Sister Nivedita University
Department of Mathematics

A Satyam Roychowdhury initiative

Syllabus for M. Sc. In Applied Mathematics
(Under UGC – CBCS)

Framed according to the
National Education Policy (NEP 2020)

Avishek Adhikari Anisha Dutta

M. Sc. In Applied Mathematics

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):

M.Sc. Applied Mathematics graduates are expected to achieve within a few years of graduation:

PEO 1: Students will successfully advance into doctoral programs (Ph.D.) or high-level R&D positions in industry, contributing original research and innovative solutions to complex mathematical, computational, and interdisciplinary problems.

PEO 2: Graduates will lead professional teams in quantitative fields such as Data Science, Financial Engineering, and Computational Modelling, using their advanced analytical, modelling, and programming skills to create economic or scientific value.

PEO 3: Students will adapt effectively to dynamic global workplaces, demonstrate ethical responsibility in handling complex data and proprietary models, and engage in lifelong learning to stay current with emerging mathematical theories and computational technologies.

Program Specific Outcomes (PSOs):

Upon successful completion of the M.Sc. in Applied Mathematics program, students will be able to:

PSO 1: Demonstrate the ability to construct, rigorously analyze, and interpret abstract mathematical models for diverse physical and social systems, leveraging concepts from Functional Analysis, Topology, and Complex Analysis.

PSO 2: Designing, coding, and efficiently executing high-performance computational solutions for large-scale applied problems, including those found in machine learning and optimization, and effectively communicating the results.

PSO 3: Proficiently apply specialized theories, such as Integral Transforms, Fractional Calculus, and Continuum Mechanics, to perform in-depth analysis and solve advanced modelling challenges across engineering, finance, and physics domains.

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Program Outcomes (POs):

Upon successful completion of the M.Sc. in Applied Mathematics program, students will be able to:

PO1: Attain a profound and advanced understanding of advanced mathematical structures, including Topology, Functional Analysis, and Operator Theory, and apply these abstract concepts to the rigorous analysis of practical problems.

PO2: Formulate, analyze, and critically evaluate complex real-world phenomena by constructing high-level mathematical models using differential equations, continuum mechanics, and integral transforms.

PO3: Expertly implement and validate mathematical algorithms using powerful programming tools, particularly Python, and apply them to solve problems in Numerical Analysis and advanced computational science.

PO4: Integrate advanced mathematical principles from Linear Models, Foundation of Mathematics for Machine Learning, and Optimization to develop and critically assess algorithms used in Artificial Intelligence and Data Science.

PO5: Apply specialized mathematical knowledge, such as Financial Mathematics, Biomathematics, and Non-linear Dynamics, to address interdisciplinary problems and drive innovation in specific industry sectors.

PO6: Conduct independent, original research in a specialized area of applied mathematics, culminating in a significant scholarly contribution and defense of the Master Project / Dissertation.

PO7: Synthesize diverse mathematical concepts from Fractional Calculus and Relativity to Optimization and Operations Research to creatively solve complex, previously unseen problems that lack standard solutions.

PO8: Effectively communicate complex mathematical results and their implications to both technical and non-technical audiences using written, computational, and oral means, while adhering to the highest standards of professional ethics.

Credit Definition

Type	Duration (inHour)	Credit
Lecture (L)	1	1
Tutorial (T)	1	1
Practical (P)	2	1

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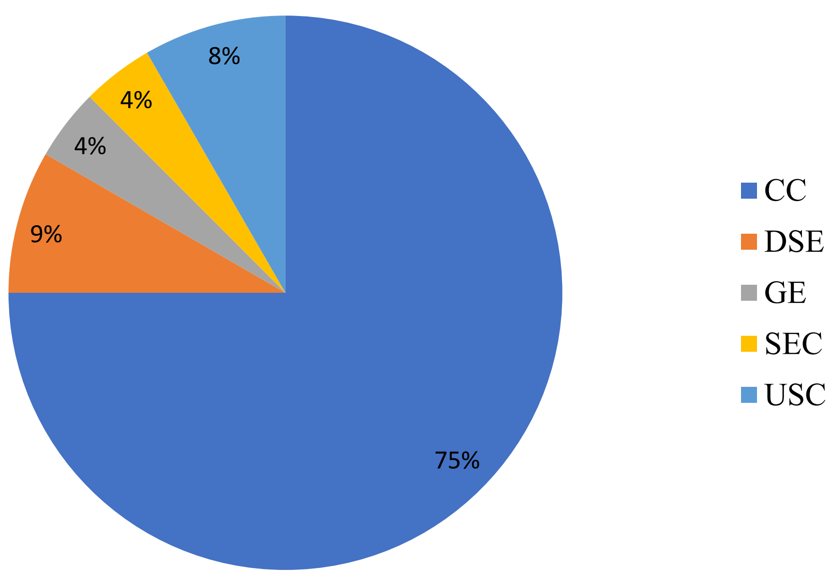
Total Credit

Year	Semester	Hr./Week	Credit
1st	1st	27	27
	2nd	34	30
2nd	3rd	27	27
	4th	27	15
Total			**99**

Category Codification with Credit Break up

Definition of Category	Code	No	Credit
Core Courses	CC	1	76
Discipline Specific Elective	DSE	2	7
General Elective	GE	3	4
Skill Enhancement Courses	SEC	4	4
University specified course	USC	5	8
Total			**99**

Category wise Credit Distribution



Subject Codification

Place value	1	2	3	4	5	6	7	8	9	10
Code	Course Category	Department Code		Program Code			Semester (for semester scheme)/Year(for annual scheme)	Subject Type (Theory/Practical/Sessional/Project /Internship)	Subject Serial Number	

SEMESTER: I

Mandatory Induction Program – Duration 3 weeks

- Physical Activity
- Creative Arts
- Universal Human Values
- Literary
- Proficiency Modules

Sl No	Course Title	Code	Credit	Type		
				L	T	P
CC1	Abstract Algebra and Partial differential equation	1210021101	4	3	1	0
CC2	Real Analysis and Generalized functions	1210021102	4	3	1	0
CC3	Complex Analysis and ordinary differential equation	1210021103	4	3	1	0
CC4	Introduction to Continuum Mechanics	1210021104	4	3	1	0
CC5	Discrete Mathematics, Graph theory and Non-linear dynamics	1210021105	4	3	1	0
DSE1	Linear models	2210021101	4	3	1	0
USC1	Foreign Language – I	6210021101	2	2	0	0
SEC1	Mentor Seminar I	5210021601	1	1	0	0
Total Credit (CC: 20, DSE: 4, GE: 4, SEC: 1, USC: 2)			27	27 (hrs./Week)		

SEMESTER: II

Sl No	Course Title	Code	Credit	Type		
				L	T	P
CC6	Numerical Analysis	1210022301	6	3	1	4
CC7	Integral transforms and integral equations	1210022102	4	3	1	0
CC8	Python Programming	1210022303	6	3	1	4
CC9	Elastic deformation	1210022104	4	3	1	0

DSE2	Management information system	1210022105	3	3	0	0
USC2	Foreign Language II	6210022102	2	2	0	0
SEC2	Mentor Seminar II	5210022602	1	1	0	0
GE1	Generic Elective		4	4	0	0
Total Credit (CC: 20, DSE: 3, USC: 2, SEC:1)			30	34 (hrs./Week)		

