# Sister Nivedita University

# Department of Mathematics


**Syllabus for Mathematics Undergraduate Programme**

**Framed according to the**

**National Education Policy (NEP 2020)**

## B.Sc. Mathematics (Honours)

**Programme Outcomes (PO):**

**By the end of the program the students will be able to:**

PO1: Ability to acquire in-depth knowledge of algebra, calculus, geometry, differential equations and several other branches of mathematics. This also leads to study of related areas like computer science and physical science. Thus, this Program helps learners in building a solid foundation for higher studies in mathematics.

PO2: The skills and knowledge gained has intrinsic beauty, which also leads to proficiency in analytical reasoning. This can be utilized in modeling and solving real life problems.

PO3: To recognize patterns and to distinguish between essential and irrelevant aspects of problems.

PO4: Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.

PO5: Ability to share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to learn behave responsibly in a rapidly changing interdependent society.

PO6: Ability to communicate mathematics effectively by written, computational and graphic means.

PO7: Create mathematical ideas from basic axioms.

PO8: Ability to apply multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

PO9: Able to present mathematics clearly and precisely, make vague ideas precise by formulating them in the language of mathematics, describe mathematical ideas from multiple perspectives and explain fundamental concepts of mathematics to non-mathematicians

PO10: This Program will also help students to enhance their employability for jobs in banking, insurance and investment sectors, data analyst and in various other public and private enterprises.

**Category definition with credit breakup**

| Semester | Credits | | | | | | | | | | Credits/ semester |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MC/ME | ME | | Non-Major | | MDC | AEC | SEC | VAC | INT | |
| | | Course | Project | NM | NV | | | | | | |
| I | 4+4 | | | 5 | 1+1 | | 2 | 3 | 2 | | 22 |
| II | 4+4 | | | | 1+1 | 3 | 2 | 3 | 2 | | 20 |
| III | 4+4 | | | 4 | 1+1 | 3 | 2 | | | | 19 |
| IV | 4+4+3 | | | 4 | 1+1 | 3 | 2 | | | | 22 |
| V | 4+4+4 | | | | 1+1 | | | 3 | 2 | | 19 |
| VI | 4+4+4 | | | 4 | 1+1 | | | | | 3 | 21 |
| VII | 4+4+4+4 | | | 4 | | | | | | | 20 |
| VIII | | 8/20 | 12/0 | | | | | | | | 20 |
| Credits/ Course | 98 | | | 33 | | 9 | 8 | 9 | 6 | 3 | |
| Total Credit | | | | | | | | | | | 163 |

Major – Major program Specific Course – Compulsory (MC); Major Program Specific Course – Elective (ME); NM – Non-Major Specific Subject Course; NV – Non-Major vocational education training; MDC – Multidisciplinary courses; AEC – Ability Enhancement Courses; SEC – Skill Enhancement Courses; VAC – Value Added Courses; INT – Internship; Project – Project.

## Course structure for B.Sc. in Mathematics

| Category | Course name | Credit | Teaching Scheme | | |
|---|---|---|---|---|---|
| | | | L | T | P |
| Semester I | | | | | |
| MC1 | Classical And Abstract Algebra | 4 | 4 | | |
| MC2 | Real Analysis | 4 | 4 | | |
| NM1 | Fundamental of Computer Science and introduction to C Programming | 4 | 4 | | |
| | C Programming Lab | 1 | | | 2 |
| NV1 | Vocational – EAA I (Yoga/ Sports/ NCC/ NSS) | 1 | | | 2 |
| NV2 | Vocational – Soft Skill Development I | 1 | 1 | | |
| AEC 1 | Communicative English I | 2 | 2 | | |
| SEC 1 | Computer Application | 3 | 3 | | |
| VAC 1 | Environmental Science I | 2 | 2 | | |
| Total Credit = 22 | | | Teaching Hour = 24 | | |
| Semester II | | | | | |
| MC3 | Linear Algebra and Field Extension | 4 | 4 | | |
| MC4 | Discrete Mathematics and Riemann Integration and Series of Functions | 4 | 4 | | |
| NV3 | Vocational – Mentored Seminar I | 1 | 1 | | |
| NV4 | Vocational – Soft Skill Development II | 1 | 1 | | |
| MDC 1 | Selected by the candidate (Elective) | 3 | 3 | | |
| AEC 2 | Communicative English II | 2 | 2 | | |
| SEC 2 | Basic Management Skill | 3 | 3 | | |
| VAC 2 | Environmental Science II | 2 | 2 | | |
| Total Credit = 20 | | | Teaching Hour = 20 | | |
| Semester III | | | | | |
| MC5 | Analytical Geometry and Vector Analysis | 4 | 4 | | |
| MC6 | Probability and Statistics | 4 | 4 | | |
| NM2 | Selected by the candidate | 4 | 4 | | |
| NV5 | Vocational – Mentored Seminar II | 1 | 1 | | |
| NV6 | Vocational – Soft Skill Development III | 1 | 1 | | |

