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ताळगांव पठार,
गोंय – ४०३ २०६
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(Accredited by NAAC)

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GU/Acad –PG/BoS -NEP/2025-26/176 Date: 26.06.2025

CIRCULAR

The Academic Council & Executive Council of the University has approved Ordinance OA-35A relating to PG Programmes offered at the University campus and its affiliated Colleges based on UGC 'Curriculum and Credit Framework for Postgraduate Programmes'. Accordingly, the University has proposed introduction of Ordinance OA-35A from the Academic year 2025-2026 onwards.

The Programme structure and syllabus of Semester I and II of the **Master of Science in Mathematics** Programme approved by the Academic Council in its meeting held on 13th & 14th June 2025 is attached.

The Dean & Vice-Dean (Academic) of the School of Physical and Applied Sciences and the Principals of the affiliated Colleges offering the **Master of Science in Mathematics** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned**.**

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2025.06.26 16:02:10 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,
1. The Dean, School of Physical and Applied Sciences, Goa University.
2. The Vice-Dean (Academic), School of Physical and Applied Sciences, Goa University.
3. The Principals of the affiliated Colleges offering the Master of Science in Mathematics Programme.

Copy to:
1. Chairperson, BoS in Mathematics, Goa University.
2. Programme Director, M.Sc. Mathematics, Goa University.
3. Controller of Examinations, Goa University.
4. Assistant Registrar Examinations (PG), Goa University.
5. Director, Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

GOA UNIVERSITY

MASTER OF SCIENCE IN MATHEMATICS

(Effective from the Academic Year 2025-26)

ABOUT THE PROGRAMME

The M.Sc. Mathematics Programme offers advanced training in core areas of Mathematics, specifically Analysis, Algebra, Topology, and Differential Equations, along with exposure to allied disciplines and computational tools. It blends theoretical depth with practical skills through vocational courses and research opportunities. The curriculum aims to build strong analytical abilities, encourage independent thinking, and prepare students for research, teaching, or industry roles in mathematics.

OBJECTIVES OF THE PROGRAMME

1. To strengthen foundational knowledge in key areas of mathematics.
2. To develop logical reasoning and proof-writing skills.
3. To equip students with problem-solving techniques for theoretical and applied contexts.
4. To promote effective mathematical communication, both oral and written.
5. To foster the ability to model real-world problems using mathematical tools.
6. To instill a lifelong interest and motivation for learning in mathematical sciences.
7. To prepare students for research, teaching, and careers in academia or industry by fostering independent learning and mastery of mathematical concepts for advanced study and professional growth.
8. Foster a sense of professional ethics, academic integrity, and responsibility in mathematical work and research.

Approved by: Academic Council on 13th & 14th June 2025

PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	Recognize and recall the fundamental concepts in Mathematics.(K1,K2)
PSO 2.	Explain and interpret standard mathematical proofs to demonstrate understanding of logical reasoning and proof techniques.(K1,K2, K4)
PSO 3.	Choose the appropriate procedures, modify them if needed and apply them to solve algorithmic/procedural problems.(K1,K2,K3,K4)
PSO 4.	Assess and plan approaches for solving unseen problems using mathematical reasoning. (K1,K2,K4,K5)
PSO 5.	Formulate innovative methods by integrating diverse mathematical concepts to develop effective solutions/proofs to unseen problems. (K1,K2,K3,K4,K5,K6)
PSO 6.	Communicate mathematical ideas both orally and in writing(K1,K2,K6)

PROGRAMME STRUCTURE

Master of Science in Mathematics

Effective from Academic Year 2025-26

SEMESTER I				
Discipline Specific Core (DSC) Courses (16 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	MAT-5000	Real Analysis	4+0=4	400
2	MAT-5001	Advanced Linear Algebra	4+0=4	400
3	MAT-5002	Ring Theory	4+0=4	400
4	MAT-5003	Advanced Complex Analysis	4+0=4	400
Total Credits for DSC Courses in Semester I			**16**	
Discipline Specific Elective (DSE) Course (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	MAT-5201	Integral Equation	4+0=4	400
2	MAT-5202	Methods of Applied Mathematics	4+0=4	400
3	MAT-5203	Special Functions	4+0=4	400
4	MAT-5204	Discrete Mathematical Structures	4+0=4	400
5	MAT-5205	Computational Mathematics Using Python	0+2=2	400
6	MAT-5206	Number Theory	2+0=2	400
Total Credits for DSE Courses in Semester I			**4**	
Total Credits in Semester I			**20**	

SEMESTER II				
Discipline Specific Core (DSC) Courses				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	MAT-5004	Topology	4+0=4	500
2	MAT-5005	Differential Equations	4+0=4	500
3	MAT-5006	Several Variable Calculus	4+0=4	500
4	MAT-5007	Functional Analysis	4+0=4	500
Total Credits for DSC Courses in Semester II			**16**	
Discipline Specific Elective (DSE) Courses (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	MAT-5201	Integral Equation	4+0=4	400
2	MAT-5202	Methods of Applied Mathematics	4+0=4	400
3	MAT-5203	Special Functions	4+0=4	400
4	MAT-5204	Discrete Mathematical Structures	4+0=4	400
5	MAT-5205	Computational Mathematics Using Python	0+2=2	400
6	MAT-5206	Number Theory	2+0=2	400
Total Credits for DSE Courses in Semester II			**4**	
Total Credits in Semester II			**20**	

Blooms Taxonomy Cognitive Levels	
Cognitive Level	**Notations**
K1	Remembering
K2	Understanding
K3	Applying
K4	Analyzing
K5	Evaluating
K6	Create

SEMESTER I

Discipline Specific Core Courses

Title of the Course	Real Analysis
Course Code	MAT-5000
Number of Credits	04
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil
Course Objectives:	• To introduce the fundamental principles and theoretical framework of Real Analysis, including key definitions, theorems, and properties, enabling students to gain conceptual clarity and familiarity with the subject. • To cultivate the ability to construct and understand rigorous mathematical proofs, reinforcing logical reasoning and the ability to establish mathematical truths within the scope of Real Analysis. • To develop procedural fluency in selecting, adapting, and applying appropriate analytical methods to solve standard and structured problems in Real Analysis. • To promote higher-order thinking by challenging learners to tackle novel and complex problems, and to construct precise, logically coherent mathematical arguments as part of the solution process.

