



CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025-26/176 dated 26.06.2025

In supersession to the above referred Circular, the syllabus for Semester III and IV of the **Master of Science in Mathematics** Programme approved by the Academic Council in its meeting held 7th November 2025, is attached.

Further, the Syllabus of Semester I and II approved earlier by the Academic Council in its meeting held on 13th & 14th June 2025 is also 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 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.

Copy to:

3. Chairperson, BoS in Mathematics, Goa University.
4. Programme Director, M.Sc. Mathematics, Goa University.
5. Controller of Examinations, Goa University.
6. Assistant Registrar Examinations (PG), Goa University.
7. 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)

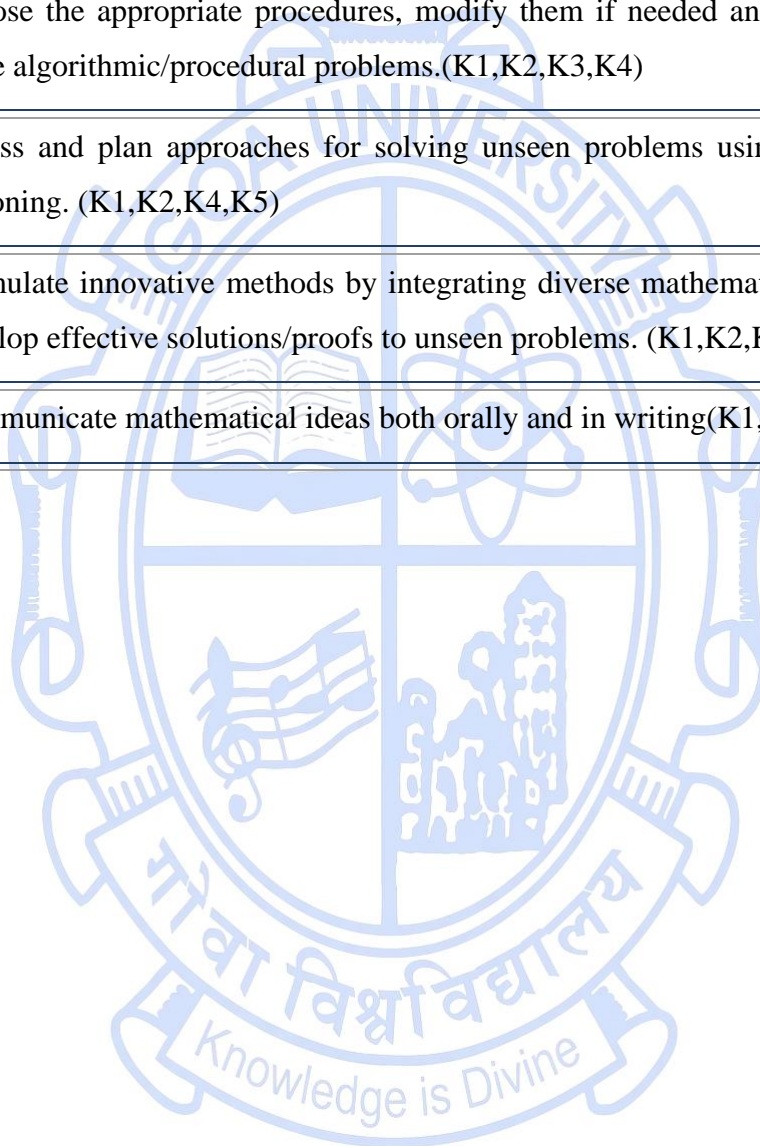
ABOUT THE PROGRAMME

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.

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	<u>MAT-5000</u>	Real Analysis	4+0=4	400
2	<u>MAT-5001</u>	Advanced Linear Algebra	4+0=4	400
3	<u>MAT-5002</u>	Ring Theory	4+0=4	400
4	<u>MAT-5003</u>	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	<u>MAT-5201</u>	Integral Equation	4+0=4	400
2	<u>MAT-5202</u>	Methods of Applied Mathematics	4+0=4	400
3	<u>MAT-5203</u>	Special Functions	4+0=4	400
4	<u>MAT-5204</u>	Discrete Mathematical Structures	4+0=4	400
5	<u>MAT-5205</u>	Computational Mathematics Using Python	0+2=2	400
6	<u>MAT-5206</u>	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	

SEMESTER III				
Research Specific Elective (RSE) Courses (12 credits)				
Sr. No.	Course Code	Title of the Course	Credits (T+P)	Level
1	MAT-6000	Mathematical Modelling	4+0=4	500
2	MAT-6001	Number Theory-II	4+0=4	500
3	MAT-6002	Graphs and Networks	4+0=4	500
4	MAT-6003	Measure Theory-I	4+0=4	500
5	MAT-6004	Differential Geometry	4+0=4	500
6	MAT-6005	Advanced Graph Theory	4+0=4	500
7	MAT-6006	Galois Theory	4+0=4	500
8	MAT-6007	Commutative Algebra	4+0=4	500
9	MAT-6008	Lie Algebra	4+0=4	500
10	MAT-6009	Research Methodology	4+0=4	500
Total Credits for RSE Courses in Semester III			12	
Discipline Specific Vocational Elective (DSVE) Courses (8 credits)				
Sr. No.	Course Code	Title of the Course	Credits (T+P)	Level
1	MAT-6401	Mathematical Typesetting using LaTeX	0+2=2	500
2	MAT-6402	Numerical Methods	1+1=2	500
4	MAT-6403	Mathematics for Machine Learning	2+2=4	500
5	MAT-6404	Finite Element Methods	2+2=4	500
6	MAT-6405	Partial Differential Equations	2+2=4	500
7	MAT-6406	Academic Writing and Documentation using Latex (Same as PHY-6401)	4+0=4	500
Total Credits for DSVE Courses in Semester III			8	
Total Credits in Semester III			20	

Discipline Specific Dissertation (DSD) (40 Credit Dissertation)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	MAT-6501	Dissertation	40	500

SEMESTER IV				
Generic Elective (GE) Courses (20 credits)				
Sr. No.	Course Code	Title of the Course	Credits (T+P)	Level
1	MAT-6201	Probability and Statistics	4+0=4	500
2	MAT-6202	Mathematics for Finance	4+0=4	500
3	MAT-6203	Mathematics for Financial Markets	4+0=4	500
4	MAT-6204	History of Mathematics	4+0=4	500
5	MAT-6205	Difference Equations	2+0=2	500
6	MAT-6206	Operations Research	4+0=4	500
7	MAT-6207	Computational Algebra with sagemath	0+2=2	500
Generic Elective (GE) Courses for Advanced Learners				
8	MAT-6208	Operator Theory	4+0=4	500
9	MAT-6209	Foundations of Computational Fluid Dynamics	4+0=4	500
10	MAT-6210	Partial Differential Equations-II	2+0=2	500
11	MAT-6211	Functional Analysis-II	4+0=4	500

Discipline Specific Dissertation (DSD)/ Internship (20 Credit Dissertation)				
Sr. No.	Course Code	Title of the Course	Credits (T+P)	Level
1	MAT-6502	Dissertation	20	500
Total Credits in Semester IV			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:	<ul style="list-style-type: none">• 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 than 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, Lindelöf 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:	<ol style="list-style-type: none"> Principles of Mathematical Analysis, Walter Rudin, McGraw-Hill International Editions, 1976. A Foundation Course in Mathematics, Ajith Kumar, S.Kumaresan, B.K. Sarma, Narosa Publishing House, 2018. A Basic Course in Real Analysis, Kumar and Kumaresan, CRC Press, 2015. Real Analysis, N.L. Carothers, Cambridge University Press, 2000. Calculus with Applications, Peter D. Lax, Maria Shea Terrel, Springer, 2014. 			

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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:	<ul style="list-style-type: none"> • 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:	CO 1. Display familiarity and knowledge of Vector Spaces, Linear Transformations and associated concepts.	Mapped to PSO 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:	<ol style="list-style-type: none"> 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. 			

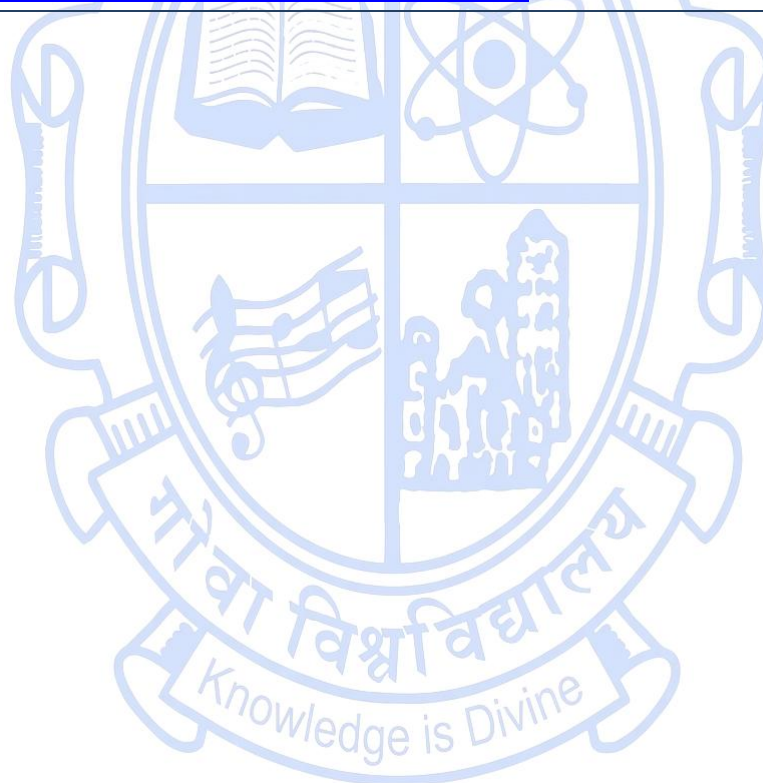
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Title of the Course	Ring Theory	
Course Code	MAT-5002	
Number of Credits	4	
Theory/Practical	Theory	
Level	400	
Effective from AY	2025-26	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • 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:	<ol style="list-style-type: none"> 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			

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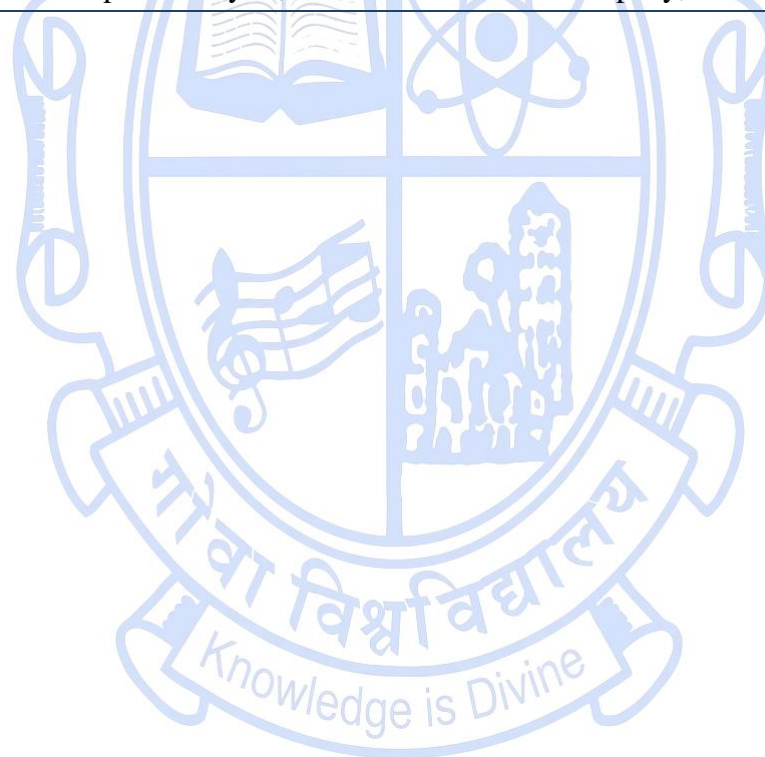


Title of the Course	Advanced Complex Analysis	
Course Code	MAT-5003	
Number of Credits	4	
Theory/Practical	Theory	
Level	400	
Effective from AY	2025-26	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Nil.	
Course Objectives:	<ul style="list-style-type: none"> • 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; Rouché'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:	<ol style="list-style-type: none"> 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. 			

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SEMESTER II

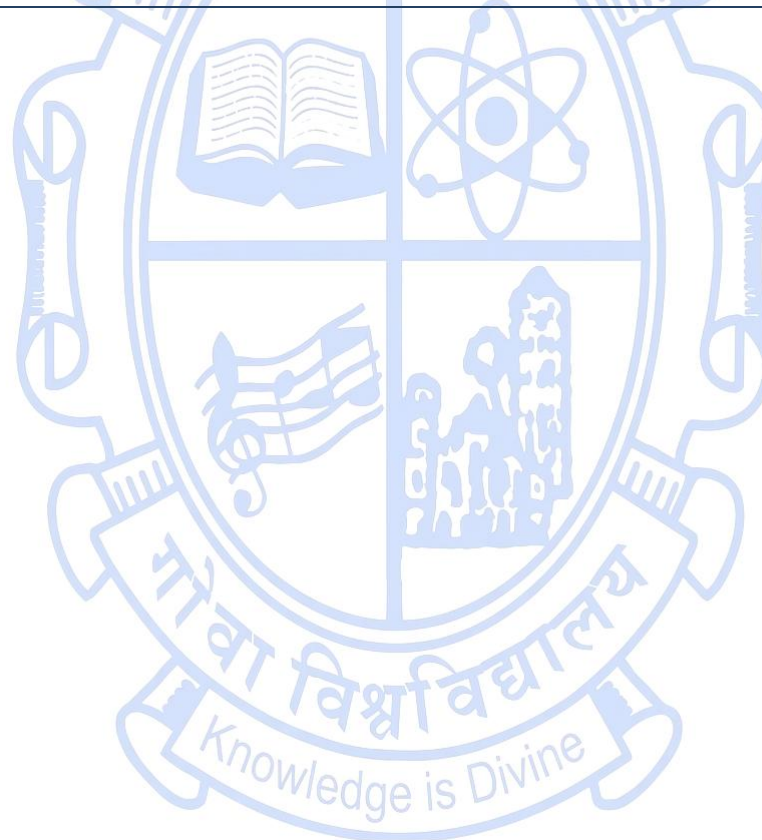
Discipline Specific Core (DSC) Courses

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:	<ul style="list-style-type: none">• 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:	CO 1.The learner will be able to display familiarity and knowledge of Topological Spaces, Metric Spaces, Homeomorphisms and associated concepts.		Mapped to PSO	
	CO 2.The learner will be able to demonstrate proofs to establish truths related to Topological Spaces, Metric Spaces, Homeomorphisms and associated concepts.		PSO1, 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		PSO2, 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.		PSO3, 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:	<ol style="list-style-type: none"> 1. Stephen Willard, General Topology, Dover Pubns,2004. 2. M A Armstrong, Basic Topology, Springer Verlag, 1983. 3. James Dugundji, Topology, Allyn and Bacon, 1966. 4. George F. Simmons, <i>Introduction to Topology and Modern Analysis</i>, McGraw-Hill, 1963. 5. Fred H. Croom, <i>Principles of Topology</i>, Cengage Learning, 1989.
Web Resources:	https://archive.nptel.ac.in/courses/111/106/111106054/

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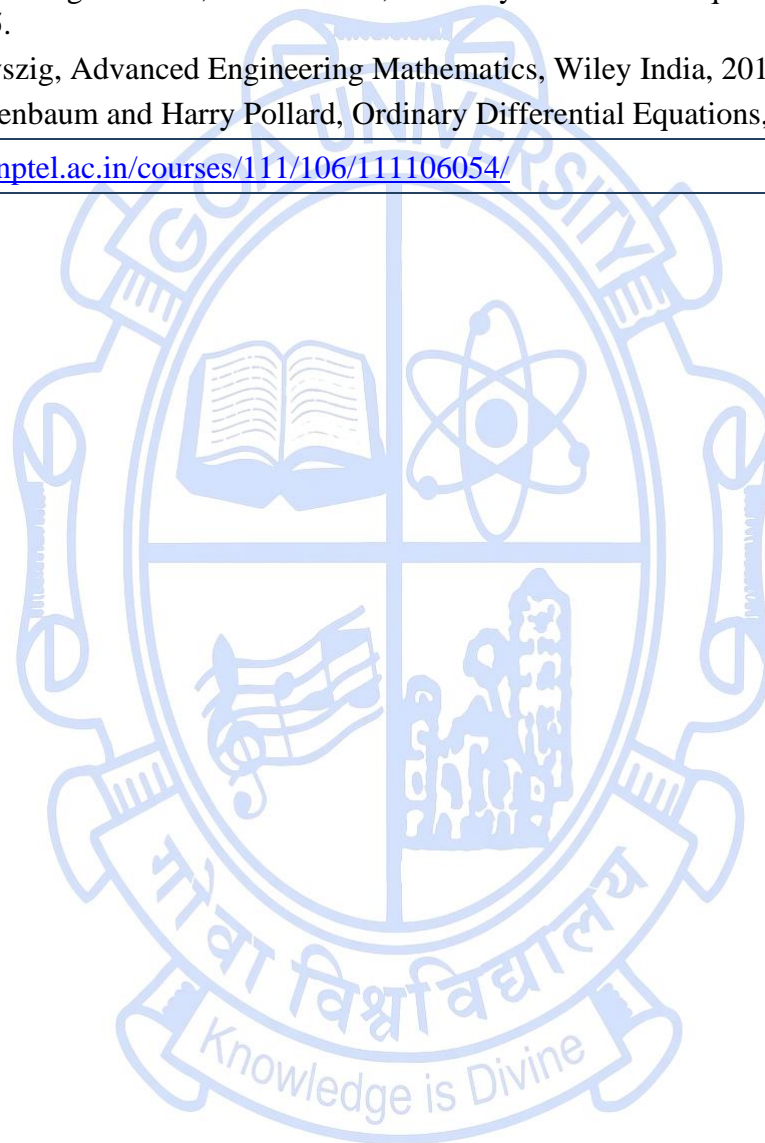
Title of the Course	Differential Equations
Course Code	MAT-5005
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	MAT-5000 Real Analysis , MAT-5001 Advanced Linear Algebra	
Course Objectives:	<ul style="list-style-type: none"> • 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:	<ol style="list-style-type: none"> 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. 			

	<ol style="list-style-type: none">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/

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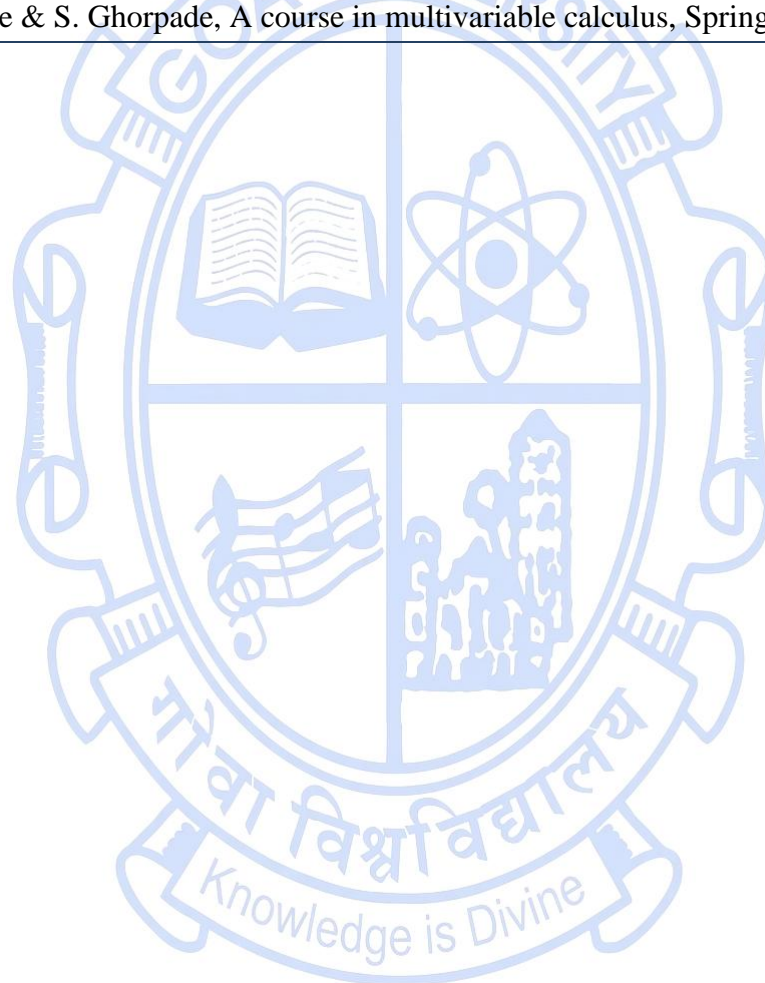
Title of the Course	Several Variable Calculus
Course Code	MAT-5006
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • 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 \mathbb{R}^n 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:	<ol style="list-style-type: none"> 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.