SEMESTER: III

Sl No	Course Title	Code	Credit	Type		
				L	T	P
CC10	Topology, functional analysis and operator theory	1210023101	4	3	1	0
CC11	Artificial Intelligence and Data Science	1210023102	4	3	1	0
CC12	Optimization and operations research	1210023103	4	3	1	0
CC13	Foundation of Mathematics for Machine Learning	1210023104	4	3	1	0
CC14	Financial Mathematics and Biomathematics	1210023105	4	3	1	0
CC15	Fractional Calculus and Theory of Relativity	1210023106	4	3	1	0
USC3	Foreign Language III	6210023103	2	2	0	0
SEC3	Mentor Seminar III	5210023603	1	1	0	0
Total Credit (CC: 24, USC: 2, SEC:1)			27	27 (hrs./Week)		

SEMESTER: IV

Sl No	**Course Title**	**Code**	**Credit**	**Type**		
				L	**T**	**P**
CC16	Master Project / Dissertation	1210024501	12	0	0	24
USC4	Foreign Language IV	6210024104	2	2	0	0
SEC4	Mentor Seminar IV	5210024604	1	1	0	0
Total Credit (CC: 12, USC: 2, SEC:1)			15	27 (hrs./Week)		

SEMESTER I

Course CC1: ABSTRACT ALGEBRA AND PRTIAL DIFFERENTIAL EQUATION
Credit 4: (3L-1T-4P)

Learning Objective:
To develop a deep understanding of abstract algebraic structures and partial differential equations, and apply them to solve theoretical and applied mathematical problems.

Pre-requisites:
Basic knowledge of linear algebra, calculus, and ordinary differential equations is essential.

SYLLABUS OUTLINE:

Module 1: Basic Group Theory and Its Structure: [10L]

Dihedral groups, Cayley’s Theorem, generators, commutator subgroup, automorphisms, conjugacy classes, centralizer/normalizer, class equation, group actions, Cauchy’s theorem, Sylow’s theorems, direct product of groups, structure theorem for finitely generated Abelian groups.

Module 2: Rings, Fields, and Factorization Theory [10L]

Rings, integral domains, fields, ring homomorphisms, ideals, quotient rings, maximal and prime ideals, Euclidean domains, UFD, polynomial rings, division algorithm, factorization in R[x].

Module 3: Galois Theory and Field Extensions [8L]

Field extensions, algebraic extensions, splitting fields, finite fields, Galois group of a polynomial, fundamental theorem of Galois theory.

Module 4: First and Second Order PDEs [12L]

First-order PDEs (Cauchy problem, characteristics), classification of second-order PDEs, fundamental solutions (Laplace, wave, diffusion), method of separation of variables, method of characteristics, D’Alembert’s solution, Green’s function method, max-min principles.

Module 5: Nonlinear PDEs [8L]

Nonlinear PDEs and transformation to linear form, travelling wave solutions, Burgers’, KdV, and nonlinear Schrödinger equations.

Reference Books :

1. I.N. Herstein, Abstract Algebra, Macmillan, New York, 1990.
2. J.B. Fraleigh, A first in Abstract Algebra, Narosa, New Delhi, 1986.
3. N. Jacobson, Basic Algebra, vol.1 and 2, Hindusthan, New Delhi, 1984.
4. I. N. Sneddon, Elements of Partial Differential Equations, Mcgraw Hill.
5. K. S. Rao, Partial differential equations.
6. W. E. Williams Partial Differential Equations.
7. F. H. Miller, Partial Differential Equations
8. I. G. Petrovsky, Lectures on Partial differential equations.
9. Courant and Hilbert, Methods of Mathematical Physics, Vol – II

***Pedagogy for Course Delivery**: Chalk, Board, Study Materials, pictures.*
***List of Professional Skill Development Activities (PSDA)**: N/A*
***Continuous assessment**:* Quiz/assessment/presentation/problem solving etc.

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

CO1: Describe fundamentals of ring theory and partial differential equations..

CO2: Demonstrate the significance of the nature of PDE in real life problems.

CO3: Relate Sylow theorems, structure theorem for Abelian groups.

CO4: Verify the structure of the symmetries of roots of polynomials.

CO5: Formulate the solution of nonlinear PDEs by appropriate transformations.

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	0	1	0	0	1	3	1	2
CO2	1	3	2	1	3	0	1	2	2	2	3
CO3	3	1	0	0	0	0	1	1	3	0	1
CO4	2	2	1	1	1	0	2	1	2	1	2
CO5	1	3	2	1	2	0	3	2	1	3	3

Course CC2: REAL ANALYSIS AND GENERALIZED FUNCTIONS
Prog: M. Sc. in Applied Mathematics
Credit 4: (3L-1T-0P)

Module 1: Differentiability and Implicit Mappings **[10L]**

Derivative matrix and the differential, Mean Value Theorem for general mappings, Chain rule for general mappings, Inverse Function Theorem and Implicit Function Theorem (for general mappings), Related examples illustrating the above concepts**.**

Module 2: Metric Spaces and Functional Mappings **[10L]**

Bounded and totally bounded metric spaces, Compact and separable metric spaces, Functions on metric spaces: Limit, continuity, uniform continuity, Contraction mapping, Banach Fixed Point

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Theorem, Introduction to Banach spaces and Hilbert spaces: Simple properties

Module 3: Approximation, Variation and Continuity **[8L]**

Weierstrass Approximation Theorem, Functions of bounded variation, Decomposition Theorem, Derived function and derivatives, Absolutely continuous functions: definition and properties.

Module 4: Fourier Series and Hilbert Space Methods **[8L]**

Trigonometric Fourier Series of functions, Convergence at a point, Cesàro summability of Fourier series, Fourier series in Hilbert spaces, Plancherel's Formula

Module 5: Generalized Functions and Fourier Transforms **[12L]**

Bolzano-Weierstrass Theorem, Classes of functions, test function space, space of generalized functions, Support, regular and singular generalized functions, Principal part of 1/x, Change of variables, multiplication, and differentiation in generalized functions, Properties of generalized derivatives, Convolution of generalized functions (statement only), Test functions of rapid decay, functions of slow growth, Generalized functions of slow growth, Fourier transform of generalized functions of slow growth, Fourier transform of Heaviside function, Poisson's sum formula.

Reference Books:

1. H.L. Royden, Real Analysis, 3rd ed., Macmillan Publishing Co., Inc., New York, 1989.
2. E.C. Titchmarsh, Theory of Functions, Clarendon Press, 1932.
3. T.M. Apostal, Mathematical Analysis, Wesley, Reading, 1974.
4. I.P. Natanson, Theory of Functions of a Real Variable, Vols. I & II, Akademie-Verlag, Berlin, 1981.
5. Methods of the theory of Generalized functions – V. S. Vladimirov
6. A collection of problems on the equations of mathematical physics - V. S. Vladimirov

COURSE OUTCOMES:

CO1: **Explain** the concepts of metric spaces, continuity, compactness, and fixed-point theorems.

CO2: Use Mean Value Theorem, Chain Rule, and Inverse/Implicit Function Theorems to **analyze** differentiability in multivariable mappings.

CO3: Examine functions of bounded variation and absolute continuity including Fourier series convergence and approximation.

CO4: Verify the structure and properties of generalized functions.

CO5: Construct solutions using generalized function theory and Fourier analysis.

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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	2	2	–	–	–	1	3	2	2
CO3	3	3	2	2	–	–	–	1	3	2	2
CO4	3	3	2	2	–	1	–	1	3	2	3
CO5	3	3	2	3	2	1	2	1	3	2	3

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Course CC3: COMPLEX ANALYSIS AND ORDINARY DIFFERENTIAL EQUATIONS
Credit 4: (3L-1T-0P)

Module 1: Foundations of Complex Analysis [8 L]
This module introduces complex numbers, the topology of the complex plane, and sequences of complex numbers. It includes stereographic projection, analytic functions, Cauchy-Riemann equations, zeros of analytic functions, and the concept of multivalued functions with branch cuts and Riemann sheets.