Course Outcomes:			**Mapped to PSO**	
	CO 1. The learner will be able to display familiarity and knowledge of Real Analysis and associated concepts.		PSO1, PSO5, PSO6	
	CO 2. The learner will be able to demonstrate proofs to establish truths related to Real Analysis and associated concepts.		PSO2, PSO5, PSO6	
	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Real Analysis.		PSO3, PSO5, PSO6	
	CO 4. The learner will be able to analyze and solve unseen problems in Real Analysis and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Real Number System:** Peano's Axioms for Natural Numbers and Induction Principle, equivalence of induction, strong induction and the well-ordering principle, Finite sets, cardinality of finite sets, Subset of finite sets , a proper subset of a finite set has cardinality strictly less that the super set, Integers and Rational numbers (Discussion), Ordered sets and LUB Property, Ordered Field Axioms, Field of Real Numbers and Completeness, Archimedean property, integral part of a real number, density of rationals, and irrationals in the reals, Existence of n^{th} roots of nonnegative reals, proof of existence of decimal representation of reals, Countable sets – definition and equivalent reformulations of countability, Countability of unions and Cartesian products of sets, Uncountable sets, Countability of Rationals, Uncountability of Reals, Extended Real Number System.	**18**	CO1, CO2, CO3, CO4.	K1, K2, K3, K4, K5, K6
Module 2:	**Elements of Point Set Topology:** Metric Spaces, Euclidean Spaces, Open balls and Open sets in R^n, Structure of open sets in R^1, Adherent points and Accumulation points, Closed sets, Perfect sets, Every non-empty perfect set of R^n is uncountable, Bolzano- Weierstrass Theorem, Cantor Intersection Theorem, Lindel$\ddot{o}$f Covering Theorem, The Heine-Borel Covering Theorem, Compactness in R^n, Compactness	**14**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	in metric spaces, Connected sets in metric spaces, Connected subsets of R^n, Cantor set-construction and basic properties, Cantor set and ternary expansion.			
Module 3:	**Limits and Continuity:** Convergent sequences in a Metric space , Cauchy sequences and Complete metric spaces, Limit inferior and Limit superior of a sequence, Limit of a Function- (Real valued, complex valued, vector valued functions), Continuous Functions, Continuity and Compactness, Continuity and Connectedness, Bolzano's Theorem and Intermediate value Theorem, Uniform Continuity, Uniform Continuity and Compactness, Discontinuities of Real valued Functions, Monotonic Functions, Infinite limits and Limits at infinity.	**14**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Derivatives:** Derivatives and Continuity, Algebra of Derivatives and Chain rule (Statements only),One sided derivatives and Infinite Derivatives, Functions with non-zero derivatives, Zero derivatives and Local extrema, Rolle's Theorem, Mean value Theorems and consequences, Intermediate value Theorem for Derivatives, Taylor's Formula with Remainder, Derivatives of Vector valued Functions and Complex valued Functions, Derivatives of Higher Order, L'Hospital's Rules with proof.	**14**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	Mathematical Analysis, Tom M. Apostol, Narosa Publishing House, 1996.			
References/ Readings:	1. . Principles of Mathematical Analysis, Walter Rudin, McGraw-Hill International Editions,1976. 2. A Foundation Course in Mathematics, Ajith Kumar, S.Kumaresan, B.K. Sarma, Narosa Publishing House, 2018. 3. A Basic Course in Real Analysis, Kumar and Kumaresan, CRC Press, 2015. 4. Real Analysis, N.L. Carothers, Cambridge University Press, 2000. 5. Calculus with Applications, Peter D. Lax, Maria Shea Terrel, Springer, 2014.			

Title of the Course	Advanced Linear Algebra
Course Code	MAT-5001
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• Understand fundamental concepts in Linear Algebra. • Work with linear functionals, dual spaces, annihilators, and transpose of linear transformations. • Study eigenvalues, eigenvectors, and invariant subspaces. • Understand the significance and compute rational and Jordan canonical forms. • Decomposition of vector spaces.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Display familiarity and knowledge of Vector Spaces, Linear Transformations and associated concepts.	PSO1, PSO6
	CO 2. Demonstrate proofs to establish truths related to Vector Spaces, Linear Transformations and associated concepts.	PSO2, PSO6

	CO 3. Choose the appropriate procedures and modify them if needed to solve method-based problems in Linear Algebra.		PSO3, PSO6	
	CO 4. Analyze and solve unseen problems in Linear Algebra and invent mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Review:** System of linear equations, Vector spaces, Basis and Dimension, Linear Transformations, Matrix of a Linear Transformation. Polynomial Algebra, Polynomial Ideals, Greatest Common Divisors of Polynomials and Prime Factorization of Polynomials.	**10**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Linear Functionals**: Linear Functional on Vector Spaces, Dual of Vector Spaces and Properties, Double Dual, Annihilator, The Transpose of a Linear Transformation and the Matrix, Row Rank equal to Column Rank.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Elementary Canonical Forms**: Characteristic Values and Characteristic Vectors, Characteristic Spaces, Annihilating Polynomials, Invariant Subspaces, Simultaneous Triangulation; Simultaneous Diagonalization, Direct Sum Decompositions, Invariant Direct Sums, The Primary Decomposition Theorem.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**The Rational and Jordan Forms**: Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form, Computation of Invariant Factors.	**18**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	Kenneth Hoffmann and Ray Kunze, Linear Algebra, PHI, Second Edition, 1997.			
References/ Readings:	1. S. Kumaresan, Linear Algebra, PHI, 2000. 2. I. R. Shafarevich and A. O. Remiz Linear Algebra and Geometry, Springer Verlag, 2013. 3. Y.I. Manim, Linear Algebra and Geometry, CRC Press, 1997.			

