in various fields of mathematics. **vii.** To know about the advances in various branches of mathematics. **viii.** Capability to understand and apply the programming concepts of C to mathematical investigations and problem solving. **ix.** Ability to work independently and do in-depth study of various notions of mathematics. **x.** Ability to think, acquire knowledge and skills through logical reasoning and to inculcate the habit of self learning.

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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives :** To provide methods for studying the evolution of stars, ocean currents, weather patterns, plate tectonics and even blood circulation. Some important technological applications of fluid dynamics include rocket engines, wind turbines, oil pipelines and air conditioning systems. **Expected Outcomes:** ▪ The student will understand stress-strain relationship in fluids, classify their behavior and also establish force balance in static systems. Further they would develop dimensionless groups
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.	that help in scale-up and scale-down of fluid flow systems. ▪ Students will be able to apply Bernouli principle and compute pressure drop in flow systems of different configurations ▪ Students will compute power requirement in fixed bed system and determine minimum fluidization velocity in fluidized bed ▪ Students will be able to describe function of flow metering devices and apply Bernoulli equation to determine the performance of flow-metering devices ▪ Students will be able to determine and analyze the performance aspects of fluid machinery specifically for centrifugal pump and reciprocating pump .
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

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives :** To concerns with the mathematical description of shape for use in computer graphics, manufacturing, or analysis. To draws upon the fields of geometry, computer graphics, numerical analysis, approximation theory, data structures and computer algebra
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.	**Expected Outcomes:** Bézier curves can be used in robotics to produce trajectories of an end-effector due to the virtue of the control polygon's ability to give a clear indication of whether the path is colliding with any nearby obstacle or object.[30] Furthermore, joint space trajectories can be accurately differentiated using Bézier curves. Consequently, the derivatives of joint space trajectories are used in the calculation of the dynamics and control effort (torque profiles) of the robotic manipulator.[30]
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	The unique factorization theorem, congruences.	**Objectives :** • To illustrate how general methods of analysis can be used to obtain results about integers and prime numbers • To investigate the distribution of prime numbers • To consolidate earlier knowledge of analysis through applications
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.	**Expected Outcomes:** The number theory helps discover interesting relationships between different sorts of numbers and to prove that these are true . Number Theory is partly experimental and partly theoretical. Experimental part leads to questions and suggests ways to answer them. The best known application of number theory is public key cryptography, such as the RSA algorithm. Public key cryptography in turn enables many technologies we take for granted, such as the ability to make secure online transactions. ... Random and quasi-random number generation.
Unit-IV	Chebyshev theorem on the distribution of prime numbers.	
Unit-V	Weyl's theorems on uniform distribution & Kronecker's theorem.	

<u>Book Recommended</u>

K. Chandrasekharan : Introduction to Analytic Number Theory, Springer-Verlag, 1968.
Chapters: 1,2,3,4,6,7,8.

(Fourier Analysis-I)
(Marks-100)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Trigonmetric series and fourier series.	**Objectives :** • **To know** a particular method which is used to define the periodic waveform in the best way and that too in terms of the basic trigonometric functions such as sine and cosine. • TO represent periodic functions using Fourier series **Expected Outcomes:** • Get an idea of power series method to solve differential equations Familiar with Legendre equation and Legendre polynomial • Understands laplace transforms • Learns complex numbers and their properties
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	• Learns about analytic function and how to check analyticity based on Cauchy – Riemann equation To evaluate complex integral by various methods • Knowing basic difference between real and complex calculus

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)

Paper-I	Content	Objectives and Expected Outcomes

Unit-I	Fractals examples : The triadic cantor dust, the sierpinski gasket, A space of strings.	**Objectives :**
		Fractal geometry is a tool used to characterize irregularly shaped and complex figures. It can be used not only to generate biological structures (e.g., the human renal artery tree), but also to derive parameters such as the fractal dimension in order to quantify the shapes of structures.
		Expected Outcomes:
		Students will able to
		• Know classical fractals.
		  • express the concept of self-similarity in nature.
		  • express the classical fractals like Sierpinski triangle, Koch curve.
		• Define the notion of YFS and give new examples of attractor.
		  • Explain the notion of attractor.
		  • Create new attractor examples.
		• Define the notions of Countable IFS and Graph-diected IFS and give new example as an attractor of them.
		  • Define the notions of CIFS and GIFS.
		  • Create new attractor examples for CIFS and GIFS.
		• Able to define Hausdorff metric and calculate Hausdorff distance between two sets.
		• Able to obtain fractals using a computer program.

