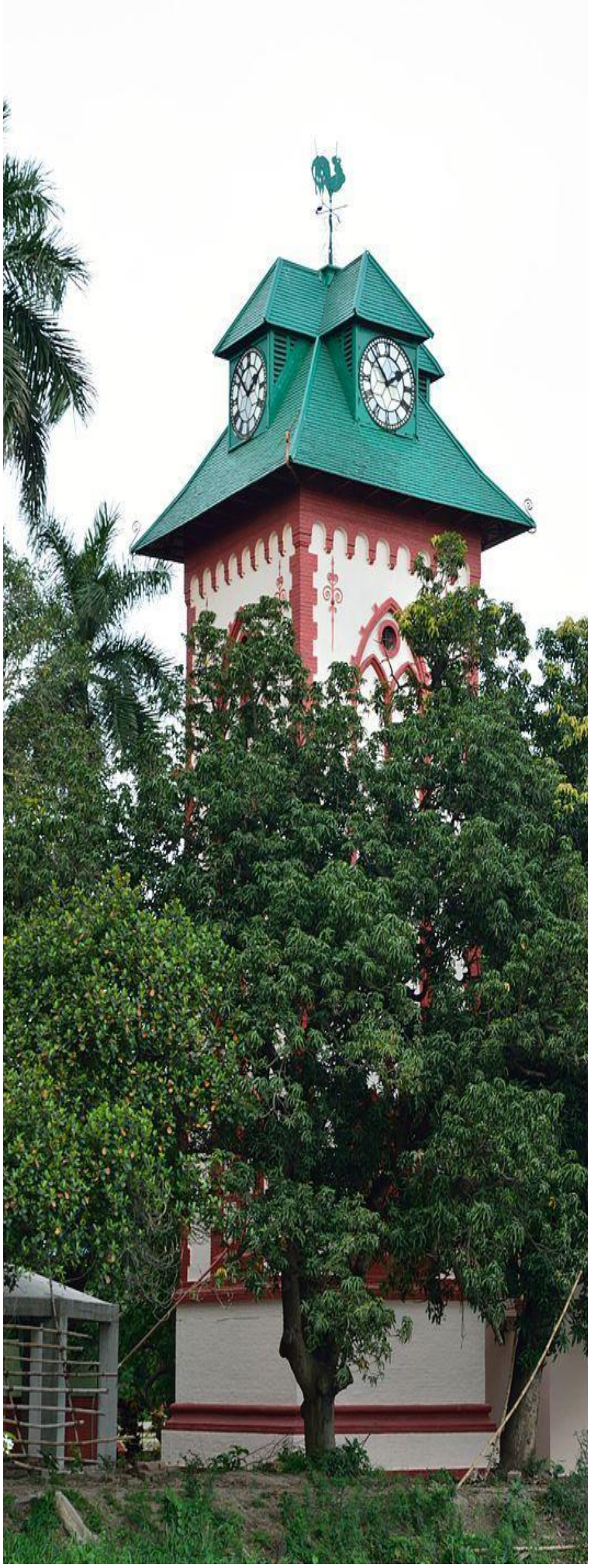

# Department of Mathematics

## Postgraduate Programme

**Course Structure and Syllabus**

(Effective from 2025-26 admitting batch onwards)

**Indian Institute of Engineering Science and Technology (IIEST), Shibpur**

**Botanic Garden, Howrah**

**COURSE STRUCTURE FOR M. Sc.**
**Credits to be Earned: 90-96**
**[Mandatory Credits: Project: 20, Term Paper: 04, Internship: 02, OE: 06, VAC: 03, Rest: PC/ PSE (Theory/ Practical)]**
**[Per semester credits: 20-26]**

***First Semester***

| Sl. No. | Type | Course Name | Course code | Class Load/Week L | Class Load/Week T | Class Load/Week P | Credit | Class load/ week | Marks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | PC | Mathematical Analysis | MA5101N | 3 | 1 | 0 | 4 | 4 | 100 |
| 2 | PC | Complex Analysis and Numerical Analysis | MA5102N | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | PC | Linear Algebra and Abstract Algebra | MA5103N | 3 | 1 | 0 | 4 | 4 | 100 |
| 4 | PSE | Computational Techniques and Programming/ Probability and Statistical Methods(Some Selected Topics) | MA5121N/ MA5122N | 3 | 0 | 0 | 3 | 3 | 100 |
| 5 | OE | Discrete Mathematics | MA5161N | 3 | 0 | 0 | 3 | 3 | 100 |
| | | **Theory Sub-total** | | | | | **18** | | **500** |
| 6 | PC | Programming Lab | MA5171N | 0 | 0 | 3 | 2 | 3 | 50 |
| 7 | PC | Mini Project - I | MA5172N | 0 | 0 | 3 | 2 | 3 | 50 |
| | | **Practical Sub-total** | | | | | **4** | | **100** |
| | | **First Semester Total** | | | | | **22** | | **600** |

***Second Semester***

| Sl. No. | Type | Course Name | Course code | Class Load/Week L | Class Load/Week T | Class Load/Week P | Credit | Class load/ week | Marks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | PC | Ordinary Differential Equations and Dynamical Systems | MA5201N | 3 | 1 | 0 | 4 | 4 | 100 |
| 2 | PC | Partial Differential Equations and Calculas of Variation | MA5202N | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | PC | Topology and Tensor Analysis | MA5203N | 3 | 1 | 0 | 4 | 4 | 100 |
| 4 | PSE | Mathematical Biology/Mathematical Optimization Techniques | MA5221N/ MA5222N | 3 | 0 | 0 | 3 | 3 | 100 |
| 5 | OE | Numerical Solutions for ODEs and PDEs | MA5261N | 3 | 0 | 0 | 3 | 3 | 100 |
| | | **Theory Sub-total** | | | | | **18** | | **500** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | PC | Simulation Lab | MA5272N | 0 | 0 | 3 | 2 | 3 | 50 |
| 7 | PC | Mini Project - II | MA5271N | 0 | 0 | 3 | 2 | 3 | 50 |
| | | **Practical Sub-total** | | | | | **4** | | **100** |
| 8 | P | Term-paper | MA5291N | 0 | 0 | 4 | 2 | 4 | 50 |
| 9 | O | Term Paper Viva Voce | MA5292N | 0 | 0 | 0 | 2 | 0 | 50 |
| | | **Term Paper Sub-total** | | | | | **4** | | **100** |
| | | **Second Semester Total** | | | | | **26** | | **700** |

| ***Third Semester*** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sl. No.** | **Type** | **Course Name** | **Course code** | **Class Load/Week** | | | **Credit** | **Class load/ week** | **Marks** |
| | | | | **L** | **T** | **P** | | | |
| 1 | PC | Continuum Mechanics | MA6101N | 3 | 1 | 0 | 4 | 4 | 100 |
| 2 | PC | Operation Research and Integral Transformations | MA6102N | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | PC | Functional Analysis and Integral Equations | MA6103N | 3 | 1 | 0 | 4 | 4 | 100 |
| | | **Theory Sub-total** | | | | | **12** | | **300** |
| 4 | PC | Computational Laboratory | MA6171N | 0 | 0 | 3 | 2 | 3 | 50 |
| | | **Practical Sub-total** | | | | | **2** | | **50** |
| 5 | P | M. Sc. Thesis Part-I (Progress report) | MA6191N | 0 | 0 | 12 | 6 | 12 | 100 |
| 6 | O | Progress report Viva voce | MA6192N | 0 | 0 | 0 | 2 | 0 | 100 |
| 7 | I | Summer internship (6-8 weeks) evaluation | MA6193N | NA | NA | NA | 2 | NA | 50 |
| | | **M. Sc. Thesis Sub-total** | | | | | **10** | | **250** |
| | | **Third Semester Total** | | | | | **24** | | **600** |

| ***Fourth Semester*** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sl. No.** | **Type** | **Course Name** | **Course code** | **Class Load/Week** | | | **Credit** | **Class load/ week** | **Marks** |
| | | | | **L** | **T** | **P** | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **VAC** | Value Added Course | | 3 | 0 | 0 | 3 | 3 | 100 |
| 2 | PC | Electrodynamics and Classical Mechanics | MA6201N | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | PSE | Wave and Vibrations in Elastic Solid Media/ Advanced Fluid Dynamics | MA6221N/ MA6222N | 3 | 0 | 0 | 3 | 3 | 100 |
| | | **Theory Sub-total** | | | | | **10** | | **300** |
| 4 | P | M.Sc Thesis | MA6291N | 0 | 0 | 16 | 8 | 16 | 200 |
| 5 | O | Thesis Seminar and Viva-voce | MA6292N | 0 | 0 | 0 | 4 | 0 | 100 |
| | | **M. Sc. Thesis Sub-total** | | | | | **12** | | **300** |
| | | **Fourth Semester Total** | | | | | **22** | | **600** |

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|---|---|
| **Total Credits:** | **94** |

**Type of courses**

Basic Science Course (BSC)
Engineering Science Course (ESC)
Humanities and Social Sciences Course (HSC)
Program Core Courses (PC)
Program Specific Elective Course (PSE)
Open Electives (OE)
Value Added Course (VAC)
Project (P)
Internship (I)
Other (O) such as seminar, viva voce, etc.