Title of the Course	Ring Theory
Course Code	MAT-5002
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To introduce the foundational concepts of Ring Theory, including the definitions and properties of rings, integral domains, homomorphisms, and ideals, to build a strong conceptual framework. • To develop the learner's ability to understand and articulate standard proofs and logical arguments concerning the structural properties of rings, polynomials, factor rings, and ideals. • To provide learners with the skills to select and apply appropriate algebraic techniques for solving computation-based problems involving ring operations, polynomial factorization, and ideal-related structures. • To foster analytical thinking and mathematical reasoning by engaging learners in solving unfamiliar problems in Ring Theory and formulating precise, logically sound justifications for their solutions.	
Course Outcomes:		**Mapped to PSO**
	CO 1. The learner will be able to display familiarity and knowledge of basic definitions, structures, and theorems in Ring Theory, including rings, integral domains,	PSO1, PSO6

	homomorphisms, and ideals.			
	CO 2. The learner will be able to demonstrate and explain standard proofs and logical arguments related to properties of rings, polynomials, factor rings, and ideals.		PSO2, PSO6	
	CO 3. The learner will be able to choose appropriate methods and procedures to solve computation-based problems involving ring operations, polynomial factorization, and ideal structures.		PSO3, PSO6	
	CO 4. The learner will be able to analyze and solve novel problems using the concepts of Ring Theory, and construct mathematically sound arguments to support their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Basic Topics in Rings:** Rings, Homomorphisms and Isomorphisms, Division Rings, Skew Fields, Integral Domains, Theorems in Integral Domains, Characteristic of a Ring, Fermat's and Euler's Theorems, Application to solution of linear congruences, Field of Quotients of an Integral Domain, Uniqueness of field of Quotients.	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4
Module 2:	**Ring of Polynomials** Polynomials, The polynomial ring R[x], The Evaluation Homomorphism, Zero of a Polynomial, Factorization of Polynomials over Fields, The Division Algorithm, Factor Theorem, Irreducible Polynomials, Eisenstein's Criterion and consequences.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4
Module 3:	**Ideals and Factor Rings:** Ring Homomorphisms, Properties of Homomorphisms, Quotient Rings, Ideals, Fundamental Homomorphism Theorem, Prime and Maximal Ideals Prime Fields.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4
Module 4:	**Factorization in Integral Domains:** Division in Rings, Unique Factorization Domain and Principal Ideal Domain, Every PID is a UFD and consequence to F[x] and integers, If D is a UFD then D[x] is a UFD, Euclidean Domains, Every	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4

	Euclidean Domain is a PID, Arithmetic in Euclidean Domains, Gaussian Integers, Fermat's $p = a^2 + b^2$ theorem.			
Pedagogy:	Classroom discussion, assignments, online resources			
Texts:	John B. Fraleigh, A First Course in Abstract Algebra, Seventh Edition, Pearson, 2013			
References/ Readings:	1. Joseph A. Gallian, Contemporary Abstract Algebra, Eight Edition, Cengage India Private Ltd, 2019 2. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Edition, Wiley, 2011 3. Michael Artin, Algebra, Second Edition, Pearson Edition, 2015			
Web Resources:	**https://archive.nptel.ac.in/courses/111/106/111106137**			

Title of the Course	Advanced Complex Analysis
Course Code	MAT-5003
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil.	
Course Objectives:	• Develop a rigorous understanding of power series and complex functions. • Understand and analyze key theorems in complex analysis. • Study conformal mappings. • Apply the calculus of residues to evaluate complex integrals and improper real integrals.	
Course Outcomes:		**Mapped to PSO**
	CO 1. The learner will be able to display familiarity and knowledge of complex functions, power series, conformal mappings, singularities, residues, and associated concepts.	PSO1, PSO6
	CO 2. The learner will be able to construct and demonstrate rigorous mathematical proofs of key theorems in Advanced Complex Analysis.	PSO2, PSO6

	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Advanced Complex Analysis.		PSO3, PSO6	
	CO 4. The learner will be able to analyze and solve unseen problems in Advanced Complex Analysis and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Power Series**: Uniform Convergence of Power Series; Exponential and Trigonometric Functions; Logarithmic Functions.	**8**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Complex Integration:** Curves in the complex plane; Properties of complex line integrals; Cauchy-Goursat Theorem; Consequences of Simply Connectivity; Winding number of a curve; Homotopic Version of Cauchy's Theorem; Cauchy Integral Formula; Taylor's Theorem; Zeroes of analytic functions; Laurent's Theorem. Maximum Principle and Schwarz Lemma: Maximum Modulus Principle and Minimum Modulus Theorem; Schwarz Lemma and its consequences; Zeroes of Certain Polynomials;	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Conformal Mappings and Mobius Transformations:** Principle of Conformal Mapping; Basic properties of Mobius maps; Fixed points and Mobius maps; Triples to Triples under Mobius maps; Cross ratio and its invariance property; Principle of Symmetry.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Classification of Singularities:** Isolated and Non-Isolated singularities; Removable singularities; Poles; Isolated singularities at infinity; Meromorphic functions; Essential singularities and Picard's Theorem Calculus of Residues and Applications: Residue at a point, Residue at a point at infinity; Residue theorem; Number of Zeroes and Poles - The Argument Principle; Rouche's Theorem; Open mapping theorem; Definite integrals involving sines and cosines; Evaluation of improper integrals; Singularities	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	along the Real Axis; Integrating along branch cuts; Estimation of Sums.			
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	S. Ponnusamy: Foundations of Complex Analysis, 2nd Edition, Narosa Publishing House, 2005.			
References/ Readings:	1. R. Shastri: Complex Analysis, Laxmi Publications, 2010. 2. E. B. Saff and A. D. Snider: Fundamentals of Complex Analysis with Applications to Engineering and Science, 3rd Edition, Pearson Education, 2008. 3. E. M. Stein and R. Shakarchi: Complex Analysis, Princeton University Press, 2005. 4. J. B. Conway: Functions of a Complex Variable, Springer-Verlag, 1973. 5. J. Brown and R. Churchill: Complex Variables and Applications, 8th Edition, McGraw Hill Education, 2017. 6. L. V. Ahlfors: Complex Analysis, McGraw-Hill Book Company, 1979.			