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Design and analyis Techniques(i) : Introduction growth of function, Recurrence, Divide and Conquer	**Objectives:** The objective of the course is to teach techniques for effective problem solving in computing. The use of different paradigms of problem solving will be used to illustrate clever and efficient ways to solve a given problem. In each case emphasis will be placed on rigorously proving correctness of the algorithm. **Expected Outcomes:** students will demonstrate: - The abilities (1) to apply knowledge of computing and mathematics to algorithm design; (2) to analyze a problem and identify the computing requirements appropriate for its solution; (3) to design, implement, and evaluate an algorithm to meet desired needs; and (4) to apply mathematical foundations, algorithmic principles, and computer science theory to the modeling and design of computer-based systems in a way that demonstrates comprehension of the trade-offs involved in design choices. - An ability to apply design and development principles in the construction of software systems of varying complexity. - An ability to function effectively as a member of a team in order to accomplish a common goal. - Recognition of the need for and an ability to engage in continuing professional development. - An ability to use current techniques, skills, and tools necessary for computing practice
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..	

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

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%)

<u>Book Recommended</u>

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)

<table>
<tr><th>Paper-I</th><th>Content</th><th>Objectives and Expected Outcomes</th></tr>
<tr><td>Unit-I</td><td>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.</td><td rowspan="4">Objectives :
To store image data in as little space as possible in a file. ... Using a wavelet transform, the wavelet compression methods are adequate for representing transients, such as percussion sounds in audio, or high-frequency components in two-dimensional images, for example an image of stars on a night sky.
Expected Outcomes:

Student will get a mathematical introduction to the wavelet theory: Continuous and discrete wavelet transform, wavelet base and wavelet packages, wavelets and singular integrals. Applications related for example to signal analysis, image processing, numerical analysis will also be discussed. 2. Skills The students should be able to handle problems and conduct researches related to theoretical and applied problems related to wavelet theory, and, more generally, time-frequency analysis. In particular techniques connected with signal and image processing, data banks should be studied. 3. Competence The students should be able to participate in scientific</td></tr>
<tr><td>Unit-II</td><td>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.</td></tr>
<tr><td>Unit-III</td><td>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.</td></tr>
<tr><td>Unit-IV</td><td>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.</td></tr>
</table>

Unit-V	Motivation-From MRA to a Discrete Transform, The Quadrature Mirror Filter Conditions, The Discrete Wavelet Transform(DWT), Scaling Functions from Scaling Sequences.	discussions and conduct researches on high international level in wavelet theory and its applications as well as to collaborate in joint interdisciplinary researches.

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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)

Paper-I	Content	Objectives and Expected Outcomes
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 and Lasso , Linear Discriminant Analysis , Logistic regression .	**Objectives :** • to explore, sort and analyze megadata from various sources in order to take advantage of them and reach conclusions to optimize business processes or for decision support. **Expected Outcomes:** • Students will develop relevant programming abilities. • Students will demonstrate proficiency with statistical analysis of data. • Students will develop the ability to build and assess data-based models. • Students will execute statistical analyses with professional statistical software. • Students will demonstrate skill in data management. • Students will apply data science concepts and methods to solve problems in real-world contexts and
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)	will communicate these solutions effectively
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 discriminant 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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Solution of Linear system of equations, Direct methods, Gauss elimination method, Pivoting strategy, Matrix factorization techniques crout, Dolittle and Cholesky's method	**Objectives :** To design and analysis of techniques to give approximate but accurate solutions to hard problems, the variety of which is suggested by the following: Advanced numerical methods are essential in making numerical weather prediction feasible. **Expected Outcomes:** Student can Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations. Analyse and evaluate the accuracy of common numerical methods.
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Finite fields and Quadratic residues, Knapsack problem in public key cryptography, Zero knowledge protocols.	**Objectives :** • To discover interesting and unexpected rela- tionships between different sorts of numbers and to prove that these relationships are true. • To understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic.
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.	• To understand fundamental algorithms for symmetric key and public-key cryptography. • To understand the number-theoretic foundations of modern cryptography and the principles behind their security. **Expected Outcomes:** • To implement and analyze cryptographic and number-theoretic algorithms. • To be able to use Maple to explore mathematical concepts and theorems.
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Signed measure, Hahn decomposition theorem, mutually singular measures, Raydon-Nikodim theorem, Lebesgue decomposition , Riesz representation theorem, Extension theorem(Caratheodary).	**Objectives :** To study how signed measures are essentially got by taking the difference of two measures. The notion of absolute continuity is introduces and the famous Radon-Nikodym theorem is proved for σ-finite signed measures. The notion of singularity, of one measure with respect to another. **Expected Outcomes:**
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.	