Module 2: Complex Integration and Theorems [10 L]
This module covers curves in the complex plane and complex integration. Key theorems include Jordan's Lemma, Cauchy's theorem, Morera's theorem, and the Cauchy integral formula. Additional topics include the maximum modulus principle, open mapping theorem, Schwarz Lemma, Liouville's theorem, and the fundamental theorem of algebra.

Module 3: Series, Singularities, and Conformal Mappings [10 L]
This module explores convergence of series, including uniform convergence, power series, Taylor series, Laurent series, and the uniqueness theorem. It also includes analytic continuation, classification of singularities, Cauchy's residue theorem, evaluation of integrals using residues, argument principle, conformal mapping, and Möbius transformations.

Module 4: Theory and Solutions of Ordinary Differential Equations [10 L]
This module focuses on the existence and uniqueness of solutions to initial value problems for first-order ordinary differential equations, singular solutions, linear homogeneous ODEs with ordinary and singular points, series solutions using the Frobenius method, Fuchs's theorem, and

equations of Fuchsian type. It also covers linear non-homogeneous ODEs and the method of variation of parameters.

Module 5: Special Functions and Dynamical Systems **[10 L]**
This module covers Sturm–Liouville problems, eigenvalue problems, and the variational method. It includes completeness of eigenfunctions, Green's function, and the integral representation of solutions. The module also introduces systems of ODEs, including flow diagrams, phase portraits, isoclines, and the nature of fixed points with their stability. Topics on special functions include Legendre and Bessel functions, their orthogonality, Rodrigues formulas, and recurrence relations.

Reference Books:

1. E.T. Copson, An introduction to theory of functions of a complex variable, Oxford, Clarendon Press, 1962.
2. E.T. Whittaker and G.N. Watson, A course of modern analysis, Cambridge University Press, 1958.
3. R.V. Churchill, J.W. Brown and R.E. Vermay, Complex variables and applications, McGraw Hill, 1984.
4. T.M. MacRobert, Functions of a complex variable, MacMillan, 1962.
5. I.N. Sneddon, Special functions of Mathematical Physics and Chemistry, Longman, 1980.
6. E.A. Coddington and N. Levison, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1955.
7. E.L. Ince, Ordinary Differential Equations, Dover, 1956.
8. E.D. Rainville, Special Functions, MacMillan, 1960.
9. N.N. Labedev, Special Functions, and their applications, Dover, 1972.
10. L.V. Ahlfors, Complex Analysis, McGraw Hill, 1978.
11. W. Rudin, Real and Complex Analysis, McGraw Hill, 1986.
12. H.A. Priestley, Introduction to complex analysis, Indian Edition, 2006.
13. J.B. Conway, Functions of one complex variable I and II, Springer-Verlag, New York, 2005 and 1995

Course Outcomes (COs)
CO1: Define complex analytic functions, multivalued functions, and the topology of the complex plane.

CO2: Apply complex integration theorems to evaluate contour integrals and analyze analytic behavior.

CO3: Analyze series expansions, singularities, and conformal mappings in complex analysis.

CO4: Solve ordinary differential equations using power series and Frobenius methods.

CO5: Evaluate eigenvalue problems and dynamical systems using special functions and stability concepts.

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MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	3	1	2	2	-	1	2	3	1	2
CO2	3	3	2	2	2	-	1	2	3	2	1
CO3	3	3	2	2	2	1	1	2	3	2	2
CO4	3	2	2	3	2	1	1	2	3	2	3
CO5	3	2	2	3	2	1	1	3	3	2	3

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Course CC4: INTRODUCTION TO CONTINUUM MECHANICS
Credit: 4 (3L-1T-0P)

Module 1: Tensor Analysis and Deformation of Continuum [8 L]
Cartesian tensor, Lagrangian and Eulerian methods, finite strain, infinitesimal strain tensor, stretch and rotation, change in volume.

Module 2: Strain and Stress Analysis [14 L]
Relative displacement, strain quadratic, principal strains, strain invariants, compatibility conditions, body and surface forces, stress tensor, normal and shear stresses, principal stress, stress invariants, equilibrium and motion equations, symmetry of stress tensor.

Module 3: Elasticity and Generalized Hooke's Law [6 L]
Strain energy, generalized Hooke's law, isotropic elastic solids, elastic moduli for isotropic media, Beltrami-Michell compatibility equations.

Module 4: Fundamentals of Fluid Mechanics [8 L]
Basic concepts of fluid, classification of fluids, constitutive equations, equations of motion, streamlines, path-lines, vortex lines, circulation, vorticity.

Module 5: Inviscid and Viscous Fluid Flow [12 L]
Equation of continuity, Euler's equation of motion, Bernoulli's equation, Kelvin's minimum energy theorem, sources and sinks, Navier-Stokes equations, viscous flow between parallel plates.

Reference Books:
1. G. E. Mase: Theory and Problems of Continuum Mechanics, Schaum's Outline Series, Mc GrawHill Book Company.

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

Course Outcomes (COs)

CO1: Define tensor analysis and deformation methods in continuum mechanics.

CO2: Analyze strain and stress components and their equilibrium in solids.

CO3: Apply generalized Hooke's law and elasticity principles to isotropic materials.

CO4: Describe fundamental fluid mechanics concepts and fluid flow characteristics.

CO5: Solve governing equations for inviscid and viscous fluid flows.

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	2	2	2	-	1	2	3	2	3
CO2	3	3	2	3	2	-	1	2	3	2	3
CO3	3	2	2	3	2	-	1	2	3	2	3
CO4	3	2	2	2	2	-	1	2	3	2	3
CO5	3	2	3	3	2	-	1	2	3	3	3

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Course CC5: Discrete Mathematics, Graph Theory and Non-linear Dynamics
Credit 4: (3L-1T-0P)

Module 1: Foundations of Logic, Proof Techniques, and Combinatorics [10 L]
Propositional logic, Propositional equivalence, Predicates, Quantifiers, Methods of proof, Normal forms, Applications of logic, Pigeon-hole principle, Pascal's triangle, Principle of inclusion and exclusion.

Module 2: Generating Functions, Recurrence Relations, and Ordered Structures [10 L]
Generating functions, Recurrence relations, Partially Ordered sets, Lattices, Distributive lattices, Complete lattices, Dilworth's theorem, Diagram of binary relations, Matrix representation of relations, Switching circuits, Logic minimization, Clocks, Flip-flops.

Module 3: Fundamentals of Graph Theory and Tree Structures [12 L]
Graphs and examples, Paths, Cycles, Radius, Diameter, Girth, Circumference, Weighted distance metric, Euler Walk, Hamiltonian cycle, Connectivity, Subgraphs, Isomorphism, Properties of trees, Rooted Binary trees, Spanning Trees, Prim's algorithm, Kruskal's algorithm, Cycle subspace, Cut-set subspace, Relation between bases and spanning trees.

Module 4: Advanced Graph Concepts: Colouring, Planarity, and Flows [10 L]
Graph colouring, Chromatic number, Guthrie's four colour problem, Heawood's five colour map, Planarity, Crossing Number, Kuratowski's theorem (statement only), Directed graphs, Network flow, Max-flow min-cut theorem (statement only), Ford and Fulkerson algorithm.

Module 5: Introduction to Nonlinear Dynamics and Bifurcation Theory [6 L]
Flows on a line, Fixed points, Stability, Population growth, Diverstability, Analysis, Impossibility of oscillation, Potentials, Saddle-node bifurcation, Transcritical bifurcation, Pitchfork bifurcation, Imperfect bifurcation, Catastrophes, Insect outbreak.