SEMESTER II

Discipline Specific Core Courses

Title of the Course	Topology
Course Code	MAT-5004
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil
Course Objectives:	• To introduce the foundational concepts of Topology, including Topological Spaces, Metric Spaces, and Homeomorphisms, fostering a strong theoretical understanding of their definitions and properties. • To develop the learner's ability to construct and understand rigorous mathematical proofs related to key topological concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate topological methods and techniques to solve structured problems.

	• To encourage analytical thinking and creativity in solving unfamiliar problems in Topology, enabling learners to construct logically sound and precise mathematical arguments.			
Course Outcomes:			**Mapped to PSO**	
	CO 1. The learner will be able to display familiarity and knowledge of Topological Spaces, Metric Spaces, Homeomorphisms and associated concepts.		PSO1, PSO6	
	CO 2. The learner will be able to demonstrate proofs to establish truths related to Topological Spaces, Metric Spaces, Homeomorphisms and associated concepts.		PSO2, PSO6	
	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Topology		PSO3, PSO6	
	CO 4. The learner will be able to analyze and solve unseen problems in Topology and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Topological Spaces and Continuous Functions:** Definition of Topological spaces, Basis, Subbasis, Order topology, Product Topology, Subspace topology, Closed sets, limit points, closure, interior, Continuous functions, Metric topology and Quotient topology.	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Connectedness**: Connected spaces, connected subsets of, path connected spaces, Product and continuous images of connected spaces, locally connected spaces, components and path components.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Compactness:** Compact subsets of topological spaces, Compact subsets of R, Products and continuous images of compact subsets, Compact Hausdorff spaces, Limit point compactness, Sequential compactness, Compact metric spaces, Lebesgue number lemma, Locally compact spaces and one-point compactification.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Countability and Separation Axioms:** The Countability axioms, Lindelof space, Separable space, Separation axioms, Regular Spaces, Normal spaces.	**12**	CO1, CO2, CO3,CO4	K1, K2, K3, K4, K5, K6

Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.
Texts:	James Munkres, Topology and Introduction, Pearson Education, 2002.
References/ Readings:	1. Stephen Willard, General Topology, Dover Pubns,2004. 2. M A Amstrong, Basic Topology, Springer Verlag, 1983. 3. James Dugundji, Topology, Allyn and Bacon, 1966. 4. George F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963. 5. Fred H. Croom, *Principles of Topology*, Cengage Learning, 1989.
Web Resources:	https://archive.nptel.ac.in/courses/111/106/111106054/

Title of the Course	Differential Equations
Course Code	MAT-5005
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	MAT-5000 Real Analysis , MAT-5001 Advanced Linear Algebra	
Course Objectives:	• Study the basic concepts of first and second order Linear Differential Equations • Understand and Analyse the qualitative theory and some properties of solutions of Differential Equations. • Study and prove results in systems of Differential Equations. • Work with Self-adjoint second order differential equation.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Explain various concepts in first order differential equations, second order differential equations, and systems of differential equations.	PSO1, PSO6
	CO 2. Demonstrate proofs of standard results in Differential Equations.	PSO2, PSO6
	CO 3. Analyse qualitative properties of solutions of differential equations.	PSO3, PSO6

	CO 4. Apply concepts in Differential Equations to create solutions to unseen and complex problems, demonstrating rigorous mathematical reasoning.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Review:** Linear Differential Equations of the first and higher order. Linear differential equations with constant and variable coefficients. Exact equations, Wronskian, Separable equations, Euler's equation, reduction of order of equation, variation of parameters, Abel's Formula.	**10**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Existence and uniqueness of solutions of first order Differential Equations:** Lipschitz condition, Picard's successive approximation method, Gronwall's type integral inequality. Continuation of Solution and dependence on initial conditions. Non local existence of solution.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Systems of Linear Differential Equations:** Existence and Uniqueness of solutions. Vector matrix form. Linear system with Constant and variable coefficients. Fundamental matrix, matrix exp, and repeated eigenvalue. Non homogeneous linear systems and variation of parameters. Conversion of nth order equation to system of first order.	**22**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Self-adjoint second order differential equation:** Sturm Liouville Problem. Greens functions. Picard's theorem. Zeros of solutions. Comparison Theorems. Linear oscillations. Oscillations of $x''(t) + a(t)x(t) = 0$.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	Deo S.G.; Raghvendra V.; RasmitaKar, Lakshmikantham V. : Text book of Ordinary Differential equations, 3rd edition, Tata McGraw Hill, New Delhi 2015.			
References/ Readings:	1. E.A. Coddington; An introduction to Ordinary Differential Equations, Prentice Hall, India,2003. 2. Kelly W. Patterson A.C.: Theory of Differential Equations, Springer, 2010. 3. Simmons G.F.; Differential Equations with Historical Notes, Tata Mcgraw Hill, 2017.			

	4. S.G. Deo, V. Raghavendra, Rasmita Kar, Ordinary Differential Equations, 3rd Edition, Tata McGraw Hill, New Delhi, 2015. 5. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley India, 2014. 6. Morris Tenenbaum and Harry Pollard, Ordinary Differential Equations, Dover Publications, 1985.
Web Resources:	https://archive.nptel.ac.in/courses/111/106/111106054/

Title of the Course	Several Variable Calculus
Course Code	MAT-5006
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• Understand and analyze several variable functions. • Apply optimization techniques in several variable contexts. • Appreciate and apply fundamental multivariable theorems • Develop proficiency in Riemann integration in multiple dimensions. • Master advanced integral techniques in several variables.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Recall and explain concepts related to derivatives of functions of more than one variable, inverse function theorem, implicit function theorem and Riemann integration.	PSO1, PSO6
	CO 2. Demonstrate the proofs of theorems in several variable calculus.	PSO2, PSO6

