Programme Outcomes, Programme Specific Outcomes and Course Outcomes

For PG Programmes running in DDE, NBU, campus

Programme Name: M. Sc in Mathematics

Number of Semesters: 4

DIRECTORATE OF DISTANCE EDUCATION
University of North Bengal
West Bengal, INDIA

Programme Outcomes

- Inculcate critical thinking to carry out scientific investigation objectively without being biased with preconceived notions.
- Equip the student with skills to analyze problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.
- Prepare students for pursuing research or careers in industry in mathematical sciences and allied fields
- Imbibe effective scientific and/or technical communication in both oral and writing.
- Continue to acquire relevant knowledge and skills appropriate to professional activities and demonstrate highest standards of ethical issues in mathematical sciences.
- Create awareness to become an enlightened citizen with commitment to deliver one's responsibilities within the scope of bestowed rights and privileges.

Programme Specific Outcomes

- Understanding of the fundamental axioms in mathematics and capability of developing ideas based on them.
- Inculcate mathematical reasoning.
- Prepare and motivate students for research studies in mathematics and related fields.
- Provide knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in other scientific and engineering domains.
- Provide advanced knowledge on topics in pure mathematics, empowering the students to pursue higher degrees at reputed academic institutions.
- Strong foundation on algebraic topology and representation theory which have strong links and application in theoretical physics, in particular string theory.
- Good understanding of number theory which can be used in modern online cryptographic technologies.
- Nurture problem solving skills, thinking, creativity through assignments, project work.
- Assist students in preparing (personal guidance, books) for competitive exams e.g. NET, GATE, etc

Course Outcomes

SEMESTER—I		
Course Code	Course Name	Course Outcomes
DEMATH1CORE1	Abstract Algebra	Knowledge gained: 1. Concept of Homomorphism of Groups, Isomorphism Theorems. 2. Structure Quotient Ring. 3. Prime and irreducible elements, Maximal and Prime Ideals, Irreducible and prime elements in a Ring. and relations among them. 4. Concept of Ring Homomorphism, Isomorphism Theorems , Ideal and Quotient Ring Skills gained: 1. Solving problems using the powerful concept of group action. 2. Facility in understanding the structure of a problem where the problem involves Class Equation. 3. Ability to understand a large class of commutative rings by regarding them as quotients of polynomial rings by suitable ideals. . Competency developed: 1. Applying the concept of a group action to real life problems such as Counting 2. Facility in handling problems Conjugacy Relation, Cauchy's Theorem, Sylow's Theorems and applications. 3. Facility in working with situations involving commutative rings, in particular monogenic algebras of matrices. Implies facility in working with matrices, a concept that finds a large number of applications in real life including the graphs and networks.
DEMATH1CORE2	Complex Analysis I	Knowledge gained: 1. Metric spaces (in particular, the complex plane). Analytic functions, Cauchy-Riemann differential equations, harmonic functions. 2. Power series, zeros ,singularities 3. Cauchy's theorem, Cauchy's integral formula, and applications. 4. Cauchy's residue theorem, and applications. 5. Mobius transformations.. 6. Skills gained: 1. Differentiation of functions on $\mathbb{C}$, deciding if a function on $\mathbb{C}$ isanalytic. 2. Development of functions into power series, classifying singularities. 3. Integration of functions on $\mathbb{C}$, applications to counting zeros and poles. 4. Evaluation of indefinite real integrals using complex analysis.

		5. Constructing Mobius transformations mapping given circles to given circles. Competency developed: 1. Understanding of topological and geometric properties of the complex plane. 2. Differentiation and integration of functions on $\mathbb{C}$, with applications to problems from real analysis. 3. Viewing analytic functions as conformal mappings
DEMATH1SCORE3	Analysis of Several Variables	Knowledge gained: 1. Differentiability of maps from $\mathbb{R}^m$ to $\mathbb{R}^n$ and the derivative as a linear map. 2. Determinant as mapping; its continuity and differentiability. Existence and meaningfulness of e^{A} and its continuity as well as differentiability (A is a real square matrix). 3. Chain Rule, mean value theorem for differentiable functions. 4. Multiple integrals, Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e., product of intervals. 5. Inverse and implicit function theorems (without proof). 6. Curves in $\mathbb{R}^2$ and $\mathbb{R}^3$. Line integrals, Surfaces in $\mathbb{R}^3$, Surface integrals, Integration of forms, Divergence, Gradient and Curl operations, Green's theorem. Skills gained: 1. The notion of differentiability of maps from $\mathbb{R}^m$ to $\mathbb{R}^n$ and the derivative as a linear map. 2. Differentiability of functions in several variables and their relation to partial derivatives. 3. Realizing the differentials in terms of geometric properties. Competency Developed: 1. Ability to handle convergence of series and sequence of functions. 2. Ability to differentiate functions in $\mathbb{R}^m$ to $\mathbb{R}^n$. 3. Apply Implicit and inverse function theorem, moving towards Differential manifolds 4. Realizing Curves in $\mathbb{R}^2$ and $\mathbb{R}^3$. Line integrals, Surfaces in $\mathbb{R}^3$, Surface integrals, Integration of forms, Divergence, Gradient and Curl operations, Green's theorem.
DEMATH1ELEC4	Differential Geometry	Knowledge gained: 1. Riemannian manifolds and submanifolds 2. Geometry of space curves. 3. Regular surfaces, differential functions on surfaces, the tangent plane and the differential maps between regular surfaces. 4. Knowledge of operators on forms and integrations, Lie derivative, Stokes theorem, Gauss-Bonnet formula and Index theorem. 5. Second fundamental form, principle curvatures, Gaussian and

		mean curvatures. Skills gained: 1. Show fundamental theorem for space curves. 2. Analyse some properties of family of curves. 3. Find the Equation of Straight lines, Helix, Bertrand curve. 4. Explain Gauss map, shape operator. 5. Derive some properties of Developable surface.
DEMATH1ELEC5	p-adic Analysis	Knowledge gained: 1. Congruence and Modular equation. 2. p-adic norm and the p-adic numbers. 3. The topology of $\mathbb{Q}_p$. 4. p-adic algebraic number theory Skills gained: 1. Convergence of *infinite series of* p-adic numbers. 2. Realizing the topology in terms different metric. Competency Development: 1. Ability to handle new number system. 2. Ability to topology of $\mathbb{Q}_p$. 3. Some elementary p-adic Analysis.

SEMESTER—II		
Course Code	Course Name	Course Outcomes
DEMATH2CORE1	Real Analysis	Knowledge gained: 1. Basic definition of metric space, norm linear space and inner product space, extended real numbers. 2. Algebraic operations and convergence in extended real numbers. 3. Lebesgue outer measure, Measurable sets. 4. Borel and Lebesgue measurability. Skills gained: 1. Viewing Measurable Functions, Borel and Lebesgue measurability. 2. Borel and Lebesgue measurability. Competency Development: 3. Understanding Mesure of a sets, Measurable sets, Borel sets.

DEMATH2CORE2	Point Set Topology	Knowledge gained: 1. Topological spaces 2. Connectedness, compactness, separation axioms 3. Continuity 4. Metric spaces review 5. Fundamental groups 6. Covering spaces 7. Compactifications. Skills gained: 1. Generalization of concepts like continuity 2. Generalizations of theorems 3. Distinguishing spaces up to homeomorphisms Competency gained: 1. Understanding of topological spaces and having a grasp on basic results.
DEMATH2SCORE3	Ordinary Differential Equations	Knowledge gained: 1. Ordinary differential equations and linear system of ODEs.. 2. Power Series methods with properties of Bessel functions , Legendré polynomials and Hermite polynomials. 3. Cauchy-Peano existence and uniquenessTheorem. 4. Picard-Lindelof Theorem, Continuation of solutions. 5. Solution to eigen value, boundary value problems. Skills gained: 1. Solve ordinary differential equations. 2. Solve linear system of homogeneous and non-homogeneous ODE.s. 3. idea about interval of existence, continuous dependence. 4. Idea about Sturm comparison theorems and oscillations. Competency development: 1. Ability to handle ordinary differential equations and solve the appropriate assumptions. 2. Ability to solve a linear system of ODE.'s 3. Apply the solvability of the initial value problems in appropriate conditions
DEMATH2ELEC4	Theory of Rings and Modules	Knowledge gained: 1. Module theory as linear algebra over general rings.. 2. Special classes of modules: free modules, projective modules, flat modules etc. 3. Theory of modules over PID and its application to Jordan and Rational canonical forms. 4. Basic concepts in homology: Hom, Tensor etc. Skills gained: 1. Ability to handle complicated matrices and systems of equations via decomposing into nice forms. 2. Ability to deal with module theory which is indispensable in wide ranges of mathematical disciplines such as algebra, topology, number theory, operator theory etc.

		3. Ability to handle modern algebraic notions like quotients, generators and relations, universal mapping property etc. Competency developed: 1. Deeper insight into and further comfort with linear algebra 2. Ability to think about classical problems in algebra that involves systems of equations in terms of language of modern algebra. 3. Basic preparation various research areas in pure mathematics like algebraic geometry, Algebraic Number Theory, Topology etc. 4. An abstract perspective to many real life problems can be solve.
DEMATH2ELEC5	Complex Analysis II	Knowledge gained: 1. Basic definitions of Harmonic Conjugate of a Harmonic function. 2. Some concepts about Poisson's integral formula , Mean value property, The maximum and minimum principles, Characterization of harmonic function by mean value property. 3. General principle of convergence of infinite product 4. Factorization of Integral function . Skills gained: 1. The function n(r), Exponent of Convergence of Zeros. 2. Canonical products, Hadamard's factorization theorem. 3. Genus. Competency Development: 1. Ability to handle convergence of series and Infinite products. 2. Ability to factorization of integral function. .
SEMESTER—III		
Course Code	Course Name	•
DEMATH3CORE1	Linear Algebra	Knowledge gained: 1. Matrix theory, determinants and their application to systems of linear equations. 2. Eigen values, diagonalization of matrices and reduction of systems of linear equations into simpler systems of easily tractable nature. 3. Diagonal forms, triangular forms, Direct Sum Decompositions, Invariant Direct sums, The Primary Decomposition Theorem. 4. Applications of matrix algebra. 5. Jordan Blocks and Jordan forms. Skills gained: 1. Handing of systems of linear equations. 2. Use mathematical software to solve problems on linear

		systems. 3. Ability to go abstract from concrete: from concrete notion of solution spaces to vector spaces. 4. Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms. Competency developed: 1. Solving Systems of linear equations. 2. Qualitative analysis of systems of linear equations. 3. Vector Spaces, linear independence and foundations of abstract algebraic thinking. 4. Invariant Direct sums, The Primary Decomposition Theorem.
DEMATH3CORE2	Functional Analysis	Knowledge gained: 1. Concept of normed linear spaces and inner product spaces. 2. Concept of bounded linear operators between these spaces. 3. Concept of the dual space of a normed linear space. 4. Concept of compact, self-adjoint and normal operators. 5. Concept of the spectrum of a bounded linear operator. Skills gained: 1. Using topology to work with infinite dimensional vector spaces. 2. Using careful analysis to show that certain spaces of functions are complete. 3. Comparing the differences between finite and infinite dimensional spaces. 4. Comparing the differences between Banach and Hilbert spaces. 5. Analysing the structure of the spectrum of certain operators. Competency developed: 1. Working with a complete orthogonal set a.k.a. Schauder basis ina Hilbert space. 2. Investigating the best approximation of a given vector by vectors ina given subspace. 3. Computing the dual spaces of certain Banach spaces. 4. Working with weak and weak* topologies on normed linear spaces
DEMATH3SCORE3	Partial Differential Equations	Knowledge gained: 1. Classification of Second Order Partial Differential Equations: normal forms and characteristics. 2. Heat equation: initial value problem, fundamental solution, weak and strong maximum principle and uniqueness results. 3. Uniqueness, D'Alembert's method, method of spherical means and Duhamel's principle. 4. Solution to the Laplace equations. Skills gained: 1. Solve partial differential equations. 2. idea about D'Alembert's method. 3. Methods of separation of variables for heat, Laplace and

		wave equations. Competency development: 1. Ability to handle partial differential equations and solve the appropriate assumptions. 2. Existence of solutions using Perron`s method. 3. Apply the solvability of the initial and Boundary value problems in appropriate conditions.
DEMATH3OLEC4	Discrete Mathematics	Knowledge gained: 1. Basic set theory, cardinal numbers, different concepts of infinity. 2. Basic combinatorics, induction, inclusion exclusion, pigeon hole principle. 3. More advance topics in combinatorics: recurrence relations ,generating functions, Polya's theorem, graphs, trees, topics in matching such as Marriage theorem. 4. Ramsey theory, planar graph. 5. Partially ordered set: Dilworth's theorem and extremal set theory. 6. Application to real life problems such as network theory, data structure, optimization etc. Skills gained: 1. Efficiency in handling with discrete structures. 2. Efficiency in Set theory and handling formal of notions of size. 3. Efficiency in notions of matching, ordering, planarity. 4. Efficiency in solving concrete combinatorial problems whose presence is ubiquitous in science and engineering. Competency developed: 1. Ability to deal with notions of mapping and via that notion ability to tackle various notions of infinity like countable, uncountable etc. 2. Ability to use graphs as unifying theme for various combinatorial problems. 3. Ability to apply combinatorial intuitions in network theory, data structure and various other fields of science
DEMATH3OLEC5	Elementary Number theory	Knowledge gained: 1. Definitions of divisibility and relate dalgorithms 2. Basic congruence results 3. Quadratic reciprocity 4. Distribution of primes 5. Basic additive results 6. Diophantine approximation and transcendental numbers Skills gained: 1. Solutions of Diophantine equations 2. Arithmetical functions 3. Distribution of primes

		Competency developed: 1. Useful tools in cryptography and related applied subjects
SEMESTER–IV		
Course Code	Course Name	Course Outcomes
DEMATH4CORE1	Abstract Measure theory	Knowledge gained: 1. Abstract measure spaces: σ-algebra of sets, limit of sequences of sets, Borel σ-algebra, measure on a σ-algebra. 2. measurable space and measure space. 3. Borel and Lebesgue measurability of functions on $\mathbb{R}$. Skills gained: 1. Computation of Lebesgue measures. 2. Establishing measurability or non-measurability of sets and functions. 3. Completion of Measure space. Competency developed: 1. Extension of measures in abstract sense. 2. Viewing Cantor ternary set and Cantor lebesgue function. .
DEMATH4SCORE2	Numerical problem solving by computer programming (THEORY)	Knowledge gained: 1. Wide variety of numerical techniques to solve mathematical problems arising in diverse scientific contexts. Implementation of stable algorithms for finding roots of nonlinear equations, solving linear system of equations, and solution for ODEs, etc. 2. Influence of data representation on computers on numerical algorithms. Skill gained: 1. Implementing numerical algorithms through computer programs. 2. Analysis of errors of numerical algorithms. Competency gained: 1. Obtain approximate stable solution to mathematical problems making use of numerical algorithms.
DEMATH4SCORE3	Numerical problem solving by computer programming (PRACTICAL)	Knowledge gained: 1. Interpolation: Newtown forward, Newtown backward, Stirling, Lagrange etc. 2. Differentiation: Using interpolated polynomials. 3. Integration: Trapizoidal Method, Simpson Method, Romberge Method, Gauss Quadrature Method. 3. 4. Matrix inversion: Gauss Jordan method. Skill gained: 3. Implementing numerical algorithms through computer programs. 4. Analysis of errors of numerical algorithms. Competency gained: 1. Obtain approximate stable solution to mathematical problems

		making use of numerical algorithms.
DEMATH4ELEC4	Integral equation and integral transform	1. classifications, successive approximations, separable kernels, Fredholm alternative,. 2. Hilbert-Schemidt theory of symmetric kernels. 3. Calculus of Variations, Euler-Lagrange's equations. 4. Geodesics, Minimum surface of revolution. 5. Laplace and Fourier transforms. Skills gained: 1. Applications to boundary Value Problems. 2. Applications Inversion formulae, Convolutions and applications. Competency development: 1. Ability to handle Integral equations and solve the appropriate assumptions. 2. Existence of applications of wave, heat and Laplace equation. 3. Apply the solvability of the initial and Boundary value problems in appropriate conditions.
DEMATH4ELEC5	Field extension and Galois theory	Knowledge gained: 1. Solving polynomial equations using formulas for roots 2. How to test if a polynomial is irreducible Finite Field (Galois Fields) 3. Understanding which equations can be solved using radicals. Skills gained: 1. Ability to understand/obtain the roots of a polynomial equation if the same has (or can be reduced to) degree less than five. 2. Facility in working with finite fields 3. Applying the concept of a field extension to various mathematical problems including geometric constructions and perfect division of a circle into parts.
DEMATH4ELEC6	Algebraic Topology	Knowledge gained: 1. Concept of homotopy of maps and topological spaces 2. Concept of chain complexes of abelian groups 3. Concept of homology and cohomology groups of spaces 4. Exposure to the language of categories and factors. Skills gained: 1. Ability to compute homology groups using long exact sequences 2. Ability to exercise geometric intuition and visualization. 3. Ability to translate geometric intuition into rigorous proofs 4. Working with geometric objects which exist only in higher dimensions.

		Competency developed: 1. Ability to differentiate between some more topological spaces 2. Working with homological methods in algebra 3. Using algebraic methods to solve topological problems 4. Using topological methods to solve algebraic problems.
DEMATH4ELEC7	General theory of Integration	Knowledge gained: 1. Tagged Gauge Partitions. Definitions, Cousins Theorem, Right-left Procedure, Straddle Lemma. 2. Henstock–Kurzweil Integral. 3. Definition and basic properties. 4. Fundamental Theorem, Saks-Henstock Lemma, Inclusion of the Lebesgue integral. 5. Squeez Theorem . Skills gained: 1. Application in continuity, Intrinsic Power. 2. Viewing differentiation using tagged partition. Competency developed: 1. Ability to differentiate between some more topological spaces.