| Course Code | MA5101N | Course Name | Mathematical Analysis | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | Differential and Integral Calculus | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | MATHEMATICS | | Data Book / Codes/Standards | |

| Course Objective | The course aims at imparting the students with knowledge of multivalued differential calculus and the theory of integration in the general framework. It is basic to the understanding of almost all areas of mathematics. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | Functions of several variables. Differentiability of mappings $f$: $R^n \rightarrow R^m$. Derivative as a linear transformation. Role of Jacobian. Derivative of composite mappings, Contraction mapping principle, Implicit function theorem, Inverse function theorem, Rank of a mapping, Rank theorem. | 22 | Knowledge of multivalued calculus is imparted. |
| 2 | Differential forms, k-forms in $R^n$ and their properties, Theory of integration on differential form, Stoke's Theorem.<br><br>Measurable space. Construction of measurable sets and measure through outer measure. Almost everywhere properties of functions. Measurable functions and their integration. Finite measures. Consideration of Lebesgue integral on $R^n$, Fatau's lemma monotone convergence theorem, dominated convergence theorem. Convergence in measure. | 34 | Integration theory in real and abstract spaces is imparted in details. |
| | | 56 | |

| Course Outcome | For the students it is an essential knowledge base in higher studies of mathematics and its applications. It helps the students to understand the use of analytic techniques of applied mathematics. |
|---|---|
| Learning Resources | 1. Bruckner A. M., Bruckner, J. B., Thomson B.S., Real Analysis, Prentice Hall Inc, NJ, 1997.<br>2. Rudin W., Principles of Mathematical Analysis, McGraw-Hill, 1976. |

| | |
|---|---|
| | 3. Royden H.L., Real Analysis, MACMILLAN, 1963. |

| Course Code | MA5102N | Course Name | Complex Analysis and Numerical Analysis | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | Real analysis, Calculus, Classical algebra. | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | MATHEMATICS | | Data Book / Codes/Standards | |

| Course Objective | The objective here is to introduce to the students the basics of complex analysis and numerical analysis as core areas of mathematics and computation respectively. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Complex Analysis:** Topological structure of Complex Plane, Simply connected and multiply connected domains. Homotopic version. Spherical representation of extended complex plane, Analytic Functions, Harmonic functions, Subharmonic functions and applications, Littlewood's condition for subharmonic functions,<br><br>Complex integration, Cauchy's Theorem and Integral Formula, Winding Numbers, Cauchy's estimate, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra. Maximum modulus principle, Schwarz Lemma, Taylor series, Laurent series, Zeros and poles of complex functions, Meromorphic functions. Hurwitz Theorem, Classification of singularities, Residue theorem, Argument Principle, Theorems of Rouche and Gauss-Lucas, Contour integration and its applications to improper integrals, Evaluation of real integrals, Improper integrals involving sines and cosines, Definite integrals involving sines and cosines, Integration through branch cut,<br><br>Conformal Mapping, Mobius Transformations, Schwarz-Christoffel Transformation. Weirstrass' theorem, Montel's theorem and its application to establish Vitali's theorem. Harnack's inequality and its use in establishing Harnack's principle. | 42 | The materials taught will provide the framework of learning several advanced topics of mathematics including dynamical systems, integral transforms, etc. |

| | | | |
|---|---|---|---|
| 2 | **Numerical Analysis:** Eigenvalues and Eigenvectors of real matrix: Power method for extreme eigenvalues and related eigenvectors, Jacobi's and Householders methods for symmetric matrices.<br>Spline Interpolation: Cubic Spline.<br>Approximation of Functions: Least squares polynomial approximation, Approximation with orthogonal polynomials, Chebyshev polynomial, Lanczos economization.<br>Numerical Integration: Newton-Cotes' formula of closed type, Gaussian Quadrature.<br>Numerical solution of initial value problems for Ordinary Differential Equation (ODE): Multistep Predictor-Corrector methods, Adams-Bashforth method, Adams-Moulton method, Milne's method, Convergence and Stability.<br>Two-point boundary value problems for ODE: Finite difference and Shooting methods. | 14 | Knowledge of numerical analysis is provided forming the basis of computation. |
| | | **56** | |

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| **Course Outcome** | The students are introduced with complex analysis to the essential depth required for further studies in applied mathematics. This knowledge is an indispensable component of the Applied Mathematics program having requirement in most of the subjects taught herein.<br>The students are introduced to the underlying theory of computation through the study of numerical analysis. |

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|---|---|
| **Learning Resources** | **Complex Analysis**:<br>1. Churchill, R. V. and Brown, J. W., "Complex Variables and Applications" 5th edition, McGrawHill. 1990.<br>2. Gamelin, T. W., "Complex Analysis", Springer-Verlag 2001.<br>3. Greene R., and Krantz, S. G., "Function Theory of One Complex Variable", 3rd Edition, GSM, Vol. 40, American Mathematical Society. 2006.<br>4. Lang, S., "Complex Analysis", Springer –Verlag, 2003.<br>5. Narasimhan, R. and Nivergelt, Y., "Complex Analysis in One Variable", Birkhauser, Boston, 2001.<br>6.Ahlfors, L. V., "Complex Analysis", 3rdEdn., McGrawHill, New York,1979.<br>7.Conway, J.B. "Functions of one complex variable", Springer –Verlag, 1978.<br>**Numerical Analysis**:<br>1. Introductory Methods of Numerical Analysis – S.S. Sastry (PHI Publications)<br>2. Introduction to Numerical Analysis – A. Gupta and S.C. Bose (Academic Press)<br>3. Numerical Methods for Scientists and Engineers – K. Sankara Rao (PHI Publications)<br>4. Numerical Analysis – N. Datta and R.N. Jana (Shreedhar Prakashani). |

| Course Code | MA5103N | Course Name | Linear Algebra and Abstract Algebra | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | Vector spaces, Linear Transformation, Basic Group theory | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | |

| Course Objective | The objective of this course is<br>• to provide a comprehensive understanding of the fundamental concepts of Linear Algebra and Abstract Algebra and<br>• to prepare students to enhance both computational techniques and theoretical foundations for advanced mathematical studies and real-world applications. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| I | **Linear Algebra**<br><br>Quick review of Vector Space and Linear Transformation<br><br>Canonical Forms**:** Eigenvalues and eigenvectors of linear operators, Minimal polynomial, Cayley-Hamilton Theorem, Triangulation (Schur's theorem), Diagonalisation, Invariant subspaces, Generalized eigenvectors, Cyclic subspaces and annihilators, Rational canonical form, Jordan canonical representation.<br><br>Inner Product Space**:** Definition, Gram-Schmidt ortho-normalization, Orthogonal projections. Linear operators and adjoints, Self - adjoint, unitary and normal operators, Spectral theorem for normal operators.<br><br>Bilinear forms**:** Symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness. | 28 | By the end of this module, students will be able to:<br>1. Analyze and classify linear operators using canonical forms such as Jordan and rational canonical forms.<br>2. Apply spectral theory to diagonalize normal, self-adjoint, and unitary operators in complex inner product spaces.<br>3. Utilize bilinear and quadratic forms to study geometric and algebraic properties of vector spaces. |

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|---|---|---|---|
| **II** | **Abstract Algebra**<br><br>Group Theory: Review of basic Group Theory, Homomorphism, Isomorphism of groups, First and second isomorphism theorems, automorphisms and automorphism group, Inner automorphisms, Direct and semi-direct products, Group Actions, Kernel and Stabilizer of Group Actions, Cayley's Theorem, Burnside theorem, Conjugacy classes, Class Equation, Cauchy's theorem on finite groups, p-group, Centre of p-groups, Sylow's Theorem and applications: simplicity of groups, Classification of finite Abelian groups, Finite groups, Structure theorem for finite Abelian groups, Normal and Subnormal series, Composition series, Jordan–Holder theorem, Solvable groups and Nilpotent groups.<br><br>Ring Theory: Review of basic Ring Theory, Properties of Ideals, Prime and Maximal Ideals, Two-sided ideals and Quotient Rings, Euclidean Domain, Euclidean Algorithm, Principal Ideal Domain, Euclidean Domain is a Principal Ideal Domain, UFD, PID implies UFD, Polynomial Rings, Irreducibility of Polynomials, Eisenstein's criterion of irreducibility | 28 | By the end of this module, students will be able to:<br>1. Prove and apply key theorems in group theory, including Sylow's theorems, classification of finite Abelian groups, and group actions.<br>2. Analyze ring structures, including ideals, quotient rings, and factorization properties in integral domains and unique factorization domains. |
| | | 56 | |

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| **Course Outcome** | By the end of the course, students will be able to:<br>• understand the concept of similarity and its role in classifying linear operators.<br>• apply the properties of rings and fields to solve algebraic problems and understand polynomial algebra. |

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| **Learning Resources** | <u>Linear Algebra</u>**:**<br>1. Linear Algebra (4th Edition) by Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Pearson Education India, 2015<br>2. Linear Algebra (2nd Edition) by K. Hoffman and R. Kunze, Prentice Hall of India, 2005<br><u>Abstract Algebra</u>:<br>1. Abstract Algebra by David S. Dummit & Richard M. Foote, John Wiley & Sons, 2011<br>2. Fundamentals of Abstract Algebra by D. S. Malik, John N. Mordeson & M. K. Sen. The McGraw-Hill Companies, Inc., 1997<br>3. Abstract Algebra by I. N. Herstein, Prentice-Hall, 1996 |

| Course Code | MA5121N | Course Name | **Computational Techniques and Programming** | **Course Category** | Theory (PSE) | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

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|---|---|---|---|---|---|
| **Pre-requisite Courses** | Basic Mathematics & Introduction to computer fundamentals | **Co-requisite Courses** | Programing Lab | **Progressive Courses** | |
| **Course Offering Department** | | Mathematics | | **Data Book / Codes/Standards** | |

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| **Course Objective** | The primary objective of a "Computational Techniques and Programming" course is to equip students with the skills to solve problems using computational methods, specifically through the C programming language. Students can apply numerical methods for solving mathematical and engineering real problems using C. Students learn about different data structures (e.g., arrays, pointers, linked lists) and how to use them effectively in their programs. The objective is to equip learners with the skills to write, debug, and execute Python code, and to build a foundation for more complex programming tasks. |

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| I | **Numerical Methods** : Finite Difference Technique,<br>Numerical solution of different types of Partial Differential Equations by Finite Difference method,<br>Explicit and Implicit Methods,<br>Crank Nicholson Method. | 5 | • Apply numerical methods to solve problems in various domains |
| II | **Introduction to C Programing** : Flowchart, Algorithm, C language overview, Character set, Identifiers, Keywords and data types.<br>Arithmetic Operators.<br>Library Functions, Input/Output Statements, Relational Operators, Logical Operators, Bitwise Operators, Unary Operator, If-Else Statement, Switch statement. For Loop, While Loop, Do Loop, Nested Loop, Continue and Break statements. | 12 | • Use computers to solve problems by logical steps, sequence of action, repeated and iterative solution methods |

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|---|---|---|---|
| III | **Array and Structures** : Declaration, Concept of One Dimensional and Multi-Dimensional arrays, Defining Structure, Declaration of Structure Variable, Accessing Structure members, Nesting of structures, Array of structures, String manipulations, and Searching/Sorting algorithm. | 8 | • Able to store, access and manipulate complex data structures |
| IV | **Modular programing & Data Structure:** "C" function, User defined and Library functions, Prototype of function, Call by Value, Pointer Variable, Call by Reference, Nesting of functions, Recursion, Array as function-argument, Linked list, Stack, Queue, Binary Tree. | 10 | • Able to use modular programing & dynamic memory allocation . |
| V | **Introduction to Python** :Data types, Control Flow, Functions, String operations, Object-Oriented Programming. | 7 | • Able to develop problem solving skills by applying Python to solve real-world problems. |
| | | Total(Hrs.)=42 | |