| | | | | | |
|---|---|---|---|---|---|
| MDC 2 | Selected by the candidate (Elective) | 3 | 3 | | |
| AEC3 | Logical Ability I / Foreign Language I | 2 | 2 | | |
| Total Credit = 19 | | | Teaching Hour = 19 | | |
| Semester IV | | | | | |
| MC7 | Numerical Analysis | 3 | 3 | | |
| | Numerical Analysis Lab | 1 | | | 2 |
| MC8 | Optimization techniques | 4 | 4 | | |
| MC9 | Python Programming | 3 | 3 | | |
| NM3 | Selected by the candidate | 4 | 4 | | |
| NV7 | Vocational - Mentored Seminar III | 1 | 1 | | |
| NV8 | Vocational – Soft Skill Development IV | 1 | 1 | | |
| MDC3 | Selected by the candidate (Elective) | 3 | 3 | | |
| AEC4 | Logical Ability II / Foreign Language II | 2 | 2 | | |
| Total Credit = 22 | | | Teaching Hour = 23 | | |
| Semester V | | | | | |
| MC10 | Complex Analysis and Applications of Calculus | 4 | 4 | | |
| MC11 | Metric Space and Topology | 4 | 4 | | |
| MC12 | Ordinary differential equation and Multivariate Calculus | 4 | 4 | | |
| NV9 | Vocational- Mentored Seminar IV | 1 | 1 | | |
| NV10 | Vocational – Soft Skill Development V | 1 | 1 | | |
| SEC3 | Data Analysis | 3 | 3 | | |
| VAC3 | Ethics Study and IPR | 2 | 2 | | |
| Total Credit = 19 | | | Teaching Hour = 19 | | |
| Semester VI | | | | | |
| MC13 | Analytical Dynamics and Statics | 4 | 4 | | |
| MC14 | Financial Mathematics and Bio Mathematics | 4 | 4 | | |
| MC15 | Partial Differential equation and Differential Geometry | 4 | 4 | | |
| NM4 | Selected by the candidate | 4 | 4 | | |
| NV11 | Vocational | 1 | 1 | | |
| NV12 | Vocational – Soft Skill Development VI | 1 | 1 | | |
| INT1 | Internship | 3 | | | 6 |

| | | | | | |
|---|---|---|---|---|---|
| Total Credit = 21 | | | Teaching Hour = 24 | | |
| Semester VII | | | | | |
| MC16 | Continuum Mechanics | 4 | 4 | | |
| MC17 | Supervised Learning with Regression and Classification Technique I and II | 4 | 3 | | 2 |
| MC18 | Integral Transforms | 4 | 4 | | |
| MC19 | Advanced ODE and dynamical system | 4 | 4 | | |
| NM5 | Selected by the candidate | 4 | 4 | | |
| Total Credit = 20 | | | Teaching Hour = 21 | | |
| Semester VIII | | | | | |
| MC20 | Generalized functions and special functions | 4 | 4 | | |
| MC21 | Calculus of variations and integral equations | 4 | 4 | | |
| ME- Project/ Courses | Project/ Research Design and Communication (Mandatory), [Unsupervised learning and challenges for Big data Analytics, Advanced Computational Methods, Automata Theory] | 12/ (4+4+4) | 0/12 | | 24/0 |
| Total Credit = 24 | | | Teaching Hour = 36 | | |

**Course MC1: Classical and Abstract Algebra**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to: Present concept and properties of various algebraic structures and discuss the importance of algebraic properties relative to working within various number systems and develop the ability to solve simple and complex problems of algebra.*

***Prerequisite:*** *Before learning the course learners should have a basic knowledge about polynomial, number systems and sets, relations, mapping.*

***SYLLABUS OUTLINE:***

**Module I: Classical Algebra: [12L]**

Euclid's algorithm. Coprimes. Congruences**,** Chinese remainder theorem. Fermat's Theorem, Phi functions. Euler's theorem**,** Relation between roots and coefficients. Newton's formula. Descartes' rules, Cubic solution. Cardan's method**,** Biquadratic solution. Ferrari's method**,** Diophantine equation.

**Module II: Set Theory: [6L]**
Set partition, Partial order relation and Poset, Permutations of set ,Binary operations

**Module III: Group Theory : [16L]**
Semigroup, Groupoid. Group**,** Abelian group. Cardinality**,** Order of element. Subgroup. Lagrange theorem**,** Generating element. Cyclic Group**,** Homomorphism. Isomorphism (concept only)**,** Coset. Normal subgroup**,** Proof of Fermat, Chinese remainder theorem.

**Module IV: Ring and Field Theory : [16L]**
Ring. Subring. Ring isomorphism**,** Ideal. Primary ideal. Principal ideal. Maximum ideal**,** Zero divisor, Integral domain**,** Euclidean domain. Principal ideal domain. Field.

**Text & Reference books:**

**Text Books:**

1. S. K. Mapa , Higher Algebra.
2. S. K. Mapa, Classical Algebra.
3. Ghosh and Chakraborty, Higher Algebra.
4. Fraleigh , First Course in Abstract Algebra.

**Reference Books:**

1. Burnside and Panton, The Theory of Equations (Vol. I).
2. Barnard and Child, Higher Algebra .
3. Surjeet Singh & Zameruddin ,Modern Algebra .
4. N. P. Chaudhuri, Abstract Algebra (Tata Mc. Graw Hill).

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****: NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

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

**XX.CO1: Understand** the fundamentals of Classical algebra including integers and solve problems.
**XX.CO2: Recognize** the polynomials and **understand** the nature of roots and solve problems including higher order equations with respective methods.
**XX.CO3: Understand** inequalities and solve problems.
**XX.CO4: Understand** set, relation, equivalence relation, equivalence class and functions and types of functions and **solve** problems.
**XX.CO5: Understand** the concept of group structure and **identify** groups, subgroups and their types and properties to **solve** problems.
**XX.CO6: Identify** fundamental structures of abstract algebra including rings, fields.