		Students taking this course will develop an appreciation of the basic concepts of measure theory. These methods will be useful for further study in a range of other fields, e.g. Stochastic calculus, Quantum Theory and Harmonic analysis. The above outcomes are related to the development of the Science Faculty Graduate Attributes, in particular: 1.Research, inquiry and analytical thinking abilities, 4. Communication, 6. Information literacy
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, Poisson-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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives:** The objective of CFD is to model the continuous fluids with Partial Differential Equations (PDEs) and discretize PDEs into an algebra problem (Taylor series), solve it, validate it and achieve simulation based design. **Expected Outcomes:** The students will train the numerical solution of model problems by developing and testing own MATLAB programs. The students will learn to assess the quality of numerical results and the efficiency of numerical methods for basic fluid flow model problems. Knowledge: After completion of this course, the student will have knowledge
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.	on: - Classification of the basic equations of fluid dynamics. - Basic space and time discretization methods. - Numerical solution of advection, diffusion and stationary problems. - Numerical solution of conservation laws. - Analysis of accuracy and stability of finite difference methods for model equations. Skills: After completion of this course, the student will have skills on: - Practical use and programming of numerical methods in fluid dynamics. - Checking and assessing the accuracy of numerical results. - Assessing the efficiency of numerical methods. - Consistency analysis and von Neumann stability analysis of finite difference methods. - Choosing appropriate boundary conditions for model problems. General competence: After completion of this course, the student will have general competence on: - Numerical solution of model problems in fluid dynamics. - Checking and assessing basic numerical methods for fluid flow problems.
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)

Paper-I	Content	Objectives and Expected Outcomes

Unit-I	Turing Machine, Variants of Turing Machine.	**Objectives:**
		
		The major objective is to develop methods by which computer scientists can describe and analyze the dynamic behavior of discrete systems, in which signals are sampled periodically.
		
		Expected Outcomes:
		
		Students can
		
		• Define machine models formally.
		  • Defines finite automata.
		  • Defines regular languages.
		  • Defines turing machines.
		• Synthesizes finite automata with specific properties.
		  • Applies transformation between multiple representations of finite automata.
		  • Explains the difference between deterministic finite automata and non deterministic finite automata.

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.	

		• Explains the relationship between deterministic finite automata and regular languages. • Proves the undecidability or complexity of a variety of problems • Uses pigeon-holing arguments and closure properties to prove particular problems cannot be solved by finite automata. • Illustrates concrete examples of undecidable problems from different fields. • Defines and explains the significance of the "P = NP?" question and NP-completeness. • Illustrates concrete examples of decidable problems that are known to be unsolvable in polynomial time.

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Equivalence principle and measurement of the gravitational field, How mass energy	**Objectives :** Learning Objectives Einstein's two postulates in his theory of special relativity: The principle of relativity. (Same principle as in Newtonian physics) The constancy of the speed of light. (Breaks from Newtonian physics) υ Using Einstein's two postulates, derive space and time transformations between inertial reference frames (derived transformations are same as the Lorentz transformations):

	generated curvature.	**Expected Outcomes:** After successfully completed course, student will be able to 1. Describe the basic concepts of the theory of relativity. 2. Differentiate facts from wrong general public ideas about the theory of relativity. 3. Discuss postulates of the special theory of relativity and their consequences. 4. Explain the twin paradox. 5. Explain the concept of invariance. 6. Explain the concept of space-time. 7. Discuss the equivalence principle. 8. Describe gravity as space-time curvature. 9. Describe the basic characteristics of black holes and gravity waves. 10. Describe general theory of relativity as mathematical basis of physical cosmology.
Unit-II	Weak Gravitational Field.	
Unit-III	Spherical stars.	
Unit-IV	Motion in Schwarzchild Geometry.	
Unit-V	Gravitational aspect of black holes.	