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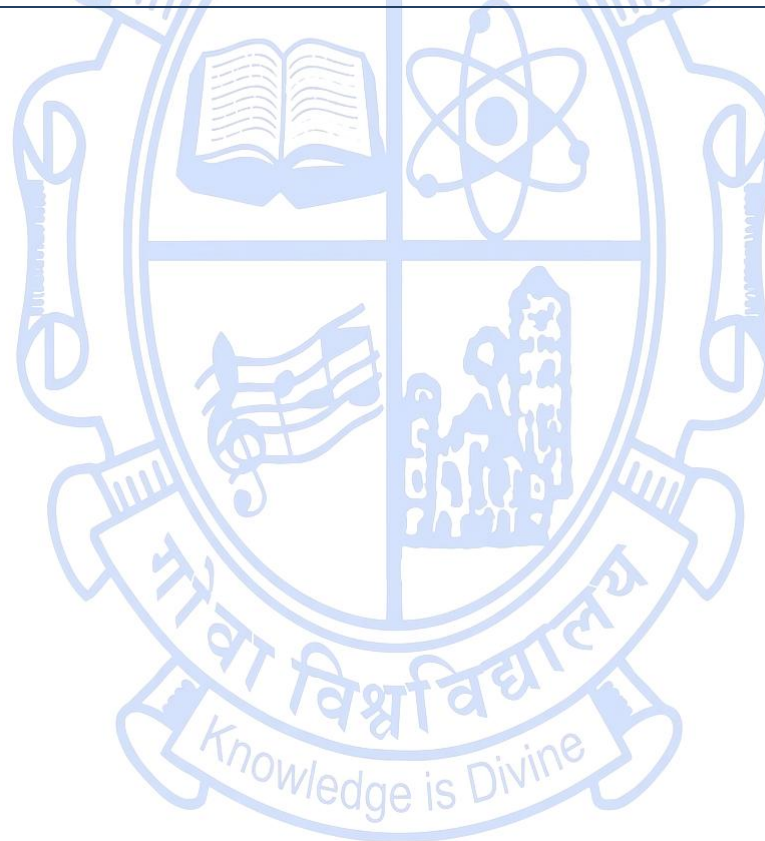
Title of the Course	Functional Analysis
Course Code	MAT-5007
Number of Credits	4+0=4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	MAT-5000: Real Analysis MAT-5004: Topology	
Course Objectives:	<ul style="list-style-type: none"> • 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:	<ol style="list-style-type: none"> 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, Birkhäuser, 1981. 5. Linear Real analysis for Scientists and Engineers, B.V.Limaye, Springer. 2016

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SEMESTER I & II

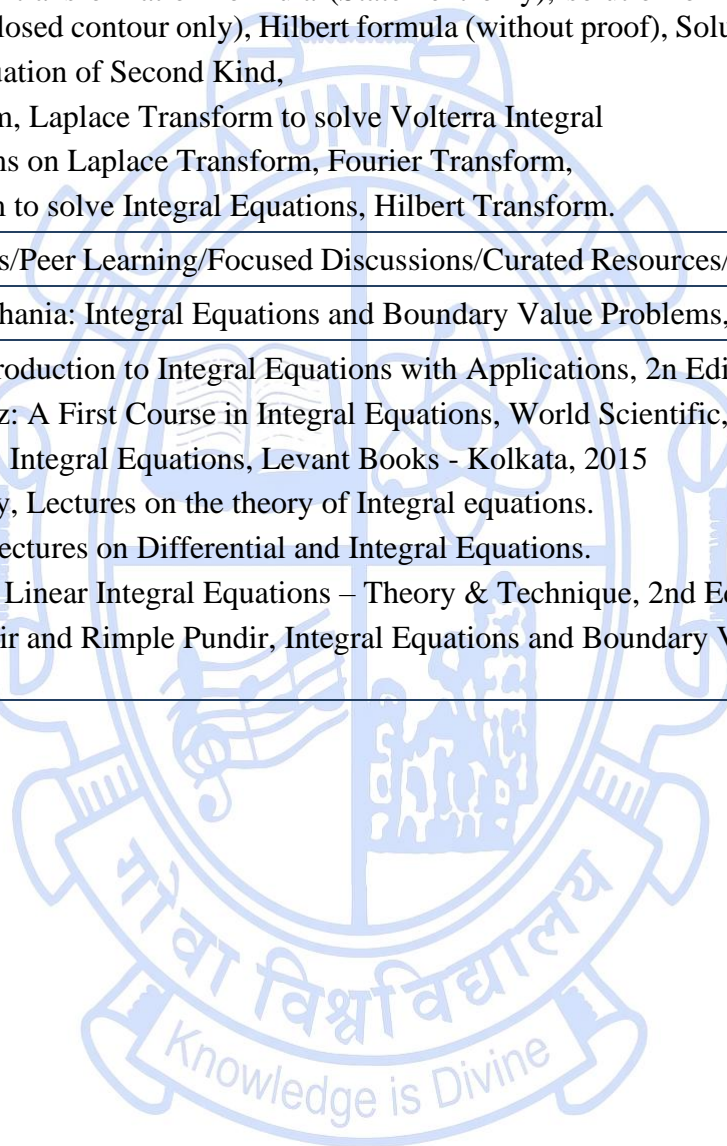
Discipline Specific Elective Courses

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:	<ul style="list-style-type: none">• 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, Hilbert-Schmidt 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, 6 th Edition, S. Chand Publication, 2013.			
References/ Readings:	2. A. J. Jerri: Introduction to Integral Equations with Applications, 2 ⁿ 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, 2 nd Edition, Birkhauser Publishers, 2012 8. Sudir K. Pundir and Rimple Pundir, Integral Equations and Boundary Value Problems. Pragati Prakasam, Meerut, 2005.			

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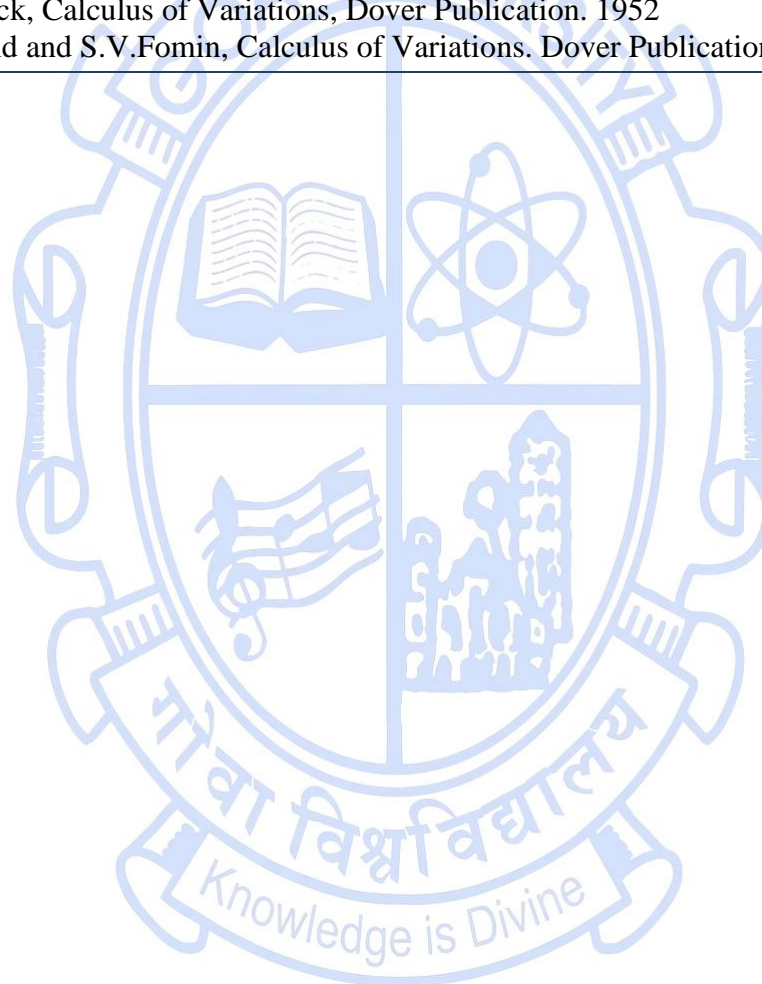
Title of the Course	Methods of Applied Mathematics
Course Code	MAT-5202
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

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 $L^1(\mathbb{R})$ — 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			

	<ol style="list-style-type: none"> 3. Equations, Prentice Hall of India, 1995. 4. Lev Elsgolts, Introduction to the Calculus of Variations, MIR Publications. 2003 5. T. Apostol Mathematical analysis, Narosa Publishers. 1973.
References/ Readings:	<ol style="list-style-type: none"> 1. G.B.Arflen 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

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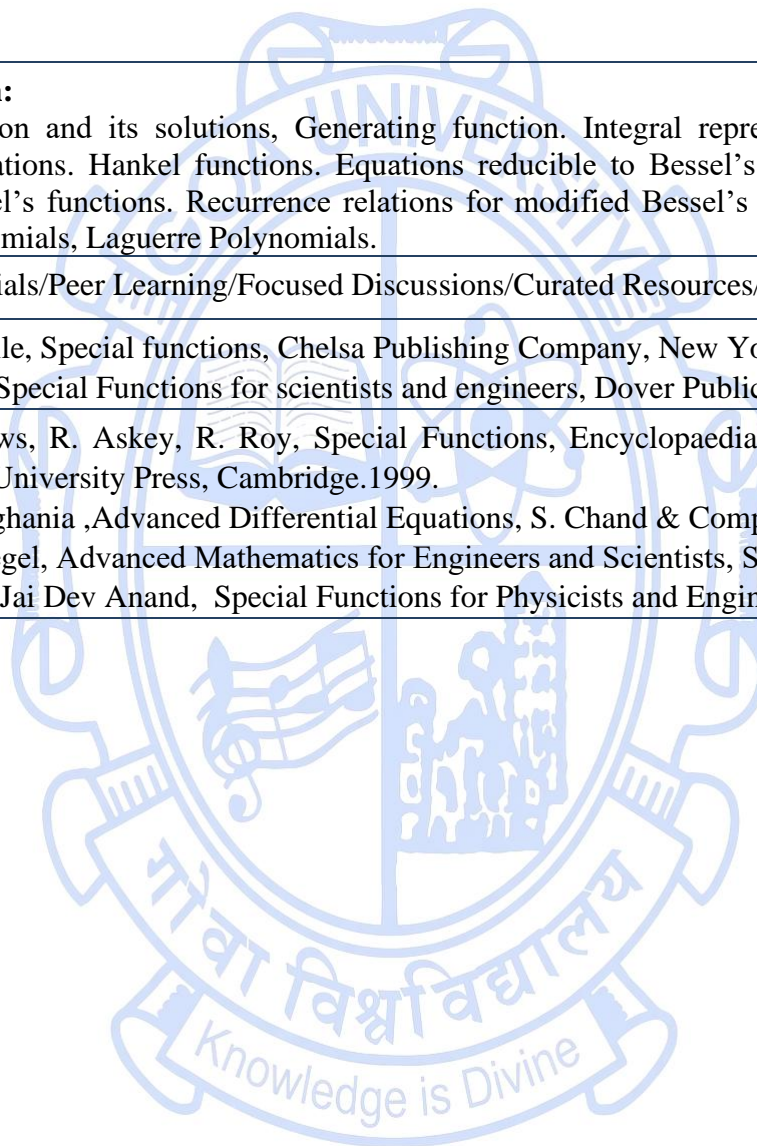


Title of the Course	Special Functions	
Course Code	MAT-5203	
Number of Credits	4	
Theory/Practical	Theory	
Level	400	
Effective from AY	2025-2026	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	MAT-5003: Complex Analysis MAT-5005: Differential Equations.	
Course Objectives:	<ul style="list-style-type: none"> • 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:	<p>Infinite products: Introduction, definition of an infinite product, a necessary condition for convergence, the associated series of logarithms, absolute convergence, uniform convergence.</p> <p>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.</p>	18	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6
Module 2:	<p>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.</p> <p>Series solution of differential equations: Method of Frobenius.</p>	16	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6
Module 3:	<p>Legendre Polynomials and Functions: Legendre equation and its solution. Generating function. Legendre series. Associated Legendre functions. Properties of associated Legendre functions.</p>	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:	<ol style="list-style-type: none"> 1. E.D. Rainville, Special functions, Chelsea Publishing Company, New York, 1960. 2. W.W. Bell, Special Functions for scientists and engineers, Dover Publications, New York, 2004. 			
References/ Readings:	<ol style="list-style-type: none"> 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. 			

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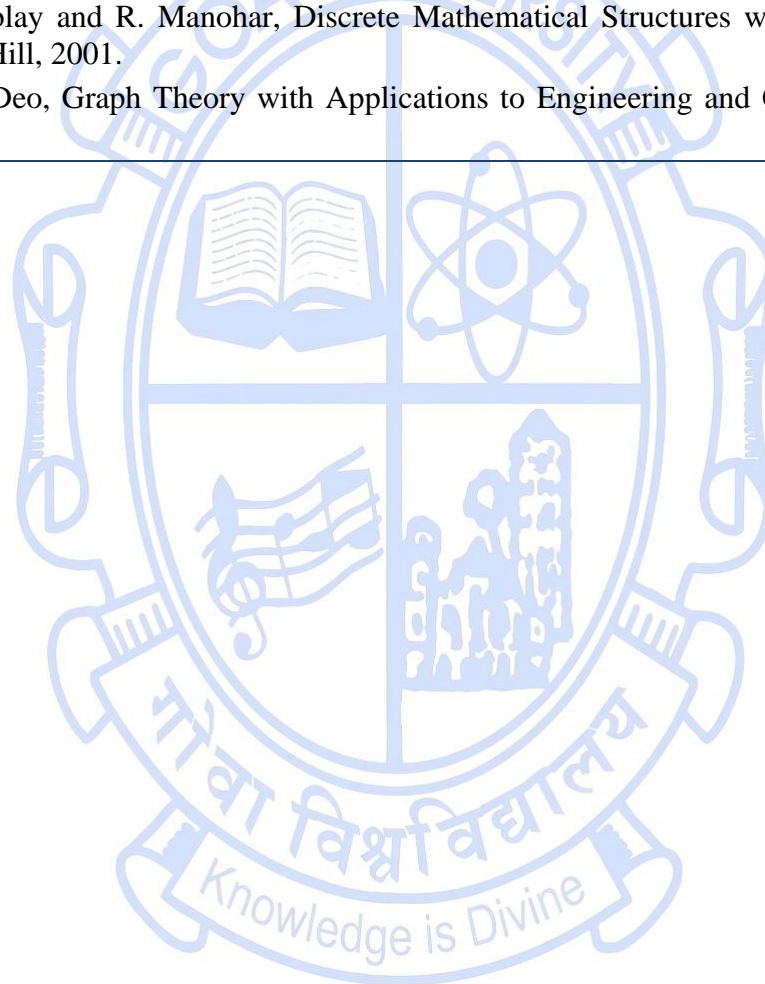


Title of the Course	Discrete Mathematical Structures	
Course Code	MAT-5204	
Number of Credits	4	
Theory/Practical	Theory	
Level	400	
Effective from AY	2025-26	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • 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 Mathematical Structures like Graphs and associated concepts.	PSO1, PSO6

	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:	<ol style="list-style-type: none">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.

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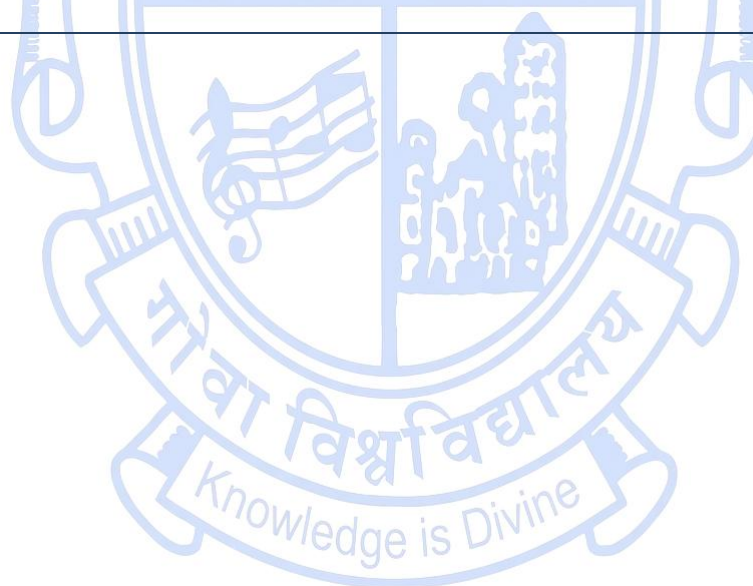
Title of the Course	Computational Mathematics Using Python	
Course Code	MAT-5205	
Number of Credits	2	
Theory/Practical	Practical	
Level	400	
Effective from AY	2025-26	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • 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 Computational Mathematics and the basics of Python Programming.	PSO1, PSO6

	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:	<p>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.</p> <p>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.</p> <p>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.</p> <p>Scope of Variables/Names Objects and Object ids, Namespaces; Global and Local variables,</p>	16	CO1, CO2, CO3 K1, K2, K3

	LEGB Rule			
Module 2:	<p>Strings Slicing, membership, basic functions and methods on strings.</p> <p>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.</p> <p>Recursion Iterative Approach and recursive approach, Program to find Minors and Determinant of a matrix.</p>	14	CO1, CO2, CO3	K, K2, K3
Module 3:	<p>Files and Exceptions File handling, writing structures to a file, exceptions</p> <p>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.</p> <p>Graphics 2D graphics, matplotlib, matplotlib installation, points, lines.</p>	16	CO1, CO2, CO3	K1,K2, K3
Module 4:	<p>Algorithms to be implemented in Python**</p> <ol style="list-style-type: none"> 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. v. Single step and multi-step Methods 	14	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	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 Diophantine 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, <i>Think Python: How to Think Like a Computer Scientist</i> , 2nd Edition, Green Tea Press / O’Reilly, 2015.			