	CO 3. Apply knowledge gained to solve method based problems in several variable calculus.		PSO3, PSO6	
	CO 4. Analyse, compare and differentiate between various concepts in several variable calculus in order to solve unseen problems in Several Variable Calculus and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Derivative of Function of more than one Variable:** Partial Derivative. Total derivative of a function of more than one Variable. Jacobian. Sufficient Condition for differentiability. Mean Value Theorem. Higher-order derivatives. Condition for Equality of Mixed Partial Derivatives. Taylor's Theorem.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Maximum Minimum:** Critical Point, Maximum Minimum, Second Derivative Condition for Maximum/minimum, Conditional Optimum, and Lagrange Multipliers.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Inverse Function Theorem:** Regular and Singular Points, Open Mapping Theorem, Inverse Function Theorem, Implicit Function Theorem.	**10**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Riemann Integration:** Rectangles in IRn and Riemann sums over Rectangles. Upper and Lower Riemann Sums.Riemann Integral of a bounded Function. Algebra of Riemann Integrals. Sets of Jordan Measure Zero. Oscillation of a Function at a point, Integrability versus points of discontinuity of a Function.	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 5:	Fubini's Theorem. Mean value theorem for multiple integrals. Partitions of unity (Statement only). Change of variable formula.	**6**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. Tom M Apostol, Mathematical Analysis, Addison Wesley Publishing Company, 1996.			

	2. M.Spivak, Calculus on Manifolds, Benjamin Cummings, London. 1965.
References/ Readings:	1. Walter Rudin, Principles of Mathematical Analysis, International Student Edition.1976. 2. James Munkres, Analysis on Manifolds, Addison Wesley Publishing Company,1991. 3. T. M. Apostol, Calculus Vol.II. John Wiley and sons, 1969. 4. B.V. Limaye & S. Ghorpade, A course in multivariable calculus, Springer 2006.

Title of the Course	Functional Analysis
Course Code	MAT-5007
Number of Credits	4+0=4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	MAT-5000: Real Analysis MAT-5004: Topology	
Course Objectives:	• Study the basic notions of Functional Analysis such as normed spaces, inner product spaces, Banach spaces, Hilbert spaces, • Study the structural properties of normed spaces and inner product spaces • Understand bounded linear operators and bounded functionals • Study the four fundamental theorems-Hahn-Banach Theorem. Uniform Boundedness Principle, Open Mapping Theorem and Closed Graph Theorem.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Display familiarity and knowledge of Normed Spaces, Inner product spaces, Banach spaces, Hilbert spaces and operators on these spaces.	PSO1, PSO6
	CO 2. Demonstrate proofs to establish truths related to Normed Spaces, Bounded linear operators and associated concepts.	PSO2, PSO6

	CO 3. Choose the appropriate procedures and modify them if needed to solve method-based problems in Functional Analysis.		PSO3, PSO6	
	CO 4. Analyze and solve unseen problems in Functional Analysis and invent mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Preliminaries from Metric Spaces** Definition of the standard sequence spaces $s, c, c_0, c_{00}, l^p; 1 \leq p \leq \infty$, and standard function spaces $C[a,b]$and $B[a,b]$. Idea of completion of a metric space, completeness and separability properties of these standard spaces.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Normed Spaces, Banach Spaces** Normed spaces- Properties and Banach spaces, Standard normed spaces – Sequence spaces, Function spaces and subspaces, Finite dimensional normed spaces and subspaces, Equivalence of norms, Compactness and finite dimension, Linear Operators-Boundedness and Continuity. Linear functional. Normed spaces of Operators, Dual space-Algebraic and Topological duals.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Inner Product Spaces, Hilbert Spaces** Inner Product Spaces- Properties and Hilbert spaces, Orthogonal Complement and Direct Sums, Orthonormal Sets and Sequences, Total Orthonormal Sets and Sequences, Representation of Functional on Hilbert Spaces, Hilbert -Adjoint Operator, Self Adjoint, Unitary and Normal Operators.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Fundamental Theorems for Normed and Banach Spaces** Hahn-Banach Theorem **(**Statements and idea of proof for the case of vector spaces, statement and proof for normed spaces**)**, Applications to Existence of Functionals, Adjoint Operators, Reflexivity of Spaces, Baire Category Theorem **(**Statement only**)**, Uniform Boundedness Theorem, Open Mapping Theorem, Closed Graph Theorem.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.
Texts:	Introductory Functional Analysis with Applications, Ervin Kreyszig, John Wiley & Sons, 1978.
References/ Readings:	1. Functional Analysis, Balmohan V. Limaye, III edition. 1996 2. Functional Analysis, A First Course, S. Kumaresan and D. Sukumar, Narosa, 2020 3. Functional Analysis, George Bachman and Lawrence Narici, Dover Publishing House, 2000 4. Basic Operator Theory, Israyel Gohberg and Seymour Goldberg, Birkh*ä*user, 1981. 5. Linear Real analysis for Scientists and Engineers, B.V.Limaye, Springer. 2016

SEMESTER I & II

Discipline Specific Elective Courses

Title of the Course	Integral Equations
Course Code	MAT-5201
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• This course helps in understanding basic concepts of Integral Equations. • It develops the ability to solve integral equations by standard methods • To develop a conceptual understanding of various classes of integral equations and their interconnections with differential equations. • To enable learners to explore the applications of integral equations in physical models using analytical techniques such as Laplace and Fourier transforms.	
Course Outcomes:		**Mapped to PSO**