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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Abel's method, Tauberian theorem.	**Objectives :** To study of linear spaces endowed with some kinds of limit-related structures like topology, norm, inner product etc. and the operators or functions acting upon these spaces.To know a linear space of functions defined on a certain set with respect to pointwise addition and scalar multiplication **Expected Outcomes:** After studying this course, student should be able to: • understand the Euclidean distance function on R^n and appreciate its properties, and state and use the Triangle and Reverse Triangle Inequalities for the Euclidean distance function on R^n
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.	• explain the definition of continuity for functions from R^n to R^m and determine whether a given function from R^n to R^m is continuous • explain the geometric meaning of each of the metric space properties (M1) – (M3) and be able to verify whether a given distance function is a metric • distinguish between open and closed balls in a metric space and be able to determine them for given metric spaces • define convergence for sequences in a metric space and determine whether a given sequence in a metric space converges state the definition of continuity of a function between two metric spaces
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)

Paper-I	Content	Objectives and Expected Outcomes
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.	**Objectives:** Classification of second order equations O Finite-difference approximations O Elliptic equations to partial derivatives O Solution of Laplace equation O Solution of Poisson's equation O Solution of elliptic equations by relaxation O Parabolic equations method O Solution of one-dimensional heat equation O Solution of two-dimensional heat equation O Hyperbolic equations O Solution of wave equation **Expected Outcomes:** On successful completion of this course students will be able to: 1. use knowledge of partial differential equations (PDEs), modelling, the general structure of solutions, and analytic and numerical methods for solutions. 2. formulate physical problems as PDEs using conservation laws.
Unit-II	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-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.	3. understand analogies between mathematical descriptions of different (wave) phenomena in physics and engineering. 4. classify PDEs, apply analytical methods, and physically interpret the solutions. 5. solve practical PDE problems with finite difference methods, implemented in code, and analyse the consistency, stability and convergence properties of such numerical methods. 6. interpret solutions in a physical context, such as identifying travelling waves, standing waves, and shock waves.
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)

Paper-I	Content	Objectives and Expected Outcomes
Unit-I	Basic facts, bounded operators, a commutative theorem.	**Objectives :** To study the study of linear operators on function spaces, beginning with differential operators and integral operators. **Expected Outcomes:** i. Capability of demonstrating comprehensive knowledge of mathematics and understanding of one or more disciplines of mathematics.
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.	**ii.** Ability to communicate various concepts of mathematics effectively using examples and their geometrical visualizations. **iii.** Ability to use mathematics as a precise language of communication in other branches of human knowledge. **iv.** Ability to employ critical thinking in understanding the concepts in every area of mathematics. **v.** Ability to analyze the results and apply them in various problems appearing in different branches of mathematics. **vi.** Ability to provide new solutions using the domain knowledge of mathematics by framing appropriate questions relating to the concepts in various fields of mathematics. **vii.** To know about the advances in various branches of mathematics. **viii.** Capability to understand and apply the programming concepts of C to mathematical investigations and problem solving. **ix.** Ability to work independently and do in-depth study of various notions of mathematics. **x.** Ability to think, acquire knowledge and skills through logical reasoning and to inculcate the habit of self learning.
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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	Exotic and Path Dependent Options (Introduction, Barrier Options, Asian Options, Lookback Options, Computational Schemes), Options on stock indices, Currencies and futures.	**Objectives :** To know practical numerical methods rather than mathematical proofs and focuses on techniques that apply directly to economic analyses. It is an interdisciplinary field between
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	mathematical finance and numerical methods. **Expected Outcomes:** Students will be able to: ▪ Analyze and simulate time series data using a stochastic process. ▪ Implement a portfolio optimization algorithm based on Modern Portfolio Theory. ▪ Demonstrate an in-depth knowledge of: • Bond Valuation Models. • Stock Valuation Models. • Options Valuation Models.
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)