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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:	<ul style="list-style-type: none"> 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

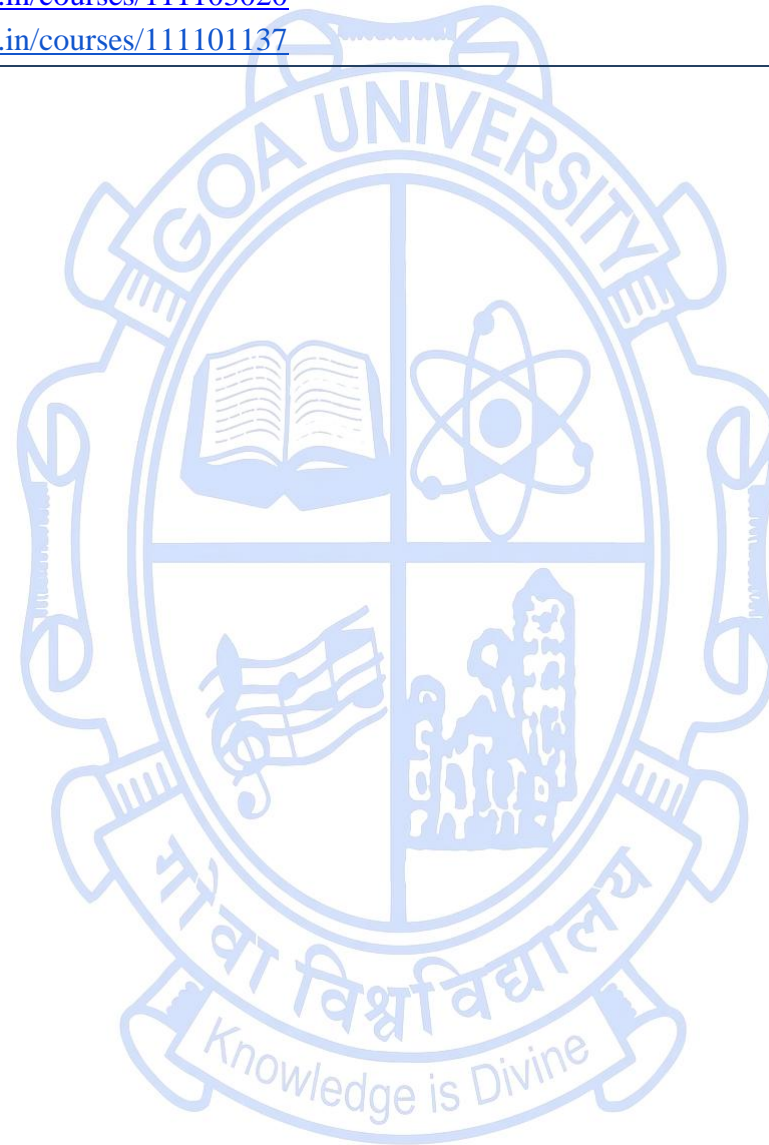
	problems in Number Theory.			
	CO 4. Analyze and solve unseen problems in Number Theory and invent mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	PRIMITIVE ROOTS AND INDICES: The order of an integer modulo n , 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:	<ol style="list-style-type: none"> 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>

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SEMESTER III

Research Specific Elective (RSE) Courses

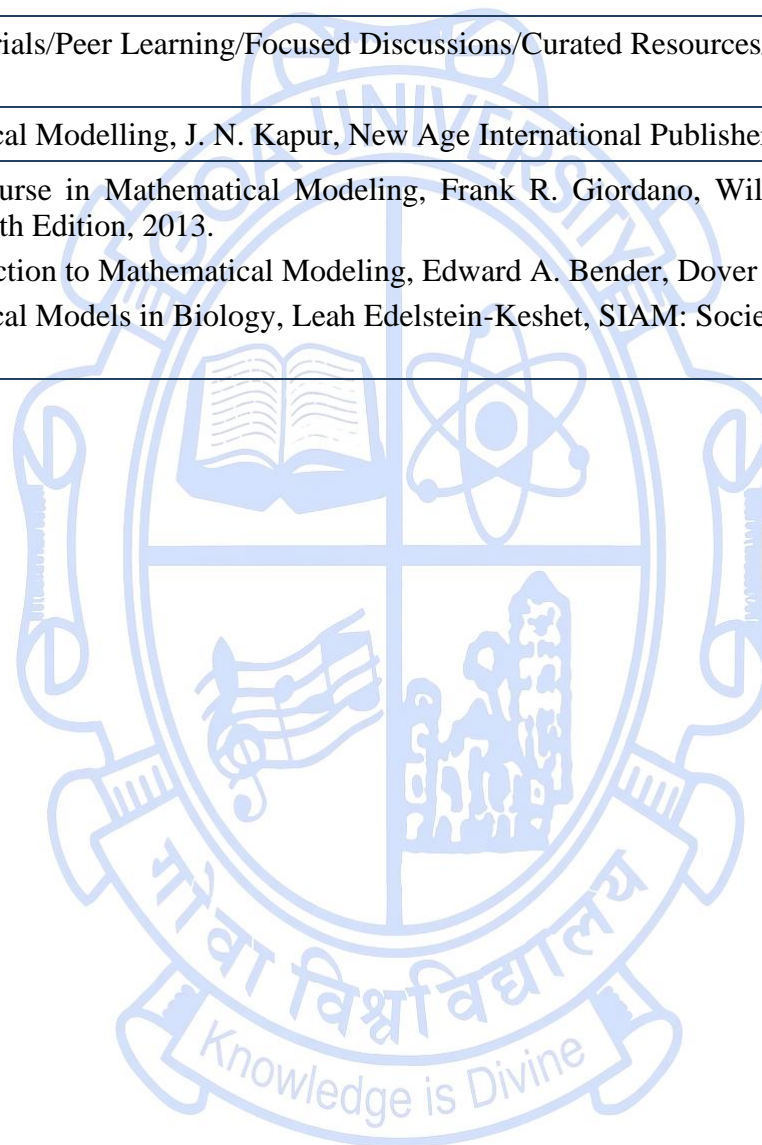
Title of the Course	Mathematical Modelling
Course Code	MAT-6000
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in the Paper MAT-5000: Real Analysis
Course Objectives:	<ul style="list-style-type: none">• To introduce the foundational concepts of Mathematical Modelling, 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 Mathematical Modelling concepts and theorems.• To equip learners with the skills necessary to identify and apply appropriate Mathematical Modelling methods and techniques to solve structured problems.

	<ul style="list-style-type: none"> To encourage analytical thinking and creativity in solving unfamiliar problems in Mathematical Modelling, enabling learners to construct logically sound and precise mathematical arguments. 			
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Mathematical Modelling and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Mathematical Modelling and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Mathematical Modelling.	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Mathematical Modelling and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Mathematical modeling: need, techniques, classification and illustrative examples; Malthus model, logistic model Mathematical modeling through ordinary differential equations of first order; qualitative solutions through sketching.	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Mathematical Modeling using system of equations: population dynamics, epidemics and compartment models; Mathematical Modeling using differential equations of order two. Examples in blood flow, economics and population dynamics. Modelling human population growth using Leslie matrix..	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Mathematical modeling through difference equations, cell division: linear and non linear, prey predator; mathematical modeling in population dynamics, epidemics and genetics, bifurcation theory; Numerical Methods.	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Mathematical modeling through partial differential equations: simple models, variational principles, initial & boundary conditions.	14	CO1, CO2, CO3,	K1, K2, K3, K4, K5, K6

			CO4
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.		
Texts:	1. Mathematical Modelling, J. N. Kapur, New Age International Publishers, 1988.		
References/ Readings:	<ol style="list-style-type: none"> 1. A First Course in Mathematical Modeling, Frank R. Giordano, William P. Fox, Steven B. Horton, Cengage Learning, 5th Edition, 2013. 2. An Introduction to Mathematical Modeling, Edward A. Bender, Dover Publications, 2000. 3. Mathematical Models in Biology, Leah Edelstein-Keshet, SIAM: Society for Industrial and Applied Mathematics, 2005. 		

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Title of the Course	Number Theory-II
Course Code	MAT-6001
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in papers MAT-5002 Ring Theory, MAT-5003 Advanced Complex Analysis, and basic knowledge of Algebra, Complex Analysis. Elementary number theory, Congruences.	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Number Theory, 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 Number Theory concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Number Theory methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Number Theory, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Number Theory and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Number Theory and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Number Theory		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Number Theory and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Fundamental Theorem of Arithmetic. Divisibility. Greatest common divisor. Prime numbers. The Fundamental Theorem of Arithmetic. The series of reciprocals of primes. The Euclidean algorithm.	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Arithmetical functions and Dirichlet multiplication. Mobius function μ . Euler totient function ϕ . Relation connecting μ and ϕ . Product formula for ϕ (n). Dirichlet product of arithmetical functions. Dirichlet inverse and Mobius inversion formula. Mangoldt function. Multiplicative functions. Liouville function. Divisor functions. Generalized convolutions. Formal power series. Bell series. Derivative of arithmetical functions.	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Averages of arithmetical functions. Big oh notation. Euler summation formula. Some elementary asymptotic formulas. Average order of $d(n)$. Average order of $\sigma\alpha(n)$. Average order of ϕ (n). Average order of $\mu(n)$ and $\Lambda(n)$.	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Some elementary theorems on distribution of prime numbers. Chebyshev's functions $P(x)$ and $f(x)$. Relations connecting functions $P(x)$ and $f(x)$.	7	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 5:	Characters of finite abelian groups. Characters of finite abelian groups. The character group. The orthogonality relations of characters. Dirichlet character.	7	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 6:	Partition Theory. Partitions of numbers. Generating function of $p(n)$. Other generating functions. Theorems of Euler. Theorem of Jacobi. Special cases of	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	Jacobi's identity.			
Module 7:	Basic Cryptology. Caesar Cipher. Shift Cipher. Affine cipher. Hill cipher.	2	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. T. M Apostol, Introduction to Analytic Number Theory, Narosa Publishing House, 1998.			
References/ Readings:	<ol style="list-style-type: none"> 1. Thomas Koshy, Elementary Number Theory with Applications, Second Edition, Elsevier India Pvt. Ltd., 2005. (Chapter 9). 2. G.H. Hardy and E.M. Wright, Introduction to Theory of Numbers. (Chapter XIX), Oxford University Press, sixth edition, 2008. 3. Heng Huat Chan, Analytic Number Theory for Undergraduates, (Monographs in Number Theory), World Scientific, 2009. 4. I. Niven, H.S. Zuckerman and H.L. Montgomery, An Introduction to the Theory of Numbers, 5th edition, Wiley-India. 5. David Burton, Elementary Number Theory, Sixth Edition, Tata McGraw-Hill Edition, 2008. 6. A. Baker, A concise introduction to the theory of numbers, Cambridge University Press, 2015. 			
Web Resources:	https://youtube.com/playlist?list=PLEAYkSg4uSQ1zCXoJK7ZtWbz_WGmlLL1-&si=TR-Z-uHT9JZCcbg			

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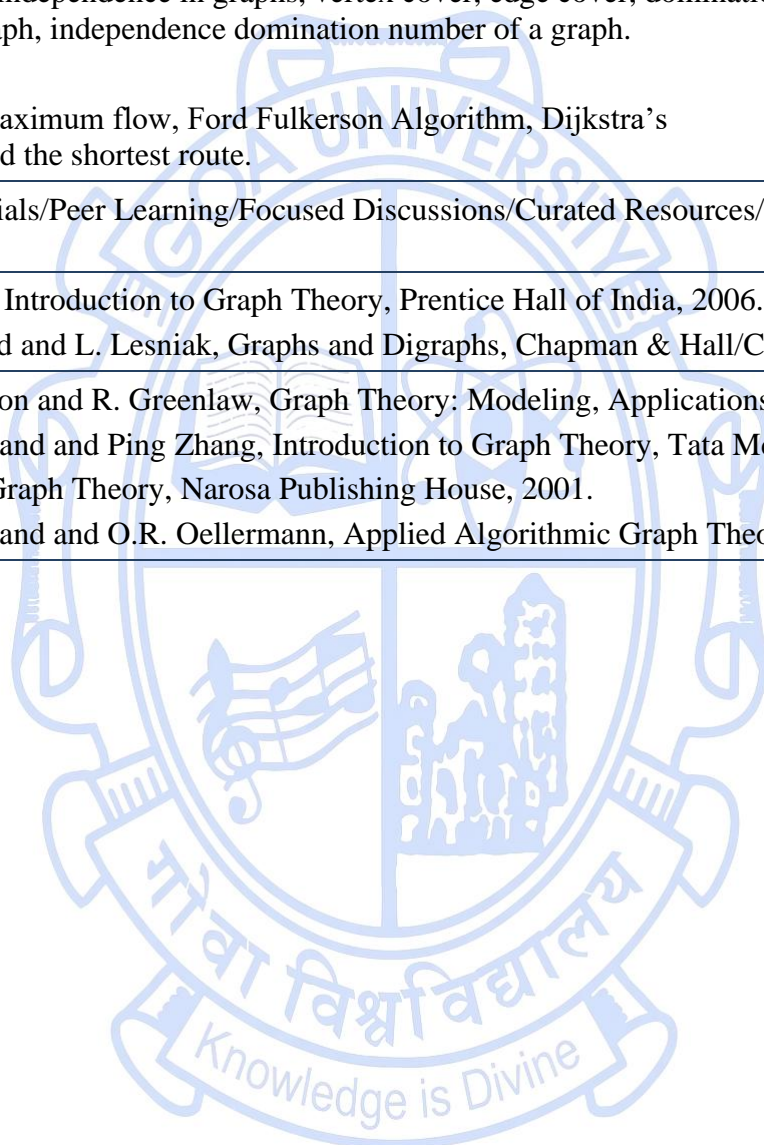
Title of the Course	Graphs and Networks
Course Code	MAT-6002
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Graphs and Networks, 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 Graphs and Networks concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Graphs and Networks methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Graphs and Networks, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Graphs and Networks and associated concepts.	PSO1, PSO6

	CO 2. demonstrate proofs to establish truths related to Graphs and Networks and associated concepts.		PSO2, PSO6	
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Graphs and Networks		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Graphs and Networks and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Introduction to graphs Graphs, subgraphs, operations on graphs, degree sequences, graphic sequences, distance in graphs, walks, trails, paths, circuits, cycles, matrices and isomorphism, complement of graph, bipartite graphs, distance in graphs, digraphs and multidigraphs, Cut-vertices bridges and blocks, classes of graphs, Petersen graphs, regular graphs, Harary graphs.</p>	19	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	<p>Trees and connectivity Elementary properties of trees, minimal spanning trees, Prim's algorithm, Kruskal's algorithm, connectivity and edge-connectivity, connectedness of digraphs, Prüfer sequence.</p> <p>Eulerian and Hamiltonian graphs Eulerian graphs and digraphs, Hamiltonian graphs and digraphs, Fleury's algorithm and Hierholzer's algorithm.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>Planar graphs Euler's formula, characterizations of planar graphs, crossing number and thickness.</p> <p>Graph colorings Vertex colorings, edge colorings, map colourings, Five Color theorem.</p>	13	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Matchings and domination in graphs	13	CO1, CO2,	K1, K2, K3,

	<p>Matchings and independence in graphs, vertex cover, edge cover, domination number of a graph, independence domination number of a graph.</p> <p>Networks</p> <p>Relevance of maximum flow, Ford Fulkerson Algorithm, Dijkstra's algorithm to find the shortest route.</p>		CO3, CO4	K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	<ol style="list-style-type: none"> 1. D. B. West, Introduction to Graph Theory, Prentice Hall of India, 2006. 2. G. Chartrand and L. Lesniak, Graphs and Digraphs, Chapman & Hall/CRC, Third edition, 1996. 			
References/ Readings:	<ol style="list-style-type: none"> 1. G. Agnarsson and R. Greenlaw, Graph Theory: Modeling, Applications and algorithms, Pearson, 2011. 2. Gary Chartrand and Ping Zhang, Introduction to Graph Theory, Tata Mc-Graw-Hill Edition, 2006. 3. F. Harary, Graph Theory, Narosa Publishing House, 2001. 4. Gary Chartrand and O.R. Oellermann, Applied Algorithmic Graph Theory, McGraw-Hill Inc. 1993. 			

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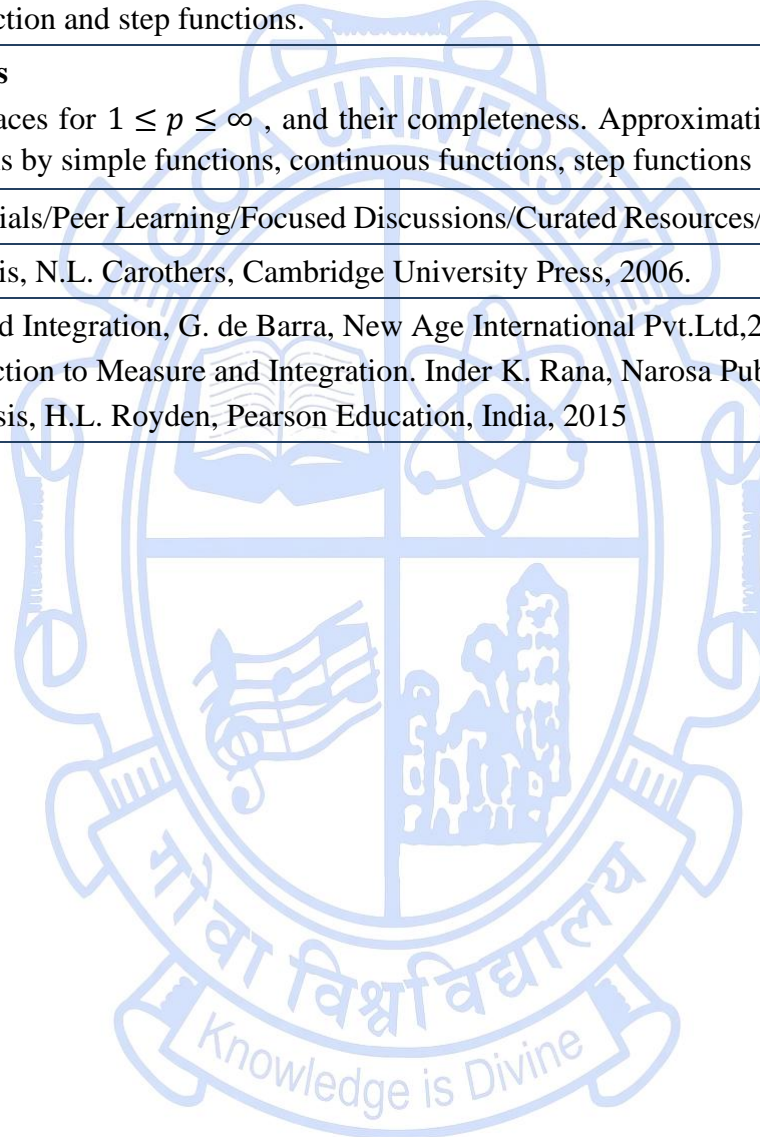
Title of the Course	Measure Theory-I
Course Code	MAT-6003
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in the Paper MAT-5000: Real Analysis	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Measure Theory, 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 Measure Theory concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Measure Theory results and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Measure Theory, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Measure Theory and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Measure Theory and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Measure Theory		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Measure Theory and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>1.1 Functions of Bounded Variation The space of functions of bounded variations $BV[a,b]$ and basic properties, norm and completeness of $BV[a,b]$, Jordan's Theorem on the characterization of functions of bounded variation</p> <p>1.2 Reimann-Stieltjes Integral Weights and measures, The Riemann-Steiltjes integral, Space of integrable functions, Integrators of bounded variation, The Riemann integral. Shortcomings of Riemann integration.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	<p>Lebesgue Measure on the Real Line The length function and Lebesgue outer measure on the real line, Measurable sets, Sigma algebra of measurable sets, Structure of measurable sets, non-measurable sets, idea of abstract measure spaces.</p> <p>Measurable Functions Measurable functions, Extended real valued functions and measurability, Sequence of measurable functions, Egorov's theorem, Approximation of measurable functions</p>	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>The Lebesgue Integral on \mathbb{R} Lebesgue integral of simple functions, non-negative functions and the general case. Chebyshev's inequality, monotone convergence theorem, Fatou's Lemma, Lebesgue dominated convergence theorem, Integral of infinite series of functions. Lebesgue integrability of Riemann integrable functions.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	Approximation of Lebesgue integrable functions by simple functions, continuous function and step functions.			
Module 4:	The L_p- spaces The L_p -spaces for $1 \leq p \leq \infty$, and their completeness. Approximation of L_p -functions by simple functions, continuous functions, step functions	10	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. Real analysis, N.L. Carothers, Cambridge University Press, 2006.			
References/ Readings:	<ol style="list-style-type: none"> 1. Measure and Integration, G. de Barra, New Age International Pvt.Ltd,2013 2. An Introduction to Measure and Integration. Inder K. Rana, Narosa Publishing House, 2005 3. Real Analysis, H.L. Royden, Pearson Education, India, 2015 			