Reference Books:

1. I.M. Copi, Symbolic Logic, Prentice Hall of India.
2. K.H. Rosen, Discrete Mathematics and Its Applications, Tata McGraw Hill.
3. Rene Cori and Daniel Lascar, Mathematical Logic, A Course with Exercise, Oxford University Press.
4. C.L. Chang and Lee, Mechanical Theorem Proving, Academic Press.
5. T.C. Bartee, Digital Computer Fundamentals, Tata McGraw Hill.
6. D.D. Givone, Introduction to Switching Circuit Theory, McGraw Hill Book Company.
7. J.L. Gross and J. Yellen, Graph Theory and its applications, CRC Press, 2005.
8. S.H. Strogatz, Non-linear Dynamics and Chaos, Addison-Wesley Publ. Co., New York, (1994).

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Course Outcomes (COs): On completion of the course, the student should be able to:

CO1. Explain fundamental concepts of propositional logic, quantifiers, and combinatorial principles.

CO2. Demonstrate the use of generating functions and recurrence relations to solve discrete mathematical problems and apply lattice theory.

CO3. Differentiate various graph structures to analyze their properties using concepts like Euler walks, spanning trees, and cycle subspaces.

CO4. Verify the correctness and effectiveness of graph coloring techniques, network flow algorithms, and planarity tests.

CO5. Formulate nonlinear dynamic models to describe real-world phenomena involving population growth, stability, and bifurcation behaviours.

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	-	-	2	3	2	-
CO2	3	3	2	2	2	-	-	2	3	3	3
CO3	3	3	2	3	2	-	-	2	3	3	2
CO4	3	3	2	3	2	-	-	2	3	3	2
CO5	3	3	2	2	3	2	2	3	3	3	3

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SEMESTER II
Course CC6: NUMERICAL ANALYSIS
Credit 4: (3L-1T-4P)

Learning objectives: On completion of the course, students will be able to solve complicated mathematical problems and real-life problems numerically. Also, they can apply MATLAB and other convenient numerical software such as Microsoft Excel to solve numerical problems with the help of simple programming.

Prerequisite: Before learning the course, the learner should have a basic knowledge about integration, differentiation, real number system, system of equations, linear algebra.

Module 1: [8 L]

Computer Number System:

Control of round-off-errors, Instabilities – Inherent and Induced, Hazards in approximate computations, Well posed computations, Well-posed and Ill-posed problems, The direct and inverse and identification problems of computation.

Numerical Solution of System of Linear Equations:

Triangular factorisation methods, Matrix inversion method, Operation counts, Iterative methods – Jacobi method, Convergence condition of Gauss-Seidel method and Gauss-Jacobi method, Importance of diagonal dominance, Successive-Over-Relaxation (SOR) method, Solution of over-determined system of linear equations – Least squares method, III conditioned matrix, Algorithms.

Module 2: [6 L]

Eigenvalues and Eigenvectors of Real Matrix:

Power method for extreme eigenvalues and related eigenvectors, Jacobi’s method for symmetric matrix (algorithm only).

Solution of Non-linear Equations:

Single Equation: Modified Newton-Raphson method (for real roots-simple or repeated). Aitken’s δ^2 -method and Steffensen’s iteration.

Module 3: [8 L]

Roots of Real Polynomial Equations:

Sensitivity of polynomial roots, Bairstow’s method of quadratic factors, Quotient-difference method (algorithm only).

Non-Linear Systems of Equations:

Newton’s method, Quasi-Newton’s method.

Polynomial Interpolation:

Weirstrass’s approximation theorem (Statement only), Runge’s phenomena, Divergence of sequences of interpolation polynomials for equi-spaced interpolation points, piecewise polynomial inter-polation – Cubic spline interpolation, Convergence properties (statement only), Inverse interpolation, Numerical differentiation using equi-spaced points.

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Module 4: [8 L]

Approximation of Functions:

Approximation with orthogonal polynomials, Chebyshev polynomials.

Numerical Integration: Problem of approximate quadrature, Gauss-Legendre and Gauss-Chebyshev quadratures, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration, Simpson's adaptive quadrature, Fredholm integral equation, Double integrals – Cubature formula of Simpson Type, Improper integrals.

Numerical Solution of Initial Value Problems for ODE:

First Order Equation: Runge-Kutta methods, Multistep predictor-corrector methods – Adams-Bashforth method, Adams-Moulton method, Milne's method, Convergence and stability.

Module 5: [6 L]

Two-point Boundary Value Problems for ODE:

Finite difference methods.

Numerical Solution of PDE by Finite Difference Methods:

Parabolic equation in one dimension (Heat equation), Explicit finite difference method, Implicit Crank-Nicolson method, Elliptic Equations, Hyperbolic equation in one-space dimension (Wave Equation) – Finite difference method.

Numerical Analysis Lab [12 L]

Jacobi method, Gauss-Seidel method and Gauss-Jacobi method, Successive-Over-Relaxation (SOR) method.

Power method for extreme eigenvalues and related eigenvectors.

Modified Newton-Raphson method (for real roots-simple or repeated).

Bairstow's method of quadratic factors, Quotient-difference method (algorithm only).

Newton's method.

Finite difference methods : Parabolic equation in one dimension (Heat equation), Explicit finite difference method, Implicit Crank-Nicolson method, Elliptic Equations, Hyperbolic equation in one-space dimension (Wave Equation).

Reference Books:

1. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, N.Y. ,1965.
2. A. Ralston and P. Rabinowitz, A First Course in Numerical Analysis, McGraw Hill, N.Y., 1978.
3. S.D. Conte and C. DeBoor, Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill, N.Y., 1980.
4. K.E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1989.
5. W.F. Ames, Numerical Methods for PDEs, Academic Press, N.Y., 1977.
6. L. Collatz, Functional Analysis and Numerical Mathematics, Academic Press, N.Y., 1966.

***Pedagogy for Course Delivery**: Chalk, Board, Study Materials, pictures.*
***List of Professional Skill Development Activities (PSDA)**: N/A*
Continuous assessment: Quiz/assessment/presentation/problem solving etc.

Course Outcomes (COs): On completion of the course, the student should be able to:

CO1: Understand the error propagation in numerical analysis

CO2: Solve the system of linear and nonlinear equations using suitable numerical techniques.

CO3: Analyze the integral equations by suitable numerical techniques.

CO4: Evaluate the double integrals and initial value problems using suitable numerical technique.

CO5: Formulate a given physical problem in the form of PDE and solve it by suitable finite difference scheme.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO1	PO2	PO3	PO4	PO5	PO6	PO 7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	3	2	1	1	1	1	3	3	2
CO2	2	3	3	3	2	2	2	1	3	3	2
CO3	2	3	3	2	2	2	2	2	3	3	3
CO4	2	3	3	3	2	2	2	2	3	3	3
CO5	3	3	3	3	3	3	3	2	3	3	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course CC7: INTEGRAL TRASNFORMS AND INTEGRAL EQUATIONS
Credit 4: (3L-1T-0P)

Module I: Fourier Transform [10 L]:
Definition and properties; Inversion formula; Convolution theorem; Parseval's relation; Applications to solving differential and boundary value problems.

Module II: Laplace Transform [10 L]:
Laplace's Transform and its properties. Inversion by analytic method and by Bromwitch path. Lerch's Theorem. Convolution Theorem; Applications.

Module III: Z–Transform and Wavelet Transform [8 L]:
Z-transform: Definition and properties. Z-transform of some standard functions. Inverse Z-transforms. Applications.
Wavelet Transforms: Definition of wavelet, Examples, Window function, Windowed Fourier transform, Continuous wavelet transform, Discrete wavelet transform, Multiresolution analysis, Application to signal and image processing.