	CO 1. The learner will be able to display familiarity and knowledge of Integral Equations.		PSO1, PSO6	
	CO 2. The learner will be able to demonstrate proofs to establish truths related to Integral Equations.		PSO2, PSO6	
	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Integral Equations.		PSO3, PSO6	
	CO 4. The learner will be able to analyze and solve unseen problems in Integral Equations and create mathematically accurate solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	Integral equations definition, Classification of Integral Equations, Special kinds of kernels, Convolution type, Iterated kernels, Resolvent kernel, Eigenvalues and Eigenfunctions, Leibnitz's rule and its application for multiple integrals, Regularity conditions, Solution of Integral Equations, Converting Differential equations to Integral Equations	**10**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Fredholm Integral Equation of second kind with separable kernel, Fredholm Theorem, Fredholm Alternative theorem, Approximation Method, Iterated Kernels, Resolvent Kernel, results on iterated kernel, Neumann's series for Fredholm Integral Equation (along with proof), problems on Iterative Method for Fredholm and Volterra Integral Equations, Volterra Integral equation of First Kind and its solution.	**15**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Fredholm's First Fundamental Theorem (Statement Only), Problems on Fredholm's First Fundamental Theorem, Fredholm's Second Fundamental Theorem (Statement Only), Fredholm's Third Fundamental Theorem (Statement Only) Properties of Eigenvalues and Eigenfunctions for symmetric kernel, Expansion in Eigenfunctions and Bilinear Form, HilbertSchmidt Theorem, Mercer's Theorem, Schmidt's Solution, Problems on Hilbert-Schmidt Theorem	**15**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Singular Integral Equation, Abel's Integral Equation, General form Abel's Integral Equation, Problems on Abel's Equation, Cauchy Principal Value of Integrals,	**20**	CO1, CO2,	K1, K2, K3, K4,

	Poincare-Bertrand transformation formula (Statement only), solution of Cauchy Type Equation (Closed contour only), Hilbert formula (without proof), Solution of Hilbert- Type Equation of Second Kind, Laplace Transform, Laplace Transform to solve Volterra Integral Equation, problems on Laplace Transform, Fourier Transform, Fourier Transform to solve Integral Equations, Hilbert Transform.		CO3, CO4	K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. M. D. Raisinghania: Integral Equations and Boundary Value Problems, 6th Edition, S. Chand Publication, 2013.			
References/ Readings:	2. A. J. Jerri: Introduction to Integral Equations with Applications, 2n Edition, Wiley Interscience, 1999. 3. A. M. Wazwaz: A First Course in Integral Equations, World Scientific, 1997. 4. F. G. Tricomi: Integral Equations, Levant Books - Kolkata, 2015 5. I. G. Petrovsky, Lectures on the theory of Integral equations. 6. K. Yoshida, Lectures on Differential and Integral Equations. 7. R. P. Kanwal: Linear Integral Equations – Theory & Technique, 2nd Edition, Birkhauser Publishers, 2012 8. Sudir K. Pundir and Rimple Pundir, Integral Equations and Boundary Value Problems. Pragati Prakasam, Meerut, 2005.			

Title of the Course	Methods of Applied Mathematics
Course Code	MAT-5202
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course develops the some tools and techniques of higher mathematics which are applicable to variety of problems of Mathematics and applied fields	
Course Outcomes:		**Mapped to PSO**
	CO 1. The learner will be able to display familiarity and knowledge of fundamental definitions and properties related to Methods of Applied Mathematics.	PSO1, PSO6
	CO 2. The learner will be able to demonstrate proofs to establish important results related to Methods of Applied Mathematics.	PSO2, PSO5, PSO6

	CO 3. The learner will be able to choose appropriate methods, modify them if necessary, and apply these methods to solve standard mathematical and physical problems in MAM.		PSO3, PSO6	
	CO 4. The learner will be able to analyze problems in MAM and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Improper Integrals**. Review , Properties and L^2 convergence.	**08**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**Fourier series**: Generalized Fourier series, Fourier sine/cosine series. Point wise and uniform convergence. Differentiation and integration of Fourier series.	**08**	CO1,CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Fourier Transforms and its properties**: : Fourier Transform of L^1 (IR)— functions. Basic properties related to translation, dilation and linearity. Computation of Fourier transform of simple functions. Fourier Inversion. Statement of Fourier inversion Theorem. Convolution. Convolution Theorem. Examples. Parsevaal's Identity. Fourier Integral Formula. An Integration Formula and Lemmas. Fourier Integral Theorem. The Cosine and Sine Integrals.	**14**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	**Variational problems**: Variational problems with fixed boundaries. Euler-Lagrange equations and Brachistochrone problem, Elementary variational problems with moving boundaries. One-side variation, Isoperimetric problem, Canonical forms of Euler equations. Sufficient conditions for extremum.	**30**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. J.W.Brown and R.V.Churchill, Fourier series and Boundary Value Problems, McGraw Hill. (2012) 2. K.SankaraRao, Introduction to Partial Differential			

	3. Equations, Prentice Hall of India, 1995. 4. Lev Elsgolts, Introduction to the Calculus of Variations, MIR Publications. 2003 5. T. Apostal Mathematical analysis, Narosa Publishers. 1973.
References/ Readings:	1. G.B.Arfken and H. Weber, Mathematical methods for Physicists. Elsevier Publications. 2012 2. R. Weinstock, Calculus of Variations, Dover Publication. 1952 3. I.M. Gelfand and S.V.Fomin, Calculus of Variations. Dover Publication. 1963

Title of the Course	Special Functions
Course Code	MAT- 5203
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	MAT-5003: Complex Analysis MAT-5005: Differential Equations.	
Course Objectives:	• To understand the fundamental properties and applications of Gamma and Beta functions. • To explore the theory and usage of the hypergeometric function in mathematical analysis. • To understand and apply series solutions of differential equations, particularly using the method of Frobenius, in solving linear ordinary differential equations. • To analyse classical orthogonal polynomials including Legendre, Hermite, and Laguerre polynomials, and study their generating functions, recurrence relations, and associated functions. • To explore Bessel functions and their variants, including modified Bessel and Hankel functions.	
Course Outcomes:		**Mapped to PSO**