Paper-II	**Content**	**Objectives and Expected Outcomes**
Unit-I	Extensions and imbedding	**Objectives :**

	theorems in Soboleve space.	Student will develop i. Capability of demonstrating comprehensive knowledge of mathematics and understanding of one or more disciplines of mathematics. **ii.** Ability to communicate various concepts of mathematics effectively using examples and their geometrical visualizations. **iii.** Ability to use mathematics as a precise language of communication in other branches of human knowledge. **iv.** Ability to employ critical thinking in understanding the concepts in every area of mathematics. **v.** Ability to analyze the results and apply them in various problems appearing in different branches of mathematics. **Expected Outcomes:** i. Ability to provide new solutions using the domain knowledge of mathematics by framing appropriate questions relating to the concepts in various fields of mathematics. **ii.** To know about the advances in various branches of mathematics. **iii.** Capability to understand and apply the programming concepts of C to mathematical investigations and problem solving. **iv.** Ability to work independently and do in-depth study of various notions of mathematics. **v.** Ability to think, acquire knowledge and skills through logical reasoning and to inculcate the habit of self learning.
Unit-II	Compactness theorems.	
Unit-III	Dual spaces, Fractional order spaces and frace theorem.	
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)

Paper-II	**Content**	**Objectives and Expected Outcomes**
Unit-I	Flow in the tubes of uniform cross section, flow between two concentric rotating cylinders.	**Objectives :**

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.	To introduce and explain fundamentals of Fluid Dynamics, which is used in the applications of Aerodynamics, Hydraulics, Marine Engineering, Gas dynamics etc. 2. To give fundamental knowledge of fluid, its properties and behavior under various conditions of internal and external flows.
Unit-III	Theory of very slow motions, Stokes equation, Oseen's equations, flow past a sphere, Lubrication theory.	**Expected Outcomes:**
Unit-IV	Theory of laminar boundary layers, Two dimensional boundary layer equations for flow over a plane wall, Blasious-Topfer solutions.	Fluid dynamics provides methods for studying the evolution of stars, ocean currents, weather patterns, plate tectonics and even blood circulation. Some important technological applications of fluid dynamics include rocket engines, wind turbines, oil pipelines and air conditioning systems.
Unit-V	Flow past porous flat plate and porous circular cylinder, Karman Karman - Pohlausen method, Energy integral equation.	

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

Paper-II	Content	Objectives and Expected Outcomes
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.	**Objectives :** To use Bezier curves in computer graphics to produce curves which appear reasonably

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.	smooth at all scales (as opposed to polygonal lines, which will not scale nicely). Mathematically, they are a special case of cubic Hermite interpolation (whereas polygonal lines use linear interpolation).
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.	**Expected Outcomes:** Bézier curves can be used in robotics to produce trajectories of an end-effector due to the virtue of the control polygon's ability to give a clear indication of whether the path is colliding with any nearby obstacle or object. Furthermore, joint space trajectories can be accurately differentiated using Bézier curves. Consequently, the derivatives of joint space trajectories are used in the calculation of the dynamics and control effort (torque profiles) of the robotic manipulator.
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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	Minkowski's theorem on lattice points on convex sets.	**Objectives :** Analytic number theory aims to **study number theory by using analytic tools** (inequalities, limits, calculus, etc). In this course we will mainly focus on studying the distribution of prime numbers by using analysis. **Expected Outcomes:** student should be able to: ▪ define fundamental objects appearing in the course such as the Gamma function, Theta functions, the Riemann Zeta function, Dirichlet L-functions, Dirichlet characters, and describe the most important properties of these; ▪ use the methods from the proof of the Prime Number Theorem, such as summation by parts, integration by parts, the Mellin transform and its inverse, and simple Tauberian Theorems; ▪ give an account of deductions and proofs of important results in the course such as Dirichlet's Class Number Formula, Jacobi's Theorems on the representation of integers as sums of squares, and apply such results in relevant situations.
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.	

