DAYALBAGH EDUCATIONAL INSTITUTE
FACULTY OF SCIENCE
DEPARTMENT OF MATHEMATICS

Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
MDC	**MAH 101**	**Mathematical logic & Computational techniques**	**2**	2

Introduction:

This course provides foundational knowledge in *Mathematical Logic and Fast Computational Methods*, essential for students looking to enhance their problem-solving efficiency and logical reasoning. The course covers fundamental topics in propositional logic, alongside a range of fast computational techniques for arithmetic operations and algebraic equations. Students will learn to apply these methods with accuracy and speed, building practical skills that are valuable for advanced mathematical studies and real-world applications..

Objectives:

1. To build a foundational understanding of mathematical logic, enabling students to analyze and construct logical statements and evaluate their truth values.
2. To introduce and develop fast computational methods for arithmetic operations, improving speed and accuracy in problem-solving.
3. To equip students with techniques for quick and efficient multiplication, division, and solving of equations, applicable to a range of mathematical problems.
4. To enhance students' reasoning abilities, helping them understand the principles behind computational shortcuts and apply them effectively.
5. To foster confidence and fluency in basic algebraic and arithmetic calculations, preparing students for advanced mathematical studies and practical applications. To develop a sound understanding of fundamental concepts in linear algebra.

Course Outcomes (CO):

This course is aimed at
CO1: Develop a foundational understanding of mathematical logic, analyze propositional formulas, and evaluate truth tables and logical equivalences.
CO2: Master quick methods for multiplication, squares, and square roots, with a focus on reasoning and efficiency.
CO3: Learn quick divisibility checks and fast division methods, enhancing problem-solving speed and accuracy..
CO4: Apply fast computational techniques to solve linear and simultaneous equations efficiently, improving algebraic problem-solving skills.
CO5: Understand and apply fast methods to solve quadratic equations, enhancing algebraic speed and accuracy.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Mathematical Logic: Propositions, Connectives, Propositional formulae, Truth tables, Equivalence of formulae, Tautological implications	CO1	
2.	Fast Computational Methods (with reasoning) for Multiplication: vertical and crosswise for multiplication of two digit, three and four digit numbers, special multiplication (by 11, 12, 111, 101 etc.), Squares, Square root	CO2	
3.	Divisibility, Fast Computational Methods (with reasoning) for Division by 9, 8 etc., straight division method	CO3	
4.	Fast Computational Methods (with reasoning) to solve various forms of Linear Equations and Simultaneous Equations	CO4	

5.	Fast Computational Methods (with reasoning) to solve various forms of Quadratic Equations		CO5	
Text Books and Reference Books:				
S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Discrete Mathematics and Its Applications	Kenneth H. Rosen	7th Edition, 2011, McGraw-Hill,	USA
2.	Vedic Mathematics	Bharati Krishna Tirthaji	Revised Edition, 1992, Motilal Banarsidass	India

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
MDC	**MAH 102**	Real Analysis	**2**	**2**

Introduction:

This course introduces foundational calculus concepts, beginning with functions, limits, and continuity, and advancing to differentiation and integration techniques. Students will learn to analyze functions, identify maxima and minima, and apply integration rules, building a strong base for advanced mathematics and real-world applications.

Objectives:

1. To introduce fundamental concepts of functions, including composition and graphing, as a basis for calculus.
2. To develop an understanding of limits and continuity, focusing on the ϵ-δ definition for rigorous analysis of real-valued functions.
3. To teach differentiation techniques and rules, enabling students to compute derivatives and analyze function behavior.
4. To apply calculus in identifying increasing/decreasing intervals and finding local maxima and minima.
5. To provide a foundational understanding of integration, covering definite and indefinite integrals, and to introduce the fundamental theorem of calculus for practical applications.

Course Outcomes (CO):

This course is aimed at

CO1: Understanding the foundational concepts of functions, including modulus, composition, and graphing, and apply these concepts to represent and analyze functions graphically.

CO2: Grasp the formal ϵ-δ definition of limits and assess the continuity of real-valued functions of one variable, developing analytical skills for understanding function behavior at points.

CO3: Develop proficiency in differentiation techniques, including the sum, product, quotient, and chain rules, to compute derivatives effectively for various functions.

CO4: Apply differentiation to analyze the monotonicity of functions, identifying intervals of increase and decrease, and determine local maxima and minima for optimization problems.

CO5: Gain a foundational understanding of integration, including both definite (via Riemannian sums) and indefinite integrals, and apply the fundamental theorem of calculus and integration rules in practical contexts.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Introduction to Functions, Modulus, Composition of functions, Graphs	CO1	Understanding Applying
2.	Limit ($\epsilon - \delta$ concept), Continuity of real-valued functions of one variable	CO2	Understanding Analyzing
3.	Differentiation, Sum Rule, Product Rule, Quotient Rule, Chain Rule	CO3	Applying Analyzing
4.	Increasing and decreasing functions, Maxima, Minima	CO4	Applying Analyzing Evaluating
5.	Integration: Definite integral (Riemannian sum concept), indefinite integral, fundamental theorem of integral calculus (statement only), Sum Rule, Product Rule, its application in finding definite integral.	CO5	Understanding Applying

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
	APPLIED MATHEMATICS FOR BUSINESS, ECONOMICS AND SOCIAL SCIENCES	Frank S Budnick	4th, 2017, Mc Graw Hill Education	

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM 101**	Statistics I	**4**	**4**

Introduction:

This course, "Statistics," is designed to provide students with a comprehensive foundation in both descriptive and inferential statistics. Through a combination of theoretical concepts and practical applications, students will learn to analyze and interpret data effectively, employing a range of statistical techniques and tools.

Objectives:

1. To develop a solid understanding of fundamental statistical concepts, including measures of central tendency, dispersion, and probability.
2. To enhance students' ability to reason statistically, allowing them to interpret data critically and draw valid conclusions from statistical analyses.
3. To provide a thorough grounding in probability theory and its applications, enabling students to tackle problems involving uncertainty and variability.
4. To equip students with the skills to differentiate between discrete and continuous random variables, and to understand the characteristics of various probability distributions.
5. To develop proficiency in applying statistical methods and techniques to solve real-world problems, using appropriate software tools where applicable.
6. To prepare students for advanced courses in statistics and related fields by providing a robust foundation in statistical theory and practice.

Course Outcomes (CO):

This course is aimed at
CO1: Understand and apply measures of dispersion, including range, mean deviation, standard deviation, coefficient of variation, quartile deviation, moments, and measures of skewness and kurtosis to describe data sets.

CO2: Grasp important concepts of probability, including mathematical probability, statistical probability, and the axiomatic approach, and apply probability theorems such as addition and multiplication theorems to solve problems.

CO3: Identify and work with random variables, differentiating between discrete and continuous types, and apply probability mass functions and probability density functions to compute expected values, variances, and covariances.

CO4: Analyze discrete probability distributions, including Bernoulli, Binomial, Poisson, Negative Binomial, Geometric, and Hypergeometric distributions, and compute their properties and moment-generating functions.

CO5: Explore continuous probability distributions, specifically the uniform and normal distributions, and apply their probability density functions and moment-generating functions to practical scenarios.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Measures of Dispersion, Range, Mean Deviation, Standard Deviation, Coefficient of Variation, Quartile Deviation, Moments, Measures of Skewness and Kurtosis.	CO1	Remembering Understanding Applying
2.	Important concepts of probability, Mathematical Probability, Statistical Probability, Axiomatic Approach to Probability, Addition Theorem of Probability, Conditional Probability, Multiplication Theorem of Probability, Independent Events, Multiplication Theorem of Probability for independent events, Pairwise Independent Events, Total Probability Rule, Bayes' Theorem.	CO2	Remembering Understanding Applying
3.	Random Variables: Discrete and Continuous, Probability mass function, Probability Density Function, Distribution Function for Discrete and Continuous Random Variables. Mathematical Expectation or Expected Value of a Random Variable, Expected Value of Function of Random Variable, Properties of Expectation, Mean, Variance and Covariance of a random variable, Means and Variances of Linear Combination of Random Variables.	CO3	Remembering Understanding Applying

4.	Discrete Probability Distributions: Probability Function and Properties of Bernaulli, Binomial, Poisson, Negative Binomial, Geometric and Hypergeometric distributions and their Moment Generating Functions	CO4	Remembering Understanding Applying
5.	Continuous Probability Distributions: Probability Density Functions of Rectangular (Uniform) Distribution, Normal Distribution and their Moment Generating Functions.	CO5	Remembering Understanding Applying

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Mathematical statistics	John E. Freund	Pearson Education India	
2.	PROBABILITY & STATISTICS FOR ENGINEERS & SCIENTISTS	Walpole & Myers	Ninth, Pearson	
3.	FUNDAMENTALS OF MATHEMATICAL STATISTICS	S. C. Gupta, V. K. Kapoor	Sultan chand and sons	
4.	PROBABILITY AND STATISTICS FOR ENGINEERS AND SCIENTISTS	Sheldon Ross	Amsterdam Elsevier	

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major /Minor	**MAM 102**	**Discrete Mathematics**	**4**	**4**

Introduction:

This course explores fundamental concepts of Discrete Mathematics and their applications in various fields, enhancing students' problem-solving abilities and providing a foundation for future studies in mathematics, computer science, engineering, and related fields.

Objectives:

1. To demonstrate the relevance of mathematical concepts in real-world applications across multiple disciplines.
2. To develop critical thinking and reasoning through mathematical modeling.
3. To enhance problem-solving skills using discrete mathematical tools.
4. To apply mathematical principles to solve practical and theoretical problems.

Course Outcomes (CO):

This course is aimed at

• CO1: Understand and apply Mathematical Logic and Graph Theory in computer science and related fields.
• CO2: Explore Set Theory, Relations, and Number Theory in mathematical proofs and practical applications.
• CO3: Utilize Mathematical Induction, Number Theory, and Combinatorics to solve problems in theoretical mathematics and computer science.
• CO4: Understand and solve problems related to Combinatorics, including permutations, combinations, and the binomial theorem.
• CO5: Apply methods such as generating functions and recurrence relations to solve real-world problems in computer science and engineering.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Mathematical Logic: Propositions, Connectives, Propositional Formulae, Truth Tables, Equivalence of Formulas, Tautological Implications, Normal Forms (Disjunctive and Conjunctive), Theory of Inference for Propositional Calculus, Predicate Calculus, Proof Methods.	- Understand basic concepts of Mathematical Logic and Proof Methods. - Apply propositional and predicate calculus to derive and validate logical statements.	Understanding, Applying
2.	Set theory and relations: Russell's paradox, arbitrary union/intersection, equivalence relation, partition of a set, composition and inverse of a function, finite/countable/uncountable sets, axiom of choice, partially ordered sets, lattices, zorn's lemma, well ordering principle.	- Understand advanced concepts in Set Theory and Relations. - Apply set-theoretic concepts to mathematical proofs and real-world problems.	Understanding, Applying, Analyzing
3.	Number Theory and Mathematical Induction: Principles of Mathematical Induction, Division Algorithm, Prime Numbers, Euclid's Lemma, GCD, Euclidean Algorithm, Fundamental Theorem of Arithmetic, Congruence, Integers Modulo	- Master Mathematical Induction and use it to prove theorems. - Apply number-theoretic methods to solve problems involving divisibility and modular arithmetic.	Understanding, Applying, Analyzing
4.	Combinatorics: Fundamental Laws of Counting, Pigeonhole Principle, Permutations, Combinations, Binomial Theorem, Multinomial Theorem, Principle of Exclusion and Inclusion, Derangements, Permutations with Forbidden Positions.	- Solve combinatorial problems using counting principles and the binomial and multinomial theorems. - Apply the inclusion-exclusion principle to solve complex counting problems.	Understanding, Applying, Analyzing

5.	Discrete Functions and Recurrence Relations: Discrete Numeric Functions, Generating Functions, Recurrence Relations.	- Understand and solve recurrence relations in practical scenarios. - Use generating functions to solve counting and combinatorial problems.	Understanding, Applying, Analyzing

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Discrete Mathematics and Its Applications	Kenneth H. Rosen	7th Edition, 2012, McGraw-Hill Education	USA
2.	Discrete and Combinatorial Mathematics: An Applied Introduction	Ralph P. Grimaldi	5th Edition, 2003, Pearson Addison Wesley	USA
3.	Applied Mathematics for Engineers and Physicists	Louis A. Pipes, Lawrence R. Harvill	3rd Edition, 2014, Dover Publications	India
4.	Mathematics for Computer Science	Eric Lehman, F. Thomson Leighton, Albert R. Meyer	2017, 12th Media Services	India

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS Major/Minor	**MAM 201**	Analysis I (Calculus of One Variable)	4	**4**

Introduction:

This course builds foundational concepts in the analysis of functions of one variable. It emphasizes the rigorous understanding of calculus, providing tools for applications in mathematics and related fields.