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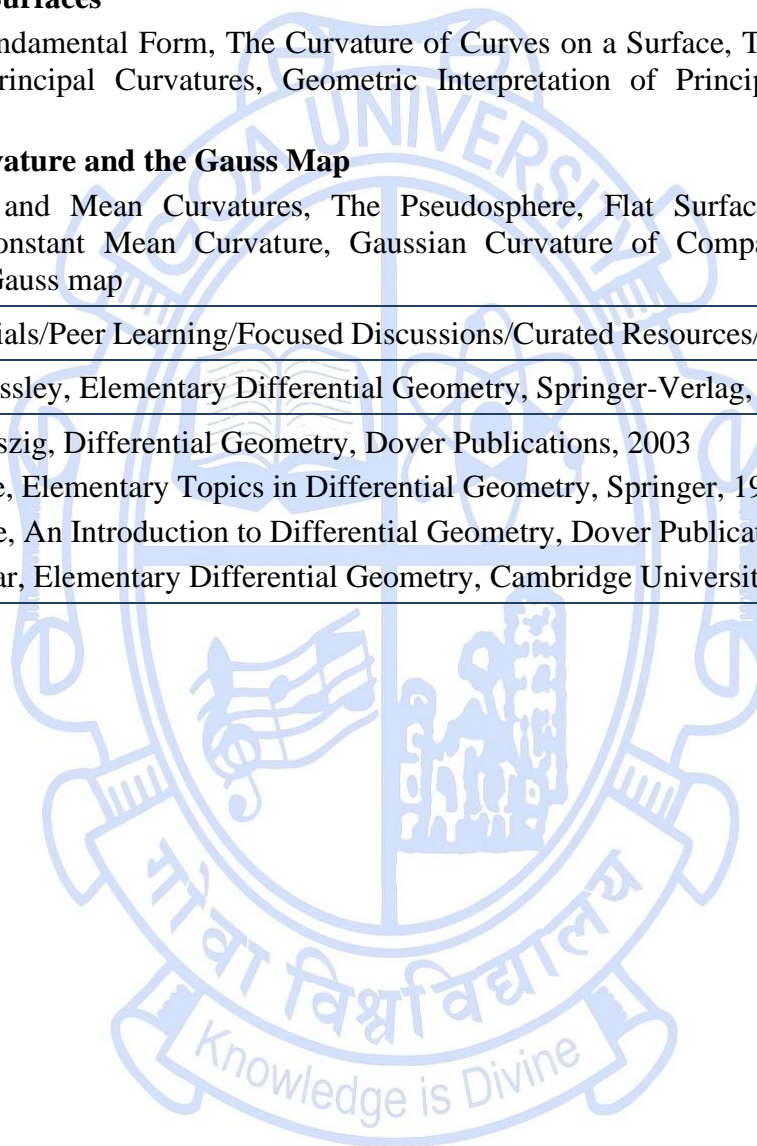
Title of the Course	Differential Geometry
Course Code	MAT-6004
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	<p>Knowledge of topics covered in the Papers</p> <p>MAT-5000: Real Analysis</p> <p>MAT-5001: Advanced Linear Algebra</p> <p>MAT-5006: Several Variable Calculus</p>
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Differential Geometry, 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 Differential Geometry concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Differential Geometry methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Differential Geometry, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Differential Geometry and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Differential Geometry and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Differential Geometry	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Differential Geometry and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Curves in the Plane and in Space Curves, Arc-Length, Reparameterization, Level Curves vs Parametrized Curves. How Much Does a Curve Curve? Curvature, Plane Curves, Space Curves	14	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Global Properties of Curves Simple Closed Curves, The Isoperimetric Inequality, The Four Vertex Theorem Surfaces in Three Dimensions Surfaces Smooth Surfaces, Tangents, Normals and Orientability, Examples of Surfaces, Quadric Surfaces, Triply Orthogonal Systems, Applications of the Inverse Function Theorem	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	The First Fundamental Form Lengths of Curves on Surfaces, Isometries of Surfaces, Conformal Mappings of Surfaces, Surface Area, Equi-areal Maps and a Theorem of Archimedes	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

Module 4:	<p>Curvature of Surfaces The Second Fundamental Form, The Curvature of Curves on a Surface, The Normal and Principal Curvatures, Geometric Interpretation of Principal Curvatures</p> <p>Gaussian Curvature and the Gauss Map The Gaussian and Mean Curvatures, The Pseudosphere, Flat Surfaces, Surfaces of Constant Mean Curvature, Gaussian Curvature of Compact Surfaces, The Gauss map</p>	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:	1. Andrew Pressley, Elementary Differential Geometry, Springer-Verlag, 2001			
References/ Readings:	<ol style="list-style-type: none"> 1. Erwin Kreyszig, Differential Geometry, Dover Publications, 2003 2. J. A. Thorpe, Elementary Topics in Differential Geometry, Springer, 1994 3. T.J.Wilmore, An Introduction to Differential Geometry, Dover Publications Inc.,2012 4. Christian Bar, Elementary Differential Geometry, Cambridge University Press, 2003 			

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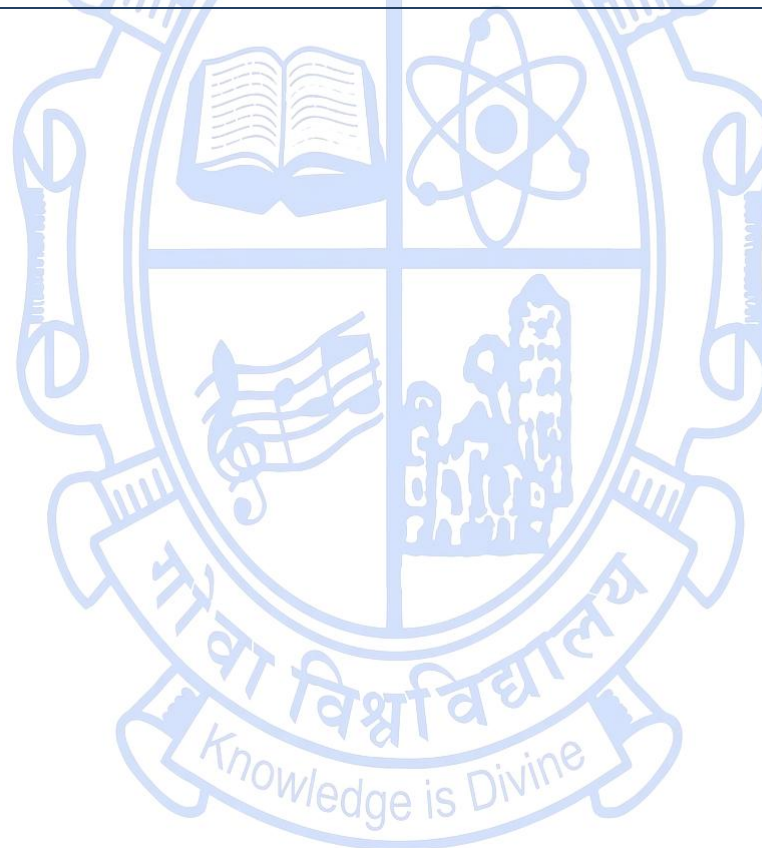
Title of the Course	Advanced Graph Theory
Course Code	MAT-6005
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Crediting MAT-6002: Graphs and Networks	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Advanced Graph Theory, 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 Advanced Graph Theory concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Advanced Graph Theory methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Advanced Graph Theory, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Advanced Graph Theory and associated concepts.	PSO1, PSO6

	CO 2. demonstrate proofs to establish truths related to Advanced Graph Theory and associated concepts.		PSO2, PSO6	
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Advanced Graph Theory		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Advanced Graph Theory and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Review of Basic Concepts: Graphs, Trees, minimal spanning trees, connectivity and edge-connectivity, Eulerian graphs, Hamiltonian graphs, Euler's formula, Planar graphs, Colourings, Matchings, Independence and Domination in a graph. Independent Sets and Cliques: Independent Sets, Cliques, Ramsey Number and Turan's Theorem.	14	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Matchings, Factors and Decompositions: Matchings & Covers, Maximum Matchings, Matchings in bipartite Graphs, Hall's Matching Condition, Min-Max Theorems, Perfect Matching, Factorizations and Decompositions.	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Labelings of Graphs: Graceful Labeling, Harmonious Labeling, Bandwidth Labeling. Colourability: Chromatic Number and Chromatic index, Brook's Theorem, Vizing's Theorem, Chromatic Polynomials.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Connectivity and Paths: k -Connected Graphs, k -Edge Connected Graphs, Menger's Theorem. Domination in Graphs: Dominating Queens, Dominating Sets in Graphs, Applications of Dominating	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	Sets, Bounds on the Domination Number (in terms of order, in terms of order and size).			
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. G. Chartrand and L. Lesniak, Graphs and Digraphs, Chapman & Hall/CRC, Third edition, 1996.			
References/ Readings:	<ol style="list-style-type: none"> 1. G. Chartrand and P. Zhang, Chromatic Graph Theory, CRC Press, 2009. 2. D. B. West, Introduction to Graph Theory, Prentice Hall of India, 2006. 3. T.W. Haynes, S.T. Hedetniemi & P.J. Slater, Fundamentals of Domination in Graphs, Marcel Dekker Inc., 1998. 			

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Title of the Course	Galois Theory
Course Code	MAT-6006
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in the Papers MAT-5001 Advanced Linear Algebra MAT-5002 Ring Theory	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Galois Theory, 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 Galois Theory concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Galois Theory methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Galois Theory, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Galois Theory and associated concepts.	PSO1, PSO6

	CO 2. demonstrate proofs to establish truths related to Galois Theory and associated concepts.		PSO2, PSO6	
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Galois Theory		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Galois Theory and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	1. Field Theory: Basic Theory of Field Extensions, Algebraic Extensions, Classic Straightedge and Compass Constructions	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	2. Splitting Field: Splitting Fields and Algebraic Closures, Separable and Inseparable Extensions, Cyclotomic Polynomials and Extensions.	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	3. Galois Theory: Basic Definitions, Equivalent Definitions of Galois Extensions, The Fundamental Theorem of Galois Theory, Finite Fields, Composite Extensions and Simple Extensions, Cyclotomic Extensions and Simple Extensions. Galois Group of Polynomials	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	4. Applications of Galois Theory: Solvable and Radical Extensions and Insolvability of Quintic, Computation of Galois Groups over rationals.	10	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. David S. Dummit and Richard M. Foote, Abstract Algebra, II Edition, John Wiley Sons Inc., 1999.			
References/ Readings:	1. I N Herstein, Topics in Algebra, Wiley Students Edition, 2006. 2. Patrick Morandi, Fields and Galois Theory, Springer-Verlag, New York, 2011 3. P.B. Bhattacharya, S.K. Jain, S.R. Nagpaul, Basic Abstract Algebra, Second Edition, Cambridge University Press, 2003 4. Vivek Sahai, Vikas Bist, Algebra, Third Edition, Narosa Publishing House, 2015			

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Title of the Course	Commutative Algebra
Course Code	MAT-6007
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in the Paper MAT-5002: Ring Theory	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Commutative Algebra, 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 Commutative Algebra concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Commutative Algebra methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Commutative Algebra, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Commutative Algebra and associated concepts.	PSO1, PSO6

	CO 2. demonstrate proofs to establish truths related to Commutative Algebra and associated concepts.		PSO2, PSO6	
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Commutative Algebra		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Commutative Algebra and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Modules: Definition, Direct sum of modules, Free modules and Vector spaces, Homomorphisms and Quotient modules, Simple modules, Modules over PID	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Modules with chain conditions, Artinian rings and modules, Noetherian rings and modules, Nil radical and Jacobson radical, Radical of an Artinian ring	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Homological algebra, Chain complexes, Exact sequences, Five lemma and Snake lemma, Homology group of a chain complex, Long exact sequences associated with exact sequence of chain complexes	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Categories and Functors: Definition of Categories and Functors, Examples, Products and Coproducts and examples, Free Objects	10	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. C. Musili, Introduction to Rings and Modules, Narosa Publishing House, 1912			
References/ Readings:	1. Balwant Singh, Basic Commutative Algebra, World Scientific Publishing Co. ,2011 2. Serge Lang, Algebra, Addison Wesley, 1985 3. David Eisenbud, Commutative Algebra with a View Towards Algebraic Geometry, Springer-Verlag, 1995 4. Gregr Kemper, A Course in Commutative Algebra, Springer, 2011 5. David S. Dummit, Richard M. Foote, Abstract Algebra, Third Edition, John Wiley & Sons, Inc, 2004			

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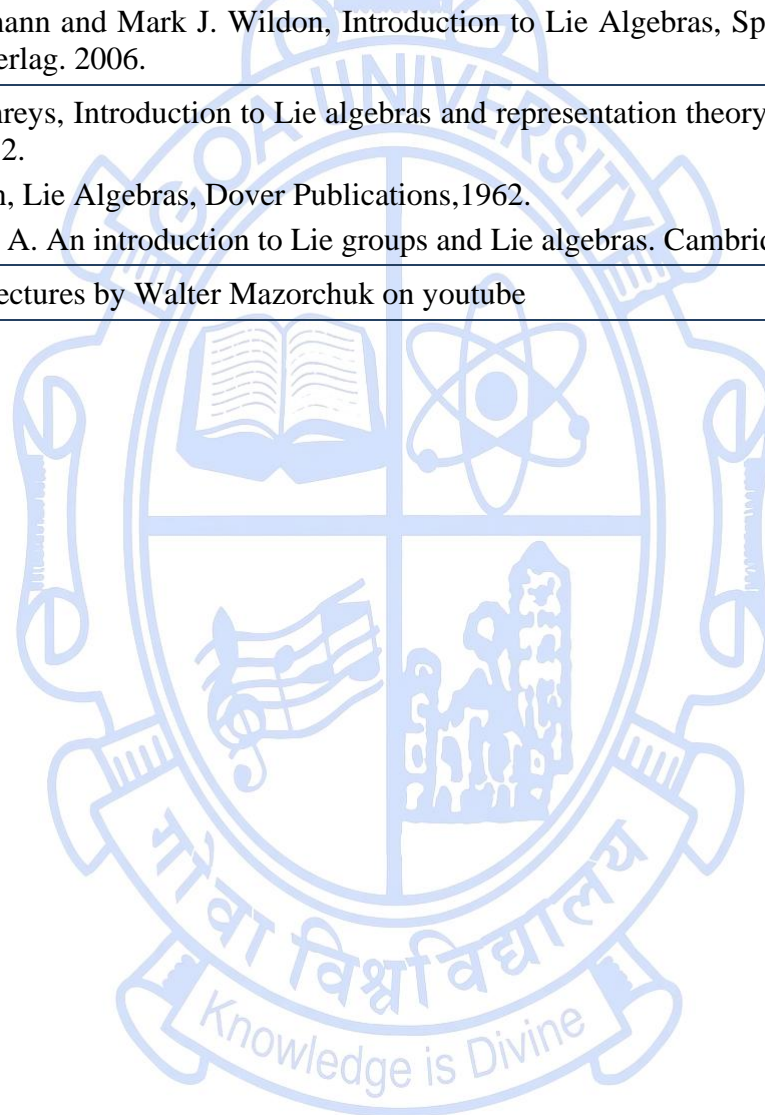
Title of the Course	Lie Algebra
Course Code	MAT-6008
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of topics covered in the Paper MAT-5001:Advanced Linear Algebra	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Lie Algebra, 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 Lie Algebra concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Lie Algebra methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Lie Algebra, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Lie Algebra and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Lie Algebra and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Lie Algebra		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Lie Algebra and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Lie algebras: Definition, Some Examples, Subalgebras and Ideals. Homomorphisms. Algebras. Derivations. Structure Constants. Ideals and Homomorphisms: Constructions with Ideals. Quotient Algebras. Correspondence between Ideals.	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Low-Dimensional Lie Algebras: Dimension 1, 2 and 3. Solvable Lie Algebras: Nilpotent Lie Algebras. Subalgebras of $gl(V)$. Nilpotent Maps. Weights. The Invariance Lemma. An Application of the Invariance Lemma. Engel's and Lie's Theorems.	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Representation Theory: Representations. Modules for Lie Algebras. Submodules and Factor Modules. Irreducible and Indecomposable Modules. Homomorphisms. Schur's Lemma. Representations of $sl(2,C)$: The Modules V_d . Classifying the Irreducible $sl(2,C)$ - Modules.	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Cartan's Criteria: Testing for Solvability. The Killing Form. Testing for Semisimplicity. Derivations of Semisimple Lie Algebras. The Root Space Decomposition: Cartan Subalgebras. Definition of the Root Space Decomposition. Cartan Subalgebras as Inner-Product Spaces. Root Systems: Bases for Root Systems. Cartan Matrices and Dynkin Diagrams.	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:	1. Karin Erdmann and Mark J. Wildon, Introduction to Lie Algebras, Springer Undergraduate Mathematics Series, Springer-Verlag. 2006.
References/ Readings:	1. J.E. Humphreys, Introduction to Lie algebras and representation theory, Graduate Text in Mathematics, Springer-Verlag, 1972. 2. N. Jacobson, Lie Algebras, Dover Publications,1962. 3. Kirillov, A. A. An introduction to Lie groups and Lie algebras. Cambridge University Press, 2008.
Web Resources:	Lie algebras. Lectures by Walter Mazorchuk on youtube

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Title of the Course	Research Methodology
Course Code	MAT-6009
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Knowledge of basic Real Analysis, Differential equations and Difference Equations.	
Course Objectives:	<p>After going through this course, the students will be able to</p> <ul style="list-style-type: none"> • Understand and explain the fundamental concepts, types, and processes of research, including problem formulation, literature review, and research design. • Apply appropriate research methods and statistical tools to collect, analyze, and interpret data in various research contexts. • Analyze and evaluate different research designs, methodologies, and published research studies to assess their validity, reliability, and ethical considerations. • Design and develop an independent research proposal or project by integrating suitable methodologies, tools, and ethical practices. 	
Course Outcomes:		Mapped to PSO

	CO 1. Explain key concepts of research methodology, including research types, problem formulation, and literature review.		PSO1, PSO2
	CO 2. Apply appropriate research designs, sampling techniques, and statistical tools for data collection and analysis.		PSO3, PSO5, PSO6
	CO 3. Analyze and evaluate research studies based on methodology, validity, reliability, and ethical considerations.		PSO2, PSO3, PSO6,
	CO 4. Design and present a research proposal or project report following standard academic and ethical practices.		PSO5, PSO6
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	BASICS OF RESEARCH: Overview of scientific research, Understanding research methodology in Mathematics, Strategies for investigating problems, Tactics for solving problems, Literature survey and critical review of the topic and a problem, Selection of a research topic, Formulating the research problem, Studying and reviewing a paper, Designing the research, Structure and components of scientific reports – Types of reports – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and language of typical reports, Importance of effective communication.	20	CO1, CO2, CO3, CO4. K1, K2, K3, K4, K5, K6
Module 2:	MATHEMATICAL SOFTWARE: Knowledge of SageMath/Scilab/Python/R/MATLAB/Mathematica for: Plotting 2D and 3D Graphs, Programming, Handling Computational Calculus, Algebra and Linear Algebra, Solving Differential Equations.	15	CO1, CO2, CO3, CO4. K1, K2, K3, K4, K5, K6
Module 3:	TYPESETTING AND PRESENTATION USING LATEX: Simple Commands, The Space Between Words, Titles, Chapters, and Sections, Page Customization, Page Numbering. Typesetting Mathematical Formulae – Modern Mathematics, Single Equations, Building Blocks for Mathematical Formulae, Multiline Equations, Units, Matrices and Determinants, Spacing in Math mode, Theorems and Proofs. Bibliographies – Bibliography environment, bib latex with biber Database files, Cross	20	CO1, CO2, CO3, CO4. K1, K2, K3, K4, K5, K6

	Referencing, Using bib latex, Controlling the bibliography, Citing commands, Generating Table of Contents. Graphics – Overview, Basic Usage, Curves and Shapes, Customizing Paths and Nodes, Coordinates, Reusing Pictures, Creating Tables, Libraries. Customising LaTeX – New Commands, Environments and Packages, Fonts and Sizes, Custom Fonts with fontspec, Colours, Lengths and Spacing, The Layout of the Document, Fancy Headers. Presentation Tools and Skills – Beamer as a tool for paper and thesis presentations, Oral and poster presentations.			
Module 4:	FUNDING: Writing a research proposal, Proposal vs Report, Funding agencies, Types of research grants.	5	CO1, CO2, CO3, CO4.	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures/ tutorials/assignments/self-study			
Texts:	1. The Art and Craft of Problem Solving, Paul Zeitz, John Wiley & Sons, 2019. 2. C. George Thomas, “Research Methodology and Scientific Writing”, Springer, 2021.			
References/ Readings:	1. How to Solve It – a new aspect of mathematical method, G. Polya, Princeton University Press, 2014. 2. Computational Mathematics with SageMath, Paul Zimmermann, Society for Industrial & Applied Mathematics, 2018. 3. Tobias Oetiker, Marcin Serwin, Hubert Partl, Irene Hyna and Elisabeth Schlegl, Latex in 157 minutes: The Not So Short Introduction to Latex, Samurai Media Limited, 2015.			