**MC2:Real Analysis**

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

***Learning objectives:*** *On completion of the course, students will be able to: understand the fundamental properties of the real numbers including their algebraic and order properties. Understand how to construct rigorous Mathematical proofs and apply them to solve problems in Real Analysis.*

***Prerequisite:*** *Before learning the course learners should have a basic knowledge about number systems and sets, relations, mapping, differentiation, integration.*

***SYLLABUS OUTLINE:***

**Module I: Sets in R: [8L]**

Intuitive idea of numbers. Mathematical operations revisited with their Properties (closure, commutative, associative, identity, inverse, distributive). Sets and Functions - definition and properties. Field Axioms. Well ordering principle, Bounded set, L.U.B. (supremum) and G.L.B. (infimum) of a set. Properties of L.U.B. and G.L.B. Definition of an Archimedean ordered field. Archimedean property of IR. Open and closed Intervals, Neighbourhood of a point. Interior point. Open set. Union, intersection of open sets. Limit point and isolated point of a set. Criteria for L.U.B. and G.L.B. of a bounded set to be limit point of the set. Bolzano-Weierstrass theorem on limit point. Definition of derived set. Closed set. Complement of open set and closed set. Union and intersection of closed sets as a consequence. Countability (finite and infinite) and uncountability of a set. Subset of a countable set is countable. Cartesian product.

**Module II: Sequences of real numbers: [10L]**

Definition, bounded sequence, Limit of a sequence, examples. Algebra of limits. Monotone sequences and their convergence. Sandwich theorem. Nested interval theorem. Limit of some important sequences. Subsequence. Sub-sequential limits. Lim sup upper (limit) and lim inf (lower limit) of a sequence using inequalities. Alternative definitions of lim sup and lim inf of a sequence using L.U.B. and G.L.B. Cauchy Sequence and related theorems.

**Module III: Infinite Series of real numbers: [10L]**

Infinite Series and it's convergence. Cauchy's criterion of convergence. Tests of convergence – Cauchy's condensation test. Comparison test, Ratio Test, Root test, Raabe's test, Gauss's test. Series of non-negative real numbers: Absolute and conditional convergence Alternating series: Leibnitz test. Non-absolute convergence: Abel's and Dirichlet's test (statements and applications). Riemann's rearrangement.

**Module V: Limit and Continuity:[ 10L]**

Continuity of real-valued functions of a real variable: Limit of a function. Sequential criteria. Algebra of limits. Algebra of continuous functions. Continuity of composite functions. Examples of continuous functions. Bounded functions. Neighbourhood properties of continuous functions regarding boundedness. Related Theorems.

**Module VI: Derivative: [10L]**

Definition of differentiability. Leibnitz theorem. Theorems on derivatives : Darboux theorem, Rolle's theorem, Mean value theorems of Lagrange and Cauchy – as an application of Rolle's theorem. Taylor's theorem on closed and bounded interval with Lagrange's and Cauchy's form of remainder deduced from Lagrange's and Cauchy's mean value theorem respectively. Maclaurin's theorem as a consequence of Taylor's theorem. Statement of Maclaurin's theorem and the expansion of some standard functions.

Statement of L'Hospital's rule and its consequences. Point of local maximum/minimum of a function in an interval. Sufficient condition for the existence of a local maximum/minimum of a function at a point (statement only). Determination of local extremum using first order derivative. Application of the principle of maximum/minimum in geometrical problems.

**Text & Reference books:**

**Text Books:**

1. Introduction to Real Analysis- S. K. Mapa.

2. Introduction to Real Analysis–Bartle & Sherbert (John Wiley & Sons.)

3. Mathematical Analysis – Tom. M. Apostol.

4. Differential Calculus – R. K. Ghosh& K. C. Maity.

**Reference Books:**


1. Basic Real & Abstract Analysis–Randolph J.P. (Academic Press).
2. A First Course in Real Analysis–M. H. Protter & G. B. Morrey (Springer Verlag, NBHM).
3. A Course of Analysis –Phillips.
4. Problems in Mathematical Analysis– B. P. Demidovich (Mir).
5. Problems in Mathematical Analysis – Berman (Mir).
6. Differential & Integral Calculus (Vol.I&II)–Courant & John.
7. Calculus of One Variable – Maron (CBS Publication).


***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1: Understand** the properties of real numbers and discuss the related theorems.

**XX.CO2: Identify** countable and uncountable sets.

**XX.CO3: Identify** the nature of sequences and series that arise in various complex problems in science and technology.

**XX.CO4: Develop** the knowledge of limits, continuity and differentiability of functions that will serve as an introduction to calculus.

**XX.CO5: Apply** the knowledge of differentiation and Mean Value Theorem to solve complex problems.

**XX.CO6: Determine** point of maximum/minimum of a function in an interval to solve practical problems.

**Course NM1: Fundamental of Computer Science and Introduction to C-programming with Lab**

**Credit 5: (4L-0T-2P)**

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

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

***SYLLABUS OUTLINE:***

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

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

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

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

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

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

**C-Programming Lab:**

**Text & Reference books:**

**Text Books:**

1. Programming with C, Gottfried, TMH
2. Practical C Programming, Oualline, SPD/O'REILLY
3. Let us C-YashwantKanetkar.

**Reference Books:**

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

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

**XX.CO1:** Understand the fundamentals of C programming.

**XX.CO2:** Recollect various programming constructs and to develop C programs.

**XX.CO3:** Choose the right data representation formats based on the requirements of the problem.

**XX.CO4:** Understanding a concept of object thinking within the framework of the functional model. Understanding a concept of functional hierarchical code organization.