Integral Equations:
Module IV: Fredholm Integral Equations [10 L]:

Reduction of boundary value problem of an ordinary differential equation to an integral equation. Fredholm equation: Solution by the method of successive approximation. Numann series. Existence and uniqueness of the solution of Fredholm equation. Equations with degenerate kernel. Eigen values and eigen solutions.

Module V: Volterra and Abel Integral Equations [10]:
Volterra equation: Solution by the method of iterated kernel, existence and uniqueness of solution. Solution of Abel equation. Solution of Volterra equation of convolution type by Laplace transform.

Reference Books:

1. I.N. Sneddon, Fourier Transform, McGraw Hill, 1951.
2. F.C. Titchmash, Introduction to the theory of Fourier Integrals, Oxford Press, 1937.
3. Peter, K.F. Kahfitting, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
4. E.J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.
5. E.I. Jury, Theory and Application of Z-Transform, John Wiley and Sons, N.Y.
6. R.V. Churchill, Operational Mathematics, McGraw Hill, 1958.
7. D. Loknath, Integral Transforms and their Application, C.R.C. Press, 1995.
8. Introduction to Wavelet Transforms – Narasimhan, Basumallik and Veena

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9. D. Porter and D.S.G. Stirling, Integral Equations, Cambridge University Press, 2004.
10. H. Hochstadt, Integral equations, Wiley-Interscience, 1989.
11. A. Wazwaz, A first course in integral equations, World Scientific, 1997.
12. F.G. Tricomi, Integral Equations, Dover, 1985.
13. Ram P. Kanwal, Linear Integral Equation – Theory and Technique, Academic Press, Inc.
14. W.V. Lovitt, Linear Integral Equations, Dover, New York.
15. S.G. Mikhlin, Integral Equations, Pergamon Press, Oxford.
16. N.I. Mushkhelishvili, Noordhoff, Singular Integral Equations, Gronignen, Holland.
17. W. Pogorzclski, Integral Equations and Their Application, Vol. I, Pergamon Press, Oxford.

Course Outcomes:

After attending this course, the students will be able to

CO1: Explain the fundamental properties and applications of Fourier and Laplace transforms.

CO2: Apply Fourier, Laplace, Z, and Wavelet transform to mathematical and engineering problems.

CO3: Analyze the role of modern transform techniques, particularly wavelets, in image and signal processing.

CO4: Evaluate different types of Fredholm and Volterra integral equations for solvability and kernel characteristics.

CO5: Develop appropriate solution techniques for real-world problems using transform and integral equation methods.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	2	3	1	2	2	2	3	3	2
CO2	3	2	2	3	2	1	3	2	3	2	2
CO3	3	3	2	3	2	3	3	2	3	3	2
CO4	3	3	2	3	2	2	3	2	3	3	3
CO5	3	3	2	2	3	2	2	3	3	3	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course CC8: PYTHON PROGRAMMING
Credit 4: (3L-1T-4P)

MODULE 1: Python Basics and Foundations [6L]

Installation and Working with Python, Understanding Python Variables, Python Basic Operators, Understanding Python Blocks, Declaring and Using Numeric Data Types: int, float, complex, Using String Data Type and String Operations, Defining List and List Slicing, Use of Tuple Data Type

MODULE 2: Control Structures and Functions [8L]

Conditional Blocks using if, else and elif, Simple for Loops in Python, For Loop using Ranges, String, List and Dictionaries, Use of While Loops in Python, Loop Manipulation using pass, continue, break and else, Programming using Python Conditional and Loops Block, Organizing Python Codes using Functions, Organizing Python Projects into Units, Importing Own Unit as well as External Modules, Understanding Packages, Powerful Lambda Function in Python, Programming using Functions, Modules and External Packages

MODULE 3: Advanced Data Handling [6L]

Building Blocks of Python Programs, Understanding String In-Build Methods, List Manipulation using In-Build Methods, Dictionary Manipulation, Programming using String, List and Dictionary In-Build Functions, Reading Config Files in Python, Writing Log Files in Python, Understanding Read Functions: read(), readline(), and readlines(), Understanding Write Functions: write() and writelines(), Manipulating File Pointer using seek(), Programming using File Operations

MODULE 4: Object-Oriented Programming and Error Handling [8L]

Concept of Class, Object and Instances, Constructor, Class Attributes and Destructors, Real-Time Use of Class in Live Projects, Inheritance, Overlapping and Overloading Operators, Adding and Retrieving Dynamic Attributes of Classes, Programming using OOPs Support, Powerful Pattern Matching and Searching, Power of Pattern Searching using Regex in Python, Real-Time Parsing of Networking or System Data using Regex, Password, Email, URL Validation using Regular Expression, Pattern Finding Programs using Regular Expression, Avoiding Code Break using Exception Handling, Safeguarding File Operation using Exception Handling, Handling and Helping Developer with Error Code, Programming using Exception Handling

MODULE 5: Applied and Advanced Python Programming [8L]

SQL Database Connection using Python, Creating and Searching Tables, Reading and Storing Config Information on Database, Programming using Database Connections, Understanding Threads, Forking Threads, Synchronizing the Threads, Programming using Multithreading,

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Installing SMTP Python Module, Sending Email, Reading from File and Sending Emails to All Users Addressing Them Directly for Marketing, Writing Python Program for CGI Applications, Creating Menus and Accessing Files, Server Client Program

Python Lab [12 L]

References :

1. Python pocket reference – Mark Lutz
2. Python for data analysis – Wes McKinney

Course Outcome (CO):

CO1: Define core Python concepts including variables, data types, and basic operators.

CO2: Illustrate the use of control flow structures, loops, and iteration in solving problems.

CO3: Implement functions, modules, and error handling to create efficient Python applications.

CO4: Analyze and manipulate data structures like strings, lists, and dictionaries for problem-solving.

CO5: Demonstrate Python skills in file operations, object-oriented programming, regex, database handling, and multithreading.

MAPPING OF COs WITH POs AND PSOs

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

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Course CC9: ELASTIC DEFORMATION
Credit 4: (3L-1T-4P)

SYLLABUS OUTLINE:

Module 1: [10 L]

Strains and rotations in orthogonal curvilinear coordinates. Determination of displacements from strain tensor. Stress equations of equilibrium and motion in orthogonal curvilinear coordinates. Anisotropic bodies. Stress-strain relations in anisotropic elasticity. Fundamental boundary value problems of elastostatics. Saint-Venant' principle. Saint-Venant'ssemi inverse method.

Module 2: [10 L]

Plane strain, plane stress and generalized plane stress. Airy's stress function in rectangular and polar coordinates. Compatibility equations. Rotating disks and other simple problems. Complex representations of 2-space biharmonic functions and boundary conditions.

Module 3: [8 L]

Kolosov-Muskhelisvili formulae for displacement and strain in terms of potential functions. Structures of complex potentials in multi-connected regions. Conformal mapping method. Solutions of simple problems such as loaded infinite plane/regions weakened by a circular hole, infinite plane with an elliptic hole, concentrated force in an infinite plate.

Module 4: [10 L]

Integro-differential equations of Muskhelisvili and their solutions for simple problems. Solutions of a boundary value problem for a half-space.

Module 5: [10 L]

Stress-strain relations in Thermo elasticity. Reduction of statistical thermo-elastic problem to a problem of isothermal elasticity. Basic equations in dynamic thermoelasticity. Coupling of strain and temperature fields. Concepts of generalized thermoelasticity and related theories.