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Discipline Specific Vocational Elective (DSVE) Courses

Title of the Course	Mathematical Typesetting using LaTeX
Course Code	MAT-6401
Number of Credits	2
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No
Pre-requisites for the Course:	NIL
Course Objectives:	<ul style="list-style-type: none"> ● To introduce the foundational concepts of Mathematical Typesetting using LaTeX, 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 Mathematical Typesetting using LaTeX concepts and theorems. ● To equip learners with the skills necessary to identify and apply appropriate Mathematical Typesetting using LaTeX methods and techniques to solve structured problems. ● To encourage analytical thinking and creativity in solving unfamiliar problems in Mathematical Typesetting using LaTeX, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Mathematical Typesetting using LaTeX and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate their skill in Mathematical Typesetting using LaTeX.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Mathematical Typesetting using LaTeX	PSO3, PSO6		
	CO 4. analyze and select appropriate commands and methods for Mathematical Typesetting using LaTeX and present mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>1. LATEX Basics: A Bit of History, Basics, LATEX input files, Input File Structure, A Typical Command Line Session, Logical Structure of your Document, Packages, The Structure of Text and Language, Files you might Encounter.</p> <p>2. Real World LATEX: Line Breaking and PageBreaking, Ready-Made Strings, Dashes and Hyphens, Slash, Ellipsis, Ligatures, Abstract, Simple Commands, The Space Between Words, Titles, Chapters, and Sections, Cross References, Footnotes, Lists, Non-Justified Text, Quotations, Code Listings, Tables, Including Graphics and Images, Floating Bodies, Big Projects.</p>	16	CO1	K1, K2, K3, K4, K5, K6
Module 2:	<p>3. Typesetting Mathematical Formulae: Modern Mathematics, Single Equations, Building Blocks for Mathematical Formulae, Multiline Equations, Units, Matrices and the Like, Spacing in Math mode, Theorems and Proofs, Fiddling with math styles, Dots, More about Fractions.</p> <p>4. Bibliographies: the bibliography environment, biblatex with biber Database files, Using biblatex, Controlling the bibliography, Citing commands, More about entries.</p> <p>5. Specialties: Indexing, Installing Extra Packages, LATEX and PDF, Creating Presentations</p>	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	6. Graphics in Your Document: Overview, Basic Usage, Curves and Shapes,	12	CO1,	K1, K2,

	Customizing Paths and Nodes, Coordinates, Reusing Pictures, Libraries		CO2, CO3, CO4	K3, K4, K5, K6
Module 4:	7. Customising LATEX: New Commands, Environments and Packages, Fonts and Sizes, Custom Fonts with fontspec, Colours, Lengths and Spacing, The Layout of the Document, Fancy Headers	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:	1. Tobias Oetiker, Marcin Serwin, Hubert Partl, Irene Hyna and Elisabeth Schlegl, The Not So Short Introduction to LATEX, 2022			
References/ Readings:	2. George Gratzer, More Math Into LATEX, Springer, 2016 3. Leslie Lamport, A Documentation Preparation System LATEX User's Guide and Reference Manual, Pearson, 2006 4. Kopka, H., Daly, P. W. Guide to LaTeX (4th ed.). Addison-Wesley, 2004.			

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Title of the Course	Numerical Methods
Course Code	MAT-6402
Number of Credits	2
Theory/Practical	Theory (1 credit) + Practical (1 credit)
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in MAT-5000: Real Analysis	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Numerical Methods, 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 Numerical Methods concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Numerical methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Numerical Methods, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Numerical Methods and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Numerical Methods and associated	PSO2, PSO6

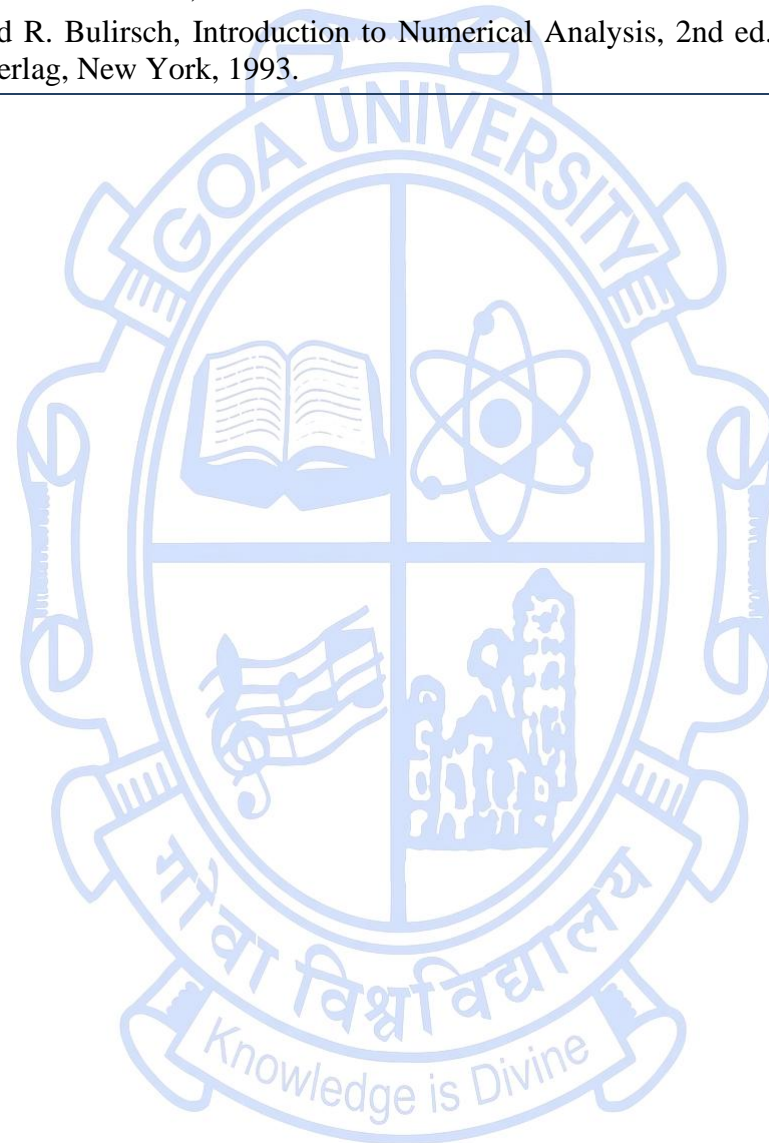
	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Numerical Methods		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Numerical Methods and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Principles of floating point computations and rounding errors. Systems of linear equations : factorization methods, pivoting and scaling, residual error correction method. Iterative methods : Jacobi, Gauss-Seidel methods with convergence analysis, conjugate gradient methods. Eigen value problems: Implementation issues.	04	CO1, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Nonlinear systems: Newton and Newton like methods and unconstrained optimization. Interpolation: Review of Lagrange interpolation techniques, piecewise linear and cubic splines, error estimates. Approximation: uniform approximation by polynomials, data fitting and least squares approximation.	04	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Numerical Integration: integration by interpolation, adaptive quadratures and Gauss methods. Initial Value problems for ordinary differential equations: Runge-Kutta methods, multi-step methods, predictor and corrector scheme, stability and convergence analysis.	04	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Two Point Boundary Value Problems: finite difference methods with convergence results.	03	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

<p>Practical Component</p>	<ol style="list-style-type: none"> 1. Floating Point & Linear Systems : Implement floating-point error analysis and solve linear systems using LU factorization with pivoting, scaling, and residual error correction. 2. Iterative Methods : Apply Jacobi, Gauss–Seidel, and Conjugate Gradient methods to solve linear systems and analyze their convergence behavior. 3. Eigenvalue Problems : Implement the power method and inverse power method to compute dominant and smallest eigenvalues of a matrix. 4. Nonlinear Systems & Optimization : Solve nonlinear equations using Newton and Newton-like methods and perform unconstrained optimization using gradient-based techniques. 5. Interpolation : Implement Lagrange, piecewise linear, and cubic spline interpolation and estimate interpolation errors. 6. Approximation : Perform uniform polynomial approximation and least squares curve fitting for a given dataset. 7. Numerical Integration : Evaluate definite integrals using Newton–Cotes formulas, adaptive quadrature, and Gauss quadrature methods. 8. Initial Value Problems (ODEs) : Solve ODEs using Runge–Kutta and multi-step predictor–corrector methods and study stability and convergence. 9. Two-Point Boundary Value Problems : Solve linear boundary value problems using finite difference methods and verify convergence numerically. 10. Lab Component: Implementation of algorithms and exposure to public domain packages like LINPACK and ODEPACK. 	<p>30</p>		
<p>Pedagogy:</p>	<p>Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.</p>			
<p>Texts:</p>	<ol style="list-style-type: none"> 1. K. E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989. 			
<p>References/ Readings:</p>	<ol style="list-style-type: none"> 1. S. D. Conte and C. De Boor, Elementary Numerical Analysis An Algorithmic Approach, McGraw-Hill, 1981. 2. K. Eriksson, D. Estep, P. Hansbo and C. Johnson, Computational Differential Equations, Cambridge Univ. Press, Cambridge, 1996. 3. G. H. Golub and J. M. Ortega, Scientific Computing and Differential Equations: An Introduction to Numerical 			

Methods, Academic Press, 1992.

4. J. Stoer and R. Bulirsch, Introduction to Numerical Analysis, 2nd ed., Texts in Applied Mathematics, Vol. 12, Springer Verlag, New York, 1993.

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Title of the Course	Mathematics for Machine Learning
Course Code	MAT-6403
Number of Credits	4
Theory/Practical	Theory(2 Credits)+Practical(2 Credits)
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

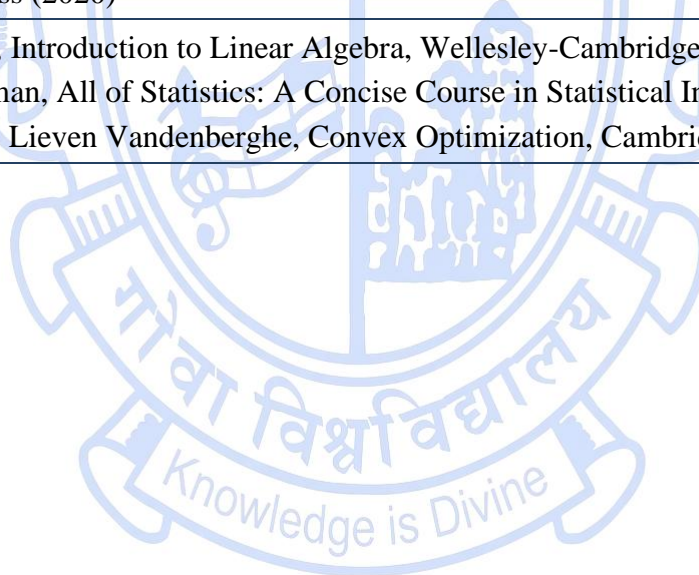
Pre-requisites for the Course:	<p>Basic knowledge of topics covered in paper</p> <p>MAT-5000: Real Analysis</p> <p>MAT-5001 Advanced Linear Algebra</p> <p>MAT-5006 Several Variable Calculus</p> <p>MAT-5205 Computational Mathematics Using Python</p>
Course Objectives:	<ul style="list-style-type: none"> • To introduce core mathematical foundations of Machine Learning — including linear algebra, calculus, probability, and optimization — fostering a rigorous understanding of their definitions, properties, and interconnections. • To develop the learner’s capacity to formulate and verify mathematical results and proofs that underpin algorithms and models in Machine Learning. • To train learners to identify, select, and apply appropriate mathematical techniques such as matrix factorizations, gradient-based optimization, and probabilistic reasoning to solve structured computational problems. • To encourage analytical reasoning, creativity, and mathematical precision in formulating, analyzing, and solving new or unfamiliar problems in Machine Learning

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. Demonstrate conceptual understanding and familiarity with the fundamental mathematical principles — including matrix decompositions, vector calculus, probability, and optimization — that form the basis of Machine Learning.	PSO1, PSO6		
	CO 2. Construct and validate mathematical derivations and proofs for results such as decomposition properties, gradient identities, and optimization conditions relevant to Machine Learning.	PSO2, PSO6		
	CO 3. Select, modify, and implement appropriate mathematical and computational methods — including SVD, backpropagation, optimization, and Bayesian inference — to solve structured problems.	PSO3, PSO6		
	CO 4. Analyze and synthesize mathematical models and formulate precise arguments to solve unseen or ill-structured problems in Machine Learning contexts, demonstrating originality and logical rigor.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Matrix Decomposition: Eigenvalues and Eigenvectors, Cholesky Decomposition, Diagonalization, Singular Value Decomposition, Matrix Approximation, Matrix Phylogeny	6	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Review of Vector Calculus: Differentiation of Univariate Functions, Partial Differential Equations, Gradients of Vector-Valued Functions, Gradients of Matrices, Backpropagation and Automatic Differentiation, Higher-Order Derivatives, Linearization and Multivariate Taylor Series	8	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Probability and Distribution: Construction of Probability Space, Discrete and Continuous Probabilities, Bayes' Theorem, Gaussian Distribution, Conjugacy and the Exponential Transformation, Change of Variables/ Inverse Transformation	8	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Continuous Optimization: Optimization Using Gradient Descent,	4	CO1, CO2,	K1, K2, K3,

	Constrained Optimization and Lagrange Multipliers, Convex Optimization		CO3, CO4	K4, K5, K6
Module 5:	Linear Regression: Problem Formulation, Parameter Estimation, Bayesian Linear Regression, Maximum Likelihood as Orthogonal Projection.	4	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
List of Practicals	<ol style="list-style-type: none"> 1. Introduction to Jupyter Notebook and Python for Mathematical Computing: Learn to use Jupyter Notebook, Markdown, and Python libraries (NumPy, SymPy, Matplotlib) for basic computation and plotting. 2. SVD for Image Compression: Use a library SVD function to implement $A=U\Sigma V^t$, focusing on low-rank approximation A_k for image data. Quantify the reconstruction error. 3. Eigendecomposition: Compute eigenvalues and eigenvectors and confirm diagonalization by calculating $A=PDP^{-1}$. 4. Symbolic Gradients and Visualization: Use symbolic programming (e.g., SymPy) to compute and plot the Gradient Vector for multivariate functions. 5. Backpropagation Simulation: Implement the forward and backward passes for a small computation graph to explicitly demonstrate the chain rule and the mechanics of Automatic Differentiation. 6. Numerical Differentiation and Visualization: Approximate derivatives and gradients numerically using finite differences; compare with symbolic results. 7. Sampling and Distribution Analysis: Generate random samples (Monte Carlo) and plot histograms, comparing the empirical results with the theoretical PDF/PMF for different distributions. 8. Change of Variables: Implement the use of the Jacobian to transform a simple probability distribution. 9. Bayesian Inference: Write code to compute a Bayesian posterior (e.g., for a coin flip) and visualize how the distribution shifts as new data is incorporated. 10. Gradient Descent Implementation: Implement vanilla Gradient Descent and at least one optimization variant (e.g., momentum or RMSprop). Apply 	60	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	<p>it to various loss functions and analyze the impact of hyperparameter tuning (learning rate).</p> <p>11. Constrained Optimization: Use a specialized library (like SciPy's optimize) to solve non-linear constrained optimization problems, relating the numerical solution back to the theory of Lagrange Multipliers.</p> <p>12. Comparative Estimation: Solve for the parameters w^* using the closed-form Normal Equation and iteratively using Gradient Descent. Compare computation time and memory usage on a large dataset.</p> <p>13. Geometric and Bayesian View: Numerically verify the orthogonal projection property. Implement and visualize a simple Bayesian Linear Regression model, showing the uncertainty captured by the posterior distribution.</p>			
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. Marc Peter Deisenroth, A Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press (2020)			
References/ Readings:	<ol style="list-style-type: none"> 1. Gilbert Strang, Introduction to Linear Algebra, Wellesley-Cambridge Press (2016) 2. Larry Wasserman, All of Statistics: A Concise Course in Statistical Inference, Springer (2010) 3. Stephen Boyd, Lieven Vandenberghe, Convex Optimization, Cambridge University Press (2004) 			

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Title of the Course	Finite Element Methods
Course Code	MAT-6404
Number of Credits	2T+2P
Theory/Practical	Theory (2 Credits)+Practical (2 Credits)
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners:	No

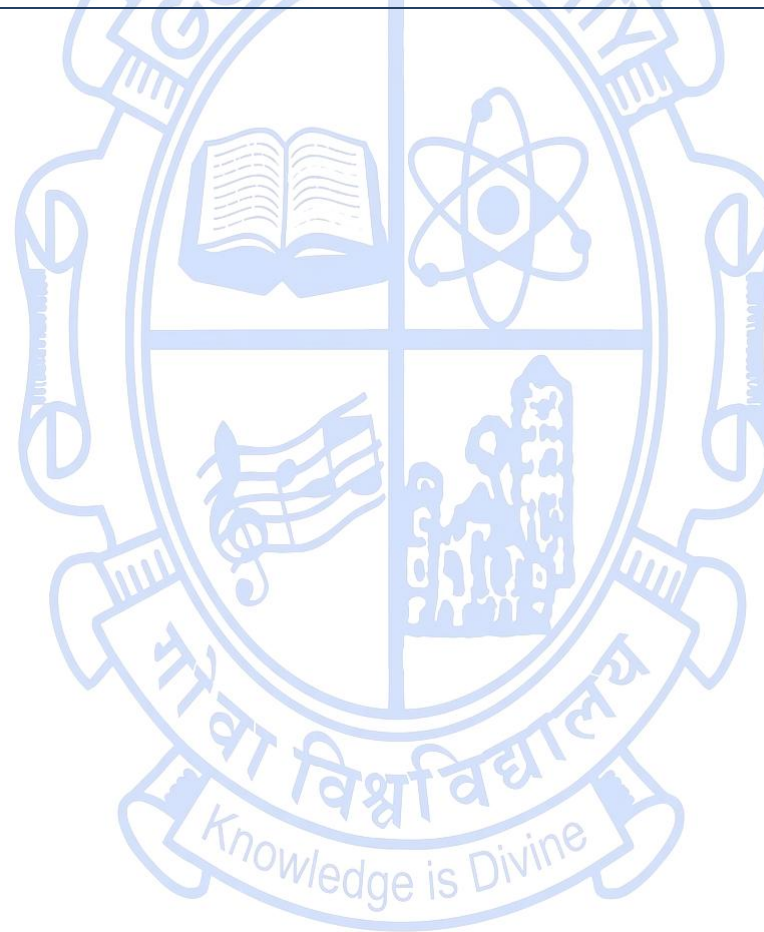
Pre-requisites for the Course:	Basic knowledge of topics covered in papers MAT-5001: Advanced Linear Algebra, MAT-5005: Differential Equations, MAT-6402: Numerical Analysis
Course Objectives:	<ul style="list-style-type: none"> ● To introduce the foundational concepts of Finite Element Methods, fostering a strong theoretical understanding of definitions and properties. ● To develop the learner's ability to construct and understand rigorous mathematical proofs related to key Finite Element Methods concepts and theorems. ● To equip learners with the skills necessary to identify and apply appropriate Finite Element Methods methods and techniques to solve structured problems. ● To encourage analytical thinking and creativity in solving unfamiliar problems in Finite Element Methods, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Finite Element Methods and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Finite Element Methods and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Finite Element Methods	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Finite Element Methods and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Introduction to Finite Element Method: Historical background, General Steps of the Finite Element Method, Discretization, selection of element type, shape functions, and assembly process. comparison with finite difference and analytical methods.	06	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Elements of calculus of variation, Strong form and weak form, Strong Form in One-Dimensional Problems, weak form in one-dimension, equivalence between strong and weak forms, Rayleigh-Ritz method. Weak Formulation of Boundary value Problems, Method of weighted residuals- Galerkin and Petrov-Galerkin approach, Least-square method, Collocation Method.	08	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Finite element analysis of one -dimensional problems, basic steps, Model boundary value problem, discretization of domain, derivation of element equation, connectivity of elements, imposition of boundary conditions, solution of equations. Applications in heat transfer, fluid mechanics and solid mechanics, Finite element formulation for Euler-Bernoulli beams, error analysis	08	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Finite element analysis of two-dimensional problems, completeness and continuity, different elements, shape functions, Gauss quadrature technique for numerical integration, boundary value problem: model equations, weak form, discretization and	08	CO1, CO2, CO3,	K1, K2, K3, K4, K5, K6

	solution, Finite element formulation for two-dimensional scalar field problems, application to heat conduction		CO4	
Practical	<p>List of practicals (using ANSYS/OpenFOAM/Python/ any other software):</p> <ol style="list-style-type: none"> 1. Introduction: Interface, geometry creation, meshing. 2. Discretization of a 1D bar and truss – creating nodes and elements manually 3. Study of shape functions for 1D linear and quadratic elements (verification using simple bar) 4. Comparison of FEM with finite difference for a 1-D rod (temperature distribution) 5. Derivation and solution of 1-D bar problem using Galerkin method 6. Rayleigh–Ritz method for a simply supported beam (comparison with analytical solution) 7. Collocation and least-square method for solving $u'' + u =$ 8. Axial deformation of a stepped bar under load 9. 1D steady-state heat conduction through composite wall 10. Deflection of Euler–Bernoulli beam under uniform load 11. Error estimation: mesh refinement in a 1D bar problem 12. 2D steady-state heat conduction in a square plate 13. Plane stress analysis of a rectangular plate 14. Axisymmetric pressure vessel analysis 15. Finite element formulation and comparison (mini project based on real life problem) 	60	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:	<ol style="list-style-type: none"> 1. Reddy J. N., An Introduction to the Finite Element Method (4th Edition), McGraw-Hill Education, 2019. 2. Fish Fish, Belytschko Ted, A First Course in Elements, John Wiley & Sons, Ltd, 2007. 			
References/ Readings:	<ol style="list-style-type: none"> 1. Bathe Klaus-Jürgen., Finite Element Procedures, Prentice-Hall Inc., 1996. Logan Daryl L., A First Course in the Finite Element Method (4th Edition), Thomson Canada Ltd, 2007. 			