**XX.CO5:** Understanding a defensive programming concept. Ability to handle possible errors during program execution.

**XX.CO6:** Implement different Operations on arrays, functions, pointers, structures, unions and files.

**Course MC3: Linear Algebra and Field Extension**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to: apply the knowledge of matrix algebra, system of equations, vector space, linear transform as a tool in the field of Image Processing, Machine Learning and artificial intelligence etc. and the knowledge of vector calculus to solve complex problems.*

***Prerequisite:*** *Before learning this course, the students should have a knowledge of basic abstract algebra.*

***SYLLABUS OUTLINE:***

**Module I: Matrices:[8L]**

Matrix. Determinant. Solving systems of linear equations. Uniqueness and existence criteria**,** Row and column spaces. LU Decomposition. LDU factorisation. Matrix transformations.

**Module II: Vector spaces:[10L]**

Definition, Subspaces, Basis. Dimension, Related Theorems. Linear Transformation, Examples of Linear Transformation, Matrix Representation, Rank-nullity theorem, Linear Operator, Eigenvalue, Eigenvector. Geometric significance. Duality. Dual mapping and space. Transposition, Characteristic polynomial. Diagonalization.

**Module III: Inner product spaces [10L]**

Definition. Orthogonality. Orthonormality, Gram schmidt orthogonalisation. QR decomposition, Adjoint of linear operator. Singular value decomposition, Principal component analysis.

**Module IV: Application in machine learning [4L]**

Ordinary least square. Linear regression, Principal Component Analysis. Dimension reduction, Gradient descent, Hyperplanes. Support vectors.

**Module V: Field extension:[16L]**

Centraliser. Class equation. Direct product, Simple group. Quotient group. Group Isomorphism theorems, Cayley' theorem. Sylow's theorem, Action of a group. Fixed point and Stabilizer. Ring Isomorphism theorems. Polynomial rings, Factorisation. Quotient rings. Irreducible polynomials, Module. Submodule. Extension of fields.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Text & Reference books:**

**Text Books:**

1. Linear Algebra: Stephen H. Freiedberg, Arnold J. Insel and Lorence E. Spence
2. Higher Algebra- S.K. Mapa
3. Contemporary Abstract Algebra: Joseph A Gallian

**Reference Books:**

4. Linear Algebra - Ghosh and Chakraborty
5. Linear Algebra – Hadley

***Course learning outcome****: (CO)*

After attending this course, the students will be able to

XX.**CO1:** Understand the fundamentals of matrix algebra and describe properties of linear systems using vectors and solve systems of linear equations and interpret their results.

XX.**CO2:** Identify vector spaces and subspaces and their properties.

XX.**CO3:** Identify a linear transform and construct the matrix representation of a linear Transform.

XX.**CO4:** Apply the knowledge of Eigenvalue, Eigenvector, Singular value decomposition and Principal component analysis to solve problems in Image Processing and Machine Learning.

XX.**CO5**: Understand important properties and types of group like quotient group, simple

group and apply Sylow's theorems to solve complex problems.

XX**CO6**: Understand ring isomorphism and apply for extension of a field.

**Course MC4: Discrete Mathematics and Riemann Integration and Series of Functions**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to: apply the knowledge of graph theory , Riemann integration and series of functionsto solve complex problem.*

***Prerequisite:*** *Before learning the concepts of Discrete Mathematics, the students should have a basic knowledge of set, relation, mapping, matrix, real number system, limit, continuity, differentiability of real functions etc.*

***SYLLABUS OUTLINE:***

**Module I: Combinatorics & Graph Theory: [14L]**

Pigeonhole principle. Inclusion-exclusion principle. Ball-bin problems. Graph. Digraph. Complement. Bipartite and complete graphs. Graph isomorphism. Connectedness. Reachability. Adjacency matrix. Euclidean path and circuit. Hamiltonian path and circuit, Tree. planar graph. Euler's formula. Dual of planar graph, Clique. Chromatic number, Generating functions. Recurrence relation

**Module II: Logic:[10L]**

Propositional calculus. Proposition and connectedness**,** Truth tables. Validity. Satisfiability**,** Equivalence and normal forms**,** Soundness and completeness.

**Module III: Riemann integration:[14L]**

Darboux sum. Integrability. Condition for Riemann's integrability, Negligible set. Condition on negligible discontinuity for Riemann integrability. MVT of integral calculus. Antiderivative, Area and volume integral in terms of double and triple integrals.

**Module IV: Series of functions:[10L]**

Power series. Uniqueness of power series. Abel's limit theorems, Uniform and absolute convergence, Fourier series. Trigonometric series, Dirichlet conditions.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Text & Reference books:**

**Text Books:**


1. Topics in Algebra, I. N. Herstein, John Wiley and Sons.
2. Digital Logic & Computer Design, M. Morris Mano, Pearson.
3. Elements of Discrete Mathematics, (Second Edition) C. L. LiuMcGraw Hill, New Delhi.
4. Graph Theory with Applications, J. A. Bondy and U. S. R. Murty, Macmillan Press, London.
5. Mathematical Logic for Computer Science, L. Zhongwan, World Scientific, Singapore.


**Reference Books:**


6. Introduction to linear algebra. Gilbert Strang.
7. Introductory Combinatorics, R. A. Brualdi, North-Holland, New York.
8. Graph Theory with Applications to Engineering and Computer Science, N. Deo, Prentice Hall, Englewood Cliffs.
9. Introduction to Mathematical Logic, (Second Edition), E. Mendelsohn, Van-Nostrand, London.


**Course learning outcome**: (CO)

After attending this course the students will be able to

XX.**CO1**: Understand the fundamental principles of Graph theory.