Objectives:

1. To introduce students to the real number system and its properties.
2. To develop skills in understanding sequences, series, and their convergence.
3. To enable students to understand the concepts of limits, continuity, and differentiability rigorously.
4. To apply calculus techniques in solving real-world problems and graphing.

Course Outcomes (CO):

CO1: Develop an understanding of the real number system, including completeness, density theorems, and related properties.
CO2: Analyze sequences and series, test for convergence, and explore the representation of real numbers.
CO3: Learn the concepts of limits, continuity, and types of discontinuities, applying theorems like the Intermediate Value Theorem.
CO4: Apply differentiation techniques to real functions, including higher-order derivatives, and theorems like Rolle's and Mean Value.
CO5: Solve problems involving maxima, minima, concavity, and graphing functions in Cartesian and polar coordinates.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Real Number System, Completeness Property, Archimedean Property, Rational/Irrational Density Theorems, n-th roots.	CO1	Understand, Apply
2.	Sequences, Limits, Monotone and Cauchy Sequences, Convergence of Series, Alternating Series, Decimal/Binary Representations, Uncountability of Real Numbers.	CO2	Understand, Apply
3.	Limits of Functions, Continuity, Types of Discontinuities, Asymptotes, Fundamental Theorems (Intermediate Value Theorem, Extreme Value Theorem).	CO3	Apply, Analyze
4.	Derivatives, Differentiation Techniques, Tangent/Normal Calculations, Higher Order Derivatives, Rolle's and Mean Value Theorems.	CO4	Apply, Analyze, Evaluate
5.	Applications of Derivatives: Indeterminate Forms, Maxima/Minima, Concavity, Inflection Points, Graphing in Cartesian/Polar Coordinates	CO5	Analyze, Create

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Calculus and Analytical Geometry	Thomas & Finney	9th Edition, 1996, Pearson	Boston, USA
. 2.	Principles of Mathematical Analysis	Walter Rudin	3rd Edition, 1976, McGraw-Hill	New York, USA
3	Introduction to Real Analysis	Robert G. Bartle & Donald R. Sherbert	4th Edition, 2011, Wiley	Hoboken, USA

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS Major/Minor	**MAM 202**	**ALGEBRA I (GROUP & RINGS)**	**4**	**4**

Introduction:

This course provides strong foundations of Abstract Algebra enabling students to understand and apply the basic concepts required for advanced studies.

Objectives:

1. Provide a sound understanding of fundamental concepts of Group and Ring Theory.
2. Develop skills to solve problems.
3. Construct and visualize rigorous proofs.
4. Develop skills to apply the concepts learned to prove various results.
5. Develop appreciation for abstraction

Course Outcomes (CO):

1. Understand groups and main examples.
2. Study foundational concepts.
3. Study group isomorphism and properties.
4. Classify groups of order upto 7.
5. Learn all automorphisms on Z_n.
6. Study ring, field and basic properties
7. Study Quotient Ring as field and ring isomorphism.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Group, Matrix groups-GL(n, R), SL(n, R), Subgroup, Cosets, Lagrange's Theorem	Understanding group, subgroup and main examples	Interpreting, explaining, implementing, differentiating
2.	Order of an Element, Cyclic Group, Fundamental Theorem of Cyclic Groups and its Applications, Normal Subgroup, Quotient Group	Study concepts of order, cyclic group and quotient group	Classifying, Implementing
3.	Group Homomorphism, Group Isomorphism, Properties, Fundamental Theorem of Group Homomorphism, Automorphism, Inner Automorphism, Aut (Z_n), Cayley's Theorem	Study group homomorphism, isomorphism and related results	Classifying, implementing
4.	Ring, Integral Domain, Field, Characteristic, Subring, Subfield, Ideal, Maximal Ideal	Studying ring and related notions	Interpreting, explaining, implementing, differentiating
5.	Quotient Ring, Quotient Ring as a Field, Homomorphism, Isomorphism, First Ring Isomorphism Theorem	Studying quotient ring as field and ring Isomorphism	Checking

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
2.	CONTEMPORARY ABSTRACT ALGEBRA	J. A. Gallian	Fourth Edition, 1999, Narosa Publishing House	New Delhi
3.	TOPICS IN ALGEBRA	I. N. Herstein	Second Edition, 2007, John Wiley & Sons	New Delhi

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM 301**	**Analysis II (Integration and Convergence)**	**4**	**4**
Introduction:				
This course focuses on advanced topics in integration, convergence of series, and elementary functions, laying groundwork for rigorous mathematical analysis and calculus applications.				
Objectives:				
• Develop a solid understanding of Riemann integration and its applications. • Study advanced techniques of integration for practical applications. • Explore convergence of sequences and series of functions. • Investigate elementary functions and special functions for real analysis.				
Course Outcomes (CO):				
• **CO1:** Comprehend Riemann integration concepts, including partitions, step functions, and fundamental calculus theorems. • **CO2:** Apply integration techniques to calculate area, volume, surface area, and arc length, and solve improper integrals. • **CO3:** Analyze convergence of power series, apply Taylor's series, and understand uniform vs. pointwise convergence. • **CO4:** Apply uniform convergence tests to sequences and series, including Weierstrass M-test and Dini's theorem. • **CO5:** Understand and differentiate elementary functions, including logarithmic, exponential, and trigonometric functions, and special functions (Beta and Gamma).				

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Riemann Integration: Partition of a Set, Step Function, Riemann Integral of a Step Function, Upper Riemann Integral, Lower Riemann Integral, Riemann Integral of a Bounded Function, Mean Value Theorem of Integral Calculus, Fundamental Theorem of Calculus.	CO1	**Remembering:** Recall definitions and theorems of Riemann integration. **Understanding:** Explain Riemann integrals and partitions. **Applying:** Use the Fundamental Theorem of Calculus to evaluate integrals.
2.	Techniques of Integration, Applications of Integration: Area, Volume, Surface Area, Length of an Arc, Improper Integrals.	CO2	**Applying:** Apply techniques of integration to solve practical problems. **Analyzing:** Analyze results in applications like area and volume.
3.	Power Series, Radius and interval of convergence, Circular, exponential functions etc as examples, Taylor's series, Uniform Convergence and Pointwise Convergence of Sequence of Functions, Cauchy Criterion for Uniform Convergence, Tests for Uniform	CO3	**Understanding:** Explain radius and interval of convergence for power series. **Applying:** Apply tests for uniform convergence. **Analyzing:** Differentiate between uniform and pointwise convergence and apply the Cauchy criterion.

	Convergence.		
4.	Uniform Convergence and Pointwise Convergence of Series of Functions, Weierstrass M test, Dini’s theorem and other tests for Uniform convergence of series. Consequences of Uniform convergence of series and sequences.	CO4	**Understanding:** Describe tests like the Weierstrass M-test. **Applying:** Apply convergence criteria to series and sequences. **Evaluating:** Assess the consequences of uniform convergence in series.
5.	Geometric and algebraic explanation of Elementary Functions, Natural Logarithms, Exponential Function, Inverse Function, Trigonometric and Inverse-Trigonometric Function, Hyperbolic Functions, their Continuity & Derivatives, Beta and Gamma Functions.	CO5	**Understanding:** Explain properties and continuity of elementary functions. **Applying:** Differentiate elementary and special functions. **Analyzing:** Analyze the behavior of special functions in calculus contexts.

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	Principles of Mathematical Analysis	Walter Rudin,	3rd Edition, 1976, McGraw-Hill Education,	USA
2.	**Introduction to Real Analysis**,	Robert G. Bartle and Donald R. Sherbert	4th Edition, Wiley,2011	USA

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS MAJOR/ MINOR	**MAM 302**	**ALGEBRA II (LINEAR ALGEBRA)**	4	**4**

Introduction:

This course provides strong foundations of Linear Algebra enabling students to understand and apply the basic concepts required for advanced studies.

Objectives:

1. Develop a sound understanding of fundamental concepts in linear algebra.
2. Provide geometric visualization.
3. Develop skills to apply the concepts learned to prove various results.
4. Develop skills to solve problems.
5. Enhance ability to apply mathematical rigour.

Course Outcomes (CO):

CO1: Understanding vector spaces and related notions, visualizing geometrically, characterizing subspaces and constructing basis for the vector spaces R^2 and R^3 over R.
CO2: Understanding linear transformations, isomorphisms and their properties, developing skills for writing proofs and applying the concepts learned.
CO3: Learning rank and nullity, association between linear transformations and matrices and methods for computation for rank.
CO4: Learning determinant of a matrix over a ring as a map and classifying it for order 2 and 3, determinant of linear transformations and matrices in block form and applications.
CO5: Visualizing and learning eigenvalues and eigenvectors, related notions and Cayley-Hamilton Theorem.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Vector Space, Subspaces, Sum of Subspaces, Linear Independence, Basis and Dimension, Co-ordinate, Change in Coordinates with Change in Basis.	Vector Space, Subspace, Basis and Dimension	Interpreting, classifying, explaining, implementing, differentiating
2.	Linear Transformation, Isomorphism, Algebra of Linear Transformations, Composition of Linear Transformations, Null Space, Range, Image of Basis, Isomorphism Between $M_3(R)$ and R^9	Linear Transformation, Isomorphism	Creating
3.	Rank and Nullity of Linear Transformations, Rank of Maps Between $P_3(x)/M_3(R)$, Rank-Nullity Theorem and its Applications, Matrix Representation of a Linear Transformation, Linear Transformation associated with a Matrix, Similarity of Matrices and Linear Transformation, Rank of Matrice	Rank-Nullity Theorem, association between linear transformations and matrices	differentiating
4.	Determinant of a Matrix over a Ring as a Map, Existence and Uniqueness of Determinant of matrices of order 2 and 3, Inverse of a Matrix over a Ring, Determinant of Matrices in Block Form, Determinant of a Linear Transformation, Right-Handed Co-ordinate System, Application to Area and Volume.	Determinant as a Map	Checking
5.	Eigen Values and Eigen Vectors of a Linear Transformation and a Matrix, Eigen Space, Characteristic Polynomial, Characteristic Polynomial and Trace, Applications of Cayley-Hamilton Theorem.	Eigen Values and Eigen Vectors, Cayley-Hamilton Theorem	Checking

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	LINEAR ALGEBRA	S. H. Friedberg, A. J. Insel and L. E. Spence	Fourth Edition, 2003, PHI Learning Private Limited	New Delhi
.	LINEAR ALGEBRA	K. Hoffman and R. Kunze	Second Edition, 2011, PHI Learning Pvt. Ltd.	New Delhi

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM 303**	**Operations Research**	**4**	**4**

Introduction:

This course provides strong foundations of Operations Research enabling students to understand and apply the basic concepts required for advanced studies.