2. Rao S. S., The Finite Element Method in Engineering (6th Edition), Elsevier, 2017.
3. Hughes Thomas J. R., The Finite Element Method: Linear Static and Dynamic Finite, Dover Publications Inc., 2003.
4. Erik G. Thompson, Introduction to the Finite Element Method: Theory, Programming and Applications, John Wiley, 2004
5. G.R. Liu and S.S. Quek, The Finite Element Method: A Practical Course, Butterworth-Heinemann Ltd, 2003.

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Title of the Course	Partial Differential Equations
Course Code	MAT-6405
Number of Credits	2T+2P
Theory/Practical	Theory(2) + Practical(2)
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in papers MAT-5000: Real Analysis, MAT-5005: Differential Equations	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Partial Differential Equations, 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 Partial Differential Equations concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Partial Differential Equations methods and techniques to solve structured problems. • To equip students with the practical skills required to model, analyze, and solve partial differential equations (PDEs) using numerical methods and software implementation. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Partial Differential Equations and associated	PSO1, PSO6

	concepts.			
	CO 2. demonstrate proofs to establish truths related to Partial Differential Equations and associated concepts.		PSO2, PSO6	
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based unseen problems in Partial Differential Equations		PSO3, PSO6	
	CO 4. implement finite difference and finite element methods in MATLAB to obtain approximate solutions of PDEs arising in science and engineering applications.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Simultaneous differential equations of the first and first degree in three variables: Methods of solutions of $dx/P = dy/Q = dz/R$. Pfaffian differential forms and equations. Solution of Pfaffian differential equations in three variables.	8	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	First order PDE's: Origin and classifications. Solution of Linear and Nonlinear First order PDE's. Methods of characteristics. Charpit's Methods. Jacobi's method.	8	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Second Order Linear Partial Differential Equations: Origin. Linear equations with constant coefficients in two independence Variables. Linear equations with variable coefficients. Classification. Reduction to Canonical Form. (only for the case of two independent variables).	8	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Method of Separation of variables. Use of Integral transforms (Laplace and Fourier). Wave Equation, Laplace Equation and Heat Equation.	6	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
List of Practical:	Following practicals must be done using appropriate Softwares (MATLAB / SCILAB / SAGE MATH etc.) 1. Solving Simultaneous Differential Equations of First Degree in Three Variables. 2. Solving Pfaffian Differential Equations.	60	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

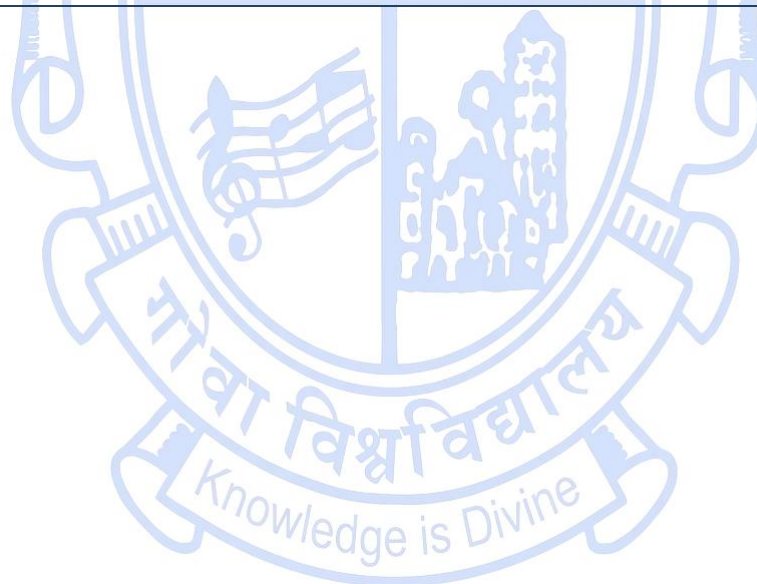
	<ol style="list-style-type: none"> 3. Classification of First Order PDEs. 4. Solution of Linear First Order PDEs using the Method of Characteristics. 5. Numerical Solution of Nonlinear First Order PDEs. 6. Charpit's Method for First Order PDEs. 7. Jacobi's Method for First Order PDEs. 8. Classification of Second Order PDEs and Reduction to Canonical Form. 9. Numerical Solution of PDEs using the Method of Separation of Variables. 10. Application of Laplace and Fourier Transforms for Solving PDEs. 11. Computation and Visualization of One-Dimensional Wave Equation using D'Alembert's Solution using software. 12. Numerical Simulation of Heat and Laplace Equations using a software. 			
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	<ol style="list-style-type: none"> 1. I. Sneddon, Elements of Partial Differential Equations, McGraw Hill. 1957 2. T. Amarnath, An elementary course in Partial Differential Equations, Narosa Publishing company, 1997. 			
References/ Readings:	<ol style="list-style-type: none"> 1. K. Sankara Rao, Introduction to Partial Differential Equations, Prentice Hall of India, 1995. 2. F. John, Partial Differential equations, Springer Verlag Ltd. 1952 3. C. R. Chester, Techniques of Partial Differential Equations. McGraw Hill. 1970 4. R. Dennemeyer, Introduction to Partial Differential Equations and Boundary Value Problems, McGraw Hill. 1968 5. T. M. Hu, L. Debnath, Linear Partial differential equations for scientists and Engineers, Birkhauser. 2007 			

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Title of the Course	Academic Writing and Documentation using LaTeX		
Course Code	MAT-6406		
Number of Credits	4		
Theory/Practical	Practical		
Level	500		
Effective from AY	2026-27		
New Course	Yes		
Bridge Course/ Value added Course	No		
Course for advanced learners	No		
Pre-requisites for the Course:	Nil		
Course Objectives:	To equip students with academic writing, communication and documentation using Latex.		
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO	
	CO 1. Understand the basic structure of academic and research writing.	PSO1, PSO6	
	CO 2. Apply standard practices in formatting an academic and research document.	PSO2, PSO6	
	CO 3. Create well-structured academic documents.	PSO3, PSO6	
	CO 4. Learn to create professional slide presentations	PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO
Module 1:	<ul style="list-style-type: none"> Understand the basic structure of academic and research writing. 	120	CO 1, CO 2,

	<ul style="list-style-type: none"> • Understand basics of LaTeX syntax, document structure, and formatting. • Design and create Articles, Letters, Question papers, Reports, Book/Thesis, Presentation, Poster, flowcharts, etc using Latex. 		CO 3, CO 4	K3, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	<ol style="list-style-type: none"> 1. Ajay Semalty, Academic Writing, BS Publications, Hyderabad, India, 2021 (ISBN: 9789390211739). 2. Anne Whitaker, A Step-by-Step Guide to Writing Academic Papers, City University Seattle, 2009 3. C P Ravikumar, On Writing a Thesis, IETE Journal of Education, Vol. 41, pp 45-52, 2000 4. Leslie Lamport, LaTeX: A document preparation system, User's guide and reference manual, Addison Wesley, 1994. 5. Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle, Chris Rowley, The LaTeX Companion, 			
Web Resources:	<ol style="list-style-type: none"> 1. https://www.overleaf.com/learn 2. https://www.latex-project.org/ 3. https://www.unigoa.ac.in/a/documentation-using-latex.html 			

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SEMESTER IV

Generic Elective (GE) Courses

Title of the Course	Probability and Statistics
Course Code	MAT-6201
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No
Pre-requisites for the Course:	Nil
Course Objectives:	<ul style="list-style-type: none">• To introduce the foundational concepts of Probability and Statistics, 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 Probability and Statistics concepts and theorems.• To equip learners with the skills necessary to identify and apply appropriate Probability and Statistics methods and techniques to solve structured problems.• To encourage analytical thinking and creativity in solving unfamiliar problems in Probability and Statistics,

	enabling learners to construct logically sound and precise mathematical arguments.			
Course Outcomes:	After going through this course the students will be able to			Mapped to PSO
	CO 1. display familiarity and knowledge of Probability and Statistics and associated concepts.			PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Probability and Statistics and associated concepts.			PSO2, PSO6
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Probability and Statistics			PSO3, PSO6
	CO 4. analyze and solve unseen problems in Probability and Statistics and create mathematically precise arguments to justify their solutions.			PSO4, PSO5, PSO6
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Basic Concepts in Probability Theory: Review of Set Theory (union, intersection, complements, De Morgan's laws, Venn diagrams), Sample spaces, events, permutations and combinations, different methods of finding probability, axioms of probability, addition rule for probability, conditional probability, multiplication rule for probability, independent events, Baye's Theorem.</p> <p>Discrete Distributions: Random variables (discrete and continuous random variables), discrete probability densities, cumulative distribution function and its properties, expectation, rules of expectation, variance and standard deviation, rules of variance, ordinary moments, central moments, moment generating function, mean and variance using moment generating function, Bernoulli distribution, Binomial distribution, Poisson distribution, Geometric distribution. Moment generating function, mean, variance and standard deviation of each of the discrete distributions. Poisson approximation to the binomial process, Poisson process, sum of independent Poisson random variables follows a Poisson distribution, cumulative distribution function of geometric distribution, Markov property of geometric distribution.</p>	11	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

Module 2:	<p>Continuous Distributions: Continuous densities, cumulative distribution, expected value, moment generating function, mean, variance. Uniform distribution, standard uniform distribution, cumulative distribution function, moment generating function, mean, variance of uniform distribution, normal distribution, moment generating function, mean, variance of normal distribution, standard normal distribution, Normal approximation to binomial distribution, Normal probability Rule(Empirical Rule or Rule of Thumb), Chebychev's Inequality (second Rule of Thumb), Gamma distribution, moment generating function, mean and variance of gamma distribution, exponential distribution and Chi-squared distributions as special cases of Gamma distribution, relation between exponential distribution and Poisson process, cumulative distribution function of exponential distribution, memoryless property of exponential distribution, summation and scaling properties of gamma distribution, transformation of variables(univariate).</p> <p>Joint Distribution: Discrete joint density, discrete marginal densities, continuous joint density, continuous marginal densities, independent random variables, expectation and covariance, univariate averages via joint density, conditional density and curve of regression, transformation of variables(bivariate).</p>	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>Simulation: Generation of discrete and continuous random variable</p> <p>Random sampling and Estimation: Random sampling, sample statistics, point estimation, sampling distribution of a statistic, distribution of the sample mean and the Central Limit Theorem. Estimation: unbiased estimator (sample mean, sample variance), Interval estimation, Confidence interval on Mean when population variance is known and when variance is estimated, estimating proportions, confidence interval on proportions, interval estimation of variability, one-sided confidence interval for mean and variance.</p>	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	<p>Statistical Inference: determining sample size, sum of squares of standard normal random variables is a chi-</p>	13	CO1, CO2,	K1, K2, K3, K4,

	<p>squared random variable, Difference of chi-squared random variables is a chi-squared random variable, construction of t-random variable using chi-squared random variable and standard normal random variable, t random variable with (n-1) d.o.f. type I, type II errors, power function, power of the test, one-tail, two-tail tests, hypothesis testing on the mean (variance known, variance unknown)</p> <p>Simple linear regression and correlation: Linear regression analysis, model and parameter estimation by least-squares method, Properties of least square estimators, confidence interval estimation and hypothesis testing, Pearson's correlation coefficient, covariance, coefficient of determination.</p>		CO3, CO4	K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. Milton, J. S. and Arnold J. C.: Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences, 4th edition, Tata McGraw-Hill, 2007.			
References/ Readings:	1. Devore, J. L.: Probability & Statistics for Engineering and the Sciences, 8th edition, Cengage Learning, 2012. 2. Joseph K. Blitzstein and Jessica Hwang: Introduction to Probability, CRC Press 2014. 3. R.J. Barlow, Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, Wiley, 1989.			

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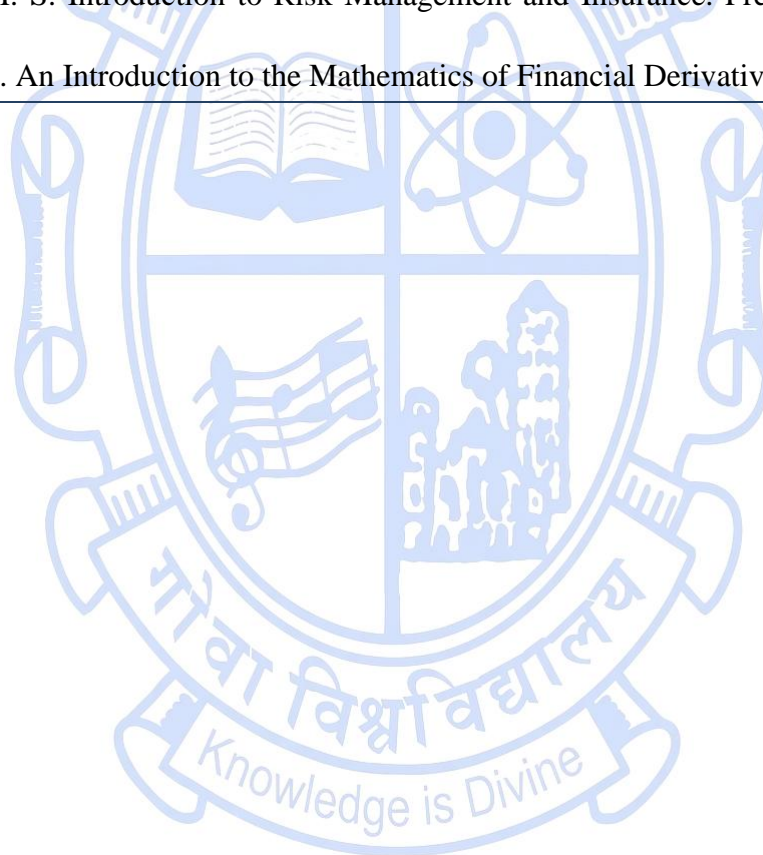
Title of the Course	Mathematics for Finance
Course Code	MAT-6202
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Mathematics for Finance, 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 Mathematics for Finance concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Mathematics for Finance methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Mathematics for Finance, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Mathematics for Finance and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Mathematics for Finance and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Mathematics for Finance		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Mathematics for Finance and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Financial Management –overview. Nature and scope of financial management. Goals and main decisions of financial management. Difference between risk, Speculation and gambling. Time value of Money - Interest rate and discount rate. Present value and future value discrete case as well as continuous compounding case. Annuities and its kinds.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Meaning of return. Return as Internal Rate of Return (IRR). Numerical methods like Newton Raphson method to calculate IRR. Measurement of returns under uncertainty situations. Meaning of risk. Difference between risk and uncertainty. Types of risks. Measurements of risk. Calculation of security and Portfolio Risk and Return-Markowitz Model. Sharpe Single Index Model Systematic Risk and Unsystematic Risk.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Taylor series and Bond Valuation. Calculation of Duration and Convexity of bonds. Insurance Fundamentals – Insurance defined. Meaning of loss. Chances of loss, Peril, Hazard, proximate cause in insurance. Costs and benefits of insurance to the society and branches of insurance-life insurance and various types of general insurance. Insurable loss exposures- feature of a loss that is ideal for insurance.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Life Insurance Mathematics – Construction of Morality Tables. Computation of Premium of Life Insurance for a fixed duration and for the whole life. Determination of claims for General Insurance – Using Poisson Distribution and Negative Binomial Distribution – the Polya Case. Determination of the amount of Claims of General Insurance – Compound Aggregate claim model and its properties, Claims of reinsurance. Calculation of a compound claim density function F, Recursive and approximate formulae for F	15	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. Ross, S. M. An Introduction to Mathematical Finance. Cambridge University Press, 2019.
References/ Readings:	<ol style="list-style-type: none"> 1. Elliott, R. J. and Kopp, P. E. Mathematics of Financial Markets. Springer Verlag, New York Inc, 2018. 2. Damodaran, A. Corporate Finance - Theory and Practice. John Wiley & Sons, Inc, 2012. 3. Hull, J. C. Options, Futures, and Other Derivatives. Prentice-Hall of India Private Ltd, 2010. 4. Daykin, C. D., Pentikainen, T. and Pesonen, M. Practical Risk Theory for Actuaries. Chapman & Hall, 2008. 5. Dorfman, M. S. Introduction to Risk Management and Insurance. Prentice Hall, Englewood Cliffs, New Jersey, 1999. 6. Neftci, S. N. An Introduction to the Mathematics of Financial Derivatives. Academic Press, Inc, 1991

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Title of the Course	Mathematics for Financial Markets
Course Code	MAT-6203
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

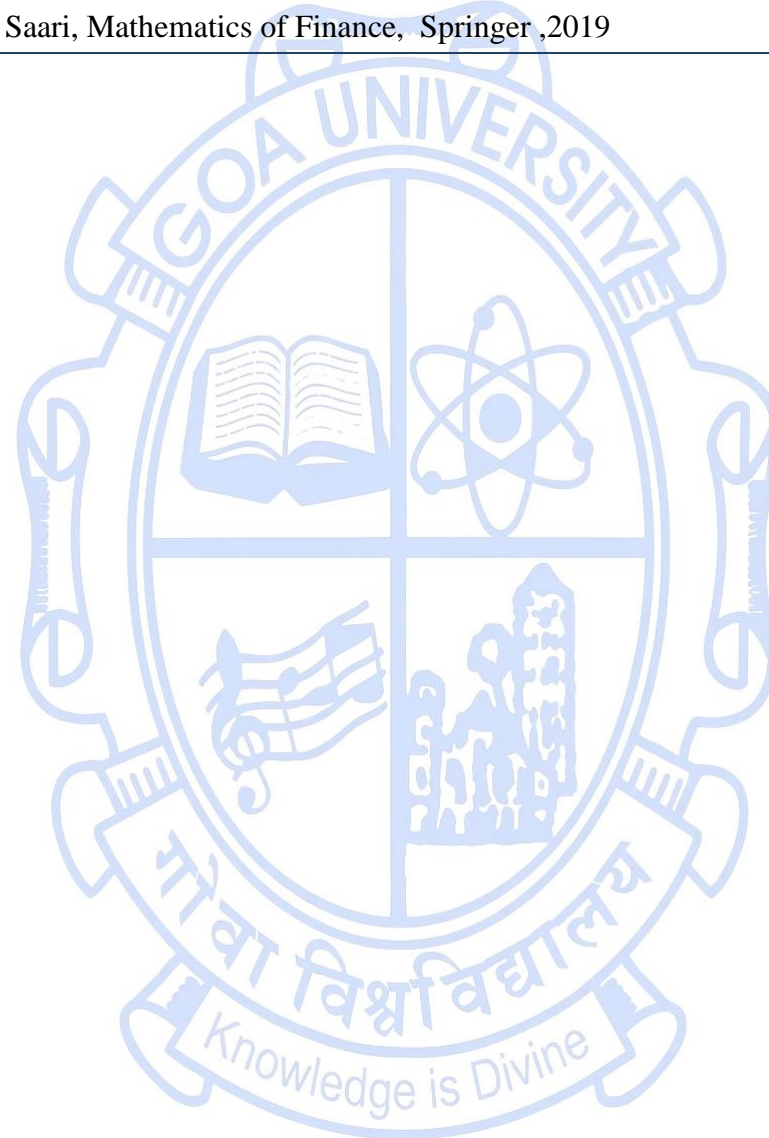
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Mathematics for Financial Markets, fostering a strong theoretical understanding of their definitions and properties. • To develop the learner's ability to construct and understand rigorous mathematical proofs related to key Mathematics for Financial Markets concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Mathematics for Financial Markets methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Mathematics for Financial Markets, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Mathematics for Financial Markets and associated concepts.	PSO1, PSO6