XX.**CO2**: Apply the concepts of graph theory to solve real life problems.

XX.**CO3**: Understand the fundamentals of Propositional Logic and identify truth tables and logical operators to analyse problems.

XX**.CO4**: Understand the properties of Riemann Integrable functions and apply the R-integration properties to solve associated problems.

XX.**CO5**: Analyse all the theorems associated with Riemann-integration and Series of Functions.

XX.**CO6**: Evaluate radius and interval of convergence of power series and understand transcendental functions in terms of power series as well as differentiation and integration of power series, the concept of Fourier series and associated results.

**Course MC5: Analytical Geometry and Vector Analysis**
**Credit 4: (4L-0T-0P)**

***Learning objectives:***

On completion of the course students will be able to apply the knowledge of analytical geometry and vector analysis in various mathematical and scientific disciplines.

***Prerequisite:*** Before learning this course the students should have proficiency in algebra, trigonometry and calculus including knowledge of functions, equations, and derivatives. Familiarity with vectors, matrices, and linear algebra concepts is beneficial.

***SYLLABUS OUTLINE:***

**Module I: 2D Geometry [20L]**

Rotation of axes and second degree equations, Classification of conics. Tangent, normal. Polar equations of conics, Equation of planes. Sides of a plane, Angle between planes, Parallelism. Perpendicularity.

**Module II: 3D Geometry [10L]**

Straight lines in 3D, Canonical equations, Skew lines. Associated Problems.

**Module III: Vector analysis [18L]**

Definition, Free vectors. Addition, multiplication, Collinearity. Coplanarity, Triple products, Work done by force. Moment of force.

**Text & Reference books:**

**Text Books:**

1. Analytical Geometry – Ghosh and Chakravorty.
2. Vector Analysis-Maity and Ghosh
2. Vector Analysis – Louis Brand.
3. Elementary Vector Analysis – C. E. Weatherburn (Vol. I & II).

**Reference Books:**

4. Vector Analysis – Barry Spain.
5. Vector & Tensor Analysis – Spiegel (Schaum).

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Understand the basic concept of 2D geometry and apply its properties to classify conics, tangent, normal.

**XX.CO2:** Understand the geometrical terminology and basics of the Planes, Straight lines in 3D.

**XX.CO3:** Identify Conic Sections and classify quadratic equations. Also learn about the line of intersection of two planes and the concept of skew lines.

**XX.CO4:** Apply the knowledge of transform the co-ordinate system to simplify and solve complex problems.

XX.**CO5**: Understand the concept of vectors and properties of vectors.

**XX.CO6:** Apply vector algebra to solve problems in geometry and mechanics.

**Course MC6: Probability and Statistics +Lab**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to:*

develop a solid understanding of key probability concepts such as sample spaces, random variables, and probability distributions. Additionally, students aim to gain proficiency in statistical analysis techniques, including hypothesis testing, regression analysis, and data interpretation, enabling them to make informed decisions and draw meaningful conclusions from data.

***Prerequisite:*** *Before learning the course*

Prerequisites for probability and statistics include a strong foundation in algebra and basic mathematical operations, as well as an understanding of descriptive statistics and basic probability concepts such as sample spaces and probability rules.

***SYLLABUS OUTLINE:***

**Module-I: Probability [24L]**

Concept of experiments, sample space, event. Definition of Combinatorial Probability. Conditional Probability, Bayes Theorem. Probability distributions: discrete & continuous distributions, Binomial, Poisson and Geometric distributions, Uniform, Exponential, Normal, Chi-square, t, F distributions. Expected values and moments: mathematical expectation and its properties, Moments (including variance) and their properties, interpretation, Moment generating function, Discrete Random variables. Special Discrete Univariate Random Variables. Continuous Random Variables. Special Continuous Univariate Random Variables. Bivariate Random Variables.

**Module-II: Introduction to Statistics [24L]**

Definition of Statistics. Basic objectives. Applications in various branches of science with examples. Collection of Data: Internal and external data, Primary and secondary Data. Population and sample, Representative sample. Descriptive Statistics: Classification and tabulation of univariate data, graphical representation, Frequency curves. Descriptive measures - central tendency and dispersion. Bivariate data. Summarization, marginal and conditional frequency distribution, Confidence Intervals, Hypothesis Testing, 1-way Anova, Simple Regression Model.

**Text & Reference books:**

**Text Books:**

1. Introduction to Probability – N. G. Das
2. Fundamentals of Statistics (Vol. I) - Goon Gupta and Das Gupta
3. Groundwork of Mathematical Probability and Statistics – Amritava Gupta

**Reference Books:**

1. Introduction to Probability – N. G. Das
2. Fundamentals of Statistics (Vol. I) - Goon Gupta and Das Gupta
3. Groundwork of Mathematical Probability and Statistics – Amritava Gupta

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Apply the concept of Basic Probability

**XX.CO2:** Solve problems using Bayes Theorem.

**XX.CO3:** Build the concept of random variable and probability distributions: discrete & continuous distributions, Binomial, Poisson and Geometric distributions, Uniform, Exponential, Normal, Chi-square, t, F distributions.

**XX.CO4:** Build knowledge about the basic statistical methods and representations of data

**XX.CO5:** Explain the concept of frequency distribution and their graphical representations, central tendency and dispersion

**XX.CO6:** Analyze the error for different probabilistic methods.

**Course MC7: Numerical Analysis and Lab**
**Credit 4: (3L-0T-2P)**

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

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

***SYLLABUS OUTLINE:***

**Module I. Error of numerical computations (4L):**

Errors in Numerical computation: Round off error, Truncation error. Approximate numbers. Significant figures. Absolute, relative and percentage error.
Operators: $\Delta$, E, $\mu$, $\delta$ (Definitions and simple relations among them).