Objectives:

1. To introduce foundational concepts in linear programming and optimization.
2. To develop problem-solving skills using various optimization and analytical methods.
3. To analyze complex decision-making processes in resource allocation, logistics, and strategic management.
4. To understand applications of Operations Research in inventory control and game theory.

Course Outcomes (CO):

This course is aimed at

1. CO1: Understand general linear programming problems, geometrical and algebraic model analyses, and apply solution methods like graphical and simplex for Linear Programming Problems (LPP).
2. CO2: Solve complex LPPs using advanced techniques (Two-phase simplex, Big-M method), understand the concept of duality, and apply duality theorems and the dual-simplex method.
3. CO3: Conduct post-optimality analysis and solve specific optimization problems (Transportation, Assignment, and Travelling-salesman problems).
4. CO4: Apply principles of Game Theory, including maximin and minimax, saddle point solutions, mixed strategies, and dominance principles for decision-making in competitive environments.
5. CO5: Understand and apply various inventory models, including Economic Order Quantity (EOQ) for deterministic and stochastic inventory scenarios.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Introduction to general linear programming problems, Geometrical and algebraic analysis of models/solutions. Definitions and Theorems, solution of LPP-graphical, simplex method.	CO1	• **Understanding**: Concepts of LPP • **Applying: G**raphical and simplex methods • **Analyzing:** Solution feasibility
2.	Two-phases of simplex, Big-M method. Concept of Duality: Weak Duality Theorem, Basic Duality Theorem, Fundamental Theorem on Duality, Complementary Slackness Theorem, Dual-simplex method.	CO2	• **Applying:** Two-phase simplex, Big-M, dual-simplex methods • **Understanding**: Duality concepts • **Analyzing**: Relationships between primal and dual solutions
3.	Post-optimality analysis: Variation in cost vector, resource vector, addition/deletion of constraints/variables. Transportation, Assignment and Travelling-salesman problems.	CO3	• **Analyzing:** Impact of parameter changes) • **Applying:** Problem-solving methods for specific problems • **Evaluating:** Best methods for resource allocation
4.	Game Theory: Definitions, Maximin and Minimax principles, Two-person zero-sum game, Games with saddle point (Pure strategy), Games without saddle points (Mixed strategy), Graphical method, Dominance principle.	CO4	• **Applying**: Game theory principles • **Analyzing**: Strategies for pure and mixed games • **Evaluating**: Best strategies for competitive outcomes
5.	Inventory Problem: Introduction, Economic Order Quantity, Deterministic inventory with no shortages: The basic EOQ model, EOQ with several production runs of unequal lengths, EOQ with fixed (finite) production (replenishment). Deterministic inventory with shortages, Stochastic inventory models.	CO5	• **Understanding:** Inventory models • **Applying:** Inventory control formulas • **Evaluating:** Inventory management decisions for cost efficiency

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	*Operations Research: An Introduction*	H. A. Taha	9th Edition, 2010, Pearson	USA
2	*Introduction to Operations Research*	F. S. Hillier and G. J. Lieberman	10th Edition, 2014, McGraw-Hill	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
Major/Minor	**MAM 501/511**	Methods of Applied Mathematics	**4**	**4**

Introduction:

This course introduces integral transforms, particularly Laplace and Fourier transforms, and their applications in solving differential equations. It also covers integral equations and methods for solving them.

Objectives:

- Develop an understanding of Laplace and Fourier transforms and their properties.
- Apply integral transforms to solve ordinary and partial differential equations.
- Study integral equations and introductory methods for solving them.
- Explore applications of Fourier series in heat and wave equations.

Course Outcomes (CO):

- **CO1:** Understand the properties of Laplace transforms, including convolution, derivatives, and transforms of periodic functions.
- **CO2:** Apply inverse Laplace transforms to solve ordinary and partial differential equations.
- **CO3:** Analyze Fourier series expansions and apply them to solve problems in heat conduction and wave equations.
- **CO4:** Use Fourier transforms to solve partial differential equations, with a focus on sine and cosine transforms.
- **CO5:** Explore integral equations, their classification, and methods of conversion and solution, including eigenfunctions.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Laplace transform and its properties, Convolution Theorem. Laplace transform of derivatives and periodic functions. Error and complementary functions and their Laplace transforms.	CO1	**Remembering:** Recall properties and applications of Laplace transforms. **Understanding:** Explain convolution and transformations of derivatives and periodic functions. **Applying:** Apply the convolution theorem and transforms to solve problems.
2.	Inverse Laplace transforms, Application of Laplace transforms to the solution of ordinary and partial differential equations.	CO2	**Understanding:** Describe inverse Laplace transforms and their uses. **Applying:** Use inverse transforms to solve differential equations. **Analyzing:** Analyze differential equations to determine appropriate transform techniques.
3.	Fourier series: an expansion theorem, Fourier sine series, cosine series, the one dimensional heat equation, surface temperature varying with time, heat conduction in a sphere, a simple wave equation, Laplace's equation in two dimensions	CO3	**Remembering:** Recall the forms and properties of Fourier series. **Applying:** Apply Fourier series to solve heat and wave equations. **Analyzing:** Examine the effects of boundary conditions on Fourier solutions.

4.	Exponential Fourier transform, Fourier Sine and Cosine transforms and their applications in solving partial differential equations.	CO4	**Understanding:** Describe Fourier transforms and their properties. **Applying:** Use Fourier transforms to solve PDEs. **Evaluating:** Evaluate solutions obtained through Fourier methods.
5.	Integral Equations: Conversion of Ordinary Differential Equations into Integral equations, Classification of Linear Integral Equations and Introductory methods of their solutions, Eigen functions of integral equations.	CO5	**Understanding:** Explain integral equations and their classifications. **Applying:** Convert ODEs to integral equations and solve using basic methods. **Creating:** Construct solutions using eigenfunctions for integral equations.

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	Operational Mathematics	RV Chruchill	3rd Edition 1972, McGraw-Hill	USA
2.	The Use of Integral Transform	I.N. Sneddon	Reprint Edition,1972,McGraw-Hill	USA

DAYALBAGH EDUCATIONAL INSTITUTE FACULTY OF SCIENCE **DEPARTMENT OF MATHEMATICS**				
Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM502/512**	**Partial Differential Equations**	**4**	**4**

Introduction:

This course provides foundational knowledge in *Partial Differential Equations (PDEs)*, essential for students advancing in mathematical and applied science studies. It covers both first- and second-order PDEs, equipping students with analytical methods and techniques to solve equations in various forms and apply them to real-world problems in physics, engineering, and other fields.

Objectives:

1. Develop an understanding of methods to solve first and second-order partial differential equations (PDEs).
2. Methods involving linear and non-linear PDE's are detailed.
3. Explore classifications of second-order PDEs and their canonical forms.
4. Apply PDEs to physical phenomena, including diffusion and wave propagation.
5. Solve boundary and initial value problems with mathematical rigor..

Course Outcomes (CO):

This course is aimed at
CO1: Understand first-order linear and non-linear PDEs, apply Lagrange's method, and solve using Charpit and Jacobi methods.
CO2: Classify and recognize canonical forms of second-order PDEs for different types.
CO3: Solve Laplace equations in various coordinates and apply boundary conditions for elliptic equations.
CO4: Derive and solve diffusion equations under different boundary conditions.
CO5:. Derive and solve wave equations, and understand solutions for vibrating strings and boundary value problems for hyperbolic equations.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Linear Partial Differential Equations: Lagrange's method, Working rule for solving Pp+Qq = R by Lagrange's method, geometrical description of Pp+Qq = R. Non-linear Partial Differential Equations of Order 1: Complete Integral, particular integral, singular integral and general integral. Standard form I: only p and q present, standard form II: z = px + qy + f(p,q), standard form III: only p q and z present, standard form IV: equations of the form $f_1(x,p) = f_2(y,p)$, Charpit method, Jacobi method. Cauchy's problem for first order PDE's.	CO1	
2.	Second order PDE's, Classification of second order linear PDE's, Canonical forms for Hyperbolic, Parabolic and Elliptic equations.	CO2	
3.	Elliptic Differential Equations- Derivation of Laplace equation, solution of Laplace equation in polar, cylindrical and spherical coordinates, separation of variable method, Neumann and Dirichlet problems.	CO3	
4.	Parabolic Differential Equations- occurrence and derivation of Diffusion equation, boundary conditions, solution of Diffusion Equation in polar, cylindrical and spherical coordinates, boundary value problems.	CO4	
5.	Hyperbolic Differential Equations- occurrence and derivation of Wave equation, Solution of wave equation in polar, cylindrical and spherical coordinates, D'Alembert's Solution, Vibrating String-Variable separable solution, boundary and initial value problems for two-dimensional wave equations- method of eigen function.	CO5	

Text Books and Reference Books:				
S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Introduction to Partial Differential Equations	K.Sankara Rao	3rd Edition, 2010, PHI Learning	India
2.	Advanced Differential Equations	M. D. Raisinghania	Revised Edition,S. Chand Publishing	India

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 503**	**Metric Spaces**	**4**	**4**

Introduction:

This course provides a foundational understanding of metric spaces, including properties of convergence, compactness, and continuity. Students will develop the theoretical basis necessary for advanced studies in analysis and topology.

Objectives:

1. To establish a strong conceptual understanding of metric spaces and their properties.
2. To enable students to analyze concepts like convergence, completeness, and compactness.
3. To foster problem-solving skills and rigorous mathematical reasoning.
4. To apply theoretical concepts of metric spaces in practical and complex scenarios.

Course Outcomes (CO):

CO1: Understanding metric spaces, exploring examples, and analyzing fundamental properties like open and closed sets, and the notion of distance.
CO2: Developing skills to understand convergence, limit points, closure, and completeness, and applying these concepts to analyze sequences in metric spaces.
CO3: Understanding continuity and uniform continuity, and being able to characterize and analyze continuous mappings in metric spaces.
CO4: Applying the concept of compactness and related theorems, including the Heine-Borel and Extreme Value Theorems, in metric spaces.
CO5: Exploring advanced theorems like Baire's Category Theorem, Cantor's Intersection Theorem, and Banach's Contraction Principle, and applying these theorems in practical analysis.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Metric spaces – Definition and examples, Hölder and Minkowski's inequalities, Open balls, Interior points and sets, Open and Closed sets, Diameter, Distance between sets	CO1	Understand, Apply
2.	Convergent Sequences, Limit and Cluster points, Closure, Cauchy sequences, Completeness, Examples of Complete Metric spaces, Bounded, Dense, and Nowhere Dense sets, Boundary	CO2	Understand, Analyze, Apply
3.	Continuous functions, Characterizations of Continuous maps, Limit of a function, Uniform Continuity	CO3	Apply, Analyze
4.	Compact spaces, Equivalence of Compactness, Limit point Compactness, Heine-Borel Theorem, Continuous maps on compact spaces, Extreme Value Theorem, Uniform Continuity and compactness	CO4	Analyze, Evaluate
5.	Baire's Category Theorem, Cantor's Intersection Theorem, Banach's Contraction Principle, Ascoli-Arzelà Theorem, Inverse Function, Implicit Function theorem, Weierstrass Approximation Theorem	CO5	Analyze, Create

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Principles of Mathematical Analysis	Walter Rudin	3rd Edition, 1976, McGraw-Hill	USA

2.	Metric Spaces	E.T. Copson	1st Edition, 1968, Cambridge Univ. Press	UK
3.	Real Analysis	H.L. Royden	4th Edition, 2010, Prentice Hall	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 504**	**Curves and Surfaces**	**4**	**4**

Introduction:

This course provides the key aspects of classical and modern differential geometry, and enables students to apply them in the concrete setting of 3-dimensional Euclidean space.