	CO 2. demonstrate proofs to establish truths related to Mathematics for Financial Markets and associated concepts.		PSO2, PSO6
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Mathematics for Financial Markets		PSO3, PSO6
	CO 4. analyze and solve unseen problems in Mathematics for Financial Markets and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	Introduction: A Simple Market Model :Basic Notions and Assumptions, No-Arbitrage Principle, One-Step Binomial Model, Risk and Return, Forward Contracts, Call and Put Options, Managing Risk with Options Risk-Free Assets : Time Value of Money, Money Market	12	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6
Module 2:	Risky Assets : Dynamics of Stock Prices, Binomial Tree Model Discrete Time Market Models : Stock and Money Market Models, Extended Models	12	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6
Module 3:	Portfolio Management : Risk, Two Securities, Several Securities, Capital Asset Pricing Model. Forward and Futures Contracts : Forward Contracts, Futures.	18	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6
Module 4:	Options: General Properties : Definitions, Put-Call Parity, Bounds on Option Prices, Variables Determining Option Prices, Time Value of Options Option Pricing : European Options in the Binomial Tree Model, American Options in the Binomial Tree Model, Black Scholes Formula	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:	1. Marek Capinski and Tomasz Zastawniak, Mathematics for Finance, An Introduction to Financial Engineering, Springer, 2003		
References/	1. Sheldon M. Ross, An Elementary Introduction to Mathematical Finance, Cambridge University Press, 2011		

Readings:

2. Arlie O. Petters and Xiaoying Dong, An Introduction to Mathematical Finance with Applications, Springer ,2016
3. Donald G. Saari, Mathematics of Finance, Springer ,2019

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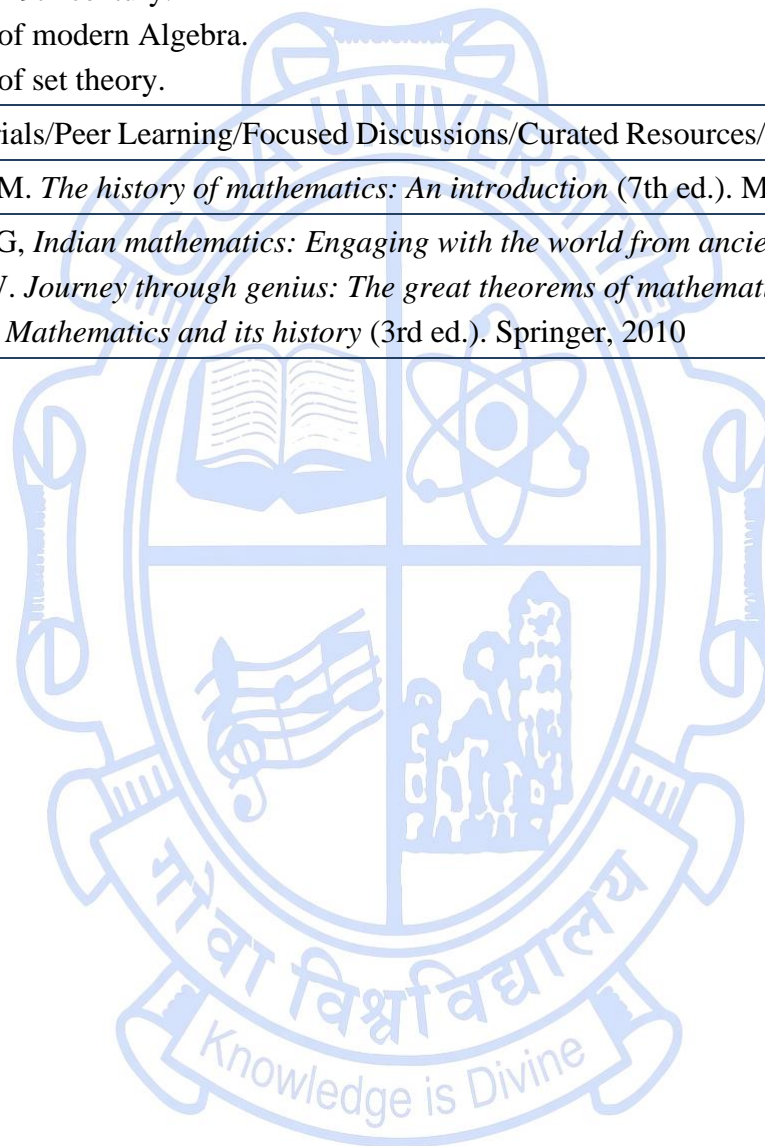
Title of the Course	History of Mathematics
Course Code	MAT-6204
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of History of Mathematics, 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 History of Mathematics concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate History of Mathematics methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in History of Mathematics, enabling learners to construct logically sound and precise mathematical arguments 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of the development of Mathematics from ancient to	PSO1, PSO6

	modern times.			
	CO 2. describe the contributions of the most inspiring mathematicians who have shaped the history of the development of the subject.		PSO1, PSO6	
	CO 3. demonstrate techniques and methods used by various cultures and civilizations to solve Math problems.		PSO2, PSO3, PSO6	
	CO 4. compare, analyze and describe the various facets of the History of Mathematics as seen through the lens of various cultures.		PSO1, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Primitive counting. Positional and non-positional number systems. Babylonian number recording. Babylonian Mathematics, Plimpton 322. Early Egyptian Mathematics. The Beginnings of Greek mathematics. The Mathematics of Archimedes	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Arab, Indian and Chinese mathematics of the first millennium. Heralding the Golden Age of Indian Mathematics: Aryabhata I and his followers. Riding the Crest of a Wave: From Brahmagupta to Mahavira. The 500 Year Climax: Bhaskaracharya and his Legacy A brief look at the life and works of Srinivasa Ramanujan.	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Italian mathematics of the late middle ages and the Renaissance. Mathematics of the humanistic era. The birth of calculus. The beginning of probability.	14	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Number theory in the 17-18 centuries.	14	CO1, CO2,	K1, K2, K3, K4,

	Analysis in the 19th century. The beginning of modern Algebra. The beginning of set theory.		CO3, CO4	K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. Burton, D. M. <i>The history of mathematics: An introduction</i> (7th ed.). McGraw-Hill Education, 2011			
References/ Readings:	1. Joseph, G. G, <i>Indian mathematics: Engaging with the world from ancient to modern times</i> . World Scientific, 2011 2. Dunham, W. <i>Journey through genius: The great theorems of mathematics</i> . Wiley,1990 3. Stillwell, J, <i>Mathematics and its history</i> (3rd ed.). Springer, 2010			

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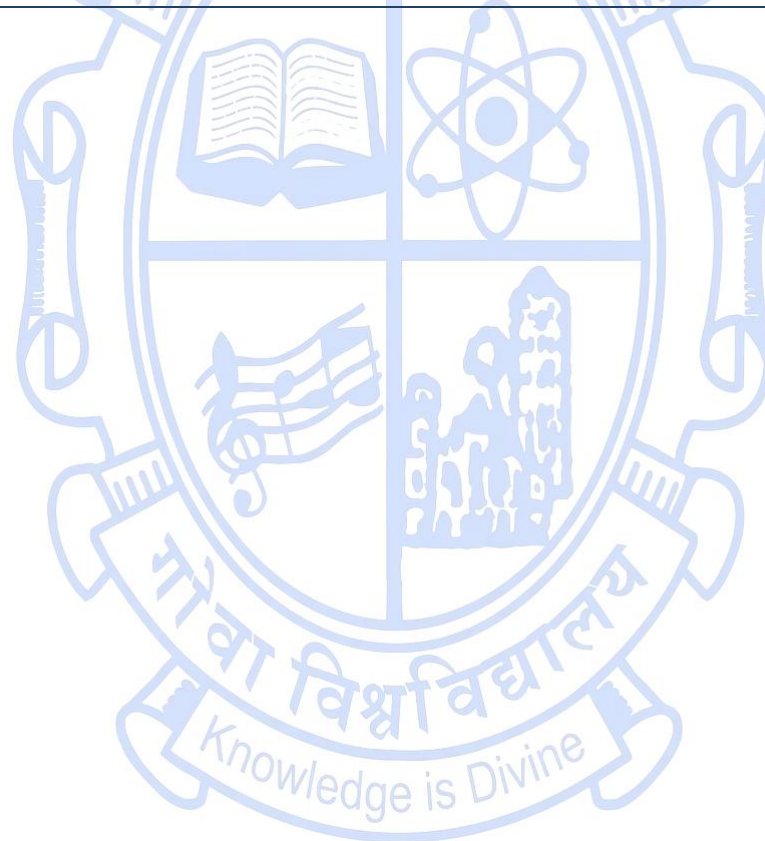
Title of the Course	Difference Equations
Course Code	MAT-6205
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in papers MAT-5000: Real Analysis, MAT-5001: Advanced Linear Algebra, and MAT-5005: Differential Equations
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Difference Equations, 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 Difference Equations concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Difference Equations methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Difference Equations, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Difference Equations and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Difference Equations and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Difference Equations	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Difference Equations and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Definition and classification of difference equations, Order and degree of a difference equation, Calculus of finite differences: Review of basic concepts. Solution of differential equations. Linear and non-linear First-Order Difference Equations: Equilibrium Points and stability, Periodic Points and Cycles	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Linear Difference Equations of Higher Order: General theory, Linear Homogeneous Equations with Constant Coefficients, Nonhomogeneous Equations: Methods of Undetermined Coefficients, Limiting Behavior of Solutions, Limiting Behavior of Solutions, Nonlinear Equations Transformable to Linear Equations, Applications	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Systems of linear Difference Equations. Basic Theory, Putzer algorithm, Algorithm for powers of matrix, Linear Periodic Systems. Stability theory of Linear Systems: Notions of Stability, Phase Space Analysis, Stability by Linear Approximation	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	The Z-Transform Method and Volterra Difference Equations: Properties of the Z-Transform, The Inverse Z-Transform, Solutions of Difference Equations: Power Series Method, The Partial Fractions Method, The Inversion Integral Method. Volterra Difference Equations of Convolution Type, Criteria for Stability of Volterra Equations.	15	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. Elaydi S. N., An Introduction to Difference Equations, Springer Verlag. 1996
References/ Readings:	<ol style="list-style-type: none"> 1. Kelley W. G., Peterson A. C., Difference Equations: An Introduction with Applications, Academic Press, 2001 2. Goldberg S., Introduction to Difference equations, Wiley Publication, 1987 3. Lakshmikantham V., Trigiante D., Theory of difference equations, Academic Press. 1988 4. Miller K., Linear Difference equations, W. A. Benjam. 1968 5. Cull Paul, Flahive Mary, Robson Robby, Difference Equations: From Rabbits to Chaos, Springer, 2000.

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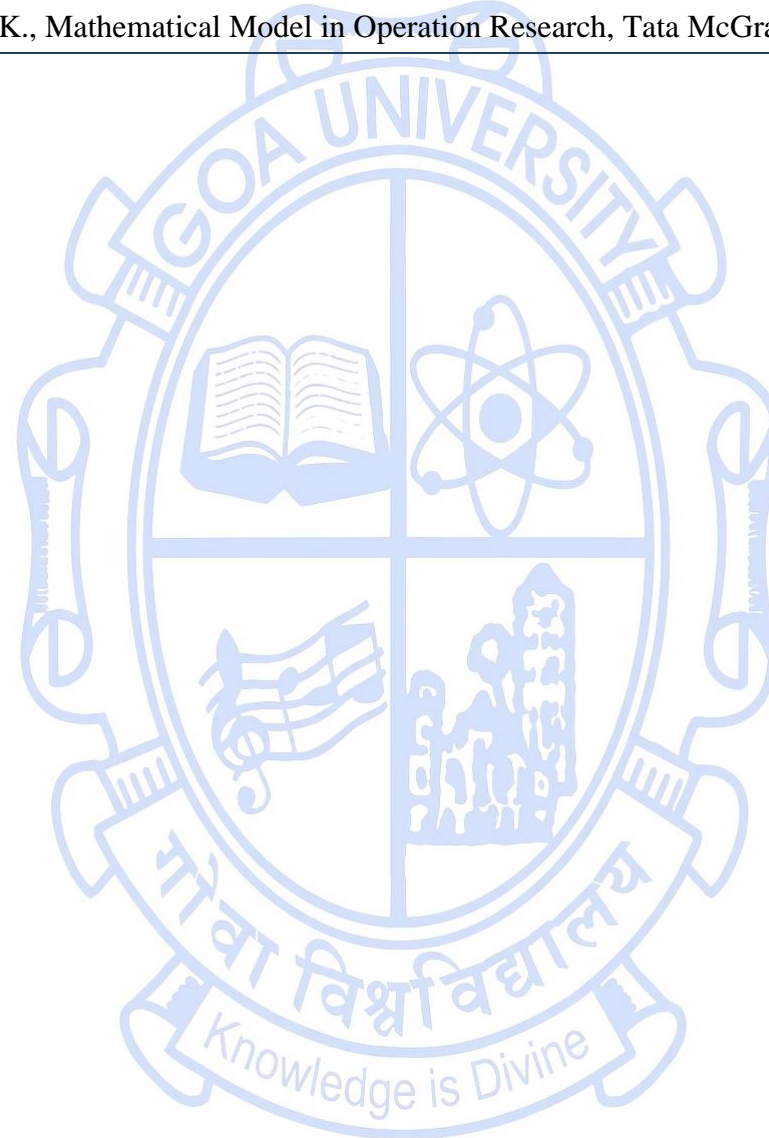
Title of the Course	Operations Research
Course Code	MAT-6206
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Operations Research, fostering a strong theoretical understanding of definitions and properties. • To develop the learner's ability to construct and understand rigorous mathematical proofs related to key Operations Research concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Operations Research methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Operations Research, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Operations Research and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Operations Research and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Operations Research		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Operations Research and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Linear programming: formulation and solution of linear programming problems by graphical, simplex methods, Big-M, degeneracy, duality in linear programming, sensitivity analysis	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Transportation problems: basic feasible solutions, optimum solutions by stepping stone and modified distribution methods, unbalanced and degenerate problems, transshipment problems. Assignment problems: solution by Hungarian method, unbalanced problem, case of maximization, travelling salesman and crew assignment problems	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Queuing theory: basic components of a queuing system, general birth-death equations, steady-state solution of Markovian queuing models with single and multiple servers (M/M/1, M/M/C, M/M/1/k, M/M/C/k)	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Game theory: two person zero sum game, game with saddle points, rule of dominance; algebraic, graphical and linear programming, concept of mixed strategy. sequencing problems: processing of n jobs through 2 machines, n jobs through 3 machines, 2 jobs through m machines, n jobs through m machines	15	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. Hillier Frederick S., Lieberman Gerald J., Introduction to Operations Research, Tata-McGraw Hill, 2010. 2. Taha, H. A. Operation Research: An Introduction.9th edition, Pearson, 2010			
References/ Readings:	1. Sharma, S. D. Operation Research, Kedarnath and Ramnath Publications, 2012 2. Swarup, K. and Gupta, P.K. Operations Research. S. Chand publisher, 2010			

- | | |
|--|---|
| | <ol style="list-style-type: none">3. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 20084. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989 |
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Title of the Course	Computational Algebra with Sagemath
Course Code	MAT-6207
Number of Credits	2
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

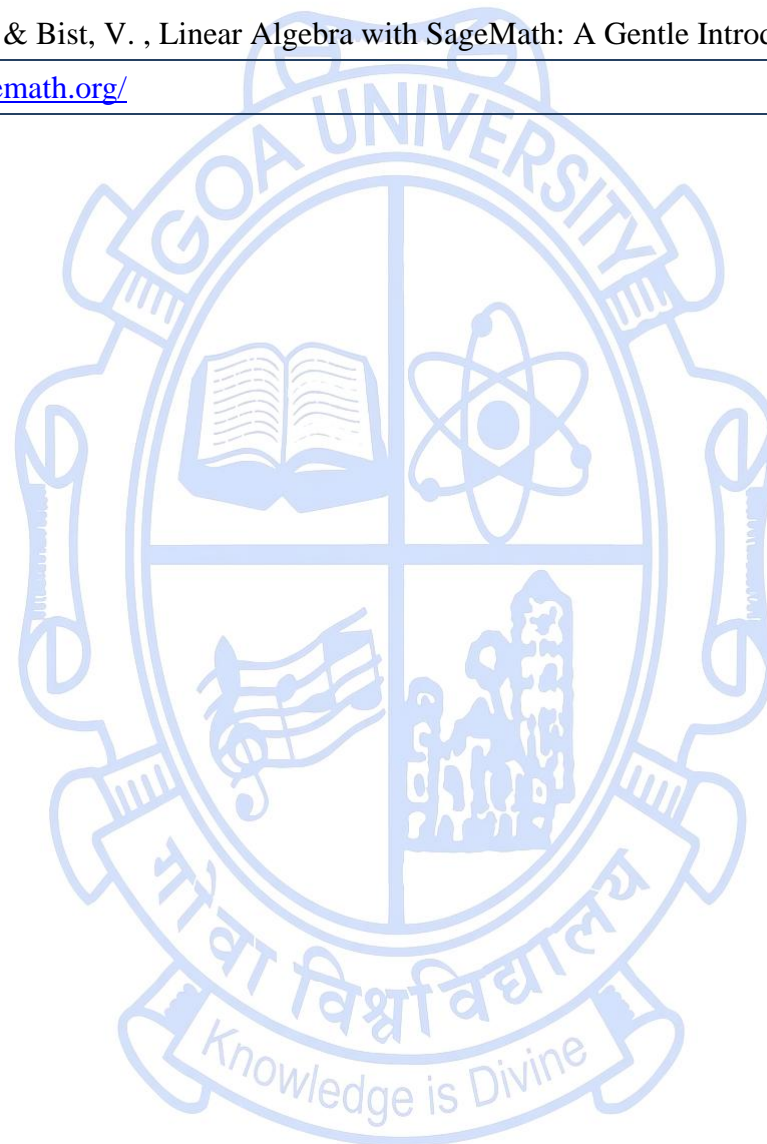
Pre-requisites for the Course:	Basic knowledge covered in papers MAT-5001 Advanced Linear Algebra MAT-5002 Ring Theory	
Course Objectives:	<ul style="list-style-type: none"> • To introduce learners to the key algebraic structures—polynomials, matrices, and finite fields—and their computational representation in SageMath. • To develop a conceptual and procedural understanding of symbolic and algebraic manipulation, emphasizing computational accuracy and efficiency. • To enable learners to apply SageMath to explore, model, and solve algebraic problems, reinforcing theoretical understanding through computation. • To cultivate the ability to analyze results, generalize computational patterns, and construct logical arguments based on symbolic and numerical outputs. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. explain and illustrate the structure of algebraic objects such as polynomials, matrices, and	PSO1, PSO6

	fields within SageMath.			
	CO 2. perform symbolic and algebraic computations using SageMath, including simplification, factorization, and manipulation of rational expressions.			PSO2, PSO6
	CO 3. model and solve algebraic problems involving polynomial equations, linear systems, and finite fields computationally.			PSO3, PSO6
	CO 4. evaluate, verify, and interpret computational results to draw algebraic conclusions and construct rigorous mathematical arguments.			PSO4, PSO5, PSO6
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>SageMath Basics & Symbolic Algebra</p> <p>Topics: Symbolic computation, variables, substitution, simplification, integer/rational arithmetic</p> <p>Practicals: Practical 1: Basic symbolic arithmetic and simplification Practical 2: Substitution and evaluation Practical 3: Simplifying nested expressions</p>	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	<p>Polynomials</p> <p>Topics: Polynomial rings, addition, multiplication, division, gcd/lcm, factorization, root finding</p> <p>Practicals: Practical 4: Construct polynomial rings Practical 5: Polynomial arithmetic and gcd/lcm Practical 6: Factorization and root-finding</p>	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>Rational Functions & Power Series</p> <p>Topics: Rational functions, partial fractions, truncated and lazy power series</p>	12	CO1, CO2, CO3,	K1, K2, K3, K4, K5, K6