**Module II. Interpolation (8L):**

Problems of interpolation, Weierstrass' approximation theorem only statement). Polynomial interpolation. Equi-spaced arguments. Difference table. Deduction of Newton's forward and backward interpolation formulae. Statements of Stirling's and Bessel's interpolation formulae. Error terms. Deduction of Lagrange's interpolation formula. Divided difference. Newton's General Interpolation formula (only statement).

**Module III. Numerical Integration (6L):**

Integration of Newton's interpolation formula. Newton-Cote's formula. Trapezoidal and Simpson's ⅓rd formulae. Their composite forms. Weddle's rule (only statement). Statement of the error terms associated with these formulae. Degree of precision (only definition).

**Module IV. Numerical solution of non-linear equations (6L):**

Location of a real root by tabular method. Bisection method. Secant/ Regula-Falsi and Newton-Raphson methods, their geometrical significance. Fixed point iteration method.

**Module V. Numerical solution of a system of linear equations (6L):**

Gauss elimination method. Iterative method – Gauss-Seidal method. Matrix inversion by Gauss elimination method (only problems – up to 3×3 order), LU decomposition method.

**Module VI. Numerical solution or Ordinary Differential Equation (6L):**

Basic ideas, nature of the problem. Picard, Euler and Runge-Kutta($4^{th}$order) methods (emphasis on the problem only).

**Numerical Analysis Lab [12L]**

1. Evaluation of numerical integrations using
(a) Trapezoidal Rule
(b) Simpson's one-third rule
2. Solution of transcendental and algebraic equations by
    (a) Bisection Method
    (b) Regula-Falsi Method
    (c) Newton Raphson's method

3. Solution of system of linear equations by
   (a) Gauss-elimination method
   (b) Gauss-Seidel iteration method

4. Interpolation: Lagrange Interpolation
5. Solution of Initial value problems using
   (a) Euler's method
   (b) RK4 method

**Text & Reference books:**

**Text Books:**


**1.** Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.

2. Sahajahan Ali Mollah, Numerical Analysis and Computational Procedures, Books & Allied Ltd.

**3.** M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 6th Ed., New age International Publisher, India, 2007.

**4.** C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.

**5.** Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.

**6.** John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.


**Reference Books:**


**1.** Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishing co.

**2.** Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978. Yashavant Kanetkar, Let Us C, BPB Publications.

3. P. S. Grover, Programming and Computing with FORTRAN 77/90 – (Allied Publishers).


***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.


***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.


**Course Outcome (CO):**

On completion of the course, student will be able to:

XX.CO1: Construct the interpolating polynomial for both equispaced and un-equispaced arguments.

XX.CO2: Apply numerical integration techniques to solve complex problems.

XX.CO3: Understand and solve the system of linear and non-linear equations using different numerical techniques.

XX.CO4: Solve algebraic and transcendental equations using numerical methods.

XX.CO5: Construct numerical solution (local) of different initial value and boundary value problems.

XX.CO6: Analyze the several errors and approximation in numerical methods.

**Course MC8: Optimization techniques**
**Credit 4: (4L-0T-0P)**

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

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

**SYLLABUS OUTLINE:**

**Module I: Introduction to OR [2L]**

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

**Module II: Linear Programming [14L]**

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

**Module III: Transportation and Assignment problems [12L]**

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

**Module IV: PERT – CPM [6L]**

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

**Module V: Inventory Control [4L]**
Functions of inventory and its disadvantages, Concept of inventory costs, Basics of inventory policy (order, lead time, types), Fixed order-quantity models – EOQ model.

**Module VI: Queuing Theory [6L]**

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

**Module VII: Game Theory [4L]**
Concept of game problem. Rectangular games. Pure strategy and Mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Necessary and sufficient condition for a given strategy to be optimal in a game. Concept of Dominance. Fundamental Theorem of rectangular games. Algebraic method. Graphical method and Dominance method of solving Rectangular games. Inter-relation between theory of games and L.P.P

**Text Books:**
1. Operations Research: An Introduction. H.A. Taha.
2. Linear Programming. G. Hadley.

**Reference Books:**
1. Linear Programming. K.G. Murthy.
2. Principles of OR with Application to Managerial Decisions. H.M. Wagner.
3. Introduction to Operations Research. F.S. Hiller and G.J. Lieberman.
4. Elements of Queuing Theory. Thomas L. Saaty.
5. Operations Research and Management Science, Hand Book: Edited By A. Ravi Ravindran.
6. Management Guide to PERT/CPM. Wiest& Levy.
7. Modern Inventory Management. J.W. Prichard and R.H. Eagle.

***Course learning outcome**: (CO)*

After attending this course the students will be able to

**XX.CO1:** Understand the concept of Operations Research , Game Theory and the basic concepts linear algebra.

**XX.CO2:** Formulate Mathematical Model of various optimization problems and solve linear programming problems using appropriate techniques.

**XX.CO3:** Determine optimal strategy for Transportation and Assignment problems.

**XX.CO4:** Determine the critical path, project time and its variance using theproject scheduling techniques – Gantt chart, PERT & CPM.

**XX.CO5:** Understand theconcept of inventory costs, Basics of inventory policy and fixed order-quantity models like EOQ, POQ.