<u>Books Recommended</u>

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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	Cesaro summability of fourier series and its consequences.	**Objectives :** To study how general functions can be decomposed into trigonometric or exponential functions with definite frequencies. There are two types of Fourier expansions: • Fourier series: If a (reasonably well-behaved) function is periodic, then it can be written as a discrete sum of trigonometric or exponential functions with specific frequencies. • Fourier transform: A general function that isn't necessarily periodic (but that is still reasonably well-behaved) can be written as a continuous integral of trigonometric or exponential functions with a continuum of possible frequencies. **Expected Outcomes:** students will be able to: 1. In-depth knowledge of Fourier analysis and its applications to problems in physics and electrical engineering. 2. An ability to communicate reasoned arguments of a mathematical nature in both written and oral form. 3. An ability to read and construct rigorous mathematical arguments.
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.	

<u>Book Recommended</u>
R.E.Edward : Fourier series, A modern introduction. Chapters : 6,7,8,9,10.

<u>Data Science II++</u>

(Marks-100)

Paper-II	Content	Objectives and Expected Outcomes

<table>
<tr><td>Unit-I</td><td>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.</td><td rowspan="5">Objectives :
To empowers better business decision-making through interpreting, modeling, and deployment. This helps in visualizing data that is understandable for business stakeholders to build future roadmaps and trajectories.
Expected Outcomes:
Students will develop relevant programming abilities.
Students will demonstrate proficiency with statistical analysis of data.
Students will develop the ability to build and assess data-based models.
Students will execute statistical analyses with professional statistical software.</td></tr>
<tr><td>Unit-II</td><td>Reinforcement learning and control- MDP, Bellman equations, value iterations and policy iteration, Linear quadratic regulation, LQG, Q-learningValue function approximation, Policysearch, Reinforce POMDPs</td></tr>
<tr><td>Unit-III</td><td>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.</td></tr>
<tr><td>Unit-IV</td><td>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</td></tr>
<tr><td>Unit-V</td><td>Practical Methodology: Performance Metrics, Default Baseline Models, Determining Whether to Gather More Data, Selecting Hyperparameters, Debugging Strategies,</td></tr>
</table>

	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 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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	Self similarity : Ratio lists, String models, Graph self similarity.	Objectives: To quantitatively describe self-similar or self-affined landscape shapes and facilitate the complex/ holistic study of natural objects in various scales. **They also allow one to compare the values of analyses from different scales** Expected Outcomes:
Unit-II	Measures for strings, Hausdorff measure, Examples, Self similarity.	Students will
Unit-III	Graph self similarity,	• Knows classical fractals.

	Other fractional dimensions.	• express the concept of self-similarity in nature. • express the classical fractals like Sierpinski triangle, Koch curve.
Unit-IV	A three demensional dragon overlap.	• Define the notion of YFS and give new examples of attractor. • Explain the notion of attractor. • Create new attractor examples.
Unit-V	Self affine sets, Other examples.	• Define the notions of Countable IFS and Graph-diected IFS and give new example as an attractor of them. • Define the notions of CIFS and GIFS. • Create new attractor examples for CIFS and GIFS.

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)

Paper-II	Content	Objectives and Expected Outcomes
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.	**Objectives :** Design and Analysis of Algorithm is very important for designing algorithm to solve different types of problems in the branch of computer science and information technology. : **Expected Outcomes** : Students who have completed this course should be able to 1. Apply design principles and concepts to algorithm design (c)
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.	2. Have the mathematical foundation in analysis of algorithms (a, j) 3. Understand different algorithmic design strategies (j) 4. Analyze the efficiency of algorithms using time and space complexity theory (b) Assessment methods of all of the above: quizzes, exams, assignments
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%)

<u>Book Recommended</u>

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)

Paper-II	Content	Objectives and Expected Outcomes
Unit-I	Vanishing Moments, Equivalent Conditions for Vanishing Moments, The Daubechies Wavelets, Image Analysis with Smooth Wavelets	**Objectives :** To overcome the disadvantage of STFT since CWT uses a windowing technique with variable sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. **Expected Outcomes:** Student can Recognize the key limitations of the Fourier transform and the STFT, which provides a
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.	fixed temporal resolution for all frequency components. • Understand the multi-resolution logic behind wavelet analysis, which provides finer temporal (spatial) resolution for higher frequency components, and coarser temporal (spatial) resolution for lower frequency components.
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-Verlag (1999).