References:

1. I. S. Sokolnikoff: Mathematical Theory of Elasticity. McGraw Hill, 1956.
2. A. E. H. Love: A treatise on mathematical theory of elasticity. Dover, 1954.
3. P.L. Gould: Introduction to linear elasticity. Springer-Verlog, 1994.
4. N. I. Muskhelisvili: Some basic problems on the theory of elasticity. Nordhoff, 1953.
5. Y. C. Fung: Foundation of solid mechanics. Prentice Hall, 1965.
6. L. D. Landau and E. M. Lifshitz: Theory of Elasticity. Pergamon Press, 1989.
7. J. D. Achenbach: Wave Propagations in Elastic Solids, North Holland Publishing Company.
8. K. F. Graff: Wave Motion in Elastic Solids, Dover Publications Inc.
9. W. Nowacki. Thermoelasticity, Addison-Wesley Publishing Co., 1962.
10. W. Nowacki: Dynamic Problems of Thermoelasticity, Noordhoff International Publishing
11. J. L. Nowinski. Theory of thermoelasticity with applications. Sijthoff and Noardhaoff International Publishers, 1978.
12. R. B. Hetnarski, M. R. Eslami : Thermal Stresses – Advanced Theory and Applications, Springer.

13. M. R. Eslami, R. B. Hetnarski, J. Ignaczak, N. Noda, N. Sumi, Y. Tanigawa: Theory of Elasticity and Thermal Stresses, Springer.
14. Ranjit S. Dhalwal and Avtar Singh. Dynamic Coupled Thermoelasticity, Hindustan Publishing Corporation, 1986.

Pedagogy for Course Delivery*: Chalk, Board, Study Materials, pictures.*
List of Professional Skill Development Activities (PSDA)*: N/A*
Continuous assessment: Quiz/assessment/presentation/problem solving etc.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Define the fundamental measures of strain, rotation, and displacement in orthogonal curvilinear coordinates, and state the corresponding equilibrium and compatibility conditions.

CO2: Explain the stress–strain relations in isotropic and anisotropic elastic bodies and the underlying concepts of Saint-Venant’s principle and boundary-value formulations.

CO3: Apply Airy’s stress function, Kolosov–Muskhelishvili potentials, and conformal mapping techniques to solve plane elasticity problems under various boundary conditions.

CO4: Analyze elastostatic and thermoelastic problems, including rotating disks, circular and elliptical holes, and multi-connected regions, using complex potential methods and equilibrium equations.

CO5: Evaluate thermoelastic interactions and coupled field effects by formulating and interpreting solutions of boundary value problems in dynamic and static thermoelasticity.

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	1	1	3	1	2
CO2	3	3	1	2	1	1	1	1	3	1	2
CO3	2	3	2	3	1	1	1	1	3	2	3
CO4	2	3	2	3	2	1	1	1	3	2	3
CO5	2	3	2	3	2	2	2	2	3	2	3

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SEMESTER III

CC10: Topology, Functional Analysis and Operator Theory
Credits: 4 (3L-1T-0P)

Module 1: Basic Topology and Topological Structures [6L]

Topological spaces: Elementary concepts, continuity, convergence, homeomorphism, Open bases and open subbases, Weak topologies, First and second countability, separable spaces.

Module 2: Compactness, Connectedness and Separation Axioms [8L]

Compactness, connectedness, local and path connectedness, Separation axioms, Urysohn's Lemma and Tietze Extension Theorem, Subspaces, product spaces, quotient spaces, Tychonoff's theorem, Metrizability, paracompactness, Urysohn'sMetrization Theorem.

Module 3: Normed Spaces and Hilbert Space Geometry [12L]

Normed linear spaces, linear topological spaces, Banach spaces, Hilbert spaces, Orthogonality in Hilbert spaces and related theorems:Orthogonal Projection Theorem, Best Approximation, Generalized Fourier Series, Bessel's Inequality, Complete orthonormal set, Parseval's Theorem

Module 4: Linear Functionals and Weak Topologies [10L]

Linear functionals: Dual spaces, reflexive property, Hahn-Banach Extension Theorem, Representation of linear functionals on Hilbert spaces (Riesz Representation Theorem)Strong and weak convergence of a sequence of elements and functionals, Weak topologies in Banach spaces, Banach-Alaoglu Theorem

Module 5: Linear Operators and Spectral Theory [12L]

Linear operators in normed linear spaces, Uniform and pointwise convergence of operators, Banach-Steinhaus Theorem (Uniform Boundedness), Open Mapping Theorem, Bounded Inverse Theorem, Closed linear operators, Closed Graph Theorem, Adjoint operator, self-adjoint operators, Normal and unitary operators, Compact symmetric operator, Hilbert-Schmidt Theorem, Eigenvalues and their properties, Spectral Theorem for bounded normal operators, Linear integral operator: Fredholm and Volterra types, Fredholm Alternative

Reference Books:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, Singapore, 1963.
2. J.R. Munkres, Topology, A First Course, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
3. H.L. Royden, Real Analysis, 4th ed., Macmillan Pub. Co., New York, 1993.
4. J.L. Kelley, General Topology, Von Nostrand, New York, 1995.
5. J. Dugundji, Topology, Allyn and Bacon, 1966 (Reprinted by PHI, India).

6. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.

Course Outcomes:

CO1: Discuss the concepts of topological spaces, continuity, compactness, and connectedness.

CO2: Use the principles of normed linear spaces and Hilbert space theory to **analyze** problems of orthogonality, projections, and Fourier series representations.

CO3: Examine the behaviour of linear functionals and sequences in Banach and Hilbert spaces, including their strong and weak convergence properties and duality.

CO4: Verify the continuity and boundedness of linear operators, and validate major theorems.

CO5: Construct rigorous proofs and construct operator-theoretic models abstract mathematical problem.

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	2	2	–	–	–	1	3	2	2
CO3	3	3	2	2	–	1	–	1	3	2	3
CO4	3	3	2	3	2	1	2	1	3	2	3
CO5	3	3	2	3	2	1	2	1	3	2	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

Course CC11: Artificial Intelligence and Data Science
Subject code: MATHP201T06
Credit 4: (3L-1T-0P)

Learning objectives: *On completion of the course, students will be able to: Develop an understanding of the fundamental concepts, algorithms, and applications of Artificial Intelligence and Data Science, demonstrate knowledge of machine learning and deep learning paradigms, and apply statistical and probabilistic models for intelligent decision-making. Students will also analyze the ethical, social, and creative dimensions of AI in real-world contexts.*

Prerequisite: *Before learning the course, learners should have a basic knowledge of linear algebra, probability theory, statistics, and programming concepts, including functions, loops, and data structures.*

SYLLABUS OUTLINE:

Module I: Foundations of Artificial Intelligence: [10L]

Introduction to Artificial Intelligence, Definition and Scope of AI, Historical overview and key milestones, Differentiating AI from human intelligence, AI Subfields and Technologies, Machine learning: Supervised, Unsupervised, and Reinforcement learning. Deep learning and neural networks, Natural language processing (NLP), and computer vision.

Module II: Applications of AI: [8L]

AI in healthcare: Diagnosis, treatment, and medical Imaging.
AI in finance: Fraud detection, algorithmic trading, and risk assessment,
AI in transportation: Autonomous vehicles and traffic optimization,
AI in customer service and chatbots AI in education: Personalized learning and intelligent tutoring systems, Ethical and Social Implications of AI, Bias and fairness in AI systems, Privacy and data protection concerns, Impact of AI on employment and the workforce, AI and social inequality, Other Important Issues, Ethical guidelines and responsible AI practices, AI and Innovation, Emerging trends and future directions in AI,
AI and creativity: Generative models and artistic Applications.