Objectives:

1. To build practical and theoretical foundation in understanding the geometry of curves and surfaces.
2. To provide geometric visualization.
3. To develop skills to solve complex geometry problems on curves and surfaces.
4. To develop skills for mathematical rigour.
5. To develop skills to apply the concepts in interdisciplinary fields.

Course Outcomes (CO):

This course is aimed at
CO1: Understanding and analyizing the geometry of space curves by computing their curvature, torsion, tangent, normal and binormal vectors.
CO2: Understanding and describing local theory of surfaces in R^3, curves on these surfaces and their first fundamental form.
CO3: Understanding the significance of normal and geodesic curvatures in geometry of curves on surfaces, computing Christoffel symbols and analyzing extrinsic properties of surfaces through second fundamental form.
CO4: Understanding the concept of orientability of surfaces, analyizing and determining the geodesics on different surfaces.
CO5: Deriving and using Weingarten equations to describe behavior of surface normal, computing principal directions and principal curvatures for various surfaces, analyzing Gaussian and mean curvatures, Line of Curvature, asymptotic curves, and the conditions under which a surface is minimal.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Curves in Space, Arc length, Velocity, Acceleration, Curvature and Torsion, Frenet-Serret formula, Osculating Plane, Normal Plane, Tangent Plane.	CO1	
2.	Spherical Curves, Fundamental Theorem of Curves, Co-ordinate Patch, Surfaces, Parametric Curves, First Fundamental Form, Surface of Revolution, Ruled Surface.	CO2	
3.	Normal Curvature, Geodesic Curvature, Gauss Formula, Christoffel Symbols, Second Fundamental Form.	CO3	
4.	Orientability, Geodesics, Geodesics on a Surface of Revolution, Geodesics on Sphere, Geodesics on Cylinder.	CO4	
5.	Weingarten Equations, Principal Directions, Principal Curvatures, Gaussian Curvature, Mean Curvature, Line of Curvature, Asymptotic Curve, Minimal Surface.	CO5	

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	ELEMENTS OF DIFFERENTIAL GEOMETRY	Richard S. Millman, George D. Parker	Pearson; Facsimile edition (29 March 1977)	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 505**	**Introduction to C**	**2**	**2**

Introduction:

This course is an introduction to the fundamentals of programming with the C programming language.

Objectives:

1. To provide students with foundational knowledge of algorithms, algorithmic problem solving and performance.
2. To teach fundamental programming concepts, including data types, operators, expressions, and control structures, using the C programming language.
3. To teach students how to work with arrays, pointers, strings in C.
4. To introduce the concept of modular programming using functions in C.
5. To introduce programming concepts such as structures, unions, enumerations and file I/O operations in C.

Course Outcomes (CO):

CO1: Students will be able to understand fundamental programming concepts, the syntax and semantics of the C language, and apply the C programming language operators, expressions, type conversion, and conditional expressions in programming.
CO2: Students will be able to apply selection constructs (if-else and switch) and iterative constructs (while, for, do-while) to solve programming problems and analyze the flow of control in decision-making and looping scenarios.
CO3: Students will understand the concept of arrays, pointers, array and pointer interchangeability and strings and apply them to solve different problems.
CO4: Students will understand the concept of modular programming with functions, understand recursion and its applications, prototypes, macros, and apply these concepts in the design of modular programs.
CO5: Students will understand structures, unions, enumerations, and file I/O and apply these concepts to create programs manipulating structured data. Students will also learn to evaluate the time complexity of their algorithms/ code.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Introduction to Algorithms, Overview of the C programming Language, literals, variables and data types, type modifiers, type conversion, operators, operator precedence, expressions, conditional expressions, statements and blocks, console I/O.	CO1	
2.	Selection (If-Else and Switch), Iteration (while, for and do-while), break and continue.	CO2	
3.	Arrays (one, two and multidimensional), pointers, strings.	CO3	
4.	Functions: General form, scope rules, function arguments, return statement, recursion; prototypes, preprocessor and directives, macros.	CO4	
5.	Structures, unions, enumerations, typedef, File I/O, Time Complexity of Algorithms.	CO5	

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	How to Solve it by Computer	R.G. Dromey	2007, Pearson	Indian Edition
2.	The C Programming Language	Brian W. Kernighan and Dennis Ritchie	2015, Pearson	Indian Edition
3.	C: The Complete Reference	Herbert Schildt	2017, Mc Graw Hill Education	Indian Edition

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM506**	**Programming Lab I (C)**	**4**	**2**

Introduction:

This C Programming Lab course introduces students to essential programming concepts, focusing on problem-solving through algorithms and flowcharts. It covers the fundamentals of C programming, including control statements, functions, arrays, pointers, and file handling. Through practical lab exercises, students will gain hands-on experience in writing, testing, and debugging code, building a strong foundation for developing modular and efficient programs.

Objectives:

1. To introduce students to the fundamentals of programming, focusing on problem-solving approaches using algorithms and flowcharts.
2. To provide a thorough understanding of the C programming language, including syntax, operators, expressions, and control statements.
3. To develop the skills necessary for writing modular code using functions, including recursion.
4. To enable students to manage data efficiently through the use of arrays, pointers, structures, and unions.
5. To introduce file handling in C for data storage and retrieval, supporting more comprehensive program development.

Course Outcomes (CO):

This course aims to:

CO1: Develop a foundational understanding of programming logic, including algorithm creation and flowchart design, to enhance structured problem-solving skills.

CO2**:** Gain proficiency in the basics of C programming, focusing on operators, expressions, data input/output, and control structures, and apply these concepts in constructing simple programs.

CO3**:** Build skills in writing modular code by creating functions, including recursive functions, to improve code reusability and efficiency.

CO4**:** Demonstrate the ability to work with arrays, pointers, structures, and unions, gaining insights into memory management and data organization.

CO5**:** Acquire skills in file handling techniques in C to manage data storage and retrieval effectively, ensuring data persistence across program executions.

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM601/611**	**Numerical Analysis**	4	**2**

Introduction:

This course introduces the fundamental methods and techniques of numerical analysis, focusing on both theoretical and practical applications.

Objectives:

1. To provide students with an understanding of error analysis and numerical solutions to equations.
2. To develop proficiency in methods for solving systems of equations, interpolation, and numerical integration.
3. To familiarize students with numerical differentiation, eigenvalue computation, and ordinary/partial differential equation solving.
4. To enable students to use iterative and finite difference methods effectively.
5. To equip students with skills to analyze the stability and convergence of numerical methods.

Course Outcomes (CO):

Upon completion of this course, students will be able to:

CO1: Students will understand types of errors, error propagation, and order of convergence, and apply these concepts to solve nonlinear equations.

CO2: Students will apply direct and iterative methods to solve systems of linear and nonlinear equations, analyzing their convergence properties.

CO3: Students will develop and use interpolation methods, including Newton's and Lagrange's techniques, and apply finite differences effectively.

CO4: Students will apply numerical differentiation, integration, and eigenvalue computation methods, including Gershgorin's theorem and QR methods.

CO5: Students will implement numerical methods to solve ordinary and partial differential equations, ensuring stability and accuracy.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Rounding off, truncation, error analysis, and propagation. Horner's method. Solution of nonlinear equations and order of convergence.	Understand and apply error analysis techniques and solve nonlinear equations.	CO1
2.	Direct and iterative methods for solving systems of equations and nonlinear equations.	Analyse the methods for solving systems of equations	CO2
3.	Finite differences, Newton's interpolation formulas, Gauss and Stirling's formula, Bessel's formula, Lagrange and Hermite interpolation, Newton's divided differences.	Use interpolation and finite difference methods for data approximation.	CO3
4.	Numerical differentiation, integration (Newton-Cotes methods, Trapezoidal and Simpson's rules). Gershgorin's theorem, power method, QR method.	Implement numerical differentiation, integration, and eigenvalue methods.	CO4
5.	Numerical solution of ODEs (Taylor's, Euler, Runge-Kutta, multistep methods). Finite difference methods for PDEs. Stability and strong stability.	Solve ODEs and PDEs using numerical methods with stability analysis.	CO5

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	An Introduction to Numerical Analysis	K. Atkinson	2nd Edition, 1989, John Wiley & Sons	New York
2	Numerical Methods for Scientific and Engineering Computation	M.K. Jain, S.R.K. Iyengar, R.K. Jain	6th Edition, 2012, New Age International	New Delhi
3	Elementary Numerical Analysis	S.D. Conte, Carl de Boor	3rd Edition, 1981, McGraw-Hill	New York

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM 602/612**	**Number Theory**	**4**	**4**

Introduction:

This course delves into the foundational concepts and advanced techniques in Number Theory. It is designed to provide students with a comprehensive understanding of number-theoretic functions, modular arithmetic, quadratic residues, and key theorems that form the backbone of this branch of mathematics. Throughout the course, students will explore both classical results and modern applications of number theory.

Objectives:

1. To develop a strong foundation in Number-Theoretic Functions
2. To master modular arithmetic and residue systems
3. To explore the concept of primitive roots and indices
4. To understand and apply quadratic residues and reciprocity
5. To develop the ability for solving advanced problems in number theory

Course Outcomes (CO):

This course is aimed at

CO1: Analyze number-theoretic functions and their applications, such as calendar computations.

CO2: Solve congruences using tools like the Chinese Remainder Theorem and theorems of Fermat, Wilson, and Euler.

CO3: Understand and find primitive roots, analyze their existence, and use indices.

CO4: Evaluate quadratic residues and apply the Quadratic Reciprocity Law, along with Legendre symbols.

CO5: Solve Diophantine equations, explore continued fractions, and understand Pell's Equation and related concepts

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Number Theoretic Functions- σ, τ, ϕ, Greatest Integer Function, Application to Calendar & Other Applications.	CO1	
2.	Complete Set of residues, Reduced Set of Residues, Linear Congruence, Chinese Remainder Theorem, Fermat's Little Theorem, Wilson's Theorem, Euler's Theorem, Applications.	CO2	
3.	Order of an element modulo n, Primitive Roots, Existence of Primitive Roots, Lagrange's Theorem, Primitive Roots of Primes, Primitive Roots for Composites, Theory of Indices.	CO3	
4.	Quadratic Residue for an Odd Prime, Quadratic Residue for a Power of an Odd Prime, Quadratic Residue for any Integer, Legendre symbol, Gauss' Lemma, Quadratic Reciprocity Law.	CO4	
5.	Pythagorean Triple, Fermat's Last Theorem for n=4, Lagrange's Four-Square Theorem, Finite Continued Fractions, Infinite Continued Fractions, Pell's Equation	CO5	

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place

1.	Elementary Number Theory	David M. Burton	McGraw-Hill Education	New York, USA
2.	An Introduction to the Theory of Numbers	G.H. Hardy and E.M. Wright	6th Edition, 2008	Oxford, UK

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS Major	**MAM 603**	Complex Analysis	4	**4**

Introduction:

This course provides a comprehensive introduction to complex functions, their properties, and applications. It covers fundamental concepts of complex analysis, including analytic functions, contour integration, and conformal mappings, laying the foundation for advanced studies in mathematics, physics, and engineering.