**XX.CO6:** Understand the concept of queuing theory and identify the queuing models like M/M/1and M/M/m.

**Course MC9: Python Programming**
**Credit 3: (3L-0T-0P)**

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

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

## *SYLLABUS OUTLINE:*

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

### Module I (6L)

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

### Module II (4L)

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

### Module III (6L)

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

### Module IV (6L)

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

### Module V (6L)

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

### Module VI (8L)

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

**Text & Reference books:**

**Text Books:**


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


**Reference Books:**


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


***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.


***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.


**Course Outcome (CO):**

**CO1:** Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements

**CO2:** Express proficiency in the handling of strings and functions.

**CO3:** Determine the methods to create and manipulate Python programs by utilizing the data structures like lists, dictionaries, tuples and sets.

**CO4:** Identify the commonly used operations involving file systems and regular expressions.

**CO5:** Articulate the Object-Oriented Programming concepts such as encapsulation, inheritance and polymorphism as used in Python.

**CO6:** Implement Conditionals and Loops for Python Programs knowledge/skill development and Use functions and represent Compound data using Lists, Tuples and Dictionaries

**Course MC10: Complex Analysis and Applications of Calculus**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** On completion of the course complex analysis, students will be able to understand complex numbers, analyze complex functions, evaluate integrals using contour

integration, solve problems using the residue theorem, and apply complex analysis techniques in various scientific disciplines. Also, students will be able to the knowledge of calculus to find out the radius of curvatures, envelopes, asymptotes of different functions.

***Prerequisite:*** Before learning the course, complex analysis includes a strong foundation in calculus, including knowledge of limits, derivatives, and integrals. A solid understanding of functions, including exponential, logarithmic, and trigonometric functions, is necessary. Knowledge of complex numbers and their algebraic operations will be beneficial to grasp the complex analysis aspects of Laplace transformation. Proficiency in solving equations and manipulating mathematical expressions is also recommended.

***SYLLABUS OUTLINE:***

**Complex Analysis:**

**Module I (12L):** Complex numbers, Topology of the complex plane, Stereographic projection. Complex Functions, Continuity and Differentiability of Complex Valued Functions, Cauchy-Riemann equations, Sequence of complex numbers, Convergence of sequence of Complex Numbers, Series of Complex Numbers, Tests of Convergence of Series of Complex Numbers.

**Module II (18L):** Analytic functions, Zeros of analytic functions, Multiple valued functions, Branch cuts, Concept of Riemann sheet. Curves in the complex plane, Complex integration, Jordan's Lemma. Cauchy's theorem, Morera's theorem, Cauchy integral formula, Maximum modulus principle, Open mapping Theorem, Schwarz Lemma, Liouville's theorem, Fundamental theorem of algebra.Series, Uniform convergence, Properties of uniformly convergent series, Power series, Taylor series, Uniqueness theorem, Analytic continuation, Laurent series. Singularities, Classification of singularities, Cauchy's residue theorem. Evaluation of some integrals, Argument principle. Conformal mapping, Mobius transformation.

**Module-III: Application of Calculus (18L)**

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax+b}\sin x\ e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, curvature, concavity and points of inflection, envelopes, rectilinear asymptotes (Cartesian & parametric form only), curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences. Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x dx$, $\int \cos^n x dx$, $\int \tan^n x dx$, $\int \sec^n x dx$, $\int (\log x)^n dx$, $\int \sin^n x \sin mx dx$, $\int \sin^n x \cos^m x dx$. Parametric equations, parametrizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution.

**Text & Reference books:**

**Text Books:**

1. 1. S. Ponnusamy, Foundation of Complex Analysis, Narosa Publishing House, ISBN: 9788173196294.

2. Differential & Integral Calculus(Vol.I&II)–Courant & John.
3. Calculus of One Variable – Maron (CBS Publication).

**Reference Books:**

4. R. V. Churchill and J. W. Brown , Complex Variables and Applications: Mcgraw-Hill; New York; 1996
5. R. V. Churchill and J. W. Brown: Complex Variables and Applications; Mcgraw-Hill; New York; 1996
6. N. W. Mclachlan, Laplace transform and their applications to differential equations.
7. 1. E.T. Copson, An introduction to theory of functions of a complex variable, Oxford, Clarendon Press, 1962.
8. 2. E.T. Whittaker and G.N. Watson, A course of modern analysis, Cambridge University Press, 1958.
9. 3. R.V. Churchill, J.W. Brown and R.E. Vermay, Complex variables and applications, McGraw Hill, 1984.
10. 4. T.M. MacRobert, Functions of a complex variable, MacMillan, 1962.
11. Problems in Mathematical Analysis– B. P. Demidovich (Mir).
12. Problems in Mathematical Analysis – Berman(Mir).

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Develop the knowledge of limits, continuity, and differentiation of complex functions.

**XX.CO2:** Identify the nature of sequences and series of complex numbers that arise in various complex problems in science and technology.

**XX.CO3:** Apply the concept of conformal map to solve complex problems in engineering and physics.

**XX.CO4:** Apply the tools of complex integration to solve integrals in real field and other practical problems.

**XX.CO5:** Determine the radius of curvature of different functions.

**XX.CO6:** identify different functions in Cartesian and polar coordinates and fund out the asymptotes, envelopes of the functions.

**Course MC11: Metric space and Topology**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** On completion of this course, student will be able to understand the concepts of metric spaces and topological spaces and their properties.

***Prerequisite:*** Before learning the course learners should have a basic knowledge about real number, limit, continuity and differentiability in real analysis.

***SYLLABUS OUTLINE:***

**Module I: Calculus of Multi-Variables:[12L]**

Topology of Rn. Euclidean norms, Convergence of sequence in Rn. Open and closed balls. Sequential compactness, Chain rule of derivatives in Rn.