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| **Course Outcome** | Upon completion of the course, the students will be able to:<br>• Use computers to solve problems by logical steps, sequence of action, repeated and iterative solution methods, which would otherwise be tedious or unsolvable by hand calculations.<br>• Apply numerical methods to solve problems in various domains.<br>• Understand and apply fundamental computational algorithms and data structures.<br>• Utilize pointers and dynamic memory allocation effectively in C programming.<br>• Demonstrate the ability to develop algorithms for solving problems and implement them in C.<br>• Students can apply their knowledge of Python in working on projects and solving real-world problems. |

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| **Learning Resources** | **References**:<br>1. Numerical Analysis – K. Atkinson & W. Cheney<br>2. Numerical Analysis and mathematics of scientific Computing - David Kincaid, & Ward Cheney<br>3. Introductory Method of Numerical Analysis – S.S. Sastry<br>4. The C Programming Language – Brian W. Kernighan, Dennis M. Ritchie<br>5. Let Us C – Yashavant Kanetkar<br>6. Programming in ANSI C – E. Balagurusamy |

| Course Code | MA 5122 | Course Name | Probability and Statistical Methods - Some Selected Topics | Course Category | PSE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | Real Analysis, Linear Algebra, Basic Probability | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | |

| Course Objective | To develop fundamental concepts of Probability Theory and Statistics with a view to applications involving real-life data |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| I | **Probability Theory**<br>Borel-Cantelli lemmas, Helly-Bray theorem, Glivenko-Cantelli theorem, Scheffe's theorem, Polya's theorem, Skorokhod representation. Characteristic functions- Lévy's continuity theorem, Applications- Central Limit Theorem (Lindeberg-Lévy), Lyapunov's CLT. | 21 | On completion of this module, students are expected to be well acquainted with some fundamental ideas and results in the domain of probability theory and be in a position to apply the same. |
| II | **Statistical Methods**<br><br>Sufficient and complete statistics, Minimal sufficient statistics, MVUE, MLE and its optimality properties, Neyman-Fisher factorization criterion, Rao-Blackwell theorem, Lehmann-Scheffe theorem, Cramer-Rao Inequality.<br><br>A brief introduction to Resampling Plans - the Jackknife and Bootstrap techniques.<br><br>Introduction to MCMC methods- Importance sampling, Gibbs sampler, The Metropolis-Hastings algorithms. | 21 | On completion of this module, students are expected to be equipped with basic statistical inference, resampling techniques and have a good working knowledge of MCMC methods. |

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| | | | |
| | | Total(Hrs.)= **42** | |

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| **Course Outcome** | On completion of the course, students are expected to:<br>• understand basic concepts of probability distributions, joint and conditional distributions etc., expectation, variance, correlation coefficient and their uses.<br>• understand various convergence concepts in probability theory and their interrelationships<br>• learn some fundamental results e.g., laws of large numbers, central limit theorem (CLT) etc.<br>• handle various inferential issues in statistics |

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|---|---|
| **Learning Resources** | • Grimmett, G. and Stirzaker, D. Probability and Random Processes. Oxford University Press.<br>• Bickel, Peter J. and Doksum. Mathematical Statistics: Basic Ideas and Selected Topics, Volume I, Second Edition.<br>• Efron, B. The Jackknife, the Bootstrap and Other Resampling Plans (CBMS-NSF Regional Conference Series in Applied Mathematics). |

| Course Code | MA5161N | Course Name | Discrete Mathematics | Course Category | OE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | NIL | Co-requisite Courses | None | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | |

| Course Objective | The main objectives of this Discrete Mathematics course are to provide students with a foundation in discrete mathematical structures, Boolean algebra, mathematical logic, and problem-solving skills relevant to science and engineering fields.<br>The objective is also to provide discrete structures such as graphs to study, model a computer network, and find the shortest path between two places in a transportation network. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module outcome |
|---|---|---|---|
| I | **Set, Relations and Functions:**<br>**Set Theory:** Concept of set, subset, super set, equality of sets, union and Intersection of sets, differences of sets, differences of sets, complement, power set, Cartesian product of sets, Venn diagram.<br>**Relation:** Binary relations-reflexivity, symmetry, anti-symmetry, transitivity, equivalence, partition of a set.<br>**Mapping:** Injective, surjective, bijective mapping, identity and inverse mappings, composition of mappings. | 6 | Students will gain foundational knowledge of sets, relations, and functions, and apply it to analyze and solve mathematical problems. |
| II | **Algebraic Structures:**<br>Algebraic system, monoids, free monoids, Definition of Group, finite Group, Subgroup, cosets, Lagrange's theorem, Homomorphisms, isomorphisms and automorphisms. Permutation groups, Normal subgroup and Factor group theory in coding theory. Definition of Ring, ring of integers, ring of integers modulo p (p being any prime or non-prime nos.), subring, ideals, module, finite module - example and properties, Submodule, ring homomorphisms, Polynomial rings, integral domain, field, finite integral domain as a field, finite fields. | 10 | The module will develop foundational understanding of algebraic structures—groups, rings, and fields—and their application in analyzing properties and interrelationships. |

| | | | |
|---|---|---|---|
| III | **Boolean Algebra:**<br>Posets, lattices, principle of duality, Boolean algebra and its properties, Atoms, Disjunctive and Conjunctive normal forms, Application to switching algebra. | 7 | The module will develop understanding of posets, lattices, and Boolean algebra, and their application to logical expressions and switching algebra. |
| IV | **Mathematical Logic:**<br>Proposition and definition of symbols, Truth tables, conjunction, Negation, Implication, Double implication, Tautology, Tautological equivalence, Proofs in propositional calculus, Conditional conclusions and indirect proofs, Truth set, Principle of induction and its variations. | 7 | The module will develop understanding of the principles of mathematical logic, including propositional calculus, truth tables, and mathematical induction, and their application in constructing and evaluating logical arguments. |
| V | **Predicate calculus:** Predicates, the statement function, variables and quantifiers, Predicate formulae, free and bound variables, valid formula and equivalence. | 3 | The module will develop understanding of predicate calculus, including predicates, quantifiers, and logical formulae, and their application in analyzing validity and equivalence of logical statements. |
| VI | **Graph Theory:**<br>Elementary and basic concepts of graph theory, path and circuits, Euler graph, Hamiltonian path and circuits, Trees and fundamental circuits, Cut sets and its application, Planner and dual graph, Vector spaces of a graph, Matrix representation of a graph, directed graph, Generating functions, Partition of integers, Recurrence relations. | 9 | The module will develop a strong understanding of fundamental graph theory concepts and the ability to apply algebraic methods to analyze paths, circuits, trees, and related structures. |
| | | Total (hrs.) = 42 | |

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|---|---|
| **Course Outcome** | Upon successful completion of this course, the students will be able to apply the logical structure of proofs and work symbolically with connectives and quantifiers to produce logically valid, correct and clear arguments, reformulate statements from common language to formal logic, and apply truth tables and the rules of propositional and predicate calculus. Students will also have knowledge of Graph theory, which arises in many engineering and physical problems. |

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|---|---|
| **Learning Resources** | **Text/Reference books**<br>1. K. H. Rosen, Discrete Mathematics and its Applications, 6th Ed., Tata McGraw-Hill, 2007.<br>2. N. Deo, Graph Theory, Prentice Hall of India, 1974.<br>3. Seymour Lipschutz, M. Lipson, Discrete Mathematics, Tata McGraw Hill, 2005. |

| Course Code | MA5171N | Course Name | **Programming Lab** | **Course Category** | Lab (PC) | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | 3 |

| **Pre-requisite Courses** | Basic Mathematics & computer fundamentals | **Co-requisite Courses** | Computational techniques & programing | **Progressive Courses** | |
|---|---|---|---|---|---|
| **Course Offering Department** | | Mathematics | | **Data Book / Codes/Standards** | |

| **Course Objective** | This course involves laboratory classes designed to give the student hands-on experience with the concepts. The course aims to provide exposure to problem-solving through programming. It aims to train the students to the basic concepts of the C-programming language and introduce the preliminary experience of MATLAB software environment. |
|---|---|

| **Module** | **Syllabus** | **Duration (class-hour)** | **Module Outcome** |
|---|---|---|---|
| I | **Basic C Programming Practice, Numerical Methods of Root Finding**: To find the sum of first n natural numbers using loop, To compute the factorial of a given number. To find the largest number in a user-defined array, Bisection Method, Regula-Falsi Method, Secant Method, Fixed Point Iteration Method, Newton-Raphson Method. | **14** | • Students can write C program on a computer, edit, compile, debug, correct, recompile and run it. |
| II | **Numerical Integration, Interpolation & ODE Solver:** Trapezoidal Rule for integration, Simpson's 1/3 Rule for integration, Forward Interpolation (Newton's Forward Method), Backward Interpolation (Newton's Backward Method). Solving ODEs using Euler Method. Solving ODEs using Runge-Kutta Method (4thOrder). | 14 | • Students can use numerical techniques and apply them to write programs and hence use computers effectively to solve problem. |
| III | **Introduction to MATLAB**: Basic commands and syntax in MATLAB, Variables and data types, Matrix | 14 | • Students will be able to use basic features of MATLAB as a programming tool. |

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| | operation, Relational, logical operations. Solution of algebraic equations. | | |
| | | Total(Hrs.)=42 | |

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| **Course Outcome** | After the course the students are expected to be able to (this is what the exams will test):<br><br>• Given a computational problem, identify the programming task involved.<br>• Find the algorithms using techniques learned and write pseudo-code.<br>• Write the C program on a computer, edit, compile, debug, correct, recompile and run it.<br>• Identify tasks in which the numerical techniques learned are applicable and apply them to write programs and hence use computers effectively to solve the task.<br>• To write modular program to solve real life problem.<br>• To use basic features of MATLAB as a programming tool. |