	CO 1. Recall and know the different Special Functions used in Applied Mathematics.		PSO1, PSO6	
	CO 2. Demonstrate the proof of important results in the course.		PSO2, PSO6	
	CO 3. Apply fundamental concepts of Special Functions to solve mathematical problems in Special Functions.		PSO3, PSO6	
	CO 4. Analyze and solve unseen problems in Special Functions and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Infinite products:** Introduction, definition of an infinite product, a necessary condition for convergence, the associated series of logarithms, absolute convergence, uniform convergence. **The Gamma and Beta functions:** The Euler and Mascheroni constant, the Gamma function, a series for $\Gamma'(z)/\Gamma(z)$, evaluation of $\Gamma(1)$ and $\Gamma'(1)$, the Euler product for $\Gamma(z)$, the difference equation $\Gamma(z+1) = z\Gamma(z)$, evaluation of certain infinite products, Euler's integral for $\Gamma(z)$, the Beta function, the value of $\Gamma(z)\,\Gamma(1-z)$, the factorial function, Legendre's duplication formulae, Gauss' multiplication theorem, a summation formula due to Euler.	**18**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	**The hypergeometric function:** The function F(a,b; c; z), a simple integral form, F(a,b,c,1) as a function of the parameters, evaluation of F(a,b,c,1), the contiguous function relations, the hypergeometric differential equation, F(a,b,c,z) as a function of its parameters, elementary series manipulations, simple transformations. **Series solution of differential equations:** Method of Frobenius.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	**Legendre Polynomials and Functions:** Legendre equation and its solution. Generating function. Legendre series. Associated Legendre functions. Properties of associated Legendre functions.	**8**	CO1, CO2,	K1, K2, K3, K4, K5, K6

			CO3, CO4	
Module 4:	**Bessel function:** Bessel's equation and its solutions, Generating function. Integral representation. Recurrence relations. Hankel functions. Equations reducible to Bessel's equation. Modified Bessel's functions. Recurrence relations for modified Bessel's functions. Hermite Polynomials, Laguerre Polynomials.	**8**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. E.D. Rainville, Special functions, Chelsa Publishing Company, New York, 1960. 2. W.W. Bell, Special Functions for scientists and engineers, Dover Publications, New York, 2004.			
References/ Readings:	1. G.E. Andrews, R. Askey, R. Roy, Special Functions, Encyclopaedia of Mathematics and its Applications 71, Cambridge University Press, Cambridge.1999. 2. M.D Raisinghania ,Advanced Differential Equations, S. Chand & Company Pvt. Ltd.Ramnagar New Delhi 2008. 3. Murray Spiegel, Advanced Mathematics for Engineers and Scientists, Shaum's Outline Series, 1971. 4. P.K. Mittal, Jai Dev Anand, Special Functions for Physicists and Engineers, Haranand Publications 2016.			

Title of the Course	Discrete Mathematical Structures
Course Code	MAT-5204
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nill	
Course Objectives:	• To introduce the fundamental concepts and terminology of Discrete Mathematical Structures, with a focus on Graph Theory and related topics, fostering familiarity with basic definitions and structures. • To develop the learner's ability to understand, construct, and explain formal mathematical proofs pertaining to graphs and other discrete structures. • To train learners to identify and apply appropriate methods and algorithms for solving structured, procedure-based problems in Discrete Mathematics, particularly involving graphs. • To cultivate analytical and critical thinking skills by engaging learners in solving unfamiliar and complex problems in Discrete Mathematical Structures and articulating precise, logically valid mathematical arguments.	
Course Outcomes:		**Mapped to PSO**
	CO 1. The learner will be able to display familiarity and knowledge of Discrete	PSO1, PSO6

	Mathematical Structures like Graphs and associated concepts.			
	CO 2. The learner will be able to demonstrate proofs to establish truths related to Discrete Mathematical Structures like Graphs and associated concepts.		PSO2, PSO6	
	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Discrete Mathematical Structures.		PSO3, PSO6	
	CO 4. The learner will be able to analyze and solve unseen problems in Discrete Mathematical Structures and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	Recurrence relations, linear recurrence relations with constant co-efficients, homogeneous solutions, particular solutions, total solution, solution by method of generating functions.	**6**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Graphs, isomorphism, complement, multipartite, basic concepts in graphs, degree sequences, distance, eccentricity, centre, periphery. Eulerian and hamiltonian graphs, algorithm for shortest path in a graph, planar graphs.	**18**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Cut-vertices, bridges, blocks, non-seperable, trees, forests, connectivity and edge connectivity. Branch, chord, fundamental cycle, fundamental edge cut, minimum spanning tree, kruskal's algorithm.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Digraphs, Transport Networks, capacity, flow, cut, Maximum flow and finding maximum flow Vertex and Edge coloring, domination number, independent domination number.	**20**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			

Texts:	1. Elements of Discrete Mathematics, C L Liu, Tata McGraw Hill, Special Indian Edition 2008 2. Graphs and Digraphs, Chartrand and Lesniak, Chapman & Hall/CRC Fourth edition, 2005
References/ Readings:	1. Kenneth H. Rosen, Discrete Mathematics and Its Applications, McGraw-Hill Education, 2017. 2. Norman L. Biggs, Discrete Mathematics, Oxford University Press, 2003. 3. Douglas B. West, Introduction to Graph Theory, Prentice Hall, 2001. 4. J.P. Tremblay and R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill, 2001. 5. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India, 2004.

Title of the Course	Computational Mathematics Using Python
Course Code	MAT-5205
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To introduce foundational algorithms in Computational Mathematics and familiarize learners with the basics of Python programming as a tool for mathematical computation. • To develop the learner's ability to understand, implement, and explain key programming concepts in Python relevant to solving mathematical problems. • To enable learners to select, adapt, and apply suitable computational methods and Python-based techniques to solve structured problems in Mathematics. • To promote problem-solving and analytical skills by guiding learners to design and code Python programs for novel and complex problems in Computational Mathematics.	
Course Outcomes:		**Mapped to PSO**
	CO 1. The learner will be able to display familiarity and knowledge of algorithms in	PSO1, PSO6

