M.Sc. (Mathematics) Program

Program Outcomes, Course Outcomes

PROGRAM OUTCOMES	M.Sc. (Mathematics) Program
PO 01	Demonstrate strong understanding of core and advanced mathematical concepts for theory and applications.
PO 02	Apply analytical and problem-solving skills to tackle complex mathematical problems.
PO 03	Use mathematical tools and techniques, including operators and integral equations, for real-world problems.
PO 04	Develop research ability and critical thinking to analyze and extend mathematical theories.
PO 05	Integrate mathematics with interdisciplinary fields like cryptography, statistics, and operations research.
PO 06	Communicate mathematical ideas clearly through writing and presentations.
PO 07	Exhibit ethical behavior and a commitment to lifelong learning in mathematics.

Course	Course Outcome (COs):
Analysis I (MATH-521)	**CO1:** Understand thing of Unaccountability of the reals. Metric spaces, compact and connected set, separability, equivalent metrics. **CO2:** Understanding of Subsequences. Cauchy sequences. Upper and lower limits of a sequence of real numbers. Series, absolute convergence and rearrangement of series. **CO3:** Idea of Limits of functions (in metric spaces) and continuity. **CO4:** Understanding the concept of Continuous functions on compact domains and on connected domains. **CO5:** Knowledge about Discontinuities and monotonic functions on intervals. **CO6:** Integration of vector-valued functions and rectifiable curves., Uniform convergence of sequences and series of functions, its relation to continuity, integrability and equicontinuity.
Complex Analysis (Math-522)	**CO1:** Understand analytic and harmonic functions, Cauchy-Riemann equations, and Möbius transformations. **CO2:** Apply contour integration and Cauchy’s theorems to evaluate complex integrals. **CO3:** Use Taylor and Laurent series, and key theorems to study analytic functions.

	CO4: Identify singularities, calculate residues, and solve integrals using residue theorem.
Algebra (MATH-523)	**CO1:** Understand group structures, isomorphism theorems, and composition series. **CO2:** Analyze group actions, class equations, and apply Sylow theorems to finite groups. **CO3:** Understand factorization in domains and apply concepts like PIDs, UFDs, and the Chinese Remainder Theorem. **CO4:** Explore field extensions, Galois theory, and properties of algebraic and transcendental elements.
Numerical Methods (Math-524)	**CO1:** Apply numerical methods to solve polynomial and linear/nonlinear systems and perform curve fitting and spline interpolation. **CO2:** Solve initial and boundary value problems using single and multistep methods. **CO3:** Solve PDEs like Laplace and Poisson equations using finite difference and iterative methods. **CO4:** Apply numerical techniques to solve parabolic and hyperbolic PDEs and analyze stability of schemes.
Ordinary Differential Equations (Math-525)	**CO1:** Understand the fundamental concepts of real function theory and the existence and uniqueness of solutions for higher-order differential equations. **CO2:** Apply knowledge of homogeneous and nonhomogeneous linear systems, and analyze Sturm-Liouville problems and orthogonality of characteristic functions. **CO3:** Expand functions using orthonormal sets and study the application of separation theorems and oscillation criteria including Picone's modification. **CO4:** Examine comparison theorems and apply Sturm-Liouville theory to differential systems including phase plane analysis and critical point behavior. **CO5:** Analyze nonlinear systems using phase portraits, study limit cycles and periodic solutions, and apply the method of Kryloff and Bogoliuboff.
Analysis II (Math-531)	**CO1:** Understand the concepts of countability, cardinality, and construction of measures using Caratheodory's extension theorem. **CO2:** Explore Borel and Lebesgue measures on $\mathbb{R}$, and analyze measurable and non-measurable sets. **CO3:** Study measurable functions, simple functions, and the Lebesgue integral along with its basic properties. **CO4:** Apply major convergence theorems and inequalities in the context of Lebesgue integration. **CO5:** Understand differentiation of monotone functions, absolute