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| **Learning Resources** | References:<br>1.Numerical Recipes in C: The Art of Scientific Computing- William H. Press (Editor), Saul A. Teukolsky, William T. Vetterling<br>2.Programming in C Language: B. S. Gottfried<br>3. Mastering Algorithm in C: K. Loudon<br>4.Let Us C – Yashavant Kanetkar<br>5.Programming in ANSI C – E. Balagurusamy<br>6.MATLAB programing: Mathematical Problem Solutions-Dingyu Xue |

| Course Code | MA5201N | Course Name | **Ordinary Differential Equations and Dynamical Systems** | **Course Category** | Theory (PC) | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| **Pre-requisite Courses** | Basics of ODEs & Complex analysis | **Co-requisite Courses** | None | **Progressive Courses** | |
|---|---|---|---|---|---|
| **Course Offering Department** | | Mathematics | | **Data Book / Codes/Standards** | |

| **Course Objective** | This ordinary differential equations course presents several tools and techniques for solving ordinary differential equations (ODEs). It also presents the properties of special functions like hypergeometric and Legendre functions with their integral representations, recurrence relations, generating functions, etc. Further, this course is designed to understand the concept of Bessel's function, Hankel functions, etc., and their properties.<br>The primary objective of studying dynamical systems is to understand, analyze and imitate the complex behavior of natural systems that change over time, including predicting future states, explaining past states, and developing theories for the underlying phenomena. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module outcome |
|---|---|---|---|
| I | **First order ODEs**: Existence and uniqueness of solutions of initial value problems involving first order ordinary differential equations (ODEs). | 5 | • Able to find conditions under which solutions exist and are unique. |
| II | **Sturm-Liouville's problems & Green's function, Homogeneous linear ODE in the complex domain**:<br>Sturm-Liouville's boundary value problems, characteristic numbers and characteristic functions, Orthogonal properties of characteristic functions, Orthonormal systems, Inhomogeneous boundary value problems: Green's function and its properties. General homogeneous linear ODE in the complex domain, Ordinary points and Singular points, Fundamental existence and uniqueness theorem, Analytic continuation of the solution, Fundamental sets of solutions, Wronskian, Series solutions near | 17 | • Learn to solve various types of ODEs near ordinary and singular points.<br>• Enable students to utilize Green function as a powerful tool for solving various problems in linear differential equations and related fields. |

| | | | |
|---|---|---|---|
| | ordinary point and regular singularity point, Method of Frobenius, Sufficient condition for regular solution, Contour integral solution, Fuchsian type ODEs. | | |
| III | **Hypergeometric , Legendre , Bessel equation & Series solution** :Hypergeometric Equation, Solution in Series: Hypergeometric Function, Riemann P-equation. Legendre Equation, Solution in Series: Legendre functions of first kind and second kind, Legendre's polynomials, Different representations of Legendre's polynomials: Rodrigue's formula, Laplace's integral, generating function for Legendre polynomial, properties of Legendre polynomials, Contour integral solution, Recurrence formulae, Associated Legendre equation. Bessel Equation, Solution in Series: Bessel functions of first kind and second kind, Contour integral solution: Hankel function, Generating function for Bessel function of integral order, Recurrence formulae, Modified Bessel equation | 19 | • Able to work with differential equations involving special functions, such as Hypergeometric, Bessel and Legendre equations. Furthermore, students will understand how special functions are used to model physical phenomena |
| IV | **Introduction to dynamical systems, Periodic solution & Limit cycle, Bifurcation & Chaos**: Discrete & continuous dynamical system, Flows, Map, Evolution, Fixed points, Linearization of general systems, Eigen value-Eigen vector method, Fundamental matrix, Phase plane analysis, Local and global stability analysis. Periodic solutions (Poincare Theorem, Bendixson's negative criterion, Dulac's criterion), Limit cycles (Poincare – Bendixson Theorem). Bifurcation in one- and two-dimensional systems, Introduction to Chaos. | 15 | • Students gain understanding of how systems evolve over time & the factors that influence their behavior.<br>• Students can analyse differential equations without necessarily having explicit solution.<br>• Students can make predictions about future system behavior, with applications. |
| | | Total (Hrs)=56 | |

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| **Course Outcome** | • After completing the course on ordinary differential equations, students will learn to solve various types of ODEs near ordinary and singular points. They will also be able to work with differential equations involving special functions, such as Hypergeometric, Bessel and Legendre equations. Furthermore, students will understand how special functions are used to model physical phenomena and appreciate their usefulness in various fields.<br>• To gain a deeper understanding of how systems evolve over time and the factors that influence their behavior<br>• To make more accurate predictions about future system behavior, with applications in areas like finance, economics, and environmental modeling. |

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| **Learning Resources** | **References**:<br>1.Ordinary Differential Equations by E. L. Ince<br>2.An Introductions to Ordinary Differential Equations by Earl A. Coddington<br>3. Special Functions and their Applications: N.N. Lebedev<br>4. Special Functions by W. W. Bell<br>5. Nonlinear dynamics and chaos with applications to physics, biology, chemistry, and engineering by Strogatz, S.H., 2018. CRC Press.<br>6. Differential Equations and Dynamical Systems by Lawrence Perko, Springer |

| Course Code | MA 5202N | Course Name | Partial Differential Equations and Calculus of Variations | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | ODE and Calculus | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | • The objective of PDE course are as follows:<br>1. To introduce the fundamental concepts of PDEs<br>2. To develop analytical skills for solving some basic type PDEs<br>3. To classify 2nd order PDEs and to reduce them to canonical forms for simplified solution techniques.<br>4. To explore the theory and applications of classical PDEs<br><br>• The objective of Calculus of Variations is to provide students with an in-depth understanding of the methods and applications of variational principles in applied mathematics. The course aims to develop the necessary skills for solving problems involving optimization of functionals, understanding the necessary conditions for extremization, and applying these principles in various fields like physics, engineering, and applied sciences. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Introduction to PDEs:** Formation of partial differential equations, General information about variety of solutions of PDEs. | 2 | Students will be able to formulate PDE and understand of the nature and variety of their solutions. |
| 2 | **First order PDEs:** Solution of first order linear, Quasi-linear, semi linear and nonlinear PDEs, Cauchy's method of Characteristics, Compatible systems of first order PDEs, Charpit's Method and Special types of first order PDEs. | 10 | Students will be able to solve different first-order partial differential equations using methods such as Cauchy's method of characteristics, Charpit's method, and identify compatible systems and special types of first-order PDEs. |

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| 3 | **Higher order PDEs:** Solution of higher order PDEs with constant coefficients, Construction of Green's function with the help of delta function.<br>Linear partial differential equations of second order with variable coefficients, classifications, reduction to Canonical forms, Characteristic curves, adjoint and self-adjoint operators, Riemann's method. | 10 | Students will be able to solve higher-order PDEs with constant coefficients, construct Green's functions, and analyze second-order linear PDEs. |
| 4 | **Elliptic differential equations:** Derivation of Laplace and Poisson equations, Properties of Harmonic functions, Separation of variables, Dirichlet and Neumann problems for rectangle and circle. | 6 | Students will be able to derive Laplace and Poisson equations, analyze the properties |
| 5 | **Parabolic differential equations:** Occurrence of the diffusion equation, Elementary solution of diffusion equation, Solution of diffusion equation in Cylindrical and Spherical coordinates. | 6 | Students will understand the origin of the diffusion equation, derive its elementary solutions. |
| 6 | **Hyperbolic differential equations:** Occurrence of the wave equation, Solution of one-dimensional wave equation, Uniqueness of the solution of wave equation. | 6 | Students will understand the origin of the wave equation, solve the one-dimensional wave equation, and analyze the uniqueness of its solution. |
| 7 | **Green's function:** Green's function for Laplace equation, wave equation, diffusion equation. | 2 | Students will be able to construct and apply Green's functions for solving Laplace, wave, and diffusion equations. |
| 8 | **Calculus of Variations:** Introduction, Euler-Lagrange equation for fixed end points, Euler-Poisson equation for functional involving derivatives of higher order, Ostrogradsky equation for functional involving functions of several independent variables, Geodesics, constraints and Lagrange's multipliers, Hamilton's principle, Lagrange's equations, generalized dynamical entities, constraints of dynamical systems.<br>Euler-Lagrange equation for variable end conditions, transversality condition,<br>Rayleigh-Ritz method, Galerkin method for approximate solution. | 14 | • Understand the concept of variational problems<br>• Formulate and solve variational problems under different conditions<br>• Employ approximate methods |
| | **Total** | **56** | |

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| **Course Outcome** | By the end of the course-<br><br>In PDE, students will be able to:<br><br>1. **Formulate and classify partial differential equations** arising in physical and engineering problems.<br>2. **Apply analytical techniques to solve first-order PDEs** including linear, quasi-linear, semi-linear, and nonlinear equations.<br>3. **Use characteristic methods, Charpit's method, and compatibility conditions** to solve specific types of first-order PDEs.<br>4. **Classify second-order PDEs** and reduce them to canonical forms to facilitate their solutions.<br>5. **Analyze and solve classical boundary value problems** for elliptic equations like Laplace and Poisson equations using separation of variables.<br>6. **Solve parabolic PDEs** such as the heat equation in rectangular, cylindrical, and spherical coordinates.<br>7. **Solve hyperbolic PDEs** such as the wave equation and demonstrate the uniqueness of their solutions.<br><br>In calculus of variation part, students will be able to understand Fundamental Principles, solve Variational Problems, apply Euler Equation, handle constrained Variational Problems, higher-order Variational Problems and numerical methods for Variational Problems. |

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| **Learning Resources** | **References:**<br>1. Introduction to Partial Differential Equations, 2nd Edition by K. Sankara Rao, Prentice- Hall of India.<br>2. Partial Differential Equations by Phoolan Prasad & Renuka Ravindram, New Age International Publishers<br>3. Linear Partial Differential Equations for Scientist and Engineers by TynMyint-U, Lokenath Debnath, Springer.<br>4. Elements of Partial differential equations by I. N. Sneddon, Dover<br>5. Introduction to Calculus of Variation by C. Fox<br>6. Calculus of Variation by A. S. Gupta, New Age.<br>7. Introduction to Calculus of Variation by Hans Sagan |

| Course Code | MA5203N | Course Name | Topology and Tensor Analysis | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | Real Analysis, Matrix Algebra. | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | The objective of the course is to acquaint the students with fundamentals of topology relevant to applications of mathematics and tensor analysis for its use in applied problems of mathematics. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Topology:** Basis of a topology. Continuous functions. Metric topology. Product topology. Box topology. Quotient topology. Compact topological spaces. Compactness in metric topology.<br><br>Connected topological spaces. Local connectedness. Path connectedness and its relation to connectedness. First and second countable topological spaces. Separation axioms-Hausdorff, regular and normal spaces. | 21<br><br>21 | Understanding of topology is a basic requirement in the understanding of the widely used analytic methods in applied mathematics. Specific areas of such applications include nonlinear analysis, dynamical systems, mathematical economics, etc. |
| 2 | **Tensor Analysis** Tensor Algebra: n-dimensional space, Transformation of co-ordinates, summation convention, Kronecker delta, scalar/invariant, covariant and contravariant vectors, covariant, contravariant and mixed tensors, e-system, $\varepsilon$-tensors. Addition and subtraction of tensors, multiplication of tensors, symmetric and skew-symmetric tensors, Quotient law, conjugate tensor.Tensor Calculus: Riemannian space, Line element and metric tensor, conjugate metric tensor, | 14 | Tensor analysis is applicable in Classical Mechanics, Continuum Mechanics, Elasticity, Solid Mechanics, Cosmology, Astrophysics. |