	Computational Mathematics and the basics of Python Programming.			
	CO 2. The learner will be able to understand, execute and explain concepts in Python Programming.		PSO2, PSO6	
	CO 3. The learner will be able to choose the appropriate procedures, modify them if needed and apply them to solve Computation problems in Mathematics.		PSO3, PSO6	
	CO 4. The learner will be able to analyze unseen problems in Computational Mathematics and solve them by creating appropriate Python Programs.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Introduction to Python (Review)** IDLE (Installation in Windows/Linux), Python strings, Relational,Operators, Logical Operators, Precedence of Operators, Variables and assignment statements, Keywords,Script mode. **Functions (Review)** Built-in functions; input, eval, composition, print, type, round, min, max, pow Type conversion, Random number generation; randintFunctions, from math module, complete list of Built-in functions using help and dir. Function Definition and call, fruitful and void functions, function, help, default parameter values, keyword arguments Importing User-defined modules, Assert statement. **Control Structures (Review)** General form of if , if-else , if-elif-else conditional statement, Nested if-elif-else conditional statement. For and While statements and their comparison, Nestedloops, Break, Continue, Pass statements Else statement associated with a For /While statement Testing, Debugging. **Scope of Variables/Names**	**16**	CO1, CO2, CO3	K1, K2, K3

	Objects and Object ids, Namespaces; Global and Local variables, LEGB Rule			
Module 2:	**Strings** Slicing, membership, basic functions and methods on strings. **Mutable and Immutable Objects** Lists, functions and methods on lists, List comprehension, copying lists, Sets, functions and methods on sets, Tuples, functions and methods on tuples, Dictionary, dictionary operations, functions. **Recursion** Iterative Approach and recursive approach, Program to find Minors and Determinant of a matrix.	**14**	CO1, CO2, CO3	K, K2, K3
Module 3:	**Files and Exceptions** File handling, writing structures to a file, exceptions **Classes and Objects** Class attributes, class variables, destructor, Person, Graphs: as an example of a class, Highest degree and least degree, operator overloading, instance method, static method, composition and inheritance. **Graphics** 2D graphics, mathplotlib, matplotlib installation, points, lines.	**16**	CO1, CO2, CO3	K1,K2, K3
Module 4:	**Algorithms to be implemented in Python**** i. Expressing the elements of the Symmetric group as a product of disjoint cycles. ii. Characteristic Equation of a nxn matrix. Synthetic Division to find rational roots of a polynomial when rational roots exist. iii. Row Reduction to (Reduced)Row Echelon form. Generating nxn Identity Matrix Inverse of a matrix using row reduction iv. Finding Basis for the Row Space, Column Space of a matrix A and solution space of AX=B.	**14**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	v. Single step and multi-step Methods vi. Dijkstra's Algorithm to find shortest path. vii. Kruskal's Algorithm to find minimum spanning tree viii. Havel and Hakimi's Algorithm for degree sequences. ix. Welsh and Powell algorithm for graph coloring x. Fitting of straight line and quadratic curve to given data xi. Solutions of linear Diaphontine Equations **Any 7 of these algorithms should be implemented.			
Pedagogy:	Lab, discussion, assignments, self study and online resources,			
Texts:	Python Programming: A modular approach by SheetalTaneja and Naveen Kumar, Pearson Education, 2020.			
References/ Readings:	1. Python Programming: Beginner to Pro by Michael Urban, Mike Murach Publishing, 2016. 2. Michael Urban, Python Programming: Beginner to Pro, Mike Murach Publishing, 2016. 3. John V. Guttag, Introduction to Computation and Programming Using Python, MIT Press, 2016. 4. Mark Lutz, Learning Python, 5th Edition, O'Reilly Media, 2013. 5. Allen B. Downey, *Think Python: How to Think Like a Computer Scientist*, 2nd Edition, Green Tea Press / O'Reilly, 2015.			

Title of the Course	Number Theory
Course Code	MAT-5206
Number of Credits	2
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To provide a solid foundation in classical number theory concepts such as primitive roots, quadratic reciprocity, and continued fractions. • To develop analytical and logical reasoning skills through theorem-based learning and proof techniques. • To enhance problem-solving abilities by applying number theoretic methods to both theoretical and computational problems.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Display familiarity and knowledge of Primitive Roots, Indices, The Quadratic Reciprocity Law, Marin Mersenne numbers, Perfect numbers and Continued Fractions.	PSO1, PSO6
	CO 2. Demonstrate the proofs of various theorems in course.	PSO2, PSO6
	CO 3. Choose the appropriate procedures and modify them if needed to solve method-based	PSO3, PSO6

	problems in Number Theory.			
	CO 4. Analyze and solve unseen problems in Number Theory and invent mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**PRIMITIVE ROOTS AND INDICES:** The order of an integer modulo n, Primitive Roots for Primes, Composite numbers having primitive roots, The theory of indices.	4	CO1, CO2, CO3, CO4	K1, K2, K3, K4,K5, K6
Module 2:	**THE QUADRATIC RECIPROCITY LAW:** Euler's criterion, the Legendre symbol and its properties, Quadratic reciprocity, Quadratic congruences with composite moduli.	6	CO1, CO2, CO3, CO4	K1, K2, K3, K4,K5, K6
Module 3:	**NUMBERS OF SPECIAL FORM:** Marin Mersenne numbers, Perfect numbers, Mersenne primes and amicable numbers, Fermat numbers.	4	CO1, CO2, CO3, CO4	K1, K2, K3, K4,K5, K6
Module 4:	**REPRESENTATION OF INTEGERS AS SUMS OF SQUARES:** Sums of two squares, Sums of more than two squares.	4	CO1, CO2, CO3, CO4	K1, K2, K3, K4,K5, K6
Module 5:	**CONTINUED FRACTIONS:** Finite continued fractions, Infinite continued fractions, Farey fractions, Pell's equation.	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4,K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	David M. Burton, Elementary Number Theory, Mc Graw, 2023			
References/ Readings:	1. Kenneth H. Rosen, Elementary Number Theory, Pearson, 2015. 2. G.H. Hardy and E.M. Wright, An Introduction to the Theory of Numbers, Oxford University Press, 2008. 3. Ivan Niven, Herbert S. Zuckerman, Hugh L. Montgomery, An Introduction to the Theory of Numbers, Wiley, 1991. 4. Richard A. Mollin, Fundamental Number Theory with Applications, CRC Press, 2008.			

Web Resources:	https://nptel.ac.in/courses/111103020 https://nptel.ac.in/courses/111101137