**Module II: Metric Space[18L]**

Metrics. Sets in metric spaces, Continuity, Connectedness, Compactness.

**Module III: Topology[18L]**

Topological spaces. Open and closed sets, Bases and subbases. Coveringm, Subspace topology, Separability. T0-T4 axioms, Compact space. Normal space.

**Text & Reference books:**

**Text Books:**

1. Randolph J.P , Basic Real & Abstract Analysis. (Academic Press).
2. B.C. Das & B. N. Mukherjee , Integral Calculus (U.N. Dhur)
3. Maity and Ghosh, Differential Calculus
4. S. Kumaresan, Topology of Metric Spaces (Narosa)

**Reference Books:**

1. G. B. Folland, FOURIER ANALYSIS AND ITS APPLICATIONS (American Mathematical Society)

2. Shanti Narayan & P.K. Mittal , Integral Calculus (S. Chand & Co. Ltd.)
3. S K MAPA, Introduction to Real Analysis (LEVANT BOOKS)
4. E. T. Copson, Metric Spaces. Cambridge University Press.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

On completion of the course, student will be able to:

**XX.CO1: Understand** the concepts of Metric spaces and Topological spaces.

**XX.CO2: Analyse** convergence of sequences in Rn.

**XX.CO3: Understand** the concept of connectedness, compactness in metric space.

**XX.CO4: Apply** continuous functions and homeomorphisms to understand the structures of topological spaces.

**XX.CO5: Create** new topological spaces using the concepts of subspaces, product and quotient topologies.

**XX.CO6: Apply** the theoretical concepts in topology to understand real world applications.

**Course MC12: Ordinary differential equations and Multivariate calculus**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** On completion of the course, student will be able to acquire the knowledge of the multivariate calculus and implement it to optimize a function with the help of the Largangian Multiplier method. Also, the knowledge of solving different types of ordinary differential equations enables someone to easily solve the initial and boundary value problems.

***Prerequisite:*** Before learning the course the learner should have a basic knowledge about calculus of one variable.

***SYLLABUS OUTLINE:***

**Module I Ordinary differential equations (30L):**
Significance of ordinary differential equation. Geometrical and physical consideration. Formation of differential equation by elimination of arbitrary constant. Meaning of the solution of ordinary differential equation. Concept of linear and non-linear differential equations.

Equations of first order and first degree: Statement of existence theorem. Separable, Homogeneous and Exact equation. Condition of exactness, Integrating factor. Rules of finding integrating factor, (statement of relevant results only).

First order linear equations: Integrating factor (Statement of relevant results only). Equations reducible to first order linear equations.

Equations of first order but not of first degree. Clairaut's equation. Singular solution.

Applications: Geometric applications, Orthogonal trajectories.

Higher order linear equations with constant coefficients: Complementary function, Particular Integral.

Method of undetermined coefficients, Symbolic operator D. Method of variation of parameters. Exact Equation. Euler's homogeneous equation and Reduction to an equation of constant coefficients.

Second order linear equations with variable coefficients: $\frac{d^2y}{dx^2} + P(x)\frac{dy}{dx} + Q(x)y = F(x)$ .Reduction of order when one solution of the homogeneous part is known. Complete solution. Method of variation of parameters. Reduction to Normal form. Change of independent variable. Operational Factors.

**Module II Multivariate Calculus I (18L):**

**Function of two and three variables**: Limit and continuity. Partial derivatives. Sufficient condition for continuity. Relevant results regarding repeated limits and double limits.

Functions $R^2 \to R$ Differentiability and its sufficient condition, differential as a map, chain rule, Euler's theorem and its converse. Commutativity of the second order mixed partial derivatives : Theorems of Young and Schwarz. Jacobian of two and three variables, simple properties including function dependence.

**Concept of Implicit function**: Statement and simple application of implicit function theorem for two variables Differentiation of Implicit function.

Taylor's theorem for functions two variables. Lagrange's method of undetermined multipliers for function of two variables (problems only).

**Text & Reference books:**

**Text Books:**


1. Vector Analysis- Maity and Ghosh
2. Vector Analysis – Louis Brand.
3. Elementary Vector Analysis – C. E. Weatherburn (Vol. I & II).
4. D.A. Murray, Introductory course in Differential Equations, Orient and Longman
5. H.T. H. Piaggio, Elementary Treaties on Differential Equations and their applications, C.B.S Publisher & Distributors, Delhi,1985.
6. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004
7. Real Analysis (Vol I)- Maity and Ghosh


**Reference Books:**


1. Vector Analysis – Barry Spain.
2. Vector & Tensor Analysis – Spiegel (Schaum).
3. G. F. Simmons, Differential Equations, Tata McGraw Hill 14


***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

On completion of the course, student will be able to:

XX.CO1: Solve different types of initial and boundary value problems (viz. exact, linear, homogeneous, or Bernoulli cases and 2nd order ODE)

XX.CO2: Understand the limit, continuity and partial derivatives for a multi-variable function.

XX.CO3: Locate the maxima and minima of a multi-variable function using the method of Lagrange's multiplier.

XX.CO4: Describe the parametric solution and singular solution for Clairaut's differential equation to obtain the Envelope of the family.

XX.CO5: Understand the implicit function theorem for multi variable functions.

XX.CO6: Formulate the problems of Mechanics (eg. Damped harmonic oscillator etc) and solve the $2^{nd}$ order ODE using different methods.

**Course MC13: Analytical dynamics and Statics**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to acquire the basic knowledge of the dynