Sister Nivedita University

Department of Mathematics

Syllabus for Mathematics Undergraduate Programme

Framed according to the

National Education Policy (NEP 2020)

Bachelor of Science Mathematics with Computing

Bachelor of Science Mathematics with Computing

VISION:

We, the Department of Mathematics envision our students as excellent Mathematicians who will be able to create high impact on the society through their scientific creativity; entrepreneurship and research as well as they can encourage the future generations to follow their path.

MISSION:

- To achieve the vision, we have diligent faculties who use effective teaching methodologies to impart updated technical education and knowledge.
- To groom our young students to become professionally and morally sound mathematicians to be a potential researcher or industry ready.
- To reach global standards in production and value-based living through an honest and scientific approach.

Programme Educational Objectives (PEOs):

The Programme Educational Objectives of the B.Sc. Mathematics with Computing curriculum is to prepare graduates to:

PEO 1: Develop a solid foundation in pure and applied mathematics along with computational skills, enabling them to analyze, model, and solve complex real-world problems effectively.

PEO 2: Pursue higher education, research, or professional careers in academia, data science, software development, finance, and other computation-driven sectors.

PEO 3: Demonstrate ethical values, teamwork, communication skills, and a commitment to continuous learning, contributing responsibly to society and the scientific community.

Program Specific Outcomes (PSOs):

Upon successful completion of the B.Sc. Mathematics with Computing program, graduates will be able to:

PSO 1: Apply advanced mathematical concepts such as analysis, algebra, differential equations, optimization, and simulation to develop models and solutions for scientific, engineering, and industrial problems.

PSO 2: Use programming languages (Python, data structures, scientific computing tools) and modern computational techniques to analyze data, perform numerical computations, and develop algorithmic solutions.

PSO 3: Demonstrate domain-specific expertise in areas such as statistical inference, computational finance, continuum mechanics, differential geometry, and big-data challenges through projects, electives, and internships.

Programme Outcomes (POs):

Upon successful completion of the B.Sc. Mathematics with Computing program, graduates will be able to:

PO1: Acquire comprehensive knowledge of mathematical theory, computing principles, and interdisciplinary applications.

PO2: Identify, analyse, and interpret complex mathematical and computational problems using logical reasoning and quantitative techniques.

PO3: Design mathematical models, algorithms, and computational frameworks that meet industry, research, and societal needs.

PO4: Apply appropriate computing tools, programming languages, numerical software, and data analysis platforms in mathematical problem-solving.

PO5: Conduct investigations using mathematical reasoning, data interpretation, simulations, and experimentation, leading to valid conclusions.

PO6: Communicate mathematical ideas, research findings, and computational outputs clearly and effectively in written, graphical, and oral forms.

PO7: Apply ethical principles, demonstrate social responsibility, and understand the environmental and societal impact of mathematical and computational solutions.

PO8: Recognize the need for, and develop the ability to engage in, independent and life-long learning in emerging areas of mathematics, computing, and technology.

Category definition with credit breakup

Semester	Credits										Credits/ semester
	MC/ME	ME		Non-Major		MDC	AEC	SEC	VAC	INT	
		Course	Project	NM	NV						
I	4+4			5	1+1		2	3	2		22
II	4+4				1+1	3	2	3	2		20

III	4+4			4	1+1	3	2				19
IV	4+4+3			4	1+1	3	2				22
V	4+4+4				1+1			3	2		19
VI	4+4+4			4	1+1					3	21
VII	4+4+4+4			4							20
VIII		8/20	12/0								20
Credits/ Course	98			33		9	8	9	6	3	
Total Credit											163

Category Definition:

Definition of Category/Type	**Abbreviation**
Major Compulsory	**MC**
Major Elective	**ME**
Non-Major Specific Subject Course	**NM**
Non-major Vocational Education and Training	**NV**
Multidisciplinary Courses	**MDC**
Ability Enhancement Courses	**AEC**
Skill Enhancement Courses	**SEC**
Value Added Courses	**VAC**
Internship	**INT**
Project	**Project**

Course structure for B.Sc. in Mathematics with computing

Category	Course name	Credit	Teaching Scheme		
			L	T	P
Semester I					
MC1	Mathematics I	4	4		
MC2	Introduction to Computing	5	4		2

NM1	Probability theory and random process	4	4		
NV1	Vocational – EAA I (Yoga/ Sports/ NCC/ NSS)	1			2
NV2	Vocational – Soft Skill Development I	1	1		
AEC 1	Communicative English I	2	2		
SEC 1	Computer Application	3	3		
VAC 1	Environmental Science I	2	2		
Total Credit = 22			Teaching Hour = 24		
Semester II					
MC3	Mathematics II	4	4		
MC4	Discrete Mathematics	4	4		
NV3	Vocational – Mentored Seminar I	1	1		
NV4	Vocational – Soft Skill Development II	1	1		
MDC 1	Selected by the candidate (Elective)	3	3		
AEC 2	Communicative English II	2	2		
SEC 2	Basic Management Skill	3	3		
VAC 2	Environmental Science II	2	2		
Total Credit = 20			Teaching Hour = 20		
Semester III					
MC5	Real Analysis	4	4		
MC6	Elementary Number theory and algebra	4	4		
NM2	Selected by the candidate	4	4		
NV5	Vocational – Mentored Seminar II	1	1		
NV6	Vocational – Soft Skill Development III	1	1		
MDC 2	Selected by the candidate (Elective)	3	3		
AEC3	Logical Ability I / Foreign Language I	2	2		
Total Credit = 19			Teaching Hour = 19		
Semester IV					
MC7	Mathematics III	3	3		
MC8	Data Structure	4	4		
MC9	Python Programming	3	3		
NM3	Selected by the candidate	4	4		
NV7	Vocational - Mentored Seminar III	1	1		
NV8	Vocational – Soft Skill Development IV	1	1		

MDC3	Selected by the candidate (Elective)	3	3		
AEC4	Logical Ability II / Foreign Language II	2	2		
Total Credit = 22			Teaching Hour = 23		
Semester V					
MC10	Optimization	4	4		
MC11	Scientific computing	4	4		
MC12	Mathematical Simulation	4	4		
NV9	Vocational- Mentored Seminar IV	1	1		
NV10	Vocational – Student's activity course I	1	1		
SEC3	Data Analysis	3	3		
VAC3	Ethics Study and IPR	2	2		
Total Credit = 19			Teaching Hour = 19		
Semester VI					
MC13	Statistical Inference and multivariate analysis	4	4		
MC14	Matrix computations	4	4		
MC15	Computational Finance	4	4		
NM4	Selected by the candidate	4	4		
NV11	Vocational	1	1		
NV12	Vocational – Student's activity course II	1	1		
INT1	Internship	3			6
Total Credit = 21			Teaching Hour = 24		
Semester VII					
MC16	Continuum Mechanics	4	4		
MC17	Classical electromagnetism and theory of relativity	4	3		2
MC18	Differential geometry and Mathematical Biology	4	4		
MC19	Nonlinear programming and Fuzzy set theory	4	4		
NM5	Selected by the candidate	4	4		
Total Credit = 20			Teaching Hour = 21		
Semester VIII					
MC20	Integral transforms and special functions	4	4		
MC21	PDE and Integral equations	4	4		

ME- Project/ Courses	Project/ Research Design and Communication (Mandatory), [Supervised learning and challenges for Big data Analytics, Advanced Computational Methods, Automata Theory, Fuzzy Mathematics]	12/ (4+4+4)	0/12		24/0
Total Credit = 24			Teaching Hour = 36		

SEMESTER I

Course MC1: Mathematics I
Credit 4: (4L-0T-0P)

Learning objectives: After completion of this course, students will be able to understand the foundational concepts of mathematics and computing, explore their interconnections, and apply basic algorithmic thinking, logic, and mathematical tools in computational problem-solving.

Prerequisite: Before learning the course, students must have basic knowledge of high school-level mathematics and familiarity with general computer usage.

SYLLABUS OUTLINE:

Module 1: Sequences, Series & Functions (Single Variable Calculus Basics): [8L]
Convergence of sequences of real numbers, Convergence of series of real numbers, Tests for convergence (briefly), Continuity of functions (epsilon-delta definition, properties)

Module 2: Differentiation & Applications (Single Variable): [8L]
Differentiability of functions, Rolle's theorem, Mean Value Theorem, Taylor's Theorem and expansions, Power series: radius of convergence, term-by-term differentiation, and integration

Module 3: Riemann Integration & Applications (Single Variable): [8L]
Riemann integrals: definition, properties, Fundamental Theorem of Calculus, Improper integrals, Applications: arc length, area, volume, surface area of revolution

Module 4: Functions of Several Variables: [8L]
Vector functions of one variable: limits, continuity, differentiability, Scalar-valued functions of several variables, Partial derivatives, directional derivatives, gradient, Differentiability and chain rule, Tangent planes and normal.

Module 5: Optimization & Multiple Integration: [8L]
Maxima and minima, second derivative test, Lagrange multiplier method, Double and triple integrals, Applications: volume, surface area, Change of variables in multiple integrals (Jacobian)

Module 6: Vector Calculus [8L]:
Vector fields, Line integrals and surface integrals, Green's Theorem, Gauss' Divergence Theorem, Stokes' Theorem, Applications of these theorems

Texts:
1. G. B. Thomas, Jr. and R. L. Finney, Calculus and Analytic Geometry, 9th Edition, Pearson Education India, 1996.

References:
1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd edition, Wiley India, 2005.
2. S. R. Ghorpade and B. V. Limaye, An Introduction to Calculus and Real Analysis, Springer India, 2006.
3. T. M. Apostol, Calculus, Volume-II, 2nd edition, Wiley India, 2003.
4. J. E. Marsden, A. J. Tromba, and A. Weinstein, Basic Multivariable Calculus, Springer India, 2002.

Course Outcomes (COs):

After completing this course, the students will be able to:

CO1: Explain fundamentals of sequence and series.

CO2: Apply differentiation and Riemann integration on practical scenarios.

CO3: Analyze functions of several variables.

CO4: Determine the behaviour of vectors in vector calculus.

CO5: Create solutions to multiple integration and extrema problems.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO 1**	**PSO2**	**PSO3**
CO1	3	2	1	1	2	2	-	1	3	1	-
CO2	3	3	2	2	3	2	-	2	3	2	1
CO3	3	3	3	2	3	2	1	2	3	2	1
CO4	2	3	3	2	3	2	1	2	2	3	2
CO5	3	3	3	2	3	2	-	2	3	2	-

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC2: Introduction to Computing
Credit 5: (4L-0T-2P)

Learning objectives: *On completion of the course, students will be able to design and program C applications by understanding the various components of the C program.*

Prerequisite: *Before learning the course, students must have the basic understanding of computational aspects as well as the knowledge of simple mathematical concepts.*

SYLLABUS OUTLINE:

Module-I: Introduction to Computer Fundamentals: [4L]
Computer architecture and components, Operating systems and software, Data representation and storage.

Module-II: Digital Logic and Boolean Algebra: [6L]
Boolean logic and Boolean operators, Truth tables and logic gates, Boolean algebra and simplification techniques.

Module-III: Introduction to C Programming: [4L]
Basics of programming and algorithm development, Data types, variables, and constants, Input/output operations

Module-IV: Control Flow in C Programming: [6L]
Decision-making structures (if-else, switch), Looping structures (for, while, do-while), Flow control statements (break, continue).

Module-V: Functions in C Programming: [6L]
Function definition and declaration, passing arguments to functions, Return values and function prototypes.

Module-VI: Structures in C Programming: [10L]
Structure declaration and initialization, Accessing structure members, Array of structures and nested structures.

C-Programming Lab:

Text & Reference books:

Text Books:

1. Programming with C, Gottfried, TMH
2. Practical C Programming, Outline, SPD/O'REILLY
3. Let us C- Yashwant Kanetkar.

Reference Books:

1. Programming in C- Ashok N Kamthane
2. The C Programming Lang., Pearson Ecl. – Dennis Ritchie.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Explain fundamentals of computer programming.

CO2: Relate digital logic and C programming in practical events.

CO3: Identify decision making codes in C programming.

CO4: Determine functions in C programming.

CO5: Develop programs and structures in C programming.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	2	2	1	2	1	2	2	2	2	2	-
CO2	3	3	2	3	2	2	2	2	2	3	1
CO3	2	3	2	3	2	2	1	2	2	3	1
CO4	2	3	2	3	2	2	1	2	2	3	1
CO5	3	3	3	3	2	3	1	2	2	3	1

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course NM1: Probability theory and random process

Credit 4: (4L-0T-0P)

Learning objectives: After completion of this course, students will be able to develop a solid understanding of probability theory and random variables, including their distributions, expectations, and transformations, analyse multivariate distributions, convergence of random variables, and fundamental limit theorems, model, and study random processes, particularly Markov chains and Poisson processes, in both discrete and continuous time.

Prerequisite: Basic calculus and linear algebra, familiarity with set theory and functions and basic concepts of mathematical logic and proofs. Exposure to introductory probability.

Module 1: Probability Spaces and Foundations [7 L]

Probability spaces; algebra of events; independence; conditional probability; Bayes' and total-probability formulae; illustrative counting arguments for finite spaces.

Module 2: Random Variables and Standard Distributions [9L]

Definition of random variables; distribution and cumulative-distribution functions; probability mass and density functions; transformations and functions of a single random variable; study of standard univariate discrete distributions (Bernoulli, Binomial, Geometric, Poisson) and continuous distributions (Uniform, Exponential, Gamma, Normal, Beta) with properties.

Module 3: Mathematical Expectation and Moment Techniques [6L]
Expectation of discrete and continuous variables; variance and higher moments; covariance and correlation; moment-generating and characteristic functions; applications to calculation of moments and identification of distributions.

Module 4: Random Vectors and Multivariate Distributions [8L]

Joint, marginal, and conditional distributions for discrete and continuous cases; independence of random variables; transformation of vectors; multivariate normal distribution; conditional expectation and its properties.

Module 5: Convergence Concepts and Limit Theorems [8L]
Modes of convergence (almost sure, in probability, in L^2, in distribution); Borel-Cantelli lemmas; weak and strong laws of large numbers; central limit theorem with applications and error estimates.

Module 6: Random Processes and Markov Chains [10L]
Definition and classification of stochastic processes; discrete-time Markov chains, Chapman–Kolmogorov equations, state classification, limiting and stationary distributions; Poisson process and its properties; continuous-time Markov chains, birth-and-death processes, generator matrices, long-run behaviour.

Texts:

1. P. G. Hoel, S. C. Port and C. J. Stone, Introduction to Probability Theory, Universal Book Stall, 2000.
2. G. R. Grimmett and D. R. Stirzaker, Probability and Random Processes, 3rd Ed., Oxford University Press, 2001.

References:

1. S. M. Ross, Introduction to Probability Models, 11th Ed., Academic Press, 2014.
2. J. Medhi, Stochastic Processes, 3rd Ed., New Age International, 2009.
3. W. Feller, An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Ed., Wiley, 1968.
4. K. S. Trivedi, Probability and Statistics with Reliability, Queuing, and Computer Science Applications, 2nd Ed., Wiley, 2001.
5. C. M. Grinstead and J. L. Snell, Introduction to Probability, 2nd Ed., Universities Press India, 2009.

Course Outcomes (COs):
After attending this course, the students will be able to

CO1: Characterize different events of probability.

CO2: Calculate standard deviation and expectations.

CO3: Correlate multivariate distributions and random vectors.

CO4: Evaluate the mode of convergence in distributions.

CO5: Construct Markov chains and random processes over practical data.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	1	1	2	2	1	2	3	1	-
CO2	3	3	2	2	3	2	-	2	3	2	-
CO3	3	3	3	2	3	2	-	2	3	2	2
CO4	3	3	2	2	3	2	1	2	3	2	2
CO5	3	3	3	2	3	2	1	2	3	3	3

1. LOW 2. MODERATE 3. SUBSTANTIA

SEMESTER II

Course MC3: Mathematics II
Credit 4: (4L-0T-0P)

Learning objectives: *After completion of this course, students will be able to learn linear-algebraic tools—matrix operations, vector spaces, linear transformations and spectral analysis for efficient modelling and solution of linear systems, to formulate, solve and interpret ordinary differential equations of various types, employing analytic, series and qualitative phase-plane techniques while understanding existence, uniqueness and stability, to integrate these linear-algebra and differential-equation methods for rigorous analysis of problems in science and engineering.*

Prerequisite:
Foundation in high school algebra and calculus, including functions, differentiation, and integration. Basic familiarity with matrix operations, coordinate geometry, and solving simple linear equations is also required.

Module 1: Matrices and Linear Systems [9L]

Systems of linear equations, augmented matrices, Gaussian elimination, echelon forms, column space, null space, rank, invertibility, determinants.

Module 2: Vector Spaces and Linear Transformations [9L]

Real and complex vector spaces, subspaces, spanning sets, linear independence, basis and dimension, linear transformations, kernel and image, rank–nullity theorem, matrix representation, change of basis, similarity.

Module 3: Spectral Theory and Inner-Product Spaces [8L]

Eigenvalues and eigenvectors, algebraic and geometric multiplicity, diagonalisation, inner-product spaces, Gram–Schmidt process, orthonormal bases, orthogonal, Hermitian, and symmetric matrices, spectral theorem for real symmetric matrices.

Module 4: First-Order Ordinary Differential Equations [8L]

Linear and nonlinear first-order equations, exact equations, integrating factors, Bernoulli equations, existence and uniqueness theorems, modelling applications.

Module 5: Higher-Order Linear Differential Equations [7L]

Homogeneous and non-homogeneous linear equations, operator methods, annihilators, method of undetermined coefficients, variation of parameters, reduction of order.

Module 6 : Series Solutions and Dynamical Systems [7L]

Series solutions about ordinary points, Legendre equation and Legendre polynomials, Bessel equation, and Bessel functions of first and second kinds, systems of first-order equations, phase-plane analysis, critical points, and stability.

Texts:

1. D. Poole, Linear Algebra: A Modern Introduction, 2nd Edition, Brooks/Cole, 2005.
2. S. L. Ross, Di_erential Equations, 3rd Edition, Wiley India, 1984.

References:

1. G. Strang, Linear Algebra and Its Applications, 4th Edition, Brooks/Cole India, 2006.
2. K. Ho_man and R. Kunze, Linear Algebra, 2nd Edition, Prentice Hall India, 2004.
3. E. A. Coddington, An Introduction to Ordinary Di_erential Equations, Prentice Hall India, 1995.
4.E. L. Ince, Ordinary Di_erential Equations, Dover Publications, 1958.

Course Outcomes (COs):

After attending this course, the students will be able to

CO1: Describe the basics of matrices and vector spaces.

CO2: Illustrate techniques in spectral theory over inner product spaces.

CO3: Analyze first order ordinary differential equations.

CO4: Determine solutions to higher order linear differential equations.

CO5: Formulate series solutions for dynamical systems.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	1	1	2	2	1	2	3	1	1
CO2	3	3	2	2	3	2	1	2	3	2	-
CO3	2	3	2	2	3	1	1	2	3	2	1
CO4	3	2	3	2	3	1	1	1	3	2	1
CO5	3	3	3	3	3	2	1	1	3	3	1

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC4: Discrete Mathematics
Credit 4: (4L-0T-0P)

Learning objectives:

After attending this course the students will be able to acquire a rigorous understanding of discrete mathematical structures such as sets, relations, logic and proofs, forming the basis for advanced study in computer science and mathematics, develop fluency in counting techniques, recurrences, generating functions, lattices and Boolean algebras for analysing combinatorial and algebraic problems, analyse and model complex networks with graph theory, applying classical algorithms on trees and graphs to design and validate solutions in scientific and engineering contexts.

Prerequisite:

Comfort with high-school algebra, basic proof techniques, and elementary algorithmic reasoning. Introductory calculus is helpful but not essential; curiosity about logical argumentation and discrete problem solving is expected.

Module 1: Sets, Relations, and Functions [6 L]:

Sets, operations, Cartesian products, relations and their properties, functions and inverses, equivalence relations, and partial orders.

Module 2: Countability, Lattices and Boolean Algebras [6L]:

Countable and uncountable sets, pigeonhole principle, lattices, Hasse diagrams, complemented and distributive lattices, Boolean algebras, and laws.

Module 3: Propositional and Predicate Logic [8 L]:

Well-formed formulae, truth tables, logical equivalence, normal forms, rules of inference, soundness and completeness ideas, predicate logic with quantifiers, proof strategies.

Module 4: Enumerative Combinatorics [8L]

Permutations, combinations, inclusion–exclusion, recurrence relations, generating functions, partitions, Fibonacci, Stirling, and Catalan numbers with applications.

Module 5: Graph Theory Foundations [10L]

Graphs and digraphs, special graphs, isomorphism, connectedness, Euler and Hamilton paths and cycles, planar graphs, Euler's formula, graph colouring and chromatic number.

Module 6: Trees and Algorithmic Graph Theory [10 L]

Trees and rooted trees, spanning trees, minimal spanning tree algorithms (Kruskal, Prim), matchings, Hall's theorem outline, Dijkstra shortest-path algorithm, introductory network applications.

Texts:

1. J. P. Tremblay and R. Manohar, Discrete Mathematics with Applications to Computer Science, Tata McGraw-Hill, 1997.
2. K. H. Rosen, Discrete Mathematics & its applications, 6th Ed., Tata McGraw-Hill, 2007.

References:

1. A. Shen and N. K. Vereshchagin, Basic Set Theory, American Mathematical Society, 2002.
2. A. Kumar, S. Kumaresan and B. K. Sarma, A Foundation Course in Mathematics, Narosa, 2018.
3. M. Huth and M. Ryan, Logic in Computer Science, Cambridge University Press, 2004.
4. V. K. Balakrishnan, Theory and Problems of Combinatorics, Schaum's Series, McGraw-Hill, 1995.
5. R. L. Graham, D. E. Knuth and O. Patashnik, Concrete Mathematics, 2nd Ed., Addison-Wesley, 1994.
6. A. Tucker, Applied Combinatorics, 6th Ed., Wiley, 2012.

Course Outcomes (CO):
After attending this course, the students will be able to

CO1: Define set theoretic relations and functions.

CO2: Express statements through Boolean algebra to solve logical problems.

CO3: Identify combinatorial problems to solve them.

CO4: Estimate optimal solutions in graph theoretic problems.

CO5: Reconstruct graphs with specific properties.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO 1**	**PSO2**	**PSO3**
CO1	3	2	1	1	2	2	1	2	3	1	1
CO2	2	3	2	2	2	2	-	1	2	2	1
CO3	3	3	2	1	3	2	1	2	3	2	2
CO4	2	3	3	3	3	2	1	2	2	3	2
CO5	2	2	3	2	2	1	-	1	2	3	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

SEMESTER III

Course MC5: Real Analysis
Credit 4: (4L-0T-0P)

Learning objectives: After attending this course the students will be able to build a rigorous understanding of metric and normed spaces to accurately describe convergence, completeness, and compactness in abstract settings, extend single-variable calculus to several variables, mastering higher-dimensional differentiation, Taylor expansions, and the inverse- and implicit-function theorems for local analysis. develop fluency with Lebesgue measure and integration, including the main convergence theorems and Lp spaces, to prepare for advanced analysis and probability.

Prerequisite: A solid course in single-variable real analysis (limits, continuity, sequences and series, Riemann integration) and familiarity with basic linear algebra. Some exposure to multivariable calculus and proof-based mathematics will greatly ease the transition to abstract concepts.

Module 1 : Metrics, Norms and Convergence [8L]

Metric spaces, examples, normed vector spaces, induced metrics, equivalent norms, limits of sequences, continuity of maps between metric spaces.

Module 2: Completeness and Compactness [6L]

Cauchy sequences, complete metric spaces, Banach fixed-point theorem, totally bounded sets, Heine–Borel property, compactness in metric spaces, applications.

Module 3: Multivariable Differentiation and Taylor Theory [9L]

Differentiability of functions $\mathbb{R}^n \to \mathbb{R}^m$,directional derivatives and gradients, chain rule, higher derivatives, Hessians, multivariable Taylor's theorem with remainder.

Module 4 : Inverse and Implicit Function Theorems [7L]

Statement and proof outlines of inverse and implicit function theorems, Jacobian criterion, regular value theorem, applications to coordinate changes and manifolds.

Module 5 : Measure Spaces and Lebesgue Measure [9L]

σ-algebras and measurable sets, outer measure, construction of Lebesgue measure on $\mathbb{R}^n$, measurable functions, approximation by simple functions.

Module 6: Lebesgue Integration and LpL^p Spaces [9L]

Definition of the Lebesgue integral, monotone convergence, Fatou's lemma, dominated convergence, comparison with Riemann integral, L^pspaces, Hölder and Minkowski inequalities, completeness of L^p.

Texts:

1. J. E. Marsden and M. J. Hoffman, Elementary Classical Analysis, 2nd Ed., W. H. Freeman, 1993.
2. M. Capinski and E. Kopp, Measure, Integral and Probability, 2nd Ed., Springer, 2007.

References:

1. N. L. Carothers, Real Analysis, Cambridge University Press, 2000.
2. G. de Barra, Measure Theory and Integration, New Age International, 1981.
3. R. C. Buck, Advanced Calculus, Waveland Press Incorporated, 2003.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Define fundamental concepts of mathematical structures and their properties.

CO2: Apply principles of differentiation and approximation in multivariable contexts.

CO3: Analyze functional relationships and transformations to solve theoretical problems.

CO4: Evaluate measures, integrals, and function spaces for rigorous mathematical reasoning.

CO5: Construct solutions to complex problems using advanced integration and analytical techniques.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	2	-	2	1	-	2	3	1	1
CO2	2	3	3	2	3	1	1	2	3	2	2
CO3	2	3	3	2	3	2	1	2	3	2	2
CO4	3	3	3	2	3	2	2	1	3	2	2
CO5	3	3	3	2	3	2	2	1	3	2	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC6: Elementary Number theory and algebra
Credit 4: (4L-0T-0P)

Learning Objective:
To develop a rigorous understanding of foundational concepts in Number Theory and Algebra, equipping students to apply abstract reasoning, solve congruences, and analyze algebraic structures relevant in both pure mathematics and cryptographic systems.

Prerequisites:
Students should have a firm grasp of basic set theory, logic, and proof techniques, including familiarity with elementary algebra and number operations.

Course Content:

Module 1: Foundations of Number Theory [8L]

Covers the well-ordering principle, mathematical induction, division algorithm, greatest common divisor (GCD), least common multiple (LCM), Euclidean algorithm, and linear Diophantine equations. These topics form the bedrock of number-theoretic reasoning and problem-solving.

Module 2: Primes and Congruences [10L]

Prime numbers, the fundamental theorem of arithmetic, properties of congruences, linear congruences, the Chinese remainder theorem, and Fermat's little theorem.

Module 3: Arithmetic Functions and Cryptography [6L]

Arithmetic functions such as Euler's totient function and the Möbius function, the Möbius inversion formula, Euler's theorem, primitive roots, and cryptographic applications including the RSA cryptosystem and the distribution of primes.

Module 4: Group Theory [8L]

Introduces groups, subgroups, cyclic and permutation groups, Cayley's theorem, cosets, Lagrange's theorem, normal subgroups, quotient groups, and group homomorphisms and isomorphisms.

Module 5: Ring Theory [8L]

Rings, integral domains, ideals, quotient rings, prime and maximal ideals, and ring homomorphisms.

Module 6: Field Theory and Extensions [8L]

Field of quotients, polynomial rings, factorization in polynomial rings, fields, field characteristic, field extensions, splitting fields, and finite fields.

Texts:

1. D. M. Burton, Elementary Number Theory, 7th Ed., McGraw Hill, 2017.
2. J. A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa, 1998.

References:

1. I. Niven, S. Zuckerman and H. L. Montgomery, An Introduction to the Theory of Numbers, 5th Ed., Wiley-India, 1991.
2. G. A. Jones and J. M. Jones, Elementary Number Theory, Springer, 1998
3. K. H. Rosen, Elementary Number Theory and its Applications, Pearson, 2015
4. I. N. Herstein, Topics in Algebra, Wiley, 2004.
5. J. B. Fraleigh, A First Course in Abstract Algebra, Addison Wesley, 2002.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Define fundamental principles and techniques for solving discrete mathematical problems.
CO2: Apply number-theoretic methods and congruence relations to solve computational and theoretical challenges.
CO3: Analyze algebraic structures and arithmetic functions to explore their properties and applications.
CO4: Evaluate mathematical methods and algorithms for correctness and efficiency.
CO5: Formulate algebraic structures and their applications to solve mathematical problems.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	1	-	1	-	-	1	3	1	1
CO2	2	3	2	1	2	-	-	1	3	2	1
CO3	2	3	2	-	2	1	-	1	2	1	2
CO4	2	3	2	1	2	-	-	1	2	2	1
CO5	2	2	3	1	2	-	-	1	3	1	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

SEMESTER IV

Course MC7: Mathematics III
Credit 4: (4L-0T-0P)

Learning Objective:
After completion of this course, students will be able to develop a deep understanding of complex functions and techniques for solving partial differential equations, including applications of Fourier and Laplace transforms in solving physical and engineering problems.

Prerequisites:
Students should have a solid foundation in calculus, differential equations, and basic real analysis including continuity, differentiability, and integration.

Course Content:

Module 1: Fundamentals of Complex Analysis [8 L]

Complex numbers, elementary properties, limits, continuity, differentiation, Cauchy-Riemann equations, analytic and harmonic functions, and basic elementary analytic functions, including anti-derivatives and line integrals.

Module 2: Integral Theorems and Analytic Properties [10L]

Cauchy-Goursat theorem, Cauchy's integral formula, Morera's theorem, Liouville's theorem, fundamental theorem of algebra, maximum modulus principle, power series, Taylor series, and zeros of analytic functions.

Module 3: Advanced Complex Function Theory [8L]

Singularities, Laurent series, Rouche's theorem, the argument principle, residues, Cauchy's residue theorem and its applications, and Möbius transformations with their geometric and analytical uses.

Module 4: Fourier Series and Transforms [8L]

Fourier series, half-range expansions, finite sine and cosine transform, Fourier transforms, and their use in solving PDEs, providing tools essential for signal processing and heat conduction problems.

Module 5: First and Second Order PDEs [8L]

First order PDEs, linear and quasilinear equations, method of characteristics, classification of second-order PDEs, and reduction to canonical forms for analysis and simplification.

Module 6: Boundary Value Problems and Laplace Methods [6L]

Wave, heat, and Laplace equations, separation of variables in rectangular and non-rectangular domains, Laplace transforms and inverse transforms, properties, convolutions, and solving ODEs and PDEs using Laplace and Fourier techniques.

Texts:

1. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 7th Edition, McGraw Hill, 2004.
2. I. N. Sneddon, Elements of Partial Di_erential Equations, McGraw Hill, 1957.
3. E. Kreyszig, Advanced Engineering Mathematics, 10th Edition, Wiley, 2015.

References:

1. J. H. Mathews and R. W. Howell, Complex Analysis for Mathematics and Engineering, 3rd Edition, Narosa,1998.
2. S. J. Farlow, Partial Di_erential Equations for Scientists and Engineers, Dover Publications, 1993.
3. K. Sankara Rao, Introduction to Partial Di_erential Equations, 3rd Edition, Prentice Hall of India, 2011.

COURSE OUTCOMES (COs):

After attending this course, the students will be able to:

CO1: Define foundational principles and techniques for analyzing complex systems and functions.
CO2: Apply integral methods and series expansions to investigate properties and solve structured problems.
CO3: Analyze advanced functional behaviors and transformations to interpret theoretical and applied scenarios.
CO4: Evaluate methods for representing and processing signals or spatial-temporal data in mathematical models.
CO5: Formulate strategies to model and solve differential and boundary-driven problems.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PSO1	PSO 2	PSO 3
CO1	3	3	2	1	2	1	1	2	3	2	2
CO2	2	3	3	2	3	1	1	2	3	3	2
CO3	2	3	3	2	2	1	1	2	3	2	3
CO4	2	3	2	3	2	2	1	2	2	3	2
CO5	2	3	3	2	3	1	1	3	3	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC8: Data Structure
Credit 4: (4L-0T-0P)

Learning Objective:

After completion of this course, students will be able to develop a foundational understanding of data structures and algorithms, including their time-space tradeoffs, design strategies, and practical applications in computing. Students will learn to analyze performance, choose appropriate data structures, and implement efficient algorithms.

Prerequisites:

Basic programming knowledge in any language (preferably C/C++ or Java) and fundamental mathematical skills including discrete mathematics and logic.

Module 1: Algorithm Analysis and Complexity [6L]

Asymptotic notation (Big-O, Big-Ω, Big-Θ), best-case, worst-case, and average-case analysis, space and time complexity concepts. Mathematical framework for analyzing the efficiency of algorithms and standard notations used to express algorithmic growth.

Module 2: Abstract Data Types and Linear Data Structures [10L]

Abstract Data Types (ADT), arrays, stacks, queues, circular queues, linked lists (singly, doubly, circular), and matrix representations. Design and implementation fundamental linear data structures and memory usage and operation efficiency.

Module 3: Trees and Hierarchical Data Structures [8L]

Binary trees, tree traversals (inorder, preorder, postorder), heaps (min-heap, max-heap), applications in priority queues. Hierarchical structure of trees, traversal algorithms, and efficient management using heaps.

Module 4: Sorting Algorithms [8L]

Mergesort, quicksort, heapsort – algorithm design, analysis, and comparison, compare divide-and-conquer and heap-based sorting algorithms.

Module 5: Graph Algorithms [6L]

Graph representations (adjacency matrix and list), BFS (Breadth First Search), DFS (Depth First Search), graph-based problem solving with traversal strategies and representation techniques.

Module 6: Hashing and Searching Techniques [10L]

Hashing techniques, linear search, binary search, binary search trees (BST), AVL trees, red-black trees, B-trees, search algorithms and balanced tree structures that maintain efficiency in dynamic datasets.

Texts:

1. T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Introduction to Algorithms, Prentice-Hall of India, 2009.
2. E. Horowitz, S. Sahani and D. Mehta, Fundamentals of Data Structures in C++, University Press, 2008.

References:

1. A. V. Aho, J. E. Hopcroft and J. D. Ullman, Data Structures and Algorithms, Pearson Education, 2006.
2. A. M. Tannenbaum, Y. Langsam and M. J. Augenstein, Data Structures Using C++, Prentice-Hall of India, 1996.
3. M. A. Weiss, Data Structures and Problem Solving Using Java, Addison-Wesley, 1997.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Define core principles of algorithm efficiency and complexity.

CO2: Apply linear and abstract data structures for efficient data handling.

CO3: Analyze hierarchical and tree-based structures.

CO4: Evaluate sorting techniques and graph traversal strategies.

CO5: Formulate searching, hashing, and balanced data structures.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	-	1	3	2	1
CO2	3	3	3	2	2	-	-	1	3	3	1
CO3	2	3	3	2	2	-	1	1	3	3	1
CO4	2	2	2	3	2	-	-	1	3	3	1
CO5	3	3	3	2	3	1	-	2	3	3	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC9: Python Programming
Credit : (4L-0T-4P)

Learning objectives: On completion of the course, students will be able to design and program Python applications by understanding the various components of the Python program.

Prerequisite: Before learning the course, students must have the basic understanding of data flow and control flow sequence as well as the knowledge of simple programming concepts .

SYLLABUS OUTLINE:

Credit 3: (3L-0T-0P)

Module 1: Introduction to Python: [6L]

Python keywords and variables, Python basic Operators, Understanding python blocks. Python Data Types, Mutable and Immutable types, Declaring and using Numeric data types.

Module 2: Conditional Blocks and Flow of control structure: [4L]

Condition: if, else and nested if, Loops: For loops, while loops, Nested loops, Enumerate, Loop manipulation: Pass, Break, Continue Statement, Programming using conditional and loop blocks

Module 3: Functions: [6L]

Def Statements with Parameters, Return Values, and return Statements, None and print, adding new function, parameters and argument, recursion, and its use, Local and Global Scope, The global Statement, Exception Handling.

Module 4: Complex data types: [6L]

string data type and string operations, list and list slicing, Use of Tuple data type. String, List and Dictionary, string manipulation methods, List manipulation. Dictionary manipulation, Programming using string, list.

Module 5: File Operations: [6L]

Reading files, different read functions. Writing files in python using write functions. File handling and organization.

Module 6: [8L]

Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's Principle. Motion about a fixed axis. Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces. Conservation of momentum and energy.

Text & Reference books:

Text Books:

1. Y. Daniel Liang," Introduction to Programming Using Python", Pearson Education.
2. Martin C Brown, "Python the Complete Reference", Tata McGraw Hill, India

Reference Books:

1. Wesley J. Chun, "Core Python Applications Programming", Pearson Education.
2. John V Guttag. "Introduction to Computation and Programming Using Python", Prentice Hall of India.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Describe fundamental programming concepts and basic data operations.

CO2: Apply decision-making and repetitive structures to develop logical solutions.

CO3: Analyze reusable code units, error handling, and systematic program design.

CO4: Implement structured data storage and information processing for practical tasks.

CO5: Formulate models to describe and compute motions and interactions of physical systems.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PSO1	PSO 2	PSO 3
CO1	3	3	2	2	2	1	1	2	2	3	1
CO2	2	3	2	3	2	1	-	2	2	3	1
CO3	2	3	3	3	3	2	1	2	3	3	2
CO4	2	3	2	3	2	1	-	2	2	3	1
CO5	3	3	3	3	3	2	1	3	3	3	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

SEMESTER V

Course MC10: Optimization
Credit 4: (4L-0T-0P)

Learning objectives: On completion of the course, student will be able to: apply the knowledge of linear programming problem, queuing theory, inventory control, Game Theory to solve complex problems.

Prerequisite: Before learning the concepts of Optimization Techniques, you should have a basic knowledge of set, vector space, probability theory.

Module 1: Introduction to OR [2L]

Origin of OR and its definition. Types of OR problems, Deterministic vs. Stochastic optimization, Phases of OR problem approach – problem formulation, building mathematical model, deriving solutions, validating model, controlling, and implementing solution.

Module 2: Linear Programming [14L]

Linear programming – Examples from industrial cases, formulation & definitions, Matrix form. Implicit assumptions of LPP. Some basic concepts and results of linear algebra – Vectors, Matrices, Linear Independence /Dependence of vectors, Rank, Basis, System of linear eqns., Hyper plane, convex set, convex polyhedron, Extreme points, Basic feasible solutions. Geometric method: 2-variable case, Special cases – infeasibility, unboundedness, redundancy &degeneracy, Sensitivity analysis. Simplex Algorithm – slack, surplus & artificial variables, computational details, big-M method, identification, and resolution of special cases through simplex iterations. Duality – formulation, results, fundamental theorem of duality, dual-simplex and primal-dual algorithms.

Module 3: Transportation and [8L]

TP - Examples, Definitions – decision variables, supply & demand constraints, formulation, Balanced & unbalanced situations, Solution methods – NWCR, minimum cost and VAM, test for optimality (MODI method), degeneracy, and its resolution.

Module 4: Assignment problems [8L]

AP - Examples, Definitions – decision variables, constraints, formulation, Balanced & unbalanced situations, Solution method – Hungarian, test for optimality (MODI method), degeneracy & its resolution

Module 5: PERT – CPM [8L]

Project definition, Project scheduling techniques – Gantt chart, PERT & CPM, Determination of critical paths, Estimation of Project time and its variance in PERT using statistical principles, Concept of project crashing/time-cost trade-off.

Module 6: Queuing Theory [8L]

Definitions – queue (waiting line), waiting costs, characteristics (arrival, queue, service discipline) of queuing system, queue types (channel vs. phase). Kendall's notation, Little's law, steady state behavior, Poisson's Process & queue, Models with examples - M/M/1 and its performance measures; M/M/m and its performance measures; brief description about some special models.

Text & Reference books:

Texts:

1. M. S. Bazaraa, J. J. Jarvis and H. D. Sherali, Linear Programming and Network Flows, 4th Ed., Wiley, 2011.
2. N. S. Kambo, Mathematical Programming Techniques, Revised Ed., Affiliated East-West Press, 2008.

References:

1. E. K. P. Chong and S. H. Zak, An Introduction to Optimization, 4th Ed., Wiley, 2013.
2. M. S. Bazaraa, H. D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Ed., Wiley, 2013.
3. D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, 4th Ed., Springer, 2016.
4. K. G. Murty, Linear Programming, Wiley, 1983.
5. D. Gale, The Theory of Linear Economic Models, The University of Chicago Press, 1989.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Formulate real-life optimization problems into appropriate mathematical models.

CO2: Solve linear programming problems using graphical and simplex-based methods.

CO3: Apply transportation and assignment techniques to obtain optimal solutions in decision-making situations.

CO4: Evaluate project networks using PERT and CPM to determine project duration and critical paths.

CO5: Analyze queuing models to determine system performance measures.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	3	1	2	2	1	1	3	1	1
CO2	3	3	2	3	2	1	-	1	3	2	-
CO3	2	3	2	3	2	1	-	1	3	2	-
CO4	2	3	3	2	2	1	1	1	3	1	-
CO5	3	3	2	2	3	1	1	1	3	2	-

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC11: Scientific Computing

Credit 4: (4L-0T-0P)

Learning Objective:

To develop the ability to apply numerical techniques for solving mathematical problems in calculus, differential equations, and linear algebra, with a focus on accuracy, stability, and convergence of algorithms. Students will also gain hands-on experience in implementing numerical methods for real-world applications.

Prerequisites:

Basic knowledge of calculus, differential equations, and linear algebra, along with some programming skills for implementing numerical algorithms.

Course Content:

Module 1: Errors and Nonlinear Equations [6L]

Types and sources of errors, numerical methods for solving scalar nonlinear equations.

Module 2: Interpolation and Approximation [8L]

Polynomial interpolation, spline interpolation, approximation techniques.

Module 3: Numerical Integration [8L]

Numerical integration based on interpolation, quadrature methods, Gaussian quadrature.

Module 4: Initial Value Problems for ODEs [10L]

Euler method, Runge-Kutta methods, multi-step methods, predictor-corrector methods, stability, and convergence analysis.

Module 5: Finite Difference Methods for PDEs [8L]

Finite difference schemes for partial differential equations, explicit and implicit schemes, consistency, stability and convergence, stability analysis using matrix and von Neumann methods, Lax equivalence theorem.

Module 6: Advanced Finite Difference Schemes [8L]

Finite difference schemes for initial and boundary value problems including FTCS, backward Euler, Crank-Nicolson, ADI methods, Lax-Wendroff method, and upwind schemes.

Text & Reference books:

Texts:

1. D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, 3rd Ed., AMS, 2002.
2. G. D. Smith, Numerical Solutions of Partial Differential Equations, 3rd Ed., Calrendorn Press, 1985.

References:

1. K. E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989.
2. S. D. Conte and C. de Boor, Elementary Numerical Analysis - An Algorithmic Approach, McGraw-Hill, 1981.
3. R. Mitchell and S. D. F. Griffiths, The Finite Difference Methods in Partial Differential Equations, Wiley, 1980.
4. Richard L. Burden and J. Douglas Faires, Numerical analysis, Brooks/Cole, 2001.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Identify sources of numerical errors and determine appropriate methods for solving nonlinear equations.
CO2: Apply interpolation and approximation techniques for constructing numerical models.
CO3: Compute numerical integrals using quadrature formulas with attention to accuracy and efficiency.
CO4: Implement numerical methods for solving ODEs to analyze their stability and convergence.
CO5: Develop finite difference schemes for PDEs to examine their consistency, stability, and convergence.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	2	2	2	1	-	1	3	2	-
CO2	3	3	2	2	2	1	-	1	3	2	-
CO3	3	3	2	3	2	1	-	1	3	2	-
CO4	3	3	3	3	3	1	1	1	3	3	-
CO5	3	3	3	3	3	1	1	1	3	3	-

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC12: Mathematical Simulation
Credit 4: (4L-0T-0P)

Learning Objective:
After completion of this course, students will be able to understand the theoretical foundations and practical techniques of Monte Carlo methods for simulating random processes and approximating solutions to complex probabilistic problems. The course also trains students in generating random variables and applying variance reduction and quasi-random techniques.

Prerequisites:
Students should have a working knowledge of probability theory, statistics, and basic programming, along with familiarity with linear algebra and calculus.

Course Content:

Module 1: Principles and Random Number Generation [8L]

Principles of Monte Carlo methods, generation of random numbers from a uniform distribution using linear congruential generators and its variations.

Module 2: Generation of Random Variables [10L]

Generation of discrete and continuous random variables using inverse transform and acceptance-rejection methods.

Module 3: Simulation of Normal Distributions [8L]

Simulation of univariate normally distributed random variables using Box-Muller and Marsaglia methods; generation of multivariate normal variables using Cholesky factorization.

Module 4: Simulation of Stochastic Processes [6L]

Generation of geometric Brownian motion and jump-diffusion sample paths.

Module 5: Variance Reduction Techniques [8L]

Techniques for variance reduction in Monte Carlo simulations including common methods like antithetic variates and control variates.

Module 6: Quasi-Monte Carlo Methods [8L]

General principles of quasi-Monte Carlo methods, low discrepancy sequences and their applications.

Text & Reference books:

Texts:

1. P. Glasserman, Monte Carlo Methods in Financial Engineering, Springer, 2004.
2. R. U. Seydel, Tools for Computational Finance, 5th Ed., Springer, 2012

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Explain the fundamental principles of Monte Carlo methods and random number generation.

CO2: Apply appropriate techniques to generate discrete and continuous random variables.

CO3: Analyze methods for simulating normal and multivariate normal distributions.

CO4: Develop stochastic process sample paths such as geometric Brownian motion and jump-diffusion processes.

CO5: Evaluate variance reduction and quasi–Monte Carlo techniques for improving simulation efficiency.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	1	2	2	1	1	1	3	2	1
CO2	2	3	3	2	2	1	1	1	3	2	1
CO3	2	3	2	3	3	1	2	-	3	2	-
CO4	1	2	3	3	2	1	1	-	3	1	-
CO5	2	3	2	3	3	2	1	1	3	-	-

1. LOW 2. MODERATE 3. SUBSTANTIAL

SEMESTER VI

Course MC13: Statistical Inference and multivariate analysis
Credit 4: (4L-0T-0P)

Learning objectives:
After completion of this course, students will be able to equip students with a strong foundation in statistical inference, estimation theory, hypothesis testing, regression, and multivariate techniques for real-world data analysis. The course emphasizes both theoretical understanding and practical applications using statistical tools.

Prerequisites:
A basic understanding of probability theory and linear algebra, along with introductory knowledge of statistical methods and distributions.

Course Content:

Module 1: Probability Foundations and Convergence Concepts [8L]

Transformation techniques, different modes of convergence, Law of Large Numbers, Central Limit Theorem.

Module 2: Sampling and Multivariate Distributions [6L]

Sampling distributions based on normal distributions, properties and applications of the multivariate normal distribution.

Module 3: Point Estimation [10L]
Sufficiency, Neyman-Fisher factorization theorem, unbiased estimation, method of moments, maximum likelihood estimation, consistency and asymptotic normality of MLE.

Module 4: Interval Estimation [6L]

Confidence coefficient and level, pivotal method, asymptotic confidence interval, Bootstrap confidence interval.

Module 5: Hypothesis Testing [10L]

Type-I and Type-II errors, power function, size and level, test function and randomized tests, most powerful tests, Neyman-Pearson lemma, likelihood ratio test, p-value.

Module 6: Regression and Multivariate Analysis [10L]

Multiple linear regression (least squares estimation, variance estimation, tests, interval estimation, multicollinearity, residual analysis, PRESS statistic, outliers, lack of fit), Multivariate analysis (PCA, factor analysis, canonical correlations, cluster analysis).

Text & Reference books:

Texts:

1. R. V. Hogg, J. W. McKean and A. T. Craig, Introduction to Mathematical Statistics, 7th Ed., Pearson, 2013.
2. D. C. Montgomery, E. A. Peck and G. G. Vining, Introduction to Linear Regression Analysis, 5th Ed., Wiley, 2012.
3. R. A. Johnson and D. W. Wichern, Applied Multivariate Statistical Analysis, 6th Ed., Prentice Hall of India, 2012.

References:

1. V. K. Rohatgi and A. K. Saleh, An Introduction to Probability and Statistics, 3rd Ed., Wiley, 2015.
2. G. Casella and R. L. Berger, Statistical Inference, 2nd Ed., Cengage Learning, 2006.
3. N. R. Draper and H. Smith, Applied Regression Analysis, 3rd Ed., Wiley, 2000.
4. S. Weisberg, Applied Linear Regression, 1st Ed., Wiley, 2005.
5. T. W. Anderson, An Introduction to Multivariate Statistical Analysis, 3rd Ed., Wiley, 2012.

Course Outcomes (COs): After attending this course, the students will be able to:

CO1: Describe the foundational principles of probability and the applications.

CO2: Discuss sampling distributions and multivariate normal distributions.

CO3: Apply estimation techniques—method of moments, maximum likelihood, sufficiency, and asymptotic properties.

CO4: Construct and interpret confidence intervals using pivotal quantities, asymptotic methods, and bootstrap techniques.

CO5: Formulate hypothesis tests, regression modelling, and multivariate analysis techniques

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	1	1	–	3	–	1	2	2	3
CO2	2	2	2	2	–	3	–	1	2	3	3
CO3	2	3	2	2	–	3	–	1	2	3	3
CO4	1	2	2	2	–	3	–	1	1	3	3
CO5	2	3	3	3	2	3	1	2	2	3	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

Course MC14: Matrix Computations
Credit 4: (4L-0T-0P)

Learning objectives:
To develop a solid understanding of numerical linear algebra techniques, focusing on solving linear systems, matrix factorizations, least squares problems, and eigenvalue computations, along with their numerical stability and sensitivity. Emphasis is placed on floating point arithmetic, algorithmic accuracy, and efficient computation.

Prerequisites:
A firm background in linear algebra and calculus, along with basic knowledge of numerical methods and computer programming.

Course Content

Module 1: Floating Point Arithmetic and Error Analysis [6L]

Floating point computations, IEEE floating point arithmetic, analysis of roundoff errors, sensitivity analysis, condition numbers.

Module 2: Linear Systems and Factorizations [10L]

Linear systems, LU decompositions, Gaussian elimination with partial pivoting, banded systems, positive definite systems, Cholesky decomposition, sensitivity analysis.

Module 3: Orthogonalization and QR Factorization [8L]

Gram-Schmidt orthonormal process, Householder transformation, Givens rotations, QR factorization, stability of QR factorization.

Module 4: Least Squares and Matrix Inverses [8L]

Solution of linear least squares problems, normal equations, SVD, polar decomposition, Moore-Penrose inverse, rank-deficient least squares problems, sensitivity analysis.

Module 5: Eigenvalue Problems and Sensitivity [8L]

Topics: Review of canonical forms of matrices, sensitivity of eigenvalues and eigenvectors, reduction to Hessenberg and tridiagonal forms.

Module 6: Iterative and Advanced Eigenvalue Algorithms [8L]

Power, inverse power and Rayleigh quotient iterations, explicit and implicit QR algorithms for symmetric and nonsymmetric matrices, reduction to bidiagonal form, Golub-Kahan algorithm for computing SVD.

Text & Reference books:

Texts:

1. D. S. Watkins, Fundamentals of Matrix Computations, 2nd Ed., John Wiley, 2002.
2. L. N. Trefethen and D. Bau, Numerical Linear Algebra, SIAM, 1997.

References:

1. J. W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997.
2. M. L. Overton, Numerical Computing with IEEE Floating Point Arithmetic, SIAM, 2001.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Explain floating-point arithmetic, rounding errors, and condition numbers.

CO2: Apply stable algorithms for solving linear systems and matrix factorizations (LU, Cholesky).

CO3: Illustrate orthogonalization and QR factorization using classical and stable methods.

CO4: Solve least squares problems with SVD-based techniques for rank-deficient systems.

CO5: Evaluate eigenvalues/eigenvectors using direct and iterative algorithms.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	2	1	–	2	–	1	2	3	2
CO2	3	3	3	2	–	2	–	1	2	3	3
CO3	3	3	3	2	–	2	–	1	2	3	3
CO4	2	3	3	2	–	2	–	1	2	3	3
CO5	2	3	3	3	1	2	–	1	2	3	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

Course MC15: Computational Finance
Credit 4: (4L-0T-0P)

Learning Objective:
On completion of the course, student will be able to build expertise in numerical methods for pricing financial derivatives, with a focus on PDE-based and Monte Carlo techniques used in real-world quantitative finance. The course emphasizes modelling, simulation, and computation of various types of financial instruments.

Prerequisites:
Basic understanding of stochastic calculus, probability theory, financial mathematics, and programming for numerical computation.

Course Content:

Module 1: Financial Models and Black-Scholes PDE [6L]

Review of financial market models for derivative pricing, interest rate modelling, and the Black-Scholes partial differential equation.

Module 2: Finite Difference Methods for PDEs [10L]

Solution of pricing PDEs using finite difference methods, American option as a free boundary problem, computation of American option prices, pricing of exotic options, upwind scheme and related methods.

Module 3: Monte Carlo Simulation Basics [8L]

Monte Carlo simulation fundamentals, generating sample paths, discretization of stochastic differential equations, Monte Carlo for option valuation and computation of Greeks.

Module 4: Monte Carlo for Complex Options [6L]

Monte Carlo methods for pricing American and exotic options, treatment of path-dependence and optimal stopping problems.

Module 5: Variance Reduction Techniques [6L]

Common variance reduction techniques including antithetic variates, control variates, stratified sampling, and importance sampling in financial applications.

Module 6: Monte Carlo for Interest Rate Models [12L]

Monte Carlo implementation of short rate models, forward rate models, LIBOR market model, volatility structure modeling, and model calibration.

Text & Reference books:

Texts:

1. R. U. Seydel, Tools for Computational Finance, 5th Ed., Springer, 2012.
2. P. Glasserman, Monte Carlo Methods in Financial Engineering, Springer, 2004.

References:

1. Y.-l. Zhu, X. Wu, I-L. Chern and Z.-z. Sun, Derivative Securities and Difference Methods, 2nd Ed., Springer, 2013.
2. D. Higham, Introduction to Financial Option Valuation: Mathematics, Stochastics and Computation, Cambridge University Press, 2004.
3. P. Wilmott, S. Howison and J. Dewynne, The Mathematics of Financial Derivatives: A Student Introduction, Cambridge University Press, 1997.
4. Y. Lyuu, Financial Engineering and Computation, Cambridge University Press, 2002.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Discuss financial models and the Black–Scholes PDE for derivative pricing.

CO2: Apply finite difference methods to solve PDEs for European, American, and exotic options.

CO3: Formulate Monte Carlo simulations for option pricing and numerical solution of SDEs.

CO4: Determine complex and path-dependent options using advanced Monte Carlo techniques.

CO5: Demonstrate variance reduction and interest-rate simulation methods to improve pricing accuracy in computational finance.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	2	2	–	3	–	1	2	3	3
CO2	2	3	3	3	–	3	–	1	2	3	3
CO3	2	3	3	3	–	3	–	1	2	3	3
CO4	2	3	3	3	–	3	–	1	2	3	3
CO5	2	3	3	3	1	3	–	1	2	3	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

SEMESTER VII

Course MC16: Continuum Mechanics
Credit 4: (4L-0T-0P)

Learning objectives:

On completion of the course, student will be able to understand and apply fundamental concepts, analyze stress and strain, formulate conservation laws, model material behaviour, solve boundary value problems, analyze fluid mechanics and waves, and apply these principles to real-world engineering problems.

Prerequisite:

Before learning the course of continuum mechanics, it is recommended to have a strong foundation in calculus, differential equations, and solid mechanics. Familiarity with concepts such as stress, strain, equilibrium, Newton's laws of motion and basic principles of mechanics is essential. A background in physics and engineering mechanics will also be beneficial.

SYLLABUS OUTLINE:

Module 1: Deformation of Continuum: [8L]

Lagrangian and Eulerian methods of describing deformation, finite strain deformation, infinitesimal strain tensor, infinitesimal stretch, and rotation, change in volume.

Module 2: Analysis of Strain: [8L]

Relative displacement, strain quadratic, principal strains, strain invariants, compatibility conditions.

Module 3: Analysis of Stress: [8L]

Body forces, and surface forces, stress tensor, normal and shearing stresses, principal stress, stress invariants. Stress equations of equilibrium and motion, Symmetry of stress tensor.

Module 4: Generalized Hooke's Law:[4L]

Strain energy, Generalized Hooke's Law, Isotropic elastic solid, Elastic moduli for isotropic media, Beltrami-Michel compatibility equations.

Module 5: Fluid: [6L]

Basic concept of fluid, classification of fluids, constitutive equations, equations of motion of fluid , stream lines, path line and vortex lines, circulation, and vorticity.

Module 6: Inviscid Incompressible Fluid: [14L]

Equation of continuity, constitutive equation of perfect fluid and viscous fluid, Euler's equation of motion, integrals of Euler's equation of motion, Bernoulli's equation, Kelvin's minimum energy theorem, Sources and sinks and doublets. Viscous Incompressible Fluid: Governing equations, Navier Stroke's equations, flow between parallel plates.

Text & Reference books:

Text Books:

1. R. N. Chatterjee: Mathematical Theory of Continuum Mechanics, Narosa.
2. G. E. Mase: Theory and Problems of Continuum Mechanics, Schaum's Outline Series, McGrawHill Book Company.

Reference Books:

1. J. N. Reddy: Princilpes of Continuum Mechanics, Cambridge University Press.
2. Y. C. Fung : A first course in Continuum Mechanics, Prentice Hall.
3. R. C. Batra: Elements of Continuum Mechanics, AIAA.
4. W. M. Lai, D. Rubin, E. Krempl, Continuum Mechanics, Butterworth Heinemann,
5. S. Nair: Introduction to Continuum Mechanics, Cambridge University Press.
6. J. L. Wegner, J. B. Haddow: Elements of Continuum Mechanics and Thermodynamics, Cambridge University Press.
7. D. S. Chandrasekharaih and L. Debnath, Continuum Mechanics, Academic Press, 1994. Inc.
8. T. J. Chung: Applied Continuum Mechanics, Cambridge University Press.
9. A.C. Eringen: Mechanics of continua, Robert E. Krieger Publishing Company, INC.
10. L. E. Malvern: Introduction to the Mechanics of a continuous medium, Prentice-Hall,
11. L.I. Sedov :Introduction to the Mechanics of a Continuous Medium, Addison Wesley Publishing Company, INC.

COURSE OUTCOMES (COs)

After completing this course, the student will be able to:

CO1: Describe deformation, strain measures, and stress components in continuous media.

CO2: Analyz strain and stress tensors, their invariants, and principal values.

CO3: Apply conservation laws and generalized Hooke's law to model elastic materials.

CO4: Examine constitutive relations and governing equations for inviscid and viscous fluids.

CO5: Solve mathematical models and boundary value problems related to elasticity and fluid mechanics.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	0	1	0	1	1	1	3	1	2
CO2	3	3	1	1	0	1	1	1	3	1	2
CO3	3	3	1	2	1	1	1	1	3	2	2
CO4	2	3	1	2	1	1	1	1	3	2	3
CO5	3	3	1	3	1	1	2	2	3	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC17: Classical electromagnetism and theory of relativity
Credit 4: (4L-0T-0P)

Learning Objective: To provide a deep understanding of classical electromagnetism and the theory of relativity, focusing on both physical principles and mathematical formulation. Students will develop the ability to solve boundary value problems, analyze electromagnetic fields and waves, and understand spacetime structure using tensor calculus.

Prerequisites:

Strong background in vector calculus, differential equations, and classical mechanics; prior exposure to special relativity and Maxwell's equations is helpful.

Course Content:

Module 1: Electrostatics Fundamentals [8L]

Coulomb's law, electric field and potential, Gauss's law and applications, electric dipole and its behavior in external fields, multipole expansion, Poisson's and Laplace equations, Green functions, method of images, solutions of Poisson and Laplace equations, energy of electrostatic fields, Green’s reciprocity theorem, electrostatic boundary conditions.

Module 2: Magnetostatics and Vector Potentials [6L]

Lorentz force, magnetic field, Ampere’s law and its applications, solenoids, Helmholtz’s theorem, vector potential, magnetic field from current loop, magnetic dipole in external field, Biot–Savart law, magnetostatic boundary conditions.

Module 3: Time-Dependent Fields and Maxwell Equations [6L]

Faraday’s law, generalization of Ampere’s law, displacement current, electromagnetic potentials, wave equations, gauge transformations, Coulomb and Lorentz gauges, plane electromagnetic waves in potential formulation, Poynting vector, advanced and retarded potentials, covariance of Maxwell’s equations.

Module 4: Foundations of Special Relativity [8 L]

Galilean transformations, inertial frames, Michelson-Morley experiment, Lorentz transformations, simultaneity, time dilation, Lorentz contraction, Minkowski diagrams, acceleration under Lorentz transformations, constancy of the speed of light.

Module 5: Tensor Analysis and Minkowski Geometry [10L]

Differentiable manifold, tangent and cotangent spaces, scalar product, covariant and contravariant tensors, transformation rules, tensor space, metric tensor, spacelike and timelike intervals, relativistic momentum and energy.

Module 6: General Relativity Concepts [10 L]

Affine connection, covariant differentiation, parallel transport, geodesic equations, examples and interpretation, and fundamental principles of general relativity.

Text & References:

Text books:

1. **J. D. Jackson**, *Classical Electrodynamics*, Wiley.
2. **David J. Griffiths**, *Introduction to Electrodynamics*, Cambridge University Press.
3. **N. David Mermin**, *Relativity: The Special and the General Theory*, Princeton University Press.

Reference books:

1. L. D. Landau & E. M. Lifshitz — *The Classical Theory of Fields*.
2. W. Greiner — *Classical Electrodynamics*.
3. John R. Reitz, Frederick Milford & R. W. Christy — *Foundations of Electromagnetic Theory*.
4. J. Vanderlinde — *Classical Electromagnetic Theory*.
5. Bernard Schutz — *A First Course in General Relativity*.

COURSE OUTCOMES (COs)

After completing this course, students will be able to:

CO1: Describe electrostatic and magnetostatic fields using fundamental laws and potential theory.

CO2: Apply Maxwell's equations to study time-dependent fields, electromagnetic waves, and energy flow.

CO3: Explain Lorentz transformations, relativistic kinematics, and spacetime diagrams.

CO4: Formulate tensor operations, coordinate transformations, and Minkowski geometry in relativistic physics.

CO5: Apply covariant differentiation, geodesics, and affine connections to interpret foundational concepts of general relativity.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	1	1	0	1	1	1	3	1	2
CO2	3	3	1	2	1	1	1	1	3	2	2
CO3	3	3	1	1	0	1	1	1	3	1	2
CO4	3	3	1	2	1	1	1	1	3	2	3
CO5	3	3	1	3	1	1	2	2	3	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC18: Differential Geometry and Mathematical Biology
Credit 4: (4L-0T-0P)

Learning Objectives

This course aims to develop a deep understanding of the geometry of curves and surfaces, their curvature properties, geodesics, and global theorems, along with the ability to model biological processes mathematically. Students will integrate geometric reasoning with differential equations and dynamical systems to analyze growth, diffusion, population dynamics, and biological pattern formation.

Prerequisite

Strong background in calculus, differential equations, linear algebra, multivariable calculus; familiarity with vector calculus and basic dynamical systems**.**

SYLLABUS OUTLINE:

Module 1: Theory of Curves: [8L]
Local theory of plane and space curves; curvature and torsion formulas; Serret–Frenet formulas; fundamental theorem of space curves.

Module 2: Theory of Surfaces: [8L]
Regular surfaces, change of parameters, differentiable functions on surfaces, tangent plane, differential of a map. First & second fundamental forms, orientation, Gauss map and its properties. Euler's theorem on principal curvatures.

Module 3: Advanced Surface Geometry: [8L]
Isometries, Gauss' Theorema Egregium, parallel transport, geodesics. Gauss–Bonnet theorem and its applications to surfaces of constant curvature. Hopf–Rinow theorem, Bonnet theorem, Jacobi fields, theorems of Hadamard.

Module 4: Population Dynamics: [8L]
Exponential and logistic growth; harvesting models; Allee effect; phase-plane analysis of population systems. Predator–prey models (Lotka–Volterra), competition and cooperation models, equilibrium points and stability.

Module 5: Epidemic Modelling, Biological Diffusion & Pattern Formation: [8L]
Basic SIR, SEIR and SIS models; reproduction number R_0; epidemic threshold; vaccination models; stability of disease-free and endemic equilibrium. Diffusion equation in biology; chemotaxis (Keller–Segel model), reaction–diffusion systems; Turing instability and pattern formation; morphogenesis basics.

Module 6: Biological Oscillators & Networks: [8L]
Limit cycles, circadian rhythms, neuron models (Intro to Hodgkin–Huxley/Integrate–and–Fire), network interactions in biological systems.

TEXTBOOKS & REFERENCES

1. Manfredo P. Do Carmo — *Differential Geometry of Curves and Surfaces*, Prentice Hall.
2. John McCleary — *Geometry from a Differentiable Viewpoint*, Cambridge University Press.
3. Michael Spivak — *A Comprehensive Introduction to Differential Geometry*.
4. Barret O'Neill — *Elementary Differential Geometry*, Academic Press.
5. Andrew Pressley — *Elementary Differential Geometry*, Springer.
6. Carl Friedrich Gauss — *General Investigations of Curved Surfaces*, Dover.
7. James D. Murray — *Mathematical Biology*, Springer.
8. Leah Edelstein-Keshet — *Mathematical Models in Biology*.
9. Linda J. Allen — *An Introduction to Mathematical Biology*.

10. Horst R. Thieme — *Mathematics in Population Biology*.
11. Fred Brauer & Carlos Castillo-Chavez — *Mathematical Models in Population Biology and Epidemiology*.

COURSE OUTCOMES (COs)

After completing this course, students will be able to:

CO1: Describe geometric properties of curves and surfaces using curvature, torsion, and fundamental forms.

CO2: Apply geodesics, parallel transport, and Gauss–Bonnet theorem to solve geometric problems.

CO3: Analyz population and epidemic models using differential equations.

CO4: Apply diffusion models, chemotaxis, and reaction–diffusion systems to explain biological pattern formation.

CO5: Construct mathematical models for complex biological systems involving oscillations, networks, and interacting species.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	0	1	0	0	1	1	3	1	2
CO2	3	3	0	2	0	0	1	1	3	1	2
CO3	3	3	1	2	1	1	1	1	3	2	3
CO4	3	3	1	2	1	1	1	1	3	2	3
CO5	3	3	1	3	1	1	2	2	3	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC19: Nonlinear programming and Introduction to Fuzzy set theory
Credit 4: (4L-0T-0P)

Learning Objective:

To equip students with mathematical and algorithmic tools for solving optimization problems using integer programming, nonlinear methods, dynamic programming, and fuzzy set theory. Emphasis is placed on both theoretical understanding and problem-solving applications.

Prerequisites:

A solid foundation in linear programming, calculus of multiple variables, and basic set theory is essential. Familiarity with optimization concepts and mathematical logic is also recommended.

Module 1: Integer Programming [8L]

Branch-and-Bound Algorithm, Cutting-Plane Algorithm.

Module 2: Nonlinear Programming [8L]

Multivariable optimization with constraints, method of Lagrange multipliers, Kuhn-Tucker necessary and sufficient conditions of optimality.

Module 3: Dynamic Programming [8L]

Bellman's principle of optimality, recursive relations, systems with multiple constraints, solution of linear programming problems using dynamic programming.

Module 4: Introduction to Fuzzy Set Theory [6L]

Concepts of crispness and fuzziness, crisp sets and fuzzy sets, set theoretic operations on fuzzy sets, decomposition principle, alpha-cut, extension principles, generalization of fuzzy sets.

Module 5: Fuzzy Numbers [8L]

Interval numbers, fuzzy numbers, defuzzification methods, fuzzy equations.

Module 6: Fuzzy Relations [10L]

Crisp and fuzzy relations, projections and cylindric extensions, binary fuzzy relations, binary relations on a single set, equivalence relations, compatibility and ordering relations, fuzzy relational equations.

Reference Books:

1. 1. M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Edition, John Wiley & Sons, 2006.
2. G. Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, 1964.
3. J.C. Pant, Introduction to Optimization: Operations Research, New Delhi, Jain Brothers, 2004.
4. H.A. Taha, Operations Research: An Introduction, Pearson Prentice Hall, 2007.
5. Fuzzy set theory and its applications: H. -J. Zimmermann
6. First Course on Fuzzy Theory and Applications: K. H. Lee
7. Fuzzy Sets and Fuzzy Logic: G. J. Klir& B. Yuan
8. Fuzzy Sets, Fuzzy Logic, Applications: G. Bojadziev& M. Bojadziev. George

COURSE OUTCOMES (COs): After completing this course, students will be able to:

CO1: explain integer programming algorithms such as branch-and-bound and cutting-plane methods to discrete optimization problems.

CO2: Solve nonlinear optimization problems using Lagrange multipliers and Kuhn–Tucker conditions.

CO3: Analyz multistage decision problems using dynamic programming techniques.

CO4: Explain fuzzy set concepts, α-cuts, and fuzzy operations to model uncertainty.

CO5: Construct fuzzy numbers, fuzzy relations, and solve fuzzy relational equations in applied contexts.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	1	2	1	0	1	1	3	2	2
CO2	3	3	1	2	1	0	1	1	3	2	2
CO3	3	3	1	3	1	1	1	1	3	3	3
CO4	3	3	0	2	0	1	1	1	3	2	3
CO5	3	3	1	3	1	1	2	2	3	3	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

SEMESTER VIII

Course MC20: Integral transforms and special functions
Credit 4: (4L-0T-0P)

Learning Objective:

To provide a comprehensive understanding of integral transforms and special functions used in solving differential equations, integral equations, and signal processing problems. Students will gain the ability to apply analytical techniques and transform methods to theoretical and applied problems.

Prerequisites:

Students should have a strong background in calculus, linear algebra, and differential equations, along with familiarity with basic complex analysis and Fourier series.

Course Content:

Module 1: Fourier Transform [10L]

Fourier series, algebraic properties, convolution, translation, modulation, analytical properties, transform of derivatives, Perseval's and Plancherel's theorems, inversion theorem, applications to ODEs and PDEs.

Module 2: Laplace Transform [8L]

Algebraic properties, transform of derivatives, inversion theorem, evaluation using residues, asymptotic expansions, applications to PDEs and integral equations.

Module 3: Z-Transform [6L]

Region of convergence, inverse Z-transform, applications to discrete-time systems, signals, and linear systems in signal processing.

Module 4: Hankel and Mellin Transforms [6L]

Properties and inversion of Hankel transform, transform of derivatives, Perseval relation, relation to Fourier transform, applications to PDEs; Mellin transform definition, properties, convolution theorem, and applications to integral equations.

Module 5: Wavelet Transforms [6L]

Definitions, examples, window function, windowed Fourier transform, continuous and discrete wavelet transforms, multiresolution analysis, applications to signal and image processing.

Module 6: Special Functions and Differential Equations [12L]

Topics: Existence and uniqueness of IVPs, singular solutions, series solutions of linear homogeneous equations, non-homogeneous solutions via variation of parameters, Sturm–Liouville problems, Green's function, Legendre functions and their properties, Bessel functions and properties, hypergeometric functions.

Text Books:

1. Fourier, Laplace, Z-, Hankel, Mellin & Wavelet Transforms
2. Debnath, L., & Bhatta, D. (2014). Integral Transforms and Their Applications (3rd ed.). CRC Press.
3. Lokenath Debnath (2002). Wavelet Transforms and Their Applications. Birkhäuser.
4. Rao, K. R., Kim, D. N., & Hwang, J. J. (2011). Fast Fourier Transform: Algorithms and Applications. Springer.
5. Elias, P. P. (1995). Z-Transform Theory and Applications. Springer.

Reference Books:

1. Erdélyi, A. (1953). Tables of Integral Transforms (Vols. 1–2). McGraw Hill.
2. Oppenheim, A. V., & Schafer, R. W. (2009). Discrete-Time Signal Processing (3rd ed.). Pearson.
3. Ingle, V. K., & Proakis, J. G. (2011). Digital Signal Processing Using MATLAB. Cengage.

COURSE OUTCOMES (COs):

After attending this course, the students will be able to:

CO1: ***Define*** the fundamental concepts of Fourier, Laplace, Z-, Hankel, and Mellin transforms along with basic properties of special functions.

CO2: ***Explain*** the algebraic and analytical properties of various integral transforms and their role in solving differential equations.

CO3: ***Apply*** Fourier, Laplace, and Z-transform techniques to solve ordinary, partial, and integral equations.

CO4: ***Analyze*** solutions of differential equations using series methods, Sturm–Liouville theory, and orthogonality of special functions.

CO5: ***Construct*** solutions to mathematical and physical problems using Green's functions, wavelet transforms, and special functions.

MAPPING OF COs WITH POs AND PSOs:

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	-	-	-	1	1	2	3	-	1
CO2	3	3	-	-	-	-	1	2	3	-	2
CO3	2	3	2	3	-	-	-	2	2	3	3
CO4	3	3	-	3	2	-	-	-	3	-	3
CO5	2	3	2	3	2	-	-	2	2	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course MC21: PDE and integral equations
Credit 4: (4L-0T-0P)

Learning Objective:

To develop a thorough understanding of partial differential equations and integral equations, including both analytical and transform-based solution techniques. The course emphasizes classification, solution behavior, and applications in mathematical physics and engineering problems.

Prerequisites:

Students should have a firm grasp of ordinary differential equations, linear algebra, multivariable calculus, and basic concepts of Fourier and Laplace transforms.

Course Content:

Module 1: Classification and Fundamental PDEs [8L]

Classification of second-order PDEs, Laplace equation, wave equation, diffusion equation, physical interpretation.

Module 2: Solution Techniques for PDEs [10L]

Separation of variables, method of characteristics, integral transform methods, Green's function method, fundamental solutions.

Module 3: Nonlinear PDEs and Applications [6L]

Concepts of nonlinearity, diffusion and dispersion, wave breaking, soliton, shock formation, solution of Burger and KdV equations.

Module 4: Introduction to Integral Equations [6L]

Reduction of boundary value problems to integral equations, classification, formulation of Fredholm and Volterra equations.

Module 5: Fredholm Integral Equations [10L]

Solution by successive approximation, Neumann series, existence and uniqueness, equations with degenerate kernels, eigenvalues and eigenfunctions.

Module 6: Volterra Integral Equations [8L]

Iterated kernel method, existence and uniqueness, solution of Abel equation, convolution type Volterra equations solved using Laplace transforms.

Text & Reference Books:
Text:

1. N. W. Mclachlan, Laplace transform and their applications to differential equations.

2. D. Porter and D.S.G. Stirling, Integral Equations, Cambridge University Press, 2004.
3. H. Hochstadt, Integral equations, Wiley-Interscience, 1989.
4. A. Wazwaz, A first course in integral equations, World Scientific, 1997.
5. F.G. Tricomi, Integral Equations, Dover, 1985.

Reference:

6.F.C. Titchmash, Introduction to the theory of Fourier Integrals, Oxford Press, 1937.

7.Peter, K.F. Kahfitting, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
8.E.J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.

COURSE OUTCOMES (COs):

After attending this course, the students will be able to:

CO1: Define the fundamental classifications and properties of partial differential equations and integral equations.

CO2: Describe analytical and transform-based techniques used to solve standard linear PDEs and boundary value problems.

CO3: Apply separation of variables, method of characteristics, and integral transform methods to solve classical PDEs arising in physics and engineering.

CO4: Analyze nonlinear partial differential equations, including Burgers' and KdV equations, to identify the behavior of solutions such as shocks, diffusion, and soliton formation.

CO5: Construct solutions to Fredholm and Volterra integral equations using Neumann series, iterated kernels, degenerate kernels, and Laplace transform methods.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PSO1	PSO 2	PSO 3
CO1	3	2	1	1	1	1	1	2	3	1	1
CO2	3	3	1	2	1	1	-	2	3	1	2
CO3	2	3	2	3	1	-	-	2	2	3	3
CO4	3	3	1	3	2	-	-	1	3	1	3
CO5	2	3	2	3	3	-	-	2	2	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

ELECTIVE PAPERS:

Course : Fractional Calculus and Fractional differential equations
Credit 4: (4L-0T-0P)

Learning Objective:
To provide foundational and advanced understanding of fractional calculus, its key special functions, and analytical and numerical methods for solving fractional differential equations. The course aims to build strong theoretical insights alongside practical applications in solving linear and nonlinear fractional order models.

Prerequisite:
Students should have prior knowledge of real analysis, differential equations, and Laplace and Fourier transforms. Familiarity with classical calculus and basic numerical techniques is essential.

Course Content:

Module 1: Special Functions of Fractional Calculus [6L]

Gamma function, Mittag-Leffler function, Wright function

Module 2: Fundamentals of Fractional Derivatives and Integrals [10L]

Grunwald-Letnikov fractional derivatives, Riemann-Liouville fractional derivatives, geometric and physical interpretation of fractional integration and differentiation, sequential fractional derivatives, properties of fractional derivatives, core theoretical structure of fractional derivatives and integrals and their physical meaning and mathematical properties.

Module 3: Integral Transforms of Fractional Derivatives [6L]

Laplace, Fourier and Mellin transform of fractional derivatives, transform methods as tools for analyzing and solving fractional differential equations

Module 4: Linear Fractional Differential Equations [10L]

Equation of a general form, existence, and uniqueness theorem as a method of solution, dependence of a solution on initial conditions, Laplace transform method, standard fractional differential equations, sequential fractional differential equations. Analytical methods for solving linear fractional differential equations, emphasizing existence, uniqueness, and initial value sensitivity.

Module 5: Solution Techniques for Fractional Order Equations [10L]

Mellin transform, power series, orthogonal polynomials. Classical and semi-analytical methods for solving fractional order equations, series and spectral methods.

Module 6: Numerical Approaches to Fractional Derivatives [6L]

Numerical evaluation of fractional derivatives, approximation of fractional derivatives, numerical algorithms, and discrete schemes for approximating fractional derivatives for practical and computational applications.

Text & References:

1. Basic Theory of Fractional Differential Equations, Y. Zhou, World Scientific, 2014.
2. Fractional Differential Equations, I. Podlubny, Academic Press, 1998.
3. The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, K.B. Oldham and J. Spanier, Dover Publications, 2006.
4. An Introduction to the Fractional Calculus and Fractional Differential Equations, K.S. Miller and B. Ross, Wiley-Interscience, 1993.

COURSE OUTCOMES (COs):

CO1: Define the fundamental special functions used in fractional calculus, including Gamma, Mittag-Leffler, and Wright functions.
CO2: Explain the principles, properties, and interpretations of fractional derivatives and integrals.
CO3: Apply Laplace, Fourier, and Mellin transform to evaluate and manipulate fractional derivatives.
CO4: Analyze linear fractional differential equations using appropriate analytical and transform-based techniques.
CO5: Evaluate numerical schemes and discrete algorithms for approximating fractional derivatives.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	-	1	-	1	1	1	3	-	1
CO2	3	2	-	1	-	-	1	1	3	-	1
CO3	3	2	1	2	-	-	-	1	2	1	2
CO4	3	3	1	3	1	-	-	1	3	1	3
CO5	2	2	3	2	1	-	-	1	1	3	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course: Advanced Data structure and algorithm
Credit 4: (4L-0T-0P)

Learning Objective:
To develop a rigorous understanding of algorithm design, analysis, and advanced data structures through both theoretical and applied perspectives. The course aims to strengthen problem-solving skills in complex algorithmic domains including graph theory, geometry, approximation, and randomized computation.

Prerequisite:
Students should have prior exposure to basic data structures, asymptotic analysis, and elementary algorithm design techniques such as greedy and divide-and-conquer methods. Familiarity with discrete mathematics and proof-based reasoning is also expected.

Course Content:

Module 1: Review of Algorithm Design Techniques [8L]

Greedy method, divide-and-conquer, and dynamic programming, with emphasis on deeper theoretical underpinnings and advanced applications.

Module 2: Amortized Analysis and Advanced Data Structures [10L]

Aggregate, accounting, and potential methods of amortized analysis along with advanced data structures such as B-trees, Fibonacci heaps (with application to Prim's MST), interval trees, and disjoint set structures.

Module 3: Graph Algorithms and Maximum Flow [8L]

Algorithms for computing maximum flow (e.g., Ford-Fulkerson, Edmonds-Karp), their correctness proofs, and important applications in networks and scheduling.

Module 4: String Matching Algorithms [6L]

Classical and advanced string matching algorithms including Knuth-Morris-Pratt, Boyer-Moore, and suffix trees, along with their time complexity analysis.

Module 5: Approximation Algorithms [8L]

Approximation strategies for NP-hard problems like set cover, max-SAT, knapsack, bin packing, scheduling, and traveling salesman problem, including performance guarantees and complexity insights.

Module 6: Randomized and Geometric Algorithms [8L]

Introduction to randomized algorithm design and analysis techniques, geometric algorithms such as convex hull, lower bounds, line segment intersection and closest pair of points.

Text & References:

Texts:

1. J Kleinberg and E Tardos, *Algorithm Design*, Addison-Wesley, 2005.
2. TH Cormen, CF Leiserson, RL Rivest, and C Stein, *Introduction to Algorithms*, 3rd Ed., MIT Press, 2009.

References:

1. AV Aho, J Hopcroft, and JD Ullman, *The Design and Analysis of Algorithms*, Addison-Wesley, 1974.

COURSE OUTCOMES (COs):

After attending this course, the students will be able to:

CO1: Explain the principles of advanced algorithm design techniques such as greedy, divide-and-conquer, and dynamic programming.

CO2: Apply amortized analysis methods and advanced data structures including B-trees, Fibonacci heaps, interval trees, and disjoint sets to computational problems.

CO3: Analyze graph algorithms and maximum-flow techniques to determine their correctness and computational efficiency.

CO4: Evaluate classical and advanced string-matching algorithms based on their performance and structural characteristics.

CO5: Design approximation, randomized, and geometric algorithms to solve complex NP-hard and large-scale computational problems.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO1	PSO2	PSO3
CO1	3	2	1	2	1	1	1	1	3	1	1
CO2	2	3	2	3	1	1	-	1	2	3	1
CO3	2	3	2	3	1	-	-	1	2	2	3
CO4	1	2	2	2	1	-	-	1	2	2	1
CO5	2	3	3	3	2	-	-	1	2	3	2

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course: Generalized Linear models
Credit 4: (4L-0T-0P)

Learning Objective:
To equip students with a solid foundation in regression-based statistical modelling, with emphasis on generalized linear models and their application to binary, categorical, and count data. The course also develops the skills to evaluate model fit, interpret results, and apply appropriate modelling strategies based on data types.

Prerequisite:
Students should have prior knowledge of probability theory, basic statistics, and linear algebra. Familiarity with linear regression, matrix operations, and hypothesis testing is essential.

Course Content/ Syllabus:

Module 1: Review of Linear Models [6L]

Simple and multiple linear regression models, model assumptions, estimation via least squares, and interpretation of coefficients in multivariable contexts.

Module 2: Foundations of Generalized Linear Models (GLMs) [10L]

GLM framework, link functions, exponential family distributions, model components, maximum likelihood estimation, iterative reweighted least squares algorithm, and deviance-based goodness of fit.

Module 3: Diagnostic Tools for GLMs [6L]

Residual analysis, leverage, influence diagnostics, AIC/BIC criteria, and strategies for model selection and validation within the GLM framework.

Module 4: Models for Binary Data [8L]

Presents logistic regression, probit model, complementary log-log model, interpretation of odds ratios, estimation, and inference methods for binary outcomes.

Module 5: Models for Multinomial and Ordinal Data [8L]

Includes multinomial logit models, continuation-ratio and cumulative logit models for ordinal data, estimation procedures, and interpretation of categorical response models.

Module 6: Models for Count Data [10L]

Covers Poisson regression, negative binomial models, zero-inflated models, overdispersion handling, analysis of contingency tables, and inference for count-based data structures.

Text & References:

1. Peter McCullagh and John Nelder, Generalized Linear Models, Second Edition, Chapman and Hall/CRC (1989).
2. Julian J. Faraway, Extending the Linear Model with R: Generalized Linear, Mixed Effects, and Non-parametric Regression Models, Second Edition, Boca Raton: CRC Press (2006).

Course Outcomes (COs):

CO1: Describe the theoretical foundations of generalized linear models, including link functions and exponential family distributions.

CO2: Apply maximum likelihood estimation and the IRLS algorithm to fit generalized linear models.

CO3: Analyze model diagnostics using residuals, leverage, influence measures, and information criteria.

CO4: Evaluate the suitability of logistic, probit, multinomial, and ordinal regression models for different data types.

CO5: Construct GLM-based solutions for count data using Poisson, negative binomial, and zero-inflated modelling frameworks.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	**PROGRAMME OUTCOMES**								**PROGRAMME SPECIFIC OUTCOMES**		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	1	1	2	2	2	3	2	3
CO2	2	3	2	3	2	1	2	2	3	2	2
CO3	2	3	2	3	3	1	-	-	3	2	1
CO4	2	3	3	3	3	2	1	1	3	1	-
CO5	2	3	3	3	3	2	1	1	3	-	

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course: Dynamical Systems:
Credit 4: (4L-0T-0P)

Learning Objective:
To provide a comprehensive understanding of continuous dynamical systems, focusing on qualitative behavior, stability, bifurcation, and the onset of chaos. The course emphasizes analytical tools and geometric intuition for examining nonlinear systems in one and two dimensions.

Prerequisite:
Students should have a solid background in differential equations and linear algebra, especially familiarity with eigenvalues and eigenvectors. Prior exposure to vector calculus and qualitative methods is recommended.

Course Content:

Module 1: Introduction to Dynamical Systems and Flows [6L]

Basic terminology and concepts of dynamical systems, flows, and the evolution of states over time.

Module 2: Fixed Points, Linearization, and the Eigenvalue Method [10L]

Identifying fixed points, linearizing nonlinear systems around equilibrium, and applying the eigenvalue-eigenvector method to determine local dynamics and system classification.

Module 3: Fundamental Matrix and Phase Plane Analysis [8L]

The role of the fundamental matrix in linear systems and techniques for analyzing trajectories using phase plane methods. Identifying system behavior through graphical and analytical means.

Module 4: Stability Analysis [8L]

Local and global stability of fixed points, Lyapunov methods, and the criteria for determining the nature of equilibrium points in nonlinear systems.

Module 5: Periodic Orbits and Limit Cycles [8L]

Periodic solutions using Poincaré's Theorem, Bendixson's negative criterion, and Dulac's criterion. Poincaré–Bendixson Theorem and classification of limit cycles in planar systems.

Module 6: Bifurcation and Chaos [8L]

Examine bifurcation phenomena in one and two dimensions, such as saddle-node, pitchfork, and Hopf bifurcations. Introduces key concepts of chaos, including sensitivity to initial conditions and nonlinear dynamics.

References:

1. Ordinary Differential Equations by E. L. Ince

2. An Introductions to Ordinary Differential Equations by Earl A. Coddington

3. Special Functions and their Applications: N.N. Lebedev

4. Special Functions by W. W. Bell

5. Strogatz, S.H., 2018. Nonlinear dynamics and chaos with applications to physics, biology, chemistry, and engineering. CRC Press.

6. Layek, G.C., 2015. An introduction to dynamical systems and chaos. New Delhi: Springer.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Define flows, trajectories, and fundamental concepts of continuous dynamical systems.

CO2: Discuss fixed points using linearization and eigenvalue methods.

CO3: Use phase plane techniques and fundamental matrices to study system behavior.

CO4: Evaluate stability of equilibria using Lyapunov and qualitative methods.

CO5: Examine limit cycles, bifurcations, and introductory chaotic dynamics in nonlinear systems.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	**PROGRAMME OUTCOMES**								**PROGRAMME SPECIFIC OUTCOMES**		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PSO 1**	**PSO2**	**PSO3**
CO1	3	2	1	1	–	2	–	1	3	2	3
CO2	3	3	2	2	–	2	–	1	3	2	3
CO3	3	3	2	2	–	2	–	1	3	2	3
CO4	3	3	2	3	–	2	–	1	3	2	3
CO5	2	3	2	3	–	2	–	1	3	2	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

Course: Stochastic Calculus
Credit 4: (4L-0T-0P)

Learning Objective:
To provide a comprehensive theoretical framework for stochastic processes, stochastic integration, and Markov processes, with applications in mathematical finance, statistical physics, and applied probability. The course focuses on building technical proficiency in concepts like Brownian motion, martingales, Ito calculus, and measure changes.

Prerequisite:
Students should have prior knowledge of measure-theoretic probability, real analysis, and basic stochastic processes. Familiarity with conditional expectation, convergence concepts, and sigma-algebras is essential.

Course Content:

Module 1: Foundations of Probability and Stochastic Processes [8L]

Probability theory and introduces filtrations, adapted processes, martingales, and Brownian motion as a central example of a continuous-time stochastic process.

Module 2: Continuous Semi-Martingales and Quadratic Variation [8L]

The structure and decomposition of continuous semi-martingales, the definition and properties of local martingales, and the construction and existence of quadratic variation processes.

Module 3: Stochastic Integration [10L]

The construction of stochastic integrals with respect to continuous semi-martingales, particularly Brownian motion, emphasizing isometry, adapted integrands, and convergence theorems.

Module 4: Ito's Formula and Key Applications [10L]

Develops Ito's formula in one and several dimensions and explores its consequences, including Levy's characterization of Brownian motion, the representation of martingales as time-changed Brownian motions, and BDG inequalities.

Module 5: Girsanov's Theorem and Measure Change [6L]

Girsanov's theorem, equivalent measure transformations, and provides applications in stochastic differential equations and financial modeling.

Module 6: Markov Processes and Feller Semigroups [6L]

The theory of Markov processes, semigroup formulations, generators, and the Feller property, including applications in transition probabilities and Kolmogorov equations.

Text & References:

1. Jean-Francois Le Gall, Browninan Motion, Martingales, and Stochastic Calculus, Graduate Texts in Mathematics 274, Springer, 2016.
2. F.C. Klebaner, Introduction to Stochastic Calculus with Applications, Imperial College Press, Third Edition, 2012.

Course Outcomes (COs):

After attending this course, the students will be able to:

CO1: Define filtrations, martingales, and Brownian motion as fundamental stochastic processes.

CO2: Compute continuous semi martingales and quadratic variations.

CO3: Construct stochastic integrals.

CO4: Apply Ito's formula and related results to derive and analyze stochastic models.

CO5: Formulate measure-change techniques and Markov process theory in stochastic modelling applications.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	1	1	–	3	–	1	3	2	3
CO2	3	3	2	1	–	3	–	1	3	2	3
CO3	3	3	2	2	–	3	–	1	3	2	3
CO4	3	3	2	2	–	3	–	1	3	2	3
CO5	2	3	2	3	1	3	–	1	3	2	3

1. LOW 2.MODERATE 3. SUBSTANTIAL