Module III: Linear Regression and Projection Techniques: [10L]

Problem Formulation, Parameter Estimation, Bayesian Linear Regression, and Maximum Likelihood Orthogonal Projection.

Module IV: Dimensionality Reduction: [10L]

Dimensionality Reduction with Principal Component Analysis, Maximum Variance Perspective, Projection Perspective, Eigenvector Computational Low-Rank Approximations, PCA in High Dimensions.

Module V: Probabilistic Modeling and Density Estimation: [10L]

Density Estimation with Gaussian Mixture Models, Gaussian Mixture Model Parameter Learning via Maximum Likelihood, EM Algorithm, Latent-Variable Perspective.

Text Books:
1. Artificial Intelligence by Elaine Rich, Kevin Knight, and Shivashankar B. Nair
2. Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville
3. Mathematics for Machine Learning by Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong.
4. Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck, and G. Geoffrey Vining.

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

CO1: Explain Artificial Intelligence and its core technologies.

CO2: Demonstrate the applications of Artificial Intelligence across various domains.

CO3: Differentiate the use of various regression techniques.

CO4: Verify the effectiveness of dimensionality reduction from different perspectives.

CO5: Construct probabilistic models for density estimation and uncover latent structures.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	1	2	1	2	1	2	3	2	3
CO2	3	3	3	2	2	2	1	2	3	3	3
CO3	3	3	2	3	3	2	2	2	2	3	3
CO4	3	3	2	3	2	-	-	2	3	3	2
CO5	3	3	2	2	3	2	2	3	3	3	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Course CC12: OPTIMIZATION AND OPERATIONS RESEARCH
Credit 4: (3L-1T-0P)

Course Content:

Module 1: Linear & Integer Programming [12L]

Linear programming, Revised simplex method, Dual simplex method, Post optimal analysis, Integer programming, Gomory's cutting plane method, Branch and bound technique.

Module 2: Nonlinear Programming [8L]

Nonlinear programming, Karush-Kuhn-Tucker necessary and sufficient conditions of optimality, Quadratic programming, Wolfe's method, Beale's method.

Module 3: Dynamic Programming & Sequencing [8L]

Dynamic programming, Bellman's principle of optimality, Recursive relations, System with more than one constraint, Solution of LPP using dynamic Programming.

Introduction to sequencing, processing N jobs through two machines, processing N jobs through three machines, processing N jobs through m machines.

Module 4: Inventory Models, Queuing, and Replacement [10L]

Inventory control, Concept of EOQ, Problem of EOQ with finite rate of replenishment, Problem of EOQ with shortages, Multi-item deterministic problem, Probabilistic inventory models.

Concepts relating to queuing systems, basic elements of queuing model, role of Poison & exponential distribution, concepts of birth and death process.

Replacement & Maintenance Models: Replacement of items, subject to deterioration of items subject to random failure group vs. individual replacement policies.

Module 5: Simulation, Network Analysis, Fuzzy Sets [10L]

Network Analysis: Network definition and Network diagram, probability in PERT analysis, project time cost trade off, introduction to resource smoothing and allocation.

Simulation: Introduction & steps of simulation method, distribution functions and random number generation.

Fuzzy Sets: Elements of Fuzzy set theory and its relevance in representing uncertainties, Fuzzy linear programming.

Reference books:

1. C. Hu, *Integer Programming and Network Flows*, Addison-Wesley, 1970.
2. G. Hadley, *Nonlinear and Dynamic Programming*, Addison-Wesley, 1972.
3. H.A. Taha, *Operations Research*, MacMillan Publ., 1982.
4. M.S. Bazaraa, H.D. Sherali, C.M. Shetty, *Nonlinear Programming*, J. Wiley & Sons.
5. J.C. Pant, *Introduction to Optimization*, New Delhi, Jain Brothers, 1983.

6. Sharma, J. K., *Operations Research: Theory and Applications*, 5th Edition, Macmillan, 2014.
7. Law, A. M., & Kelton, W. D., *Simulation Modeling and Analysis*, 5th Edition, McGraw-Hill, 2014.
8. Klir, G. J., & Yuan, B., *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall, 1995.
9. R.C. Pfaffenberger and D.A. Walker, *Mathematical Programming for Economics and Business*, The Iowa State University Press, 1976.
10. M.D. Intriligator, *Mathematical Optimization & Economic Theory*, Prentice-Hall, Inc., 1971.

Course Outcome (CO):
On completion of the course, student will be able to:

CO1: Illustrate the concepts of linear and integer programming problems using different techniques.

CO2: Solve nonlinear programming problems using various methods.

CO3: Formulate dynamic programming and sequencing models for multistage decision processes and job scheduling.

CO4: Verify inventory control models, queuing theory fundamentals, and replacement policies.

CO5: Design simulation experiments, network analysis, and fuzzy set theory to handle uncertainties.

CO-PO Mapping

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

1. LOW 2.MODERATE 3. SUBSTANTIAL

Avishik Adhikari Anisha Datta

Course CC13: FOUNDATION OF MATHEMATICS FOR MACHINE LEARNING
Credit 4: (3L-1T-0P)

Course Content:

Module 1: Vector Spaces and Linear Systems **[8L]**

vector space, linear combinations, independence, subspaces, basis, and dimension. Matrix, linear transformations and their geometric meaning, culminating in solving systems of linear equations using Gaussian elimination and LU decomposition.

Module 2: Analytic Geometry **[6L]**

Norms, Inner Products, Lengths and Distances, Angles and Orthogonality, Orthonormal Basis, Orthogonal Complement, Inner Product of Functions, Orthogonal Projections, Rotations

Module 3: Matrix Decompositions and Eigen Theory **[10L]**

Eigenvalues and eigenvectors, including their computation and relevance in dimensionality reduction techniques like PCA. Singular Value Decomposition (SVD), its properties, and broad applications. matrix factorizations such as QR and Cholesky decomposition and vector and matrix norms, condition numbers, and the implications of ill-conditioning in linear systems.

Module 4: Probability and Distributions **[8L]**

Construction of a Probability Space, Discrete and Continuous Probabilities, Sum Rule, Product Rule and Bayes' Theorem, Summary Statistics and Independence, Gaussian Distribution Conjugacy and the Exponential Family, Change of Variables, Inverse Transform

Module 5: Optimization Techniques **[8L]**

Continuous Optimization, Optimization Using Gradient Descent, Constrained Optimization and Lagrange Multipliers, Convex Optimization

Module 6: When Models Meet Data **[8L]**

Data, Models and Learning, Empirical Risk Minimization, Parameter Estimation, Probabilistic Modelling and Inference, Directed Graphical Models.

Text Book:

1. **Mathematics for Machine Learning"-** Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong
2. **"Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares"-** Stephen Boyd, Lieven Vandenberghe
3. **Pattern Recognition and Machine Learning"**-Christopher M. Bishop

The objective of the course

CO1: Explain the fundamental concepts of vector spaces and linear transformations.

CO2: Interpret analytic geometry concepts in high-dimensional data.

CO3: Formulate matrix decompositions and eigenvalue problems.

CO4: Construct probabilistic models using principles of probability theory.