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| | associated tensor, magnitude of a vector, angle between vectors, Christoffel's symbols, transformation of Christoffel's symbols, covariant derivatives of vectors and tensors. Riemann-Christoffel tensor, properties, Bianchi's identity, Ricci tensor, Ricci scalar and Einstein's tensor, flat and non-flat spaces. Curvilinear co-ordinates: co-ordinate curves and surfaces, line element, base system, reciprocal base system, physical properties. | | |
| | | **56** | |

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| **Course Outcome** | Understanding of topology is a basic requirement in the understanding of the widely used analytic methods in applied mathematics. Specific areas of such applications include nonlinear analysis, dynamical systems, mathematical economics, etc. Tensor analysis is applicable in Classical Mechanics, Continuum Mechanics, Elasticity, Solid Mechanics, Cosmology, Astrophysics. |

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| **Learning Resources** | **Reference Books**:<br>1. J. L. Kelley, General Topology, Van Nostrand, 1955.<br>2. G. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.<br>3. J. Munkres, Topology - a First Course, Prentice-Hall, 1975.<br>4. Barry Spain, Tensor Calculus: A Concise Course, Dover Publications,2003.<br>David C. Kay, Schaum's Outline of Tensor Calculus, McGraw-Hill, 2011.<br>6. *U. C. De*, Absos Ali Shaikh and Joydeep Sengupta, Tensor Calculus, Narosa Publishing House, 2016.<br>7. Zafar Ahsan, Tensor Analysis with Applications, Anshan Ltd, 2008.<br>8. J. K. Goyal and K. P. Gupta, Tensor Calculus and Riemannian Geometry, Pragati Prakashan, 2021 |

| Course Code | MA5221N | Course Name | Mathematical Biology | **Course Category** | Theory (PSE) | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| **Pre-requisite Courses** | ODE & Introduction to Dynamical System | **Co-requisite Courses** | None | **Progressive Courses** | |
|---|---|---|---|---|---|
| **Course Offering Department** | | Mathematics | | **Data Book / Codes/Standards** | |

| **Course Objective** | The primary objective is to introduce students to mathematical techniques for modeling biological systems. The course objectives typically include: understanding the fundamentals of mathematical modeling, developing and analyzing continuous and discrete models for various biological processes, and applying these models to real-world scenarios. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module outcome |
|---|---|---|---|
| I | **Continuous Population Model:** Single species models, Logistic model and its stability analysis. Harvest strategy in ecological models. Maximum sustainable yield. Fishery models. Mathematical model of two interacting species. Lotka-Volterra Prey-Predator model. Lotka-Volterra competition model. Continuous model of three interacting species. Nutrient cycling. Goodwin Model and biological oscillations, Enzyme Kinetics. Lorenz attractor and | 23 | • Students will be able to translate real-world scenarios into mathematical models using differential equations.<br>• Students develop skills in mathematical modeling, analyzing system stability, oscillation and sudden change in behavior.<br>• Able to apply these concepts to real-world problems across diverse fields like Ecology, Sustainable Harvesting, Fishery management, Biological oscillators, Artificial neural network,Chaotic systems. |

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| | chaotic system. Control equations of artificial neural network. | | |
| II | Discrete Population Model: Single species simple models. Density independent and dependent models. Cobweb method of solution. Discrete logistic model. Discrete Prey Predator model.Delay in Discrete model, Periodic solution and chaos in Discrete models. | 19 | • Students will be able to explain how population size, species interactions, and environmental factors influence the behavior of ecological systems over discrete time steps. |
| | | Total(Hrs.)=42 | |

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| **Course Outcome** | After completing the course on Mathematical Biology, students will learn<br>• to formulate mathematical models of biological systems and analyze their long-term behavior, including equilibrium states and stability, oscillation and existence of complex dynamics.<br>• to understand the respective advantages and limitations of the modeling, and apply these models to study phenomena like population dynamics, fishery management, epidemics, and drug kinetics. |

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| **Learning Resources** | **References**:<br>1. Deterministic Mathematical Models in Population Ecology, 1980, H. I. Freedman, Wiley publication.<br>2. Elements of Mathematical Ecology, 2001, Mark Kot, University press, Cambridge.<br>3. Mathematical Models in Biology, 2005, L. E. Keshet, SIAM Publication.<br>4. Mathematical Biology, 2002, J.D. Murray, Springer Publication. |

| Course Code | MA5222N | Course Name | Mathematical Optimization Techniques | Course Category | PSE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | Differential and integral calculus, matrix algebra | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | MATHEMATICS | | Data Book / Codes/Standards | |

| Course Objective | The objective is to introduce to the students several important problems of optimization along with the standard solution techniques. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Introduction to Optimization Techniques**: Problem formulation, Solution convention.<br>**Linear Programming: Duality and Sensitivity Analysis:**<br>Complementary slackness conditions, Dual Simplex Method.<br>Discrete changes in the cost vector, Discrete changes in the requirement vector, Discrete changes in the coefficient matrix, Addition of a variable, Addition of a constraint.<br>**Integer Programming:**<br>Branch- and- Bound Algorithm, Cutting-Plane Algorithm.<br>**Nonlinear Programming: Multivariable Optimization with Constraints**<br>Method of Lagrange Multipliers, Kuhn-Tucker necessary and sufficient conditions of optimality. | 30 | Through this study the basic techniques will be known to the students for possible applications in various disciplines. |
| 2 | **Network Analysis**<br>Scope and Definition of Network Models, Network Representation, Critical path computations for CPM, Critical path computations for PERT, Project time vs project cost. | 12 | Elements of network analysis and dynamic programming techniques are taught for |

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| | **Dynamic Programming:**<br>Bellman's principle of optimality, Recursive relations, System with more than one constraint, Solution of LPP using Dynamic Programming. | | possible applications. |
| | **Total** | **42** | |

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| **Course Outcome** | The students are taught with the basic techniques of optimization of various kinds which occur abundantly in many areas of applied mathematics. This knowledge will be helpful in further studies of applied mathematics, physics, chemistry and in almost all branches of technology and also in practical applications of mathematics in all the areas mentioned herein. |

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| **Learning Resources** | **References:**<br>1. M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Edition, John Wiley & Sons, 2006.<br>2. G. Hadley, Nonlinear and Dynamic Programming, Addison- Wesley, 1964.<br>3. T. C. Hu, Integer Programming and Network Flows, Addison-Wesley, 1970.<br>4. J.C. Pant, Introduction to Optimization: Operations Research, New Delhi, Jain Brothers, 2004.<br>5.H.A. Taha, Operations Research: An Introduction, Pearson Prentice Hall, 2007. |

| Course Code | MA5261N | Course Name | Numerical Solutions for ODEs and PDEs | Course Category | OE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | Graduate courses in numerical methods and in partial differential equations | Co-requisite Courses | None | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objectives | This is an advanced postgraduate-level course in numerical techniques for ordinary and partial differential equations (ODE, PDE).<br>Students should learn the principles for designing numerical schemes for ODEs and PDEs, in particular, finite difference schemes.<br>Using several examples, this course examines advanced numerical techniques for ODE and PDE problems, as well as the characteristics of these approaches.<br>Students should be able to analyze the consistency, stability and convergence of a numerical scheme.<br>Students should know, for each type of PDEs (hyperbolic, parabolic and elliptic), what kind of numerical methods are best suited for and the reasons behind these choices. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| I | **Introduction to Numerical Solution of Initial and Boundary value problems involving Ordinary Differential Equations:**<br>Numerical Solutions of Initial value problem (IVP), Numerical Solutions of Boundary value problem (BVP)- Linear BVP, finite difference methods, shooting methods, Galerkin method, stability, error and convergence analysis, nonlinear BVP, higher order BVP. | 16 | Apply numerical methods such as finite difference to solve boundary value problems involving ordinary differential equations. |
| II | **Introduction to Numerical Solution of Initial and Boundary value problems** | 2 | Classify partial differential equations as |

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|---|---|---|---|
| | **involving Partial Differential Equation (PDE):**<br>Classification of PDE- parabolic, elliptic and hyperbolic.<br>**Finite differences:** Grids, Finite difference approximations to partial derivatives, convergence and stability analysis. | | parabolic, elliptic, or hyperbolic and choose suitable numerical schemes based on the classification. |
| III | **Linear Transport Equation:** Upwind, Lax-Wendroff and Lax-Friedrich schemes, von-Neumann stability analysis, Courant-Fredrichs-Lewy (CFL) condition, Lax-Richtmyer equivalence theorem. | 4 | Implement and compare finite difference schemes for solving linear transport equations and analyze their stability using von Neumann analysis and CFL conditions. |
| IV | **Parabolic equations:** Heat equation, Explicit and Implicit schemes, Crank-Nicolson scheme, tri-diagonal system, Truncation errors and consistency, Stability analysis, Fourier analysis, convergence, Lax equivalence theorem. | 6 | Numerically solve parabolic equations (e.g., heat equation) using explicit, implicit, and Crank-Nicolson methods; evaluate their accuracy, consistency, stability, and convergence using Fourier analysis and truncation error estimation. |
| V | **Elliptic equations:** Poisson's Equation, Finite difference scheme, Iterative methods for linear systems (Jacobi, Gauss-Seidel, and successive over relaxation methods), Laplace equation using standard five-point formula and diagonal five-point formula. Peaceman-Rachford algorithm. | 8 | Solve elliptic partial differential equations such as Poisson and Laplace equations using finite difference methods and iterative methods |

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| | | | like Jacobi, Gauss-Seidel, SOR, and Peaceman-Rachford algorithm. |
| VI | **Hyperbolic equation:** Wave equation, Explicit schemes and their stability analysis, Method of characteristics, CFL condition and Fourier analysis. Stability analysis of Explicit and Implicit schemes. | 6 | Apply explicit methods and the method of characteristics to solve hyperbolic PDEs (e.g., wave equation), and perform detailed stability analysis using CFL conditions and Fourier methods. |
| | **Total** | **42** | |

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| **Course Outcome** | The course introduces numerical methods, especially the finite difference method for solving different types of ODEs and partial differential equations.<br>In numerical analysis, finite-difference methods (FDM) are a class of numerical techniques for solving differential equations by approximating derivatives with finite differences.<br>Finite difference methods convert ordinary differential equations (ODE) or partial differential equations (PDE), which may be nonlinear, into a system of linear equations that can be solved by matrix algebra techniques.<br>The main numerical issues such as convergence and stability will be discussed. |

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| **Learning Resources** | **Text/Reference books**<br>1. G. D. Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods, Oxford Applied Mathematics and Computing Science Series, 1985.<br>2. J.W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer,1995.<br>3. Richard L. Burden and J. Douglas Faires, Numerical Analysis, BROOKS/COLE, 2011.<br>4. K. W. Morton and D. F. Mayers, Numerical Solution of Partial Differential Equations, Cambridge University Press, 2nd edition (11 April 2005).<br>5. S. Saha Ray, Numerical Analysis with Algorithms and Programming, CRC Press, Taylor and Francis Group, 2016.<br>6. E. Süli, D. F. Mayers, An Introduction to Numerical Analysis, Cambridge University Press, 2003. |

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MA5272N</td><td rowspan="2">Course Name</td><td rowspan="2">SIMULATION LAB</td><td rowspan="2">Course Category</td><td rowspan="2">PC</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>3</td></tr>
</table>

<table>
<tr><td>Pre-requisite Courses</td><td>Nil</td><td>Co-requisite Courses</td><td>Nil</td><td>Progressive Courses</td><td>Nil</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">MATHEMATICS</td><td>Data Book / Codes/Standards</td><td>Nil</td></tr>
</table>

<table>
<tr><td>Course Objectives</td><td>
<ul>
<li>To introduce students to fundamental data analysis and visualization techniques using R and R-Studio, including data structures, import/export, basic statistics, and linear regression.</li>
<li>To impart practical programming skills using the Python language.</li>
<li>To focus on advanced MATLAB programing to solve real world problems.</li>
</ul>
</td></tr>
</table>

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| I | **Introduction to R** : Introduction to R & R-Studio, Vectors and Basic Data Structures, Data Import and Export, Basic Data Visualization with Base R, Basic Statistical Analysis, Introduction to Linear Regression. | 14 | • Students will be able to apply basic data manipulation, and statistical analysis techniques using R for solving real-world data problems. |
| II | **Introduction to Python language**:<br>To install and run the Python interpreter, understanding basic syntax and program structure, Conditionals and loops, Function call, Python data structures, Objected oriented programing. | 14 | • Students will be equipped with practical skills necessary to write, test, and debug Python programs for various applications. |
| III | **Advanced MATLAB Programming** : Curve fitting, Interpolation techniques, Solving Ordinary/Partial/Delay Differential Equations using ODE, PDE, DDE solver with graphical plot, Advanced visualization techniques(surface plots and contour plots). | 14 | • Students will be able to apply MATLAB for simulation of various types of mathematical models. |
| | | Total(Hrs.) =42 | |

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| **Course Outcome** | Upon successful completion of lab courses the students should become technically more skilled in solving different types of real problems. |

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| **Learning Resources** | References:<br>1. The Book of R: A First Course in Programming and Statistics- Tilman M. Davies<br>2. Introduction to Computation and Programming Using Python: With Application to Understanding Data- John V. Guttag<br>3. MATLAB programming: Mathematical Problem Solutions- Dingyu Xue |

| Course Code | MA6101N | Course Name | Continuum Mechanics | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | ODE and PDE | Co-requisite Courses | | Progressive Courses | |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | |

| Course Objective | The objective of Module 1 of this course is to equip students with a deep and comprehensive understanding of the principles and methods of solid mechanics. Students will develop a rigorous understanding of the fundamental concepts of stress, strain, and constitutive behaviour in solids.<br><br>The objective of Module 2 of this course is to provide students with an advanced understanding of the fundamental and applied aspects of fluid mechanics. Students will gain a deep theoretical understanding of fluid properties, flow behaviour, governing equations (continuity, momentum, and energy equations) and the irrotational behaviour of fluid motion. |
|---|---|

| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Theory of strain**:<br>Deformation, Infinitesimal strain tensor, Geometrical interpretation of infinitesimal strain, Principal strains, Strain invariants, Compatibility equations. | 09 | • Understand the concept of deformation.<br>• Information about strain and its properties in elastic solid medium. |
| | **Theory of stress**:<br>Forces, Stress vector, Stress tensor, Principal stresses, Stress invariants, Equilibrium equation. | 09 | • Understand the concept of stress and its properties in elastic solid medium. |
| | **Linear elasticity**:<br>Linear elastic materials, Constitutive equations in linearly elastic solids – Generalized Hooke's law, Strain energy function, Elastic symmetry – different types of materials. | 10 | • Understand the behavior of linear elastic materials and derive constitutive equations.<br>• Analyze material symmetries in different types of elastic solids. |
| 2 | **Introductory Notions and Physical Properties of Fluid:**<br>Definition and basic concept of fluid dynamics, Fundamental properties of fluids, | 06 | After completion of this chapter students will acquire knowledge |

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|---|---|---|---|
| | The continuum hypothesis , Volume forces and surface forces acting on a fluid, Hydrodynamic pressure, Conditions at a boundary between two media , Euler's momentum theorem, D'Alembert's paradox, The flow past an obstacle. | | about the basic concept and properties of fluids. |
| | **Kinematics of Fluid Motion:**<br>Introduction, Classifications of fluid flow, Specification of fluid motion:<br>(a) Lagrangian method<br>(b) Eulerian method<br>Velocity and acceleration of a fluid particle, Flux across any surface, Material, local and convective derivatives, Equation of continuity (Conservation of mass):<br>(a) Euler's form<br>(b) Lagrange's form<br>Equivalence between Euler's and Lagrange's form, Symmetrical forms of equation of continuity:<br>(a) Cylindrical symmetry<br>(b) Spherical symmetry<br>Boundary conditions:<br>(a) Kinematical<br>(b) Physical<br>Condition for boundary surface, Patterns of flow lines:<br>(a) Path lines<br>(b) Stream lines<br>(c) Streak lines<br>Stream tube and stream filament, Angular velocity vector, Flow and circulation. | 08 | After finishing of this chapter students will be able to know about the pattern of fluid flow lines and the fluid motion. |
| | **Equations Governing The Motion of a Fluid:**<br>Introduction, Euler's equation of motion of an inviscid fluid, Equation of motion relative to moving axes, Euler's generalized momentum theorem, Bernoulli's equation, Pressure equation, Pressure equation referred to moving axes, Bernoulli's theorem, Applications of Bernoulli's theorem, Steady motion, Impulsive motion, Equations of motion under impulse:<br>(a) Vector form<br>(b) Cartesian form<br>The energy equation. | 07 | To provide students the idea about the basic equations governing the fluid motion. |

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| | **General Theory of Irrotational Motion:** Introduction, Some elementary definitions, Acyclic and cyclic irrotational motion, Kelvin's circulation theorem, Permanence of irrotational motion, Kinetic energy of finite and infinite liquid, Kelvin's minimum energy theorem, Mean value of the velocity potential over a spherical surface, Mean value of the velocity potential in a periphractic region, Some uniqueness theorems. | 07 | After ending this chapter students will gather knowledge about the irrotational behavior of fluid motion. |
| | **Total** | 56 | |

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| **Course Outcome** | Upon successful completion of the course, students will be able to explain the concepts of continuum hypothesis, fundamental equations, stress, strain, and material behavior in both solids and fluids. |

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| **Learning Resources** | **References:**<br><br>1. I. S. Sokolnikoff : Mathematical Theory of Elasticity. McGraw Hill, 1956.<br>2. A. E. H. Love : A treatise on mathematical theory of Elasticity, McGraw Hill, 1954.<br>3. T. J. Chung, Applied continuum mechanics, Cambridge University Press.<br>4. D. S. Chandrasekharaiah and L.Debnath, Continuum Mechanics, Academic Press, 1994.<br><br>5. Gupta A. : Groundwork of mathematical fluid dynamics, Academic Publishers, 2013.<br>6. BatchelorG.K. : An Introduction to fluid dynamics , Cambridge University Press, 1967.<br>7. Frank M.White : Fluid mechanics. Tata Mc. Graw - Hill publishing company, New Delhi, 2008.<br>8. Goldstein S. : Modern developments in fluid dynamics , Oxford University Press, New York , 1938.<br>9. Lamb H. : Hydrodynamics , Dover Publications, New York , 1932.<br>10. MaseG.E. : Theory and problems of continuum mechanics , Schaum series.<br>11. McCormack P.D. and L. Crane : Physical fluid dynamics, Academic Press , New York, 1973. |

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| | 12. Milne-Thomson L.M. : Theoretical hydrodynamics, The Macmillan Company , New York, 1950.<br>13. Streeter V.L. : Fluid dynamics, Mc.Graw Hill Book Company Inc. New York, 1948.<br>14. Streeter V.L. : Handbook of Fluid dynamics, Mc.Graw Hill Book Company Inc. New York ,1948.<br>15. Yuan S.W. : Foundations of fluid mechanics , Prentice-Hall of India pvt.Ltd. , New Delhi , 1969. |

| **Course Code** | MA6102N | **Course Name** | Operations Research and Integral Transforms | **Course Category** | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| **Pre-requisite Courses** | MA5202N | **Co-requisite Courses** | Nil | **Progressive Courses** | Nil |
|---|---|---|---|---|---|
| **Course Offering Department** | | Department of Mathematics | | **Data Book / Codes/Standards** | Nil |

| **Course Objective** | Operations Research aims to optimize decision-making by applying scientific methods to complex problems in various fields. It can maximize profit, efficiency, or other desirable outcome. The primary objective of an integral transform is to convert a function from its original function space to another function space where the problem becomes simpler to analyze or solve. |
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| **Module** | **Syllabus** | **Duration (class-hour)** | **Module Outcome** |
|---|---|---|---|
| 1 | **Operations Research:**<br><br>**Mixed integer programming problems**- Definition, brief review of pure integer programming, Derivation of cutting plane constraints for mixed integer programming. Problems and related application in real life.<br><br>(1) **Parametric linear programming model** – Introduction parametric changes of cost vector (c), Parametric changes in Requirement vector (b), Problems and applications.<br><br>(2) **Queueing Models-** Introduction, Basic elements of queuing models, Poisson and exponential distribution in queueing model, Arrival process, Departure process, classification of queues, Model 1: $(M/M/1): (FCFS/\infty/\infty)$, Model 2: $(M/M/1): (FCFS/N/\infty)$, Model 3: $(M/M/C): (FCFS/\infty/\infty)$, Model 4: $(M/M/C): (FCFS/N/\infty; C<N)$, Model 5: $(M/M/C): (FCFS/N/N; C<N)$,Model 6: $(M/M/\infty): (FCFS/\infty/\infty)$; Problems and applications.<br><br>(3) **Dynamic Programming:** Introduction, Recursive equation of dynamic programming, subdivision problems in dynamic programming, characteristics of dynamic programming, problems and case study.<br><br>(4) **Multi-objective linear programming:** Multi-objective linear programming by | 42 | Operations Research outcomes encompass a broad range of benefits, primarily focused on improving decision-making and system efficiency. These outcomes include: Improved Decision-Making, Increased Productivity and Efficienc |

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| | (a) Weighted sum method<br>(b) E- constrained method<br>(c) Global criterion method<br>Some application of multi-objective linear programming problems.<br>(5) **Fundamental concepts of Geometric programming:** Fundamental concepts of Geometric programming unconstrained posynomial geometric programming, degree of difficulty, constrained posynomial and signomial geometric programming. Some real-life applications on geometric programming.<br>(6) **Replacement problem and system Reliability:** Replacement policy for items whose maximize costs increase with time money value is not counted.<br>Replacement policy for items whose maintenance costs increase with time and value of money also changes with time.<br>**System Reliability**: Failure rakes, bath-tub shaped failure rate, hazard rate, reliability systems in series and parallel arrangement.<br>**Inventory control**: Introduction, types of inventory models, Model 1: Single item static model, Model 2: Model with no shortages and several production run of unequal length. Model 3: Inventory model with shortages | | y, Enhanced Resource Allocation, Better Supply Chain Management, Risk Management, Reduced Costs etc. |
| 2 | **Integral Transforms:**<br>**Laplace Transform:** Definition and properties, Class A function, Sufficient conditions for the existence of Laplace Transform, Laplace Transform of some elementary functions, Laplace transform of the derivatives, Inverse of Laplace transform, Convolution Theorem, Initial and final value theorems, Applications to ordinary and partial differential equations, Applications to Integral equation.<br>**Fourier Transform:** Fourier integral Theorem, Definition and properties, Fourier transforms of some elementary functions. Fourier sine and cosine transforms, Fourier transform of the derivative, Inverse of Fourier transforms, Convolution theorem, Applications. | 14 | Integral transforms can be used to solve differential equations, signal processing, image processing, Mathematical Physics etc. |
| | | **56** | |

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| **Course Outcome** | Operations Research outcomes encompass a broad range of benefits, primarily focused on improving decision-making and system efficiency. These outcomes include: Improved Decision-Making, Increased Productivity and Efficiency, Enhanced Resource Allocation, Better Supply Chain Management, Risk Management, Reduced Costs etc.<br>Integral transforms can be used to solve differential equations, signal processing, image processing, Mathematical Physics etc. |
| **Learning Resources** | 1. A first course on Operations Research and Information Theory- S. K. Majumder. New Central Book Agency, Kolkata (First edition published in 2014, Second edition published in June 2020).<br>2. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, - 2010.<br>3. F.S. Hillier and G.J. Lieberman : Introduction to Operations Research-Concepts and Cases, 9th Edition, Tata McGraw Hill. 2010.<br>4. S. D. Sharma: Operations Research, Kedar Nath Ramnath & Co. 2012.<br>5. Mathematical Programming- N. S. Kambo. East-West Press.<br>6. Operations Research- Kanti Swarup, P. K. Gupta and Man Mohan. Sultan Chand and sons.<br>7. The Use of Integral Transforms - I. N. Sneddon.<br>8. Fourier Transforms - I. N. Sneddon.<br>9. Integral Transforms and Their Applications - B. Davies.<br>10. Integral Transforms and Their Applications - L. Debnath and D. Bhatta. |

| Course Code | MA6103N | Course Name | Functional Analysis and Integral Equation | Course Category | PC | L | T | P |
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| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | MA5103N MA5202N | Co-requisite Courses | Nil | Progressive Courses | Nil |
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| Course Offering Department | | Department of Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | The primary objective of functional Analysis is to develop in-depth understanding of normed, Banach, and Hilbert spaces, along with bounded linear operators and functionals, enabling students to apply fundamental theorems and geometric concepts in advanced mathematical analysis and its applications.<br>The primary objective of integral equations is to solve for an unknown function that appears within an integral expression. This contrasts with differential equations, which involve finding derivatives of a function. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Functional Analysis:**<br>**Normed and Banach Spaces:** Definitions and elementary properties; example of some concrete Normed and Banach Spaces; Subspaces and Quotient Spaces.<br>**Bounded Linear Operators:** Definitions, examples and basic properties; Space of bounded linear operators; Finite dimensional normed spaces and compactness; Open mapping theorem and its consequences; Closed graph theorem and its consequences.<br>**Bounded Linear Functionals:** Definitions, examples and basic properties; Hahn-Banach theorem and its consequences.<br>**The concept and Specific Geometry of Hilbert Spaces:** Definitions and basic properties of Inner product and Hilbert spaces; Completion of Inner product spaces; Orthogonality of vectors and projection theorem. | 42 | Students will be able to analyze and apply the fundamental concepts of normed, Banach, and Hilbert spaces, along with bounded linear operators and functionals, to solve problems in advanced mathematical contexts. They will also demonstrate proficiency in key theorems such as Hahn-Banach, Open Mapping, and Projection Theorems in both theoretical and practical scenarios. |
| 2 | **Integral Equations:** Linear integral equation of first and second kinds- Fredholm and Volterra type, homogeneous equation, eigen value and eigen function, separable kernel, solution of Fredholm integral equation with separable kernel, solution of Fredholm and Volterra integral equation by successive approximation, classical | 14 | Integral equations provide a mathematical framework for addressing problems where the unknown quantity is related to a continuous |

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| | Fredholm theorems (Statement only), conversion of boundary and initial value problem to integral equation, conversion of integral equation to boundary and initial value problem, singular integral equation, solution of Abel integral equation. | | accumulation or integration process, and the objective is to find the function that defines this accumulation. Integral equations are used in various fields, including physics, engineering, and mathematics, to model phenomena and solve problems that involve continuous quantities or processes. |
| | | **56** | |

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| **Course Outcome** | Students will be able to analyze and apply the fundamental concepts of normed, Banach, and Hilbert spaces, along with bounded linear operators and functionals, to solve problems in advanced mathematical contexts. They will also demonstrate proficiency in key theorems such as Hahn-Banach, Open Mapping, and Projection Theorems in both theoretical and practical scenarios. Integral equations provide a mathematical framework for addressing problems where the unknown quantity is related to a continuous accumulation or integration process, and the objective is to find the function that defines this accumulation. Integral equations are used in various fields, including physics, engineering, and mathematics, to model phenomena and solve problems that involve continuous quantities or processes. |
| **Learning Resources** | 1. Functional Analysis byBalmohan Vishnu Limaye<br>2. Functional Analysis by P. K. Jain , O. P. Ahuja<br>3. Introduction to Functional Analysis with Applications, by A. H. Siddiqi, Khalil Ahmad, PammyManchanda<br>4. Linear Integral Equations by R.P. Kanwal<br>5. Integral Equations by F.G. Tricomi<br>6. A Course of Integral Equations by A.C. Pipkin<br>7. Applied Integral Equations by A.N. Chakraborty<br>8. Integral Equations and Boundary Value Problems by S.K. Pundir&R.Pundir<br>9. Integral Equations by Roy Singhania |

| Course Code | MA6171N | Course Name | Computational Laboratory | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | 3 |

| Pre-requisite Courses | Nil | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Department of Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | Latex a typesetting system that provides robust features for incorporating complex mathematical equations, tables, figures, and references. Mathematica is a technical computing system whose primary objective is to provide a comprehensive environment for solving complex mathematical, scientific, and technical problems. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **LaTeX:** Introduction to LaTeX and Basic Document Structure, Text Formatting, Mathematical Typesetting, Advanced Math: Equations and Alignments, Including graphics using, Cross-Referencing and Hyperlinks, Bibliography and Citations, Writing Reports and Theses in Latex. | 14 | Understand the structure and basic components of a LaTeX document and create professionally formatted academic and technical documents. |
| 2 | **Mathematica:** Basic concepts: Addition, subtraction, division, multiplication; numerical value; square root, power, exponential, logarithm; trigonometric functions; inverse functions; modulus; maximum and minimum of numbers; real and imaginary part of complex numbers; conjugate, modulus and argument of complex numbers; limit, differentiation, integration; series expansion; factorisation; simplification.<br>Solving algebraic equation; find root of equations; system of equations; elimination; solving differential equations; Laplace transformation; gradient, divergence, curl; maxima minima of functions; mean, median, variance, standard deviation; matrix, determinant, eigen values of matrix.<br>Plots of algebraic functions, trigonometric functions; parametric plots; 3D plots; contour plots; density plots; list plots; pie chart; graphics; | 28 | Mathematica can perform a vast array of mathematical calculations, from simple arithmetic to complex symbolic and numerical computations. The outcome of these calculations is often displayed in a clear and easy-to-understand format.<br>Mathematica also provides tools for data analysis, including statistical analysis, machine learning, and data modeling and simulations and educational tools. The outcome of these analyses can be used to make predictions, draw conclusions, and inform decision-making. |
| | | **42** | |

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| **Course Outcome** | 1. Understand the structure and basic components of a LaTeX document and create professionally formatted academic and technical documents.<br>2. Mathematica can perform a vast array of mathematical calculations, from simple arithmetic to complex symbolic and numerical computations. The outcome of these calculations is often displayed in a clear and easy-to-understand format.<br>3. Mathematica also provides tools for data analysis, including statistical analysis, machine learning, and data modeling and simulations and educational tools. The outcome of these analyses can be used to make predictions, draw conclusions, and inform decision-making. |
| **Learning Resources** | 1. LaTeX: A Document Preparation System” by Leslie Lamport<br>2. LaTeX Wikibook: https://en.wikibooks.org/wiki/LaTeX<br>3. Website: https://www.overleaf.com/learn<br>4. The Mathematica Book by Stephen Wolfram<br>5. Wolfram Mathematica: https://www.wolfram.com/mathematica/ |

| Course Code | MA6201N | Course Name | Electrodynamics and Classical Mechanics | Course Category | PC | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | MA5203N | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Department of Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | To understand Maxwell's equations and their applications in space and matter, solve electrostatics, magnetostatics, and dynamic field problems using the Biot-Savart law. To understand and predict the behavior of macroscopic objects and systems, particularly in situations where speeds are not very high and atomic-scale effects are negligible. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Electrodynamics:** Electric and magnetic fields in space and inside matter. Biot-Savart law. Electromotive forces and electrical circuits. Maxwell's equations. Electromagnetic energy and momentum. Potential formulation of electromagnetic laws. Coulomb and Lorentz gauges. Electromagnetic waves. Electromagnetic radiation. Electromagnetic field tensor. Tensorial formulation of the Maxwell's equations. Relativistic electrodynamics and its Lorentz invariance. | 28 | After completing electrodynamics, students will be able to derive and interpret Maxwell's equations in differential/integral forms, compute EM fields for static and dynamic systems using potentials and gauges, analyze wave propagation, reflection, and radiation in different media, formulate EM laws covariantly and solve relativistic problems. |
| 2 | **Classical Mechanics:** Holonomic and non-Holonomic systems. Constraints of motion. Lagrangian of a system. Lagrange's equations of motion with illustrations. Hamiltonian and Hamilton's equations of motion. The interpretation of Hamiltonian. Small oscillations and normal modes of oscillations. Canonical transformations. Generators of canonical transformations. | 28 | Classical mechanics provides a framework for understanding the forces acting on an object and their impact on its motion and it |