	continuity, and properties of convex functions.
Programming In C (Math-533)	**CO1:** Understand the basics of algorithms, programming structure, variables, and arithmetic operations in C. **CO2:** Apply conditional statements, loops, and arrays to develop efficient C programs. **CO3:** Use functions, strings, stacks, and structures to solve programming problems. **CO4:** Implement pointers, recursion, lists, and trees in C for advanced data handling. **CO5:** Perform file operations and apply bit-level and miscellaneous features of C in real-world applications.
Partial Differential Equations (Math-551)	**CO1:** Understand Fourier series and apply them to model and solve the heat equation using separation of variables. **CO2:** Formulate and solve various wave equation problems with appropriate boundary conditions. **CO3:** Solve boundary value problems related to Laplace's equation in different geometries. **CO4:** Apply Fourier transforms to heat, wave, and Laplace equations in unbounded domains. **CO5:** Use Green's function method to solve PDEs and understand its application in physical problems.
Calculus Of Variations And Analytical Mechanics (Math-567)	**CO1:** Understand variational principles and solve classical problems like shortest distance, Brachistochrone, and isoperimetric problems. **CO2:** Apply Euler's equations to functionals involving multiple variables, higher-order derivatives, and identify natural boundary and transition conditions. **CO3:** Analyze mechanical systems using generalized coordinates, constraints, virtual displacements, and D'Alembert's principle. **CO4:** Derive and apply Lagrange's and Hamilton's equations to conservative and non-conservative systems. **CO5:** Explore advanced mechanics concepts including canonical transformations, Poisson brackets, Hamilton-Jacobi theory, and action-angle variables.
Curves And Surfaces (Math-535)	**CO1:** Understand vector-valued functions, curve properties, and Serret-Frenet formulas. **CO2:** Analyze surfaces in R^3, including tangents, normals, and surfaces of revolution. **CO3:** Apply first and second fundamental forms to study curvature and mappings of surfaces. **CO4:** Examine geodesics, geodesic curvature, and major results like Gauss's Theorema Egregium. **CO5:** Evaluate surface area and volume integrals and apply geometric inequalities like the isoperimetric inequality and four-

	vertex theorem.
Mathematical Statistics (Math-552)	**CO1:** Understand axiomatic probability, random variables, and basic inequalities like Chebyshev's inequality. **CO2:** Analyze joint, marginal, and conditional distributions, including standard discrete and continuous distributions. **CO3:** Apply transformation techniques, moment-generating functions, and study sampling distributions and confidence intervals. **CO4:** Understand concepts of stochastic convergence and limiting distributions. **CO5:** Apply Gauss-Markov theorem, estimate parameters, and perform hypothesis testing in linear models.
Discrete Mathematics (Math-553)	**CO1:** Understand sets, relations, equivalence and partial order relations, and apply inclusion-exclusion principle. **CO2:** Apply counting principles, permutations, combinations, and solve linear recurrence relations using generating functions. **CO3:** Analyze graphs, including Eulerian and Hamiltonian paths, shortest paths, and planarity concepts. **CO4:** Explore trees, traversals, binary search trees, spanning trees, and cut sets in graph theory. **CO5:** Understand lattice theory, including distributive, modular, complemented lattices, and Boolean algebras.
Topology (MATH-561)	**CO1:** Understand fundamental concepts of topological spaces, metric and ordered topologies, and set operations like closure and boundary. **CO2:** Analyze product and quotient topologies and study connectedness and path-connectedness of spaces. **CO3:** Learn separation axioms (T0 to T4), their properties, and key theorems like Urysohn's lemma and Tietze's extension theorem. **CO4:** Explore compactness concepts in general and metric spaces, including sequential compactness and local compactness. **CO5:** Apply major results such as Tychonoff's theorem and understand one-point compactification techniques.
Integral Equation And Transformation (MATH-554):	**CO1:** Classify linear integral equations and understand conversions between integral and differential equations. **CO2:** Apply various methods like decomposition, successive approximations, and direct computation to solve Fredholm and Volterra integral equations. **CO3:** Solve integro-differential and singular integral equations using series solutions and decomposition methods. **CO4:** Analyze nonlinear integral equations and apply fixed-point theorems for existence and uniqueness of solutions. **CO5:** Use integral transforms such as Fourier, Laplace, and Mellin transforms to solve integral equations and apply