CO5: Create optimization techniques 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	2	3	1	1	2	2	3	2	2
CO2	2	2	2	3	1	1	2	2	3	2	2
CO3	3	2	3	3	1	1	2	2	3	3	2
CO4	2	3	2	3	1	1	2	2	2	3	3
CO5	2	3	3	3	2	1	3	2	2	3	3

1. LOW 2.MODERATE 3. SUBSTANTIAL

Avishek Adhikari Anisha Dutta

Course CC14: FINANCIAL MATHEMATICS AND BIOMATHEMATICS
Credit: 4 [3 L + 1 T]

Learning Objectives
Upon completion of this course, students will acquire knowledge of financial concepts such as options (call and put), exercise price, exercise time, interest rates, and present value analysis. They will also understand rate of return, pricing via arbitrage, risk-neutral probabilities, the multi-period binomial model, and the arbitrage theorem. On the biological side, students will be introduced to basic concepts of ecology and mathematical modeling in epidemiology.

Prerequisite
Students are expected to have a basic understanding of **Probability and Statistics** before taking this course.

Syllabus Outline

Module I [6L]
Covers Brownian Motion (BM) and Geometric Brownian Motion (GBM), along with their derivation as limits of simpler models.

Module II [6L]
Focuses on financial mathematics topics including interest rates, present value analysis, and rate of return. Applications of continuously varying interest rates are also discussed.

Module III [14L]
Introduces option pricing and arbitrage pricing methods. It includes the arbitrage theorem, the multi-period binomial model, the Black–Scholes formula, and delta hedging. The module also covers valuation via expected utility and portfolio selection.

Module IV: [10L]
Fundamentals of biomathematics and ecology. It introduces mathematical modelling types and limitations, including discrete-time and continuous-time dynamical models. Non-age structured population models like exponential and logistic growth are formulated and solved.

Module V: [12L]
Age-structured single-species models, including continuous-time models and the Lotka integral equation. It also introduces mathematical models in epidemiology, such as SI and SIS models, their formulation, and solutions with examples.

References

1. S.M. Ross, *An Elementary Introduction to Mathematical Finance*
2. S.N. Neftchi, *An Introduction to Mathematics of Financial Derivatives*
3. R.J. Elliot and P.E. Kopp, *Mathematics of Financial Markets*
4. J.D. Murray (2001), *Mathematical Biology*, Vol. I & II, Springer-Verlag
5. Mark Kot (2001), *Elements of Mathematical Ecology*, Cambridge University Press

6. Bhupendra Singh and N. Agrawal (2008), *Bio-Mathematics*, Krishna Prakash Media (P) Ltd.

Pedagogy for Course Delivery
Hybrid mode including offline classroom teaching, presentations, video resources, MOODLE, and NPTEL materials.

Professional Skill Development Activities (PSDA)
Not Applicable (NA)

Assessment Methods
Assessment will be continuous and may include quizzes, assignments, presentations, and problem-solving exercises.
Course Outcomes

CO1: Define the mathematical formulation of Brownian Motion and Geometric Brownian Motion.

CO2: Calculate and compare different interest rates and apply present value analysis.

CO3: Analyze pricing strategies using arbitrage theory, multi-period binomial models, and the Black-Scholes formula.

CO4: Construct population models using exponential, logistic growth, and Lotka integral equations.

CO5: Formulate and solve SI and SIS epidemiological models.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	**PROGRAMME OUTCOMES**								**PROGRAMME SPECIFIC OUTCOMES**		
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO7**	**PO8**	**PSO 1**	**PSO2**	**PSO3**
CO1	3	2	2	3	1	3	1	2	2	2	3
CO2	3	2	2	3	1	2	1	2	1	2	2
CO3	3	3	2	3	2	2	1	2	3	2	3
CO4	3	2	2	3	2	2	1	3	2	2	3
CO5	3	2	2	3	2	2	1	3	2	2	3

1. LOW 2. MODERATE 3. SUBSTANTIAL

Avishek Adhikari Anisha Dutta

Course CC15: FRACTIONAL CALCULUS AND THEORY OF RELATIVITY
Credit 4: (3L-1T-0P)

Learning objectives: The objective of this course is to introduce students to the core concepts of fractional calculus and relativity, focusing on special functions, fractional derivatives, and methods for solving fractional differential equations. It also aims to develop a foundational understanding of special and general relativity through Lorentz transformations, tensor analysis, and space-time geometry, equipping students with essential tools for advanced applications in mathematics and physics.

Prerequisite: student must have basic knowledge of calculus and partial derivatives and integrals and they must know Laplace transform.

SYLLABUS OUTLINE:

Module I: Special Functions and Foundations of Fractional Calculus [10 L]
Introduction to fractional calculus: motivation and applications, Gamma function: properties and role in fractional calculus, Mittag-Leffler function: definition, series form, and applications, Wright function: significance and comparison with Mittag-Leffler, Basic concepts of fractional derivatives and integrals, Riemann–Liouville and Grunwald–Letnikov definitions, Geometric and physical interpretation.

Module II: Fractional Differential Equations and Solution Methods [10 L]
Properties of fractional derivatives: linearity, sequential derivatives. Laplace, Fourier, Mellin transforms of fractional derivatives. Linear fractional differential equations: general form. Existence and uniqueness theorem (statement only). Laplace transform method for solving FDEs. Standard and sequential fractional differential equations.

Module III: Foundations of Special Relativity [10 L]
Galilean transformations, inertial frames. Michelson–Morley experiment and its consequences. Lorentz transformations and derivation. Concepts of simultaneity, time dilation, and Lorentz contraction. Acceleration under Lorentz transformations. Constancy of the speed of light and basic postulates.

Module IV: Minkowski Geometry and Tensor Analysis [10 L]
Minkowski spacetime: diagrams and intervals. Differentiable manifolds, tangent and cotangent spaces. Covariant and contravariant tensors. Tensor transformation rules and tensor spaces. Metric tensor and scalar product in relativity. Relativistic momentum and energy, spacelike/time-like intervals.

Module V: General Relativity – Concepts and Geometry [8 L]
Affine connection and covariant differentiation. Parallel transport and its physical meaning. Geodesic equations: derivation and examples. Role of the metric in defining curvature. Basic principles and postulates of general relativity. Physical interpretation of geodesics and curvature.

Texts/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,
4. Introduction to Cosmology by Jayant V. Narlikar, Cambridge University Press
5. A First Course in General Relativity by Bernard Schutz, Cambridge University Press

Pedagogy for Course Delivery: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)
List of Professional Skill Development Activities (PSDA):NA
Continuous assessment: Quiz/assessment/presentation/problem solving etc.
Continuous assessment: Quiz/assessment/presentation/problem solving etc.

COURSE OUTCOMES:

After attending this course, the students will be able to

CO1: Define the key concepts of fractional calculus, including fractional derivatives, integrals, and special functions such as Gamma, Mittag-Leffler, and Wright functions**.**

CO2: Explain the properties of fractional differential equations and demonstrate how integral transform techniques such as Laplace and Fourier transforms are applied to obtain their solutions.

CO3: Apply Lorentz transformations and relativistic kinematic relations to analyze time dilation, length contraction, and other phenomena within the framework of Special Relativity.

CO4: Analyze Minkowski spacetime and tensor operations, including covariant and contravariant transformations, to interpret geometric and physical quantities in relativistic systems.

CO5: Evaluate the geometric principles of General Relativity by formulating geodesic equations and interpreting the role of curvature and covariant differentiation in describing gravitational phenomena.

MAPPING OF COs WITH POs AND PSOs

COURSE OUTCOMES	PROGRAMME OUTCOMES								PROGRAMME SPECIFIC OUTCOMES		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PSO 1	PSO2	PSO3
CO1	3	2	1	3	3	-	1	1	3	1	2
CO2	2	3	2	1	2	1	1	1	2	3	2
CO3	1	3	1	2	2	2	2	1	2	2	3
CO4	2	3	1	2	1	2	2	1	3	2	3
CO5	1	2	-	2	2	1	3	1	2	1	3