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| | Hamilton-Jacobi equation. Motion of a rigid body. Euler's theorem. Eulerian angles. Postulates of special relativity. Lorentz transformations. Transformations of velocities. Relativistic equations of motion. | | allows us to predict its future position and velocity. It is applicable in quantum mechanics, special relativity and general relativity. |
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| **Course Outcome** | After completing electrodynamics, students will be able to derive and interpret Maxwell's equations in differential/integral forms, compute EM fields for static and dynamic systems using potentials and gauges, analyze wave propagation, reflection, and radiation in different media, formulate EM laws covariantly and solve relativistic problems.<br>Classical mechanics provides a framework for understanding the forces acting on an object and their impact on its motion and it allows us to predict its future position and velocity. It is applicable in quantum mechanics, special relativity and general relativity. |
| **Learning Resources** | 1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, Addison Wisley, 2000.<br>2. K.C. Gupta, Classical Mechanics of Particles and Rigid Bodies, New Age International Publishers, 1997.<br>3. B. K. Bagchi, Advanced Classical Mechanics, CRC Press, 2017.<br>4. D. J. Griffiths ,Intoduction to Electrodynamics, Cambridge University Press, 2017.<br>5. W. Greiner, Classical Electrodynamics, Springer, 1998.<br>6. J. D. Jackson, Classical Electrodynamics, John Wiley & Sons, 1962. |

| Course Code | MA6221N | Course Name | Waves and Vibrations in Elastic Solid Media | Course Category | PSE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | Continuum Mechanics | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| **Course Offering Department** | | **Mathematics** | | **Data Book / Codes/Standards** | Nil |

| **Course Objective** | The objective of this course is to provide students with a comprehensive understanding of the fundamental principles governing wave propagation and vibrational phenomena in elastic solid media. The course aims to develop the ability to model, analyze, and interpret elastic wave and vibration behavior in various physical contexts. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Wave**<br>Fundamental Waves: equivoluminal and dilatational waves in isotropic elastic solid medium, Body waves: P, SV and SH waves, Kinematical and Dynamical conditions for the motion of a surface of discontinuity, Velocity of waves in isotropic and anisotropic solid media, Wave surface, Plane wave, Surface wave: Rayleigh wave, Love wave. | 24 | • Classify and describe different wave types in isotropic and anisotropic elastic solids.<br>• Concept and characteristics of P and S waves.<br>• Propagation characteristics of Rayleigh, and Love waves. |
| 2 | **Vibration**<br>General theorem of vibration, Radial and rotatory vibrations of sphere, Torsional, longitudinal and flexural vibrations of circular cylinder. | 18 | • Understand and apply the general theorem of vibration in elastic solids.<br>• Analyze different types of vibrations in sphere and circular cylinder under various boundary conditions. |
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| **Course Outcome** | By the end of this course, students will be able to:<br>Understand and explain the fundamental concepts of wave propagation and vibration in elastic solids, including stress, strain, and elasticity principles.<br>Derive and solve the governing equations for different types of elastic waves.<br>Model and predict vibrational modes and natural frequencies of elastic structures and solids under various boundary conditions. |

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| **Learning Resources** | **References**:<br>1. I. S. Sokolnikoff : Mathematical Theory of Elasticity. McGraw Hill, 1956.<br>2. A. E. H. Love : A treatise on mathematical theory of Elasticity, McGraw Hill, 1954.<br>3. K. F. Graff : Wave Motion in Elastic Solids |

| Course Code | MA6222N | Course Name | Advanced Fluid Dynamics | Course Category | PSE | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | Continuum Mechanics | Co-requisite Courses | Nil | Progressive Courses | Nil |
|---|---|---|---|---|---|
| Course Offering Department | | Mathematics | | Data Book / Codes/Standards | Nil |

| Course Objective | The objective of this course is to provide students with a rigorous understanding of advanced concepts in fluid dynamics, with a focus on vortex motion, surface progressive and stationary waves, stress-strain behavior in fluids, the dynamics of viscous flows and gravity and capillary-gravity waves on both finite and deep water. |
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| Module | Syllabus | Duration (class-hour) | Module Outcome |
|---|---|---|---|
| 1 | **Vortex Motion**<br><br>Introduction , Some elementary definitions , Properties of vortex filament , Permanence of vorticity and vortex rings , Circular vortex , Pressure due a circular vortex , Ramkine's combined vortex , Rectilinear vortex , Single vortex filament , Two vortex filaments , Vortex pair , Vortex doublet , Source and vortex , Vortex filament parallel to a plane , Vortex filament parallel to two perpendicular planes , Vortex in and outside a circular cylinder , Vortex in the presence of a circular cylinder , Vortex sheet , Single infinite row of vortices , Two infinite rows of parallel vortices , Karman vortex street , The drag due to a vortex wake. | 10 | After completion of this chapter students will gather knowledge about the rotational characteristics of fluid motion. |
| 2 | **Liquid Surface Waves**<br><br>Introduction, General equation of wave motion , Mathematical representation of<br>(a) Progressive waves<br>(b) Stationary waves<br>Kinematical condition at the free surface, Pressure condition at the free surface<br>Surface waves :<br>(a) Progressive waves on the surface of a canal of finite depth<br>(b) Progressive waves on deep water<br>(c) Stationary waves on the surface of a canal of finite depth | 11 | After finishing this chapter students will be able to know about the general equation of wave motion and the nature of surface gravity and capillary waves on both finite depth and deep water. |

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| | (d) Stationary waves on deep water<br>Kinetic and Potential energy of progressive waves , Kinetic and Potential energy of stationary waves , Steady motion :<br>(a) Progressive waves on the surface of a canal of finite depth<br>(b) Progressive waves on deep water<br>(i) First order approximation to the wave speed<br>(ii) Second order approximation to the wave speed<br>(c) Progressive waves at an interface of two liquids<br>(d) Progressive waves at an interface of two liquids when upper surface is free<br>(e) Waves over a sinuous bottom.<br>Group velocity, Dynamical significance of group velocity, Capillary waves, Effect of capillarity on surface waves, Effect of capillarity on surface waves at an interface , Effect of wind on deep water, Long waves, Steady motion for long waves, Solitary waves. | | |
| **3** | **General Theory of Stress and Rate of Strain**<br><br>Introduction, Stress across a plane at a point, Nature of stresses, Stress at a point, Symmetry of stress tensor, Stress in a fluid at rest and in motion, Transformation of stress components:<br>(a) Two- dimensional stress components<br>(b) Three- dimensional stress components<br>Stress quadric, Principal stress, Principal planes, Fundamental theorem of stress, Mohr's circle diagram, Classifications of stress.<br>Strain analysis, Nature of strain, Transformation of rate of strain components:<br>(a) Two- dimensional rate of strain components<br>(b) Three- dimensional rate of strain components<br>Strain quadric, Fundamental theorem of strain, Classifications of strain, Relation between stress and rate of strain. Stoke's relation, General motion of a fluid element. | 11 | The purpose of this chapter is to provide students the idea about the stress and strain in a fluid at rest and in motion. |
| **4** | **Fundamental Equations of Viscous Fluid** | 10 | After finishing this chapter students |

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| | Introduction, Definition of viscosity, Effect of temperature and pressure on viscosity, Newton's law of viscosity, Types of fluids, Motion of a small body through a viscous medium. Stoke's law, The viscosity hypothesis, Boundary conditions in a viscous fluid , Navier-Stoke's equations of motion for viscous fluid , Conservation of momentum , The energy equation , Conservation of energy , Dissipation of energy due to viscosity , Diffusion of vorticity , Decay of vorticity , Circulation in a viscous fluid , Effect of viscosity on water waves in deep water. | | will acquire knowledge about the viscous property of fluid, the general equations of motion for viscous fluid and the effect of viscosity on waves in deep water. |
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| **Course Outcome** | Upon successful completion of this course, students will be able to:<br>Understand and analyse vortex motion, vortex filaments and doublet, and their influence on fluid flow.<br>Model and gather knowledge about progressive and stationary waves on finite depth and deep water.<br>Make idea about gravity and capillary-gravity waves.<br>Evaluate stress and strain analysis including diffusion, decay, and the effect of viscosity on flow and wave behavior. |

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| **Learning Resources** | **References:**<br>1. Gupta A. : Groundwork of mathematical fluid dynamics, Academic Publishers, 2013.<br>2. Batchelor G.K. : An Introduction to fluid dynamics , Cambridge University Press, 1967.<br>3. Frank M. White : Fluid mechanics. Tata Mc. Graw - Hill publishing company, New Delhi, 2008.<br>4. Goldstein S. : Modern developments in fluid dynamics , Oxford University Press, New York , 1938.<br>5. Lamb H. : Hydrodynamics , Dover Publications, New York , 1932.<br>6. Mase G.E. : Theory and problems of continuum mechanics , Schaum series.<br>7. McCormack P.D. and L. Crane : Physical fluid dynamics, Academic Press , New York, 1973.<br>8. Milne-Thomson L.M. : Theoretical hydrodynamics, The Macmillan Company , New York, 1950.<br>9. Streeter V.L. : Fluid dynamics, Mc.Graw Hill Book Company Inc. New York, 1948.<br>10. Streeter V.L. : Handbook of Fluid dynamics, Mc.Graw Hill Book Company Inc. New York ,1948.<br>11. Yuan S.W. : Foundations of fluid mechanics , Prentice-Hall of India pvt.Ltd. , New Delhi , 1969. |