Objectives:

1. To introduce the algebra and geometry of complex numbers and complex-valued functions.
2. To develop an understanding of analytic functions, their properties, and applications.
3. To provide tools for evaluating complex integrals using key theorems such as Cauchy's and Residue Theorems.
4. To explore conformal mappings and their applications in solving physical and engineering problems.

Course Outcomes (CO):

CO1Understand the basic properties of complex numbers and complex functions, including analyticity and harmonic functions..
CO2: Analyze and construct Taylor and Laurent series for complex functions.
CO3: Evaluate complex integrals using Cauchy's Integral Theorem, Integral Formula, and Residue Theorem.
CO4: Apply techniques of contour integration to solve real integrals and improper integrals.
CO5: Explore conformal mappings and their applications to practical problems.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Complex Numbers, Argand Plane, Polar Form, Roots of Complex Numbers, Stereographic Projection.	CO1	Understand, Apply
2.	Complex Functions, Limits, Continuity, Differentiability, Analytic Functions, Harmonic Functions.	CO2	Understand, Analyze
3.	Complex Integration, Cauchy's Integral Theorem, Cauchy's Integral Formula, Morera's Theorem.	CO3	Apply, Evaluate
4.	Series Expansion: Taylor Series, Laurent Series, Singularities, Residues, Residue Theorem.	CO4	Analyze, Evaluate
5.	Conformal Mappings, Linear Fractional Transformations, Applications to Physics and Engineering.	CO5	Analyze, Create

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Complex variables and Applications	J.W. Brown & R.V. Churchill	9th Edition, 2013, McGraw-Hill	USA
. 2.	Complex Analysis	J.W. Brown & R.V. Churchill	3rd Edition, 1979, McGraw-Hill	USA
3	Fundamentals of Complex Analysis	E.B. Saff & A.D. Snider	3rd Edition, 2003, Pearson	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 604**	**Introduction to Data Structures**	**2**	**2**

Introduction:

This course is an introduction to the fundamentals of Data Structures using the C programming language.

Objectives:

1. Understand fundamental data structures and their representations
2. Learn to analyze and evaluate algorithm efficiency
3. Develop skills in linear and non-linear data structures
4. Learn and apply graph algorithms for problem solving
5. Master searching, sorting, and hashing techniques

Course Outcomes (CO):

CO1: Understand the basic concepts of algorithm analysis and data representation, understand ordered lists and its array representation and apply the concepts of arrays and lists to solve basic data organization problems.
CO2: Understand the functionality and use cases of stacks and queues in problem-solving and apply the linked representation to implement dynamic versions of lists, stacks and queues.
CO3: Understand the structure and properties of trees, binary trees, and heaps and their applications in hierarchical data representation, apply binary search trees to efficiently store and retrieve data and understand the application of heaps in priority queues.
CO4: Understand graph traversal techniques and their applicability, understand and apply shortest path and minimum spanning tree algorithms to solving problems and evaluate their efficiency in terms of time complexity.
CO5: Understand and apply hashing techniques and different searching and sorting algorithms, analyze the time complexity of various searching and sorting algorithms and identify the most suitable approach for a given problem.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Analysis of algorithms, ordered list, sequential representation, array representation.	CO1	
2.	Stacks, queues, evaluation of expressions, linked representation.	CO2	
3.	Trees and tree representation, binary trees, binary tree traversals, binary search tree, heaps and priority queues.	CO3	
4.	Graphs and graph representation, graph traversals, shortest path algorithms (single source all destinations, all pairs), minimum cost spanning tree algorithms (Kruskal and Prims).	CO4	
5.	Searching (Sequential and Binary), Sorting (bubble sort, insertion sort and selection sort), quick sort, merge sort and heap sorting, hashing.	CO5	

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Fundamentals of Data Structures in C	Ellis Horowitz, Sartaj Sahni and Susan Anderson-Freed	Second, 2008, Universities Press	Hyderabad
2.	Data structures and Algorithm Analysis in C	Mark Allen Weiss	Second, 2002, Pearson	Indian Edition
3.	Data Structures and Algorithms	Alfred Aho, John E. Hopcroft and Jeffery D. Ullman	First, 2002, Pearson	Indian Edition

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Course Type	Course Code	Name of Course	Lectures/Week (of 55 min each)	Credits
DS Major	**MAM 605**	**ALGEBRA III (SYLOW'S THMS.& I.P.S.)**	**4**	**4**

Introduction:

MAM 605 delves into advanced concepts in group theory and linear algebra, focusing on the structural properties of groups and their applications, as well as the theoretical framework of inner product spaces. The course covers pivotal topics such as Sylow's Theorems, classification of groups, and solvable groups, alongside the study of linear operators and their matrices. Students are introduced to foundational tools like the commutator subgroup, orthonormal bases, and adjoint operators, equipping them to analyze and solve complex problems in algebra and functional analysis. This course bridges abstract theory with practical applications, providing a strong foundation for further exploration in mathematics and related fields.

Objectives:

1. To introduce advanced concepts in group theory, including the study of conjugacy classes, Sylow's theorems, and simple groups.
2. To explore the structure and classification of groups, focusing on special groups such as the quaternion group, dihedral group, and alternating group.
3. To develop an understanding of direct products of groups, both external and internal, and their applications in solving group-related problems.
4. To examine the fundamental theorem of finite Abelian groups and its applications, along with tests for non-simplicity in groups.
5. To introduce advanced concepts in group theory, including the study of conjugacy classes, Sylow's theorems, and simple groups.
6. To explore the structure and classification of groups, focusing on special groups such as the quaternion group, dihedral group, and alternating group.
7. To develop an understanding of direct products of groups, both external and internal, and their applications in solving group-related problems.
8. To examine the fundamental theorem of finite Abelian groups and its applications, along with tests for non-simplicity in groups.

Course Outcomes (CO):

By the end of the course, students will be able to:

CO1: Understand the fundamental concepts of groups and their structure, including conjugacy classes, centralizers, and simple groups. Apply Sylow's theorems to analyze group properties.

CO2: Analyze the properties of special groups like quaternion and dihedral groups, and apply the classification of finite Abelian groups. Conduct tests for nonsimplicity in groups.

CO3: External and Internal Direct Product of Groups, Applications of Group and Ring Isomorphism Theorems

CO4: Understand the theory of solvability, commutators, and normal series in groups. Apply Cardan's method and study the solution of polynomials by radicals.

CO5: Analyze and apply concepts related to inner product spaces, including orthonormal sets, Cauchy-Schwarz's inequality, and the properties of linear operators on these spaces.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Centre, Centralizer, Conjugacy Class, Class Equation, Cauchy's Theorem, Applications of Sylow's Theorems, Simple Groups, Tests for Nonsimplicity	CO1: Understand the fundamental concepts of groups and their structure, including conjugacy classes, centralizers, and simple groups. Apply Sylow's theorems to analyze group properties.	Understand, Apply
2.	Quaternion Group, Dihedral Group, Alternating Group, Simple Group, Tests for Nonsimplicity, Applications of Fundamental Theorem of Finite Abelian Groups, Classification of Groups	CO2: Analyze the properties of special groups like quaternion and dihedral groups, and apply the classification of finite Abelian groups. Conduct tests for nonsimplicity in groups.	Analyze, Evaluate
3.	External and Internal Direct Product of Groups, Applications of Group and Ring Isomorphism Theorems	CO3: External and Internal Direct Product of Groups, Applications of Group and Ring Isomorphism Theorems	Apply, Analyze
4.	Cardan's Method, Subgroup Generated by a Subset, Commutator	CO4. Understand the theory of	Analyze, Apply

	Subgroup, Normal Series, Solvable Group, Introduction to Solution of Polynomials by Radicals	solvability, commutators, and normal series in groups. Apply Cardan’s method and study the solution of polynomials by radicals.	
5.	Inner Product Spaces, Orthogonal Sets, Orthonormal Basis, Cauchy-Schwarz's Inequality, Orthogonal Complement, Linear Operators on Finite Dimensional Inner Product Spaces	CO5: Analyze and apply concepts related to inner product spaces, including orthonormal sets, Cauchy-Schwarz's inequality, and the properties of linear operators on these spaces.	Analyze, Apply, Evaluate

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	ALGEBRA	Michael Artin	2^{nd}, 2011, Pearson	USA
2	ABSTRACT ALGEBRA	D. S. Dummit and R. M. Foote	3^{rd}, 2004, John Wiley & Sons	USA
3.	LINEAR ALGEBRA	S. H. Friedberg, A. J. Insel and L. E. Spence	4^{th}, 2018, Pearson	USA
4	CONTEMPORARY ABSTRACT ALGEBRA:	J. A. Gallian	9^{th}, 2017, Cengage Learning	USA
5	TOPICS IN ALGEBRA	I. N. Herstein	2^{nd}, 2006, Wiley	USA
6	LINEAR ALGEBRA	K. Hoffman and R. Kunze	2^{nd}, 1971, Prentice Hall	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 606**	**Programming Lab II (DATA STRUCTUES)**	4	**2**

Introduction:

This course introduces fundamental concepts and techniques for organizing, managing, and analyzing data efficiently using data structures. It focuses on the implementation of algorithms for real-world applications.

Objectives:

1. To understand the basic principles of data organization and manipulation.
2. To develop problem-solving skills in algorithm design and data structure selection.
3. To implement and analyze algorithms for various data structures in C.
4. To prepare students for advanced courses in algorithms and systems design.

Course Outcomes (CO):

Upon completion of this course, students will be able to:
CO1: Analyze and select appropriate data structures for solving computational problems.
CO2: Implement and apply data structures to real-world problems effectively.
CO3: Design efficient algorithms for operations on data structures.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Analysis of algorithms, ordered list, sequential representation, array representation	Understand algorithm efficiency and data organization	Understand, Analyze
2.	Stacks, queues, evaluation of expressions, linked representation	Implement root-finding algorithms in MATLAB	Apply, Analyze
3.	Trees and tree representation, binary trees, binary tree traversals, binary search tree, heaps, and priority queues	Apply tree structures for hierarchical data organization	Apply, Evaluate
4.	Graphs, graph representation, graph traversals, shortest path algorithms (single source all destinations, all pairs), minimum cost spanning tree algorithms (Kruskal and Prim's)	Solve graph-based problems using algorithms	Analyze, Apply, Evaluate
5.	Searching (Sequential and Binary), Sorting (Bubble Sort, Insertion Sort, Selection Sort, Quick Sort, Merge Sort, Heap Sorting), Hashing	Develop efficient algorithms for data retrieval and sorting	Apply, Analyze, Evaluate

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Fundamentals of Data Structures in C	Ellis Horowitz, Sartaj Sahni, Susan Anderson-Freed	Universities Press	India
2.	Data Structures and Algorithm Analysis in C	Mark Allen Weiss	Pearson	USA
3.	Data Structures and Algorithms	Alfred Aho, John E. Hopcroft, Jeffery D. Ullman	Addison-Wesley Series in Computer Science and Information	USA
4.	Data Structures and Algorithms Made Easy	Narasimha Karumanchi	Careermonk Publications	India

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM701/711**	**Measure and Integration**	**4**	**4**

Introduction:

This course offers a rigorous foundation in measure theory and Lebesgue integration, covering the essential aspects needed for advanced studies in real analysis and functional analysis.

Objectives:

1. To develop a comprehensive understanding of Lebesgue measure, measurable sets, and measurable functions.
2. To learn the principles of Lebesgue integration and important convergence theorems.
3. To understand and apply the properties of L^p spaces and fundamental inequalities.
4. To develop skills for applying measure and integration theory to advanced mathematical problems.

Course Outcomes (CO):

This course is aimed at

CO1: Understanding the concept of Lebesgue outer measure, properties of measurable sets, and distinguishing between Borel and measurable sets.
CO2: Constructing the Lebesgue measure, analyzing measurable sets and functions, and applying regularity properties.
CO3: Understanding Lebesgue integration of various functions and applying convergence theorems such as Fatou's Lemma and the Monotone Convergence Theorem.
CO4: Applying the general properties of Lebesgue integration and using the Dominated Convergence Theorem in practical integration scenarios.
CO5: Exploring L^p spaces as metric spaces, proving fundamental inequalities, and demonstrating the completeness of L^p spaces.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Lebesgue Outer Measure, its properties, Measurable sets and their properties, Borel sets and their measurability	CO1	Understand, Apply
2.	Construction of Lebesgue Measure, Properties of Measurable Sets, Regularity, Measurable Functions and their Properties	CO2	Understand, Apply
3.	Lebesgue Integration: Simple Function, Lebesgue integral of Simple functions, Bounded and Non-Negative measurable functions, Fatou's Lemma, Monotone Convergence Theorem	CO3	Apply, Analyze
4.	General Lebesgue Integration, Dominated Convergence Theorem, Integration of Series	CO4	Apply, Analyze, Evaluate
5.	L^p Spaces: L^p as a vector and metric space, Hölder and Minkowski inequalities, Completeness of L^p spaces	CO5	Analyze, Create

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Real Analysis |	H.L. Royden	4th Edition, 2010, Prentice Hall	USA
2.	Measure Theory and Integration,	G. de Barra	1st Edition, 1981, Elseveir	USA

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS Major	**MAM702**	**TOPOLOGY**	**4**	**4**

Introduction:

This is a first course on topology that motivates to think beyond metric spaces. This leads to classification of spaces, paving the way for further exploration in algebraic topology.

Objectives:

1. Learn fundamental concepts of topology through geometric visualization.
2. Understand difference between rubber sheet geometry and topology
3. Classify topological spaces upto homeomorphism.
4. Construct and visualize rigorous proofs.
5. Construct counter examples.
6. Develop appreciation for abstraction.

Course Outcomes (CO):

CO1: Introduce basic concepts of topology
CO2: Learn key examples-Euclidean space, Discrete Space, Indiscrete Space, Cofinite Space etc.
CO3: Study continuous maps and homeomorphism:
CO4: Construct new spaces: subspaces, product and quotient
CO6: Study topological properties- countability axioms, separation axioms, compactness, connectedness and path connectedness
CO7: Classify topological spaces upto homeomorphism

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Topology, Closed Sets, Basis, Subbasis, Metric Topology, Subspace Topology, Interior Points, Exterior Points, Boundary Points and Limit Points of a Set, Derived set, Interior and Closure of a Set, Dense Sets, Real Line, Sorgenfrey Line	Basic Concepts and Key Examples	Interpreting, explaining, implementing, differentiating
2.	Continuous Map, Open Map, Closed Map, Projection Map, Homeomorphism	Homeomorphism, Spaces being Homeomorphic	Interpreting, explaining, implementing, differentiating
3.	Product space, Quotient Space, Quotient Map, Introduction to Countability Axioms	New spaces, Countability Axioms	Interpreting, explaining, implementing, differentiating
4.	T_1, T_2, Regular, T_3, Completely Regular, $T_{3½}$, Normal and T_4 Spaces, Compact Spaces	Topological Properties	Generating
5.	Connected Spaces, Components, Path Connected Spaces, Path Components, Applications of Connectedness	Connectedness, Classification of Topological Spaces	Classifying, generating

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	TOPOLOGY- A FIRST COURSE	J. R. Munkres	Second Edition, 2015, PHI Learning Private Limited	Delhi
2.	GENERAL TOPOLOGY	J. L. Kelley	Van Nostrand, 1955	New York

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 703**	Theory of differential equations	**4**	**4**

Introduction:

This course covers essential concepts of differential equations, focusing on existence and uniqueness of solutions, stability analysis, and applications of linear and nonlinear differential equations.

Objectives:

- Introduce foundational concepts in differential equations.
- Study the behavior and solutions of linear and nonlinear systems.
- Analyze stability and oscillatory properties of differential equations.
- Explore advanced methods, such as Green's functions and integral equations.

Course Outcomes (CO):

- **CO1:** Understand basic concepts, conditions, and inequalities related to differential equations, including existence and uniqueness theorems.
- **CO2:** Solve linear differential equations with variable coefficients and analyze oscillatory behavior, Sturm-Liouville boundary conditions, and Green's functions.
- **CO3:** Develop solutions for non-homogeneous linear systems and systems with constant or periodic coefficients using the fundamental matrix.
- **CO4:** Assess stability and behavior of solutions in linear differential systems.
- **CO5:** Investigate stability in nonlinear differential equations, apply the Poincaré-Bendixson theorem, and understand basic methods for solving linear integral equations.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Elementary Concepts about Differential Equations, Lipschitz condition, Gronwall inequality, Existence and Uniqueness of solutions for scalar and systems of equations.	CO1	**Remembering:** Recall foundational concepts and conditions in differential equations. **Understanding:** Explain the significance of Lipschitz conditions and Gronwall inequality. **Applying:** Apply existence and uniqueness theorems to differential equations.
2.	Linear Differential Equations with Variable Coefficents, Linear Dependence and Independence of Solutions, Concept of Wronskian, Oscillatory and Non-oscillatory Behaviour of Solutions of Second Order Linear Differential Equations, Non-Homogenous Equations, Strum-Liouville Boundary Value Problem, Green's Function.	CO2	**Understanding:** Describe linear dependence and the Wronskian. **Applying:** Use methods to solve linear differential equations and apply Green's function. **Analyzing:** Examine oscillatory and non-oscillatory behavior in solutions.
3.	Fundamental matrix, Non-homogenous Linear Equations, Linear Systems with constant coefficients, Linear Systems with Periodic Coefficients.	CO3	**Understanding:** Explain fundamental matrix concepts in system solutions. **Applying:** Solve systems with constant and periodic coefficients. **Analyzing:** Analyze solution behaviors in non-homogeneous linear equations.

4.	Stability of Linear Systems, Behaviour of solutions of Linear Differential Equations.	CO4	**Understanding:** Explain the stability theory for linear systems. **Applying:** Analyze solution behaviors to assess system stability. **Evaluating:** Evaluate system stability under varying conditions.
5.	Stability of Nonlinear Differential Equations, Applications of Poincare Bendixon Theorem, Introductory Methods of Solution of Linear Integral Equations.	CO5	**Understanding:** Describe the Poincaré-Bendixson theorem and its applications. **Applying:** Apply stability analysis to nonlinear systems. **Creating:** Use introductory methods to formulate solutions for linear integral equations.

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	Ordinary Differential Equations	E.L. Ince	Dover Publications,	USA
2.	Differential Equations and Dynamical Systems	Lawrence Perko	3rd Edition, Springer	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 704**	**Rings & Canonical Forms**	**4**	**4**

Introduction:

This course provides strong foundations of Rings & Canonical Forms enabling students to understand and apply the basic concepts required for advanced studies.

Objectives:

1. To understand polynomial rings, division algorithms, and irreducibility criteria.
2. To explore quadratic integer rings, Euclidean domains, principal ideal domains, and unique factorization domains.
3. To grasp concepts of eigenvalues, eigenvectors, and conditions for diagonalizability.
4. To study minimal polynomials, invariant subspaces, and their relation to diagonalizability and triangulability.
5. To understand generalized eigenspaces, cycles of generalized eigenvectors, and Jordan and rational canonical forms.
6. To develop rigorous proof construction and problem-solving abilities in algebra.

Course Outcomes (CO):

This course is aimed at

1. CO1: Develop a strong understanding of polynomial rings, including concepts like roots, division algorithm, and irreducibility. Gain proficiency in using tests like Mod p and Eisenstein's criterion to assess polynomial irreducibility and explore cyclotomic polynomials.
2. CO2: Understand the structure of quadratic integer rings and related properties, including Euclidean Domains, Principal Ideal Domains (PIDs), and Unique Factorization Domains (UFDs), gaining skills to identify and work within these domains.
3. CO3: Gain a deep understanding of eigenvalues, geometric and algebraic multiplicity, and the direct sum of subspaces and eigenspaces. Learn to determine conditions for diagonalizability of matrices and linear operators.
4. CO4: Master the minimal polynomial concept and its relationship with invariant subspaces, triangulability, and diagonalizability. Develop skills in working with cyclic subspaces, the Cayley-Hamilton theorem, and the companion matrix.
5. CO5: Explore advanced canonical forms, including generalized eigenspaces, cycles of generalized eigenvectors, and the Jordan and rational canonical forms. Acquire the ability to decompose matrices into direct sums of generalized eigenspaces and understand their applications.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Polynomial Rings, Roots of a Polynomial, Division Algorithm, Irreducibility of a Polynomial, Mod p Irreducibility Test, Eisenstein Criterion, Irreducibility of pth Cyclotomic Polynomial	CO1	• **Remembering**: Identify and recall definitions of polynomial rings, roots, and irreducibility. • **Understanding**: Explain the division algorithm and irreducibility tests (e.g., Eisenstein criterion). • **Applying**: Use Mod p irreducibility tests and apply the concepts to specific polynomials. • **Analyzing**: Compare different irreducibility criteria and analyze cyclotomic polynomials.
2.	Quadratic Integer Rings, Euclidean Domain, Principle Ideal Domain, Unique Factorization Domain.	CO2	• **Remembering**: Define quadratic integer rings, Euclidean domains, principal ideal domains, and unique factorization domains. • **Understanding**: Describe properties and relationships among different ring structures. • **Applying**: Solve problems involving Euclidean domains and demonstrate unique factorization. • **Analyzing**: Differentiate between various types of rings and analyze their structures.
3.	Geometric and Algebraic Multiplicity, Direct Sum of Subspaces, Direct Sum of Eigenspaces, Diagonalizability of Matrices and Linear Operators.	CO3	• **Remembering**: Recall definitions of eigenvalues, eigenvectors, and multiplicities. • **Understanding**: Explain the concepts of geometric and algebraic multiplicity. • **Applying**: Calculate eigenvalues and eigenvectors

			for given matrices.Analyzing: Examine conditions for diagonalizability and the direct sum of eigenspaces.
4.	Minimal Polynomial, Invariant Subspaces, Conductor, Minimal Polynomial & Diagonalizability, Minimal Polynomial &Triangulability, Cyclic Subspace, Cayley-Hamilton Theorem, Companion Matrix.	CO4	• **Remembering**: Identify minimal polynomials and invariant subspaces. • **Understanding**: Summarize the relationship between minimal polynomials and diagonalizability. • **Applying**: Use the Cayley-Hamilton theorem to find minimal polynomials. • **Analyzing**: Analyze how minimal polynomials relate to triangulability and cyclic subspaces.
5.	Generalized Eigenspace, Cycle of Generalized Eigenvectors, Direct Sum of Generalized Eigenspaces, Jordan Form, Rational Form.	CO5	• **Remembering**: Recall the definitions of generalized eigenspaces and Jordan form. • **Understanding**: Explain the significance of cycles of generalized eigenvectors. • **Applying**: Construct Jordan forms for given matrices. • **Analyzing**: Compare Jordan forms with rational forms and analyze their applications.

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	LINEAR ALGEBRA	S. H. Friedberg, A. J. Insel and L. E. Spence	Fourth Edition, PHI, 2009	New Delhi

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Course Type	Course Code	Name of Course	Lectures / Week (of 55 Min each)	Credits
DS Major	**MAM706**	Analytical Mechanics	**4**	**4**

Introduction:

This is an advanced undergraduate course introducing the formalism of Lagrangian and Hamiltonian mechanics, emphasizing the variational principles of classical mechanics. The course provides a solid theoretical foundation necessary for further studies in theoretical physics, applied mechanics, and advanced mathematical modeling of dynamical systems.

Objectives:

1. 1. Understand and apply the principles of calculus of variations to mechanical systems.
2. Introduce Lagrangian mechanics through generalized coordinates and conservation laws.
3. Analyze conservative dynamical systems and small oscillations.
4. Explore variational principles such as Hamilton's principle and least action.
5. Develop Hamiltonian mechanics, including canonical equations and phase space.
6. Study rigid body motion using Euler's dynamical equations in rotating frames.

Course Outcomes (CO):

CO1	Understand the Euler-Lagrange equations and apply the calculus of variations to physical systems.
CO2	Apply generalized coordinates and velocities to derive Lagrange's equations for holonomic systems.
CO3	Analyze conservative systems in terms of kinetic energy, momentum, impulse, and small oscillations.
CO4	Formulate variational principles such as Hamilton's principle and the principle of least action.
CO5	Derive and solve Hamilton's equations, and apply canonical transformations and Poisson brackets.
CO6	Study rigid body motion using Euler's equations and analyze motion in rotating frames.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Euler-Lagrange equation, functionals (higher derivatives and multivariable), variational boundary value problems	Master variational calculus and its applications to differential equations	Understanding, Applying, Evaluating
2.	Generalized coordinates/velocities, virtual work, Lagrange's equations, momentum, impulse, small oscillations, equilibrium	Apply Lagrangian mechanics to conservative holonomic systems	Understanding, Applying, Analyzing
3.	Variational methods, Brachistochrone, Hamilton's principle, least action	Understand and distinguish key variational principles in physics	Understanding, Comparing, Applying
4.	Hamilton's equations, Hamiltonian to Lagrangian transition, Hamilton–Jacobi equation, Poisson brackets, Liouville's theorem	Analyze phase space dynamics and derive equations using Hamiltonian formalism	Generating
5.	Euler's dynamical equations, fixed-point motion, motion under no external forces, rotating axes	Apply rigid body dynamics concepts in rotating frames	Applying, Analyzing

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Classical Mechanics	H. Goldstein, C. Poole, J. Safko	3rd Edition, 2002, Pearson Education	New Delhi
2.	Analytical Mechanics	G. R. Fowles and G. L. Cassiday	7th Edition, 2005, Thomson Brooks/Cole	USA
3.	Mechanics	L. D. Landau and E. M. Lifshitz	3rd Edition, 1976, Butterworth-Heinemann	Oxford

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major/Minor	**MAM801/811**	**Advanced Optimization Techniques**	**4**	**4**

Introduction:

This course provides strong foundations of advanced optimization tecnhiques enabling students to understand and apply for advanced studies.

Objectives:

1. To understand advanced topics in queueing theory, non-linear programming, dynamic programming, and integer programming.
2. To develop the ability to solve complex optimization and decision-making problems using mathematical methods.
3. To explore the theoretical and practical aspects of queueing systems and optimization techniques.
4. To apply mathematical modeling to real-world scenarios in engineering, management, and operations.

Course Outcomes (CO):

This course is aimed at

CO1: Understand queueing models, their classifications, and solutions to Poisson queue systems.
CO2: Analyze and solve optimization problems involving non-linear functions with and without constraints.
CO3: Apply advanced methods such as Kuhn-Tucker conditions, Fibonacci search, and graphical techniques for solving non-linear programming problems.
CO4: Understand the principles of dynamic programming and solve multistage decision processes.
CO5: Solve integer programming problems using methods like Gomory's method and branch-and-bound techniques.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Queueing Theory: Introduction, Definitions and Notations, Classification of Queueing Models, Distribution of Arrivals (The Poisson Process): Pure Birth Process, Distribution of Inter Arrival Times, Distribution of Departures (Pure Death Process), Distribution of Service Time, Solution of Queueing Models, Poisson Queues- (M/M/1): (∞/FIFO), (M/M/1):(N/FIFO), (M/M/C): (∞/FIFO), (M/M/C): (N/FIFO).	CO1	**Remembering:** Define queueing terminologies such as Poisson process, arrival rates, departure rates, and service times. **Understanding:** Explain the classification of queueing models and the behavior of M/M/1M/M/1M/M/1, M/M/CM/M/CM/M/C systems. **Applying:** Solve problems involving Poisson queue models and calculate performance measures like average wait time and queue length. **Analyzing:** Compare the impact of different queue parameters on system performance.
2.	Non-Linear Programming Problem (NLPP): Introduction, Maxima and minima of functions of several variables and their solutions, Quadratic forms, Concave and convex functions, Unconstrained and constrained optimization.	CO2	**Remembering:** Recall definitions of concave and convex functions, quadratic forms, and optimization methods. **Understanding:** Explain the concepts of constrained and unconstrained optimization. **Applying:** Solve optimization problems involving multiple variables using given conditions. **Analyzing:** Evaluate the properties of functions (e.g., concavity or convexity) to determine feasible solutions.
3.	Constrained NLPP: Lagrange's method, Kuhn-Tucker conditions, Graphical Method, Concept of Quadratic programming, Frank-Wolfe method. Unconstrained NLPP: Fibonacci and Golden section search, Steepest Descent Method, Conjugate metric method.	CO3	**Remembering:** State methods like Lagrange multipliers, Kuhn-Tucker conditions, Fibonacci search, and Frank-Wolfe method. **Understanding:** Explain the theoretical basis of quadratic programming and search techniques. **Applying:** Solve constrained and unconstrained

			NLPPs using graphical, numerical, or iterative methods. **Analyzing:** Assess the effectiveness of methods like the steepest descent and conjugate metric techniques. **Evaluating:** Critique and compare solution approaches for optimization problems.
4.	Dynamic Programming: Multistage decision processes, Concept of sub-optimality, Principle of optimality, Calculus method of solution, Tabular method of solution, LPP as a case of dynamic programming.	CO4	**Remembering:** Define the principles of optimality and sub-optimality. **Understanding:** Explain multistage decision processes and how dynamic programming solves them. **Applying:** Solve problems using tabular and calculus methods in dynamic programming. **Analyzing:** Break down multistage problems into subproblems and analyze dependencies. **Evaluating:** Examine the suitability of dynamic programming approaches for specific types of problems.
5.	Integer programming: Gomory method for pure and mixed LPP, All pure and mixed integer programming, Algorithm and solution of numerical problems, Branch and bound method.	CO5	**Remembering:** Recall methods like Gomory's method and branch-and-bound. **Understanding:** Describe the differences between pure and mixed integer programming problems. **Applying:** Solve integer programming problems using algorithms like branch-and-bound. **Analyzing:** Analyze numerical solutions to integer programming problems for feasibility. **Evaluating:** Evaluate the performance of integer programming algorithms and their computational efficiency.

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Operations Research: An Introduction	Taha H.A.	10^{th} Edition, 2017,Pearson	USA
2.	Nonlinear Programming: Theory and Algorithms	Bazaraa M.S., Sherali H.D., Shetty C.M.	3rd Edition, 2013, Wiley	USA
3.	Dynamic Programming and Optimal Control	Dimitri P. Bertsekas	4^{th} Edition, 2017, Athena Scientific	USA
4.	Queueing Theory and Stochastic Processes	Bhat U. N.	2^{nd} Edition, 2015, Springer	USA

DAYALBAGH EDUCATIONAL INSTITUTE FACULTY OF SCIENCE DEPARTMENT OF MATHEMATICS				
Course Type	**Course Code**	**Name of Course**	**Lectures / Week (of 55 Min each)**	**Credits**
Major	**MAM802**	**FIELD THEORY**	**4**	**4**

Introduction:

This is a foundational course on field extensions leading to classification of finite fields and computation of group of automorphisms on field extensions.

Objectives:

1. Study finite and algebraic field extensions
2. Applications of algebraic tools to problems related to geometric constructions
3. Classification of finite fields
4. Finite Field as simple extension and splitting field
5. Computation of group of automorphisms

Course Outcomes (CO):

CO1: Study various field extensions and degree
CO2: Construction of a finite field having roots of a polynomial
CO3: Applications of field extensions to geometric constructions
CO4: Splitting field, roots of unity and cyclotomic extension
CO5: Classification of finite fields and subfields
CO6: Automorphisms of a field and computation of Galois group

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Extension of a Field, Quadratic Extensions, Degree, Multiplicativity of Degrees, Finite Extension, Subfield Generated by a Subset, Simple Extension, Roots of a Polynomial in an Extension Field, Fundamental Theorem of Field Theory.	Finite Field Extension	Interpreting, explaining, implementing, differentiating
2.	Algebraic Elements, Finite Simple Extension, Algebraic Extension, Finite and Algebraic Extension, Operations on Algebraic Elements, Applications to Geometric Constructions.	Algebraic Extension, Applications to Geometric Constructions	Interpreting, explaining, implementing, differentiating
3.	Multiplicity of Roots of a Polynomial in an Extension Field, Roots of Unity over Q and over Z_n, Separability of Polynomials, Separable Extension, Splitting Field, Cyclotomic Polynomial, Cyclotomic Extension.	Roots of Unity, Cyclotomic Extension	Differentiating, Checking
4.	Finite Fields, Classification of Finite Fields, Finite Fields as Simple Extensions and their Degree, Structure of Finite Fields, Subfields of a Finite Field.	Classification and Structure of Finite Fields	Differentiating, Checking
5.	Group of Automorphisms of a Field, Fixed Field, Galois Group, Frobenius Automorphism, Applications of Fundamental Theorem of Galois Theory.	Group of Automorphisms	Differentiating, Checking

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	ABSTRACT ALGEBRA	D. S. Dummit and R. M. Foote	Second Edition, 2009, John Wiley & Sons	New Delhi
2.	GALOIS THEORY	Joseph Rotman	Second Edition, 2010, Springer (India)	New Delhi
3.	CONTEMPORARY ABSTRACT ALGEBRA	J. A. Gallian	Fourth Edition, 1999, Narosa Publishing House	New Delhi
4.	TOPICS IN ALGEBRA	I. N. Herstein	Second Edition, 2007, John Wiley & Sons	New Delhi

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Course Type	Course Code	Name of Course	Lectures/Week (of 55 min each)	Credits
DS Major	**MAM 803**	**Functional Analysis**	**4**	**2**

Introduction:

This course introduces the foundational concepts and theorems of functional analysis, with a focus on normed and inner product spaces, bounded linear operators, and spectral theory. It provides a framework for understanding advanced topics in analysis and its applications in mathematics and physics.

Objectives:

1. To develop a strong understanding of normed linear spaces and the concept of compactness in finite-dimensional spaces.
2. To explore the properties of dual spaces and the principles of weak topology.
3. To understand fundamental theorems of functional analysis, including the Hahn-Banach theorem, Open Mapping theorem, and Uniform Boundedness principle.
4. To examine the structure and properties of Hilbert spaces, including orthogonality and Fourier expansions.
5. To analyze the behavior of operators on Banach and Hilbert spaces, with a focus on spectral theory.