	<p>Practicals: Practical 7: Rational function manipulations Practical 8: Partial fraction decomposition Practical 9: Power series expansions</p>		CO4	
Module 4:	<p>Linear Algebra Topics: Vectors, matrices, linear systems, determinants, rank, nullspace, eigenvalues/eigenvectors, diagonalization Practicals: Practical 10: Solve linear systems Practical 11: Matrix operations and determinants Practical 12: Nullspace and image computations Practical 13: Eigenvalues/eigenvectors and diagonalization</p>	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 5:	<p>Polynomial Systems & Finite Fields Topics: Multivariate polynomials, ideals, quotient rings, zero-dimensional systems, elimination, finite fields, modular arithmetic, Chinese Remainder Theorem Practicals: Practical 14: Solve multivariate polynomial systems Practical 15: Finite field computations and modular arithmetic</p>	08	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. Paul Zimmermann, Alexandre Casamayou, Nathann Cohen, Guillaume Connan, Thierry Dumont, Laurent Fousse, François Maltey, Matthias Meulien, Marc Mezzarobba, Clément Pernet, Nicolas M. Thiéry, and Paul S. Zimmermann, Computational Mathematics with SageMath, Springer, 2018.			
References/ Readings:	1. Gregory V. Bard, Sage for Undergraduates, American Mathematical Society, 2015. 2. Mezei, R. A. An introduction to SAGE programming: With applications to SAGE interacts for numerical methods,			

	Wiley, 2015.
	3. Kumar, A., & Bist, V. , Linear Algebra with SageMath: A Gentle Introduction (Open source), 2026.
Web Resources:	https://doc.sagemath.org/

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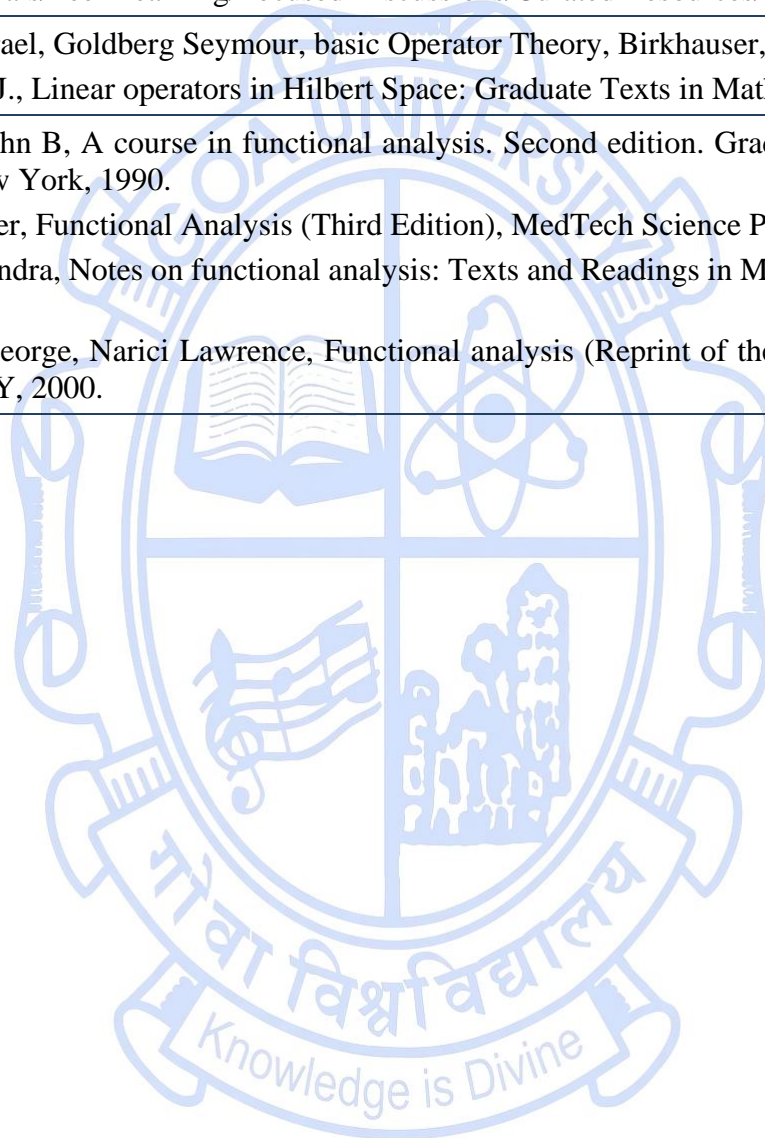
Title of the Course	Operator Theory
Course Code	MAT-6208
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in paper MAT-5007: Functional Analysis	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Operator Theory, fostering a strong theoretical understanding of definitions and properties. • To develop the learner's ability to construct and understand rigorous mathematical proofs related to key Operator Theory concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Operator Theory methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Operator Theory, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Operator Theory and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Operator Theory and associated concepts.	PSO2, PSO6

	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Operator Theory		PSO3, PSO6	
	CO 4. analyze and solve unseen problems in Operator Theory and create mathematically precise arguments to justify their solutions.		PSO4, PSO5, PSO6	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Bounded linear operator on Hilbert spaces: Properties of bounded linear operators, Examples of bounded linear operators with estimates of norms, Continuity of linear operators, matrix representations of bounded linear operators, Bounded linear functionals, Operators of finite rank, Invertible operators, Inversion of operators by iterative method, Infinite system of linear equations, Orthogonal projection, Compact operators, Invariant operators.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Spectral theory of compact self-adjoint operators: Examples of an infinite dimensional generalization, The problem of existence of eigen values and eigen vectors, Eigen values and eigen vectors of operators of finite rank, Theorem of existence of eigen values, Spectral theorem, Basic system of eigen values and eigen vectors, Second form of spectral theorem, Formula for the inverse operator, Minimum-Maximum properties of eigen values.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Spectral theory of integral operators: Hilber-Schmidt theorem, Preliminaries for Mercer's theorem, Mercer's theorem, Trace formula for integral operators, Integral operators as inverse of differential operators, Sturm-Liouville' systems. Operational calculus with applications: Functions of compact self-adjoint operator, Differential equations in Hilber space, Infinite systems of differential equations, Integro-differential equations..	18	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Solving linear equations by iterative method: The main theorem, Preliminaries for the proof, proof of main theorem, Applications to integral equations. Further development of Spectral theorem: Simultaneous diagonalization, Compact normal operators, Unity operators, Characterization of compact operators	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:	<ol style="list-style-type: none"> 1. Gohberg Israel, Goldberg Seymour, basic Operator Theory, Birkhauser, 1981 2. Weidmann J., Linear operators in Hilbert Space: Graduate Texts in Mathematics, Springer, 1980
References/ Readings:	<ol style="list-style-type: none"> 1. Conway, John B, A course in functional analysis. Second edition. Graduate Texts in Mathematics, 96. Springer-Verlag, New York, 1990. 2. Ridun Walter, Functional Analysis (Third Edition), MedTech Science Press, 2004 3. Bhatia Rajendra, Notes on functional analysis: Texts and Readings in Mathematics, Hindustan Book Agency, New Delhi, 2009 4. Bachman George, Narici Lawrence, Functional analysis (Reprint of the 1966 original), Dover Publications, Inc., Mineola, NY, 2000.

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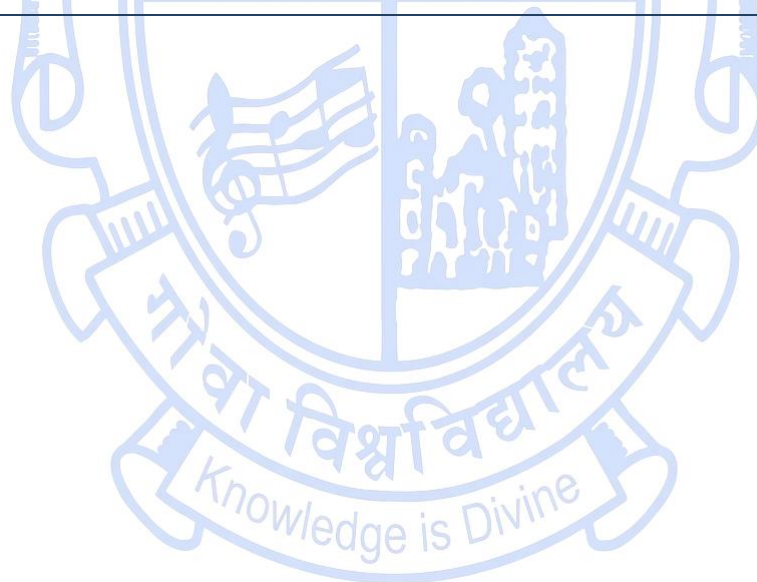
Title of the Course	Foundations of Computational Fluid Dynamics
Course Code	MAT-6209
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in papers MAT-5001: Advanced Linear Algebra, MAT-6402: Numerical Analysis, MAT-6406: Partial Differential Equations
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Foundations of Computational Fluid Dynamics, fostering a strong theoretical understanding of definitions and properties. • To develop the learner's ability to construct and understand rigorous mathematical proofs related to key Foundations of Computational Fluid Dynamics concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Foundations of Computational Fluid Dynamics methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Foundations of Computational Fluid Dynamics, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Foundations of Computational Fluid Dynamics and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Foundations of Computational Fluid Dynamics and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Foundations of Computational Fluid Dynamics	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Foundations of Computational Fluid Dynamics and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Introduction, Continuity, momentum, and energy equations, Conservation laws and physical interpretation, non-dimensionalization and dimensionless parameters, Classification of partial differential equations (elliptic, parabolic, hyperbolic), Boundary and initial conditions, Simplified model equations for fluid flow and its classification (Laplace, diffusion, wave, convection-diffusion equations)	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Concept of discretization: Grid generation and types (structured/unstructured, uniform/non-uniform), Finite difference approximations, Taylor table approach for constructing finite difference schemes of arbitrary orders of accuracy, implementation of schemes near boundaries, Truncation error, consistency, stability, mesh dependence and convergence of solution, Stability analysis, Introduction to finite volume method (FVM), Numerical errors: Round-off, discretization.	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Finite difference solution of linear systems: Discretization and solution of 1D and 2D Laplace equation, 1D and 2D diffusion equation, 1D convection-diffusion equation, Stability and accuracy of various schemes, Implementation aspects: Boundary conditions and convergence criteria	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Finite volume method for 2D steady diffusion and convection–diffusion problems:	15	CO1,	K1, K2,

	Discretization of Navier–Stokes equations, Finite volume method for one-dimensional steady state diffusion, two dimensional incompressible Navier Stokes equations, Pressure–velocity coupling, Overview of commercial CFD tools (ANSYS Fluent, OpenFOAM), Case studies: Flow in a pipe, lid-driven cavity, flow over a flat plate		CO2, CO3, CO4	K3, K4, K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	<ol style="list-style-type: none"> 1. Versteeg, H.K, Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd ed., Longman Publication, 2004. 2. Fletcher, C. A. J., Computational Techniques for Fluid Dynamics, Springer-Verlag, 1998. 			
References/ Readings:	<ol style="list-style-type: none"> 1. Patankar S. V., Numerical Heat Transfer and Fluid Flow, Atlantic Publishers & Distributors, 2019. 2. Tannehill J. C., Anderson D. A., Pletcher R. H., Computational Fluid Mechanics and Heat Transfer, Taylor & Francis, Second Edition, 2010. 3. Date A.W., Introduction to Computational Fluid Dynamics, Cambridge University Press 2005. 4. Sundararajan T., Muralidhar K., Computational Fluid Flow and Heat Transfer, Narosa Publishing House, Second Edition, 2009 			

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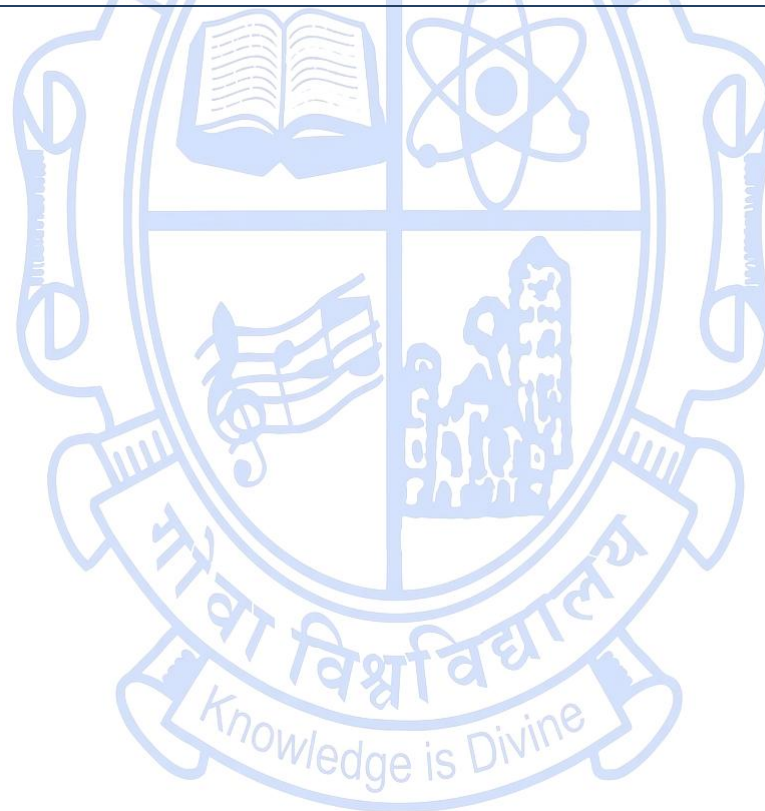
Title of the Course	Partial Differential Equations-II
Course Code	MAT-6210
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in papers MAT-5000: Real Analysis, MAT5005-: Differential Equations, MAT-6406:Partial Differential Equations
Course Objectives:	<ul style="list-style-type: none"> ● To introduce the foundational concepts of Partial Differential Equations, 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 Partial Differential Equations concepts and theorems. ● To equip learners with the skills necessary to identify and apply appropriate methods and techniques to solve structured problems. ● To encourage analytical thinking and creativity in solving unfamiliar problems in Partial Differential Equations, enabling learners to construct logically sound and precise mathematical arguments.

Course Outcomes:	After going through this course the students will be able to	Mapped to PSO		
	CO 1. display familiarity and knowledge of Partial Differential Equations and associated concepts.	PSO1, PSO6		
	CO 2. demonstrate proofs to establish truths related to Partial Differential Equations and associated concepts.	PSO2, PSO6		
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Partial Differential Equations	PSO3, PSO6		
	CO 4. analyze and solve unseen problems in Partial Differential Equations and create mathematically precise arguments to justify their solutions.	PSO4, PSO5, PSO6		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Introduction: Terminology, boundary and initial value problems, well- posed problems and ill-posed problems, First-order PDE, Complete solutions, characteristics, conservation laws.	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	Systems of PDE: introduction to weak solutions: shocks and jump conditions, entropy condition, examples: traffic flow, gas dynamics, etc.	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	Linear PDE: Review and classification, Laplace, wave and diffusion equations, Klein-Gordon equation, more on characteristics, standard methods: Separation of variables, Integral transforms, Green's functions. Regular and Singular perturbation theory, Asymptotic for complete solutions.	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	Nonlinear PDE: Equations that convert into linear PDE, some exactly solvable cases, Burgers' equation, dimensional analysis and similarity, traveling waves, nonlinear diffusion and dispersion, the KdV equation, nonlinear Schrödinger and Sine-Gordon equations, Reaction-Diffusion equations, Fisher's equation, singular perturbations: Boundary layers, Homogenization, Free-boundary value problems.	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. Whitham, G. B., Linear and nonlinear waves, Wiley, 1999..
References/ Readings:	<ol style="list-style-type: none"> 1. Salsa S., Partial differential equations in action, Springer, 2022. 2. Debnath L., Nonlinear partial differential equations for scientists and engineers. Springer, 2012. 3. Guenther, R. B., and Lee, J. W., Partial Differential Equations of Mathematical Physics and Integral Equations, Dover, 1996. 4. Levine, H., Partial differential equations. Am. Math. Soc.: International Press, 1997. 5. Kevorkian, J. Partial differential equations: analytical solution techniques. Springer, 2000.

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Title of the Course	Functional Analysis-II
Course Code	MAT-6211
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Basic knowledge of topics covered in paper MAT-5007: Functional Analysis	
Course Objectives:	<ul style="list-style-type: none"> • To introduce the foundational concepts of Functional Analysis-II, 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 Functional Analysis-II concepts and theorems. • To equip learners with the skills necessary to identify and apply appropriate Functional Analysis-II methods and techniques to solve structured problems. • To encourage analytical thinking and creativity in solving unfamiliar problems in Functional Analysis-II, enabling learners to construct logically sound and precise mathematical arguments. 	
Course Outcomes:	After going through this course the students will be able to	Mapped to PSO
	CO 1. display familiarity and knowledge of Functional Analysis-II and associated concepts.	PSO1, PSO6
	CO 2. demonstrate proofs to establish truths related to Functional Analysis-II and associated	PSO2, PSO6

	concepts.			
	CO 3. choose the appropriate procedures, modify them if needed and apply them to solve method-based problems in Functional Analysis-II			PSO3, PSO6
	CO 4. analyze and solve unseen problems in Functional Analysis-II and create mathematically precise arguments to justify their solutions.			PSO4, PSO5, PSO6
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Weak and Weak* Topologies</p> <p>Definitions and properties of weak topology and, weak convergence, Comparison of strong and weak convergences,</p> <p>Definitions and properties of weak* topology and weak*-convergence, comparison of weak and weak* convergences, The Banach- Alaoglu Theorem, Convergence of sequence of Operators -Uniform operator convergence, strong operator convergence, weak operator convergence-basic properties and the comparison of these convergences.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 2:	<p>Basics of Spectral Theory of linear operators in normed spaces</p> <p>Spectral theory in finite dimensional normed spaces, matrix operators and their spectrum, Spectral theory -Basic concepts- Regular value, resolvent set, spectrum and classification of spectrum.</p> <p>Spectral properties of bounded linear operators-spectrum closed, non-empty, spectral radius, resolvent equation, commutativity, spectral mapping theorem for polynomials, linear independence of eigen vectors, Use of complex analysis in spectral theory</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>Compact linear operators on normed spaces</p> <p>Compact operators- definition and basic properties such as continuity, compactness criterion, operators with finite dimensional domain or range, sequence of compact operators, compact operators and weak convergence, separability of the range, adjoint of compact operators, compactness of a product of two compact operators.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	<p>Spectral properties of compact operators</p> <p>Eigen values countable, characteristic properties of the eigen spaces leading to the direct</p>	15	CO1, CO2,	K1, K2, K3, K4,

	sum representations of the normed space as a sum of two closed subspaces in terms of a compact operator. Fredolhm type theorems, Fredolhm alternative, Compact Self-adjoint operators on Hilbert spaces and their spectrum		CO3, CO4	K5, K6
Pedagogy:	Lectures/ Tutorials/Peer Learning/Focused Discussions/Curated Resources/Online Resources/Assignments/Self-study.			
Texts:	1. Introductory Functional Analysis with Applications, Ervin Kreyszig, John Wiley & Sons, 1978.			
References/ Readings:	2. Functional Analysis (Second Edition), S.Kesavan, Hindustan Book Agency, 2022 3. Functional Analysis, George Bachman and Lawrence Narici, Dover Publications,2000. 4. Functional Analysis, S.Kumaresan and D.Sukumar, Narosa Publishing House, 2020 5. Basic Operator Theory, Israyel Gohberg and Seymour Goldberg, Birkh user,1981			

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