	convolution theorems.
Operations Research (Math-568)	**CO1:** Understand convex sets, functions, and formulate Linear Programming Problems (LPP) with graphical and simplex methods including Big M and Two-phase techniques. **CO2:** Analyze duality theory, solve dual problems, and apply dual simplex and sensitivity analysis; use integer programming methods like Gomory's and branch & bound. **CO3:** Formulate and solve Transportation and Assignment Problems using North-West corner, Vogel's, UV methods, and Hungarian method; understand goal programming techniques. **CO4:** Study two-person zero-sum games, solve using maximin-minimax principle, graphical and LP methods, and apply dominance and mixed strategies. **CO5:** Apply shortest path algorithms (Dijkstra, Floyd), minimal spanning tree, max flow problems, and understand max flow-min cut theorem.
Number Theory-1 (MATH-562)	**CO1:** Understand divisibility, Euclidean algorithm, fundamental theorem of arithmetic, and solve congruences using Chinese remainder theorem, Fermat's and Wilson's theorems. **CO2:** Explore residue classes, Euler's theorem, and apply number theory concepts to public key cryptography; study arithmetic functions and Möbius inversion formula. **CO3:** Analyze greatest integer function, perfect numbers, Mersenne and Fermat primes, primitive roots, indices, and properties of quadratic residues. **CO4:** Apply Legendre and Jacobi symbols, quadratic reciprocity law, and work with binary quadratic forms and their reductions. **CO5:** Solve Diophantine equations and study representations of numbers as sums of squares using positive definite binary quadratic forms.
Functional Analysis (Math-563)	**CO1:** Understand normed linear spaces, Banach spaces, and fundamental theorems including Hahn-Banach, Banach-Steinhaus, Open Mapping, and Closed Graph theorems. **CO2:** Explore dual spaces, reflexivity, weak and weak* convergence, inner product spaces, Hilbert spaces, and separability. **CO3:** Learn the Riesz Representation Theorem, properties of orthonormal sets, projections, and various classes of operators (self-adjoint, normal, unitary, compact). **CO4:** Analyze spectral theory for compact self-adjoint operators and related functional analytic techniques. **CO5:** Apply functional analysis methods to solve classical problems in analysis.
Difference Equation	**CO1:** Understand difference calculus concepts including

(MATH-564)	difference operators, summation formulas, generating functions, and Bernoulli polynomials. **CO2:** Solve first-order and higher-order linear difference equations with constant and variable coefficients, including initial value problems and eigenvalue analysis. **CO3:** Analyze stability of linear and nonlinear difference systems, apply Putzer algorithm, and explore chaotic behavior. **CO4:** Learn and apply the Z-Transform for solving difference equations, including convolution, initial and final value theorems. **CO5:** Study Volterra and Fredholm summation equations, and use asymptotic methods to analyze behavior of solutions to difference equations.
Coding Theory (MATH-565)	**CO1:** Understand basic concepts of vector spaces, finite fields, and error-correcting codes. **CO2:** Apply linear codes, encoding, decoding, and dual codes in coding theory. **CO3:** Use parity-check matrices and syndrome decoding to detect and correct errors. **CO4:** Analyze important codes like Hamming, perfect, and BCH codes with their properties. **CO5:** Explore cyclic codes, weight enumerators, and optimal code classifications like MDS codes.
Non-Commutative Rings (Math-566)	**CO1:** Understand fundamental concepts of rings, modules, ideals, and ring/module homomorphisms, including algebra of ideals and endomorphism rings. **CO2:** Analyze semi-simple modules, composition series, annihilator ideals, and study prime ideals and radicals in rings. **CO3:** Explore Jacobson radical, primitive rings, and apply Jacobson density theorem along with relations between radicals and idempotents. **CO4:** Study Artinian rings, semisimple Artinian rings, Wedderburn-Artin theorem, and properties of complement submodules. **CO5:** Understand essential and small submodules, injective and divisible modules, and the concept and examples of injective hulls, especially over principal ideal domains.
Non-Linear Optimization (MATH-571)	**CO1:** Understand convex hulls, Closure and interior of a set, Separation and support of sets, Separation theorems of convex sets, convex cones and polarity, Polyhedral sets, Extreme points and extreme directions **CO2:** Knowledge of definitions and Basic properties of convex functions generalised convex functions, Differentiable convex functions, twice differentiable convex functions, **CO3:** Able to find Minima and Maxima of Convex functions

	CO4: Apply Fritz Johnand Karush-Kuhn-Tucker optimality conditions for solving non linear programming problem **CO5:** Able to solve Linear quadratic programs
Number Theory-II (Math-572)	**CO1:** Understand Farey sequences, continued fractions, and methods for approximating real numbers by rationals, including solutions to Pell's equations. **CO2:** Apply Minkowski's theorem from the Geometry of Numbers and study its applications, along with the theory of partitions. **CO3:** Comprehend the statement and implications of the Prime Number Theorem and elementary results on the distribution of primes. **CO4:** Analyze Euler's summation formula, Abel's identity, and their roles in number theory and prime distribution. **CO5:** Gain familiarity with Dirichlet series and explore famous conjectures and theorems in number theory, including proofs of some fundamental results.
Commutative Algebra (Math-573)	**CO1:** Understand various types of ideals such as prime, semi-prime, primary, maximal, nil radical, and Jacobson radical, and apply the Chinese Remainder Theorem and concepts of co-maximal ideals and primary rings. **CO2:** Analyze modules with chain conditions, study module homomorphisms, exact sequences, tensor products, and explore properties of free and projective modules, along with Noetherian rings and Hilbert's Basis Theorem. **CO3:** Comprehend primary decomposition, Lasker-Noether theorem, Krull's intersection theorem, and their applications to principal ideal domains, Artinian rings, and discrete valuation rings. **CO4:** Examine quotient rings formed by multiplicative systems and prime ideals, including extended and contracted ideals, and their structural properties. **CO5:** Explore integral extensions, integral closures, invertible and fractional ideals, and understand Dedekind domains and factorization of ideals within them.
Algebraic-Topology (Math-574)	**CO1:** Understand homotopies, homotopy equivalence, retractions, deformation, and basic concepts of category theory including factors and natural transformations. **CO2:** Define and analyze the fundamental group of a space and its behavior under continuous mappings. **CO3:** Explore covering spaces, path liftings, and existence of universal covers. **CO4:** Compute fundamental groups using covering spaces, study projection spaces and tori, and understand deck transformation

	groups. **CO5:** Apply topological theorems including Borsuk–Ulam theorem for S2 and Brouwer fixed-point theorem in dimension 2.
Fuzzy Set Theory And Application (MATH-575)	**CO1:** Understand basic definitions of fuzzy set and their properties **CO2:** They will know about Fuzzy numbers and relation between fuzzy number and a convex fuzzy set Operations on fuzzy numbers in terms of its membership functions as piecewise defined functions, fuzzy cardinality of a fuzzy set using fuzzy numbers, arithmetic operators on fuzzy numbers **CO3:** Able to solve fuzzy equations, equation A+X = B, equation A.X = B **CO4:** Know about Crisp and fuzzy relations
Stochastic Processes (Math-576)	**CO1:** Have a reinforced knowledge of basic probability theory and effectively express themselves in statistical terms either in written or oral. **CO2:** Understand and apply sequences of random variables **CO3:** Have a firm understanding of the central limit theorem and its applications **CO4:** Understand the basic concepts of continuous random processes **CO5:** Apply the knowledge of Poisson Process and Marcov chains in practical situations **CO6:** Apply the concept of Random walk in real world problems
Applied Functional Analysis (Math-577)	**CO1:** Review basic properties of Hilbert spaces and convex programming including support functionals of convex sets. **CO2:** Understand Minkowski functional, separation theorem, Kuhn-Tucker theorem, minimax theorem, and Farkas theorem. **CO3:** Study spectral theory of operators, compact operators, operators on separable Hilbert spaces, and Krein factorization theorem. **CO4:** Explore L^2 spaces over Hilbert spaces, multi-linear forms, analyticity theorems, and nonlinear Volterra operators
Fluid Mechanics (Math-578)	**CO1:** Understand fundamental concepts of fluid motion including velocity, streamlines, and equations of continuity. **CO2:** Apply Euler’s and Bernoulli’s equations to analyze ideal and real fluid flows with boundary conditions. **CO3:** Analyze vorticity, impulsive motion, and complex potential functions for various fluid flow scenarios. **CO4:** Explain viscous effects, laminar flows, and flow characteristics through different tube cross-sections. **CO5:** Describe boundary layer theory, dimensional analysis, and wave motion phenomena in fluid systems.
Research Methodology	CO 01: Student will be able to learn how to write synopsis.

Research Methodology (RM-599)	CO 02: Student will be able to understand about basic terms of statistics. CO 03 : Student will be able to learn application of computer fundamentals in research . CO 04: Student will be understood about plagiarism and IPR.