Course Outcomes (CO):

By the end of the course, students will be able to:

CO1: Understand the structure and properties of normed linear and Banach spaces, and analyze continuity and compactness in finite-dimensional spaces.

CO2: Finding dual spaces, Apply concepts of dual spaces, weak topology, and embeddings in advanced problems of functional analysis.

CO3: Demonstrate the application of central theorems such as Hahn-Banach, Open Mapping, and Closed Graph theorems in problem-solving.

CO4: Analyze the properties and representations of Hilbert spaces, including orthonormal sets and Fourier expansions.

CO5: Evaluate and apply the spectral theorem and the properties of self-adjoint, normal, and unitary operators in mathematical and physical contexts.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Normed Linear Space, Banach Space, Finite Dimensional Normed Linear Space, Compactness and Finite Dimension, Continuity of a Linear Map.	CO1	Understand, Analyze
2.	Dual Space, Natural Embedding, Weak Topology, Principle Conjugate of an Operator.	CO2	Apply, Analyze
3.	Hahn-Banach Theorem, Open Mapping Theorem, Closed Graph Theorem, Uniform Boundedness Principle.	CO3	Analyze, Evaluate
4.	Hilbert Space, Schwarz's Inequality, Orthogonal Complement, Orthonormal Sets, Bessel's Inequality, Fourier Expansion, Gram-Schmidt Process.	CO4.	Analyze, Apply
5.	Adjoint, Self-Adjoint, Normal, and Unitary Operators, Spectral Theorem.	CO5	Analyze, Evaluate

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1	Functional Analysis	B.V. Limaye	3rd Edition, 2014, New Age International	India
2	Introduction to Functional Analysis	E. Kreyszig	2nd Edition, 1989, Wiley	USA
3.	Functional Analysis: Principles and Applications	H.K. Pathak	1st Edition, 2009, Springer	India
4	Introductory Functional Analysis with Applications	E. Kreyszig	Revised Edition, 2007, Wiley	USA
5.	A First Course in Functional Analysis	C. Goffman and G. Pedrick	1st Edition, 1974, Prentice Hall	USA

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Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 804**	**Fluid Dynamics**	**4**	**4**

Introduction:

This course provides a comprehensive understanding of the fundamental principles and equations governing the motion of fluids. It is designed to introduce students to the core concepts and mathematical formulations used to analyze fluid flow in various physical situations. From basic concepts like the equation of continuity to advanced topics such as boundary layer theory and vortex dynamics, this course equips students with the knowledge to model and solve complex fluid flow problems in engineering, physics, and applied sciences.

Objectives:

1. Develop an understanding of the equations of continuity, motion, and vorticity, and learn to apply them in various coordinate systems and boundary conditions.
2. Study the impact of viscosity on fluid flow, and solve problems using the Navier-Stokes, Euler, and Bernoulli's equations in steady flow situations.
3. Understand two-dimensional flow concepts and complex potentials, including the use of velocity potential and stream function for irrotational and incompressible flows.
4. Learn about vortex dynamics and solve problems involving complex potential theory for vortex systems and their images in different geometries.
5. Gain an understanding of boundary layers and the application of Prandtl's boundary layer theory, alongside solving problems using non-dimensional numbers.

Course Outcomes (CO):

This course is aimed at

CO1: Understand and apply the equation of continuity in different coordinate systems, and solve problems using the Lagrangian and Eulerian forms of the equation of motion.

CO2: Analyze and solve problems involving viscosity, steady flow in different geometries, and apply Navier-Stokes and Bernoulli's equations.

CO3: Understand the concepts of two-dimensional flow, velocity potential, stream function, and apply complex potential theory to various flow systems.

CO4: Analyze vortex dynamics and solve complex potential problems involving vortices and their images in different systems.

CO5: Understand the theory of boundary layers, apply Prandtl's boundary layer theory, and solve problems involving non-dimensional numbers.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	The Equation of Continuity in Cartesian, Polar and Spherical coordinates, Boundary Surface, Eulerian and Lagrangian forms of equation of continuity. Symmetrical form of equation of continuity, Equation of Motion, Pressure equation, Lagrangian equation of motion, Helmholtz vorticity equation, Cauchy's integral.	CO1	
2.	Viscosity, The Navier-Stokes equations of motion, Euler's Equation, Bernoulli's Equation, steady motion between parallel planes, steady flow through a cylindrical pipe, steady flow between concentric rotating cylinders.	CO2	
3.	Meaning of two-dimensional flow, velocity potential and Stream function, Complex potential for irrotational, incompressible flow, complex potentials for line source, sinks and doublets, two dimensional image systems, circle theorem, the theorem of Blasius.	CO3	
4.	Vortex filaments, complex potential due to a vortex of strength +k, motion due to m vortices, two vortex filaments, image of vortex w.r.t. a plane, image of vortex w.r.t. a cylinder, complex potential due to vortex doublet, vortex sheet, infinite single row of vortices of equal strength, two infinite rows of vortices, Karman's vortex sheet.	CO4	

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5.	Non dimensional numbers, Prandtl's boundary layer theory, Karman's integral equation	CO5	

Text Books and Reference Books:

S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	Fluid Mechanics	Frank M. White	8th Edition, 2016 McGraw-Hill Education	New York, USA
2.	Fundamentals of Fluid Mechanics	Bruce R. Munson, Donald F. Young, and Theodore H. Okiishi	Edition: 7th Edition, 2013 John Wiley & Sons	New Jersey, USA

DAYALBAGH EDUCATIONAL INSTITUTE
FACULTY OF SCIENCE
DEPARTMENT OF MATHEMATICS

Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 805**	**Tensor Analysis**	**4**	**4**

Introduction:

This course introduces the fundamental concepts and operations of tensor analysis which is a powerful mathematical tool for studying multidimensional systems.

Objectives:

1. To understand the structure and role of vectors, convectors and dual spaces.
2. To analyze the transformation rules and the relationship between vector spaces and their duals.
3. To classify and work with different types of tensors and tensor ranks.
4. To apply tensor products, metric tensors and transformation laws in computations.
5. To perform advanced tensor operations like contraction, trace and wedge products in various contexts.

Course Outcomes (CO):

This course is aimed at

CO1: Understanding the concept of vectors, convectors, dual spaces and their bases, applying the Einstein summation convention and interpret dual vectors in terms of tangent spaces and gradient.

CO2: Analyzing the second dual space and represent vectors as linear maps on dual vectors, deriving transformation rules for coordinate changes of tangent vectors and their duals.

CO3: Understanding multilinear maps and classifying different types and ranks of tensors on vector spaces and surfaces, distinguishing between tensor spaces and their relation to vector and dual vector spaces.

CO4: Constructing tensor products and analyzing their action on basis elements, working with metric tensors and transformation rules for various tensor components.

CO5: Identifying tensor spaces and performing operations like contraction and tracing of tensors, exploring higher-order tensor operations including wedge products, k-forms and alternating tensors.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	Vector, Dual Vector (Covectors), Dual Space and its Basis, Einstein summation convention, Action of a Dual Vector on a Vector, Application to Tangent Space at a point on Surface, Gradient of a Scalar Function as an Example of Dual Vector	CO1	
2.	Second Dual Space, Vectors as Linear Maps on Dual Vectors, Relation Between Second Dual Space and Original Vector Space, Transformation Rules for Change of Co-ordinates of Tangent Vectors and their Duals	CO2	
3.	Multilinear Maps, Tensors on Vector Spaces, Types of Tensors, Rank of a Tensor, Tensors on Surfaces, Tensor Spaces, Identification Between Tensor Spaces and Vector Space/ Dual Space	CO3	
4.	Tensor product, Action of Tensor Product on Basis Elements, Basis for Tensor Spaces, Components of a Tensor, Metric Tensor, Transformation Rules.	CO4	
5.	Identification Between Tensor Spaces and Endomorphism Space, Contraction/Trace of a Tensor and its Components, Action of One Tensor on Another Tensor, Alternating Tensors, k-Forms, Wedge Product of 1-Forms, Maps Between Tensor Spaces	CO5	

Text Books and Reference Books:				
S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1.	AN INTRODUCTION TO DIFFERENTIABLE MANIFOLDS AND RIEMANNIAN GEOMETRY:	W. M. Boothby	Second Edition, 2003, Academic Press	San Diego, California
2.	RIEMANNIAN MANIFOLDS: AN INTRODUCTION TO CURVATURE	John M. Lee	First edition, 1997, Springer	New York

DAYALBAGH EDUCATIONAL INSTITUTE FACULTY OF SCIENCE **DEPARTMENT OF MATHEMATICS**				
Course Type	Course Code	Name of Course	Lectures/Week (of 55Min each)	Credits
DS Major	**MAM 806**	MATHEMATICAL MODELLING	**3**	**3**

Introduction:

This course provides a comprehensive introduction to mathematical models across various fields, highlighting their importance in understanding complex systems. From physical systems to biological processes, mathematical models help us translate real-world problems into a form where we can use mathematics to gain insights, solve problems, and make informed decisions. The course emphasizes both the theoretical foundations and practical applications of these models.

Objectives:

1. Understand the fundamentals of mathematical modelling and the role it plays in various scientific and practical domains.
2. Understand the impact of environmental constraints on population size and how different factors influence population dynamics.
3. Gain a thorough understanding of basic epidemic models like the SIR and SEIR models.
4. Understand the role of probability in modelling uncertain systems where randomness plays a significant role.
5. Apply linear programming and nonlinear programming to solve optimization problems in fields like economics, engineering, and logistics.

Course Outcomes (CO):

After completion of the course, students will be able to:

1. Construct mathematical models for a wide range of real-world systems.
2. Analyze the behavior of different types of models using appropriate mathematical tools.
3. Make informed decisions and predictions based on the analysis of these models.
4. Solve complex optimization problems using both analytical and computational techniques.
5. Effectively communicate the results and implications of their models to stakeholders in various fields.

Unit No	Topics to be Covered	Learning outcomes	Bloom's Taxonomy
1.	INTRODUCTION Mathematical Modelling Process, Types of Models, Modelling with Discrete Dynamical systems: Modelling change with Difference Equations, approximating change with Difference Equations, Systems of Difference Equations.	CO1	
2.	POPULATION MODELS Single Species, Non-age Structured Population Models, Two Species Population Models.	CO2	
3.	EPIDEMIC MODELS Deterministic models without removals, a simple deterministic model, SIS model, SIS model with specific rate of infection as a function of time, SIS models with constant number of carriers, general deterministic models with removal, approximate solution, asymptotic behaviour of the solution, general deterministic model with immigration-steady state solution.	CO3	
4.	PROBABILISTIC MODELLING Models in Genetics, Genetic Matrices, Hardy-Weinberg Law, Correlation between Genetic composition of Siblings, Genotype and Phenotype ratios, Models for genetic improvements-Selection and Mutation.	CO4	
5.	OPTIMIZATION MODELS Role of optimization model in biology and medicine, finding optimal classification schemes, survival of systems, medical diagnosis problem, optimization models for blood testing and patient care, models for optimal control of water pollution, optimal air pollution control models, control models for solid waste disposal.	CO5	

Text Books and Reference Books:				
S. No.	Title	Author(s)	Edition, Year, Publisher	Place
1-	MATHEMATICAL MODELLING IN BIOLOGY AND MEDICINE	JN Kapur		
2.	INTRODUCTIONS TO MATHEMATICAL BIOLOGY	IA Rubinow		
3.	A FIRST COURSE IN MATHEMATICAL MODELLING	Giordano,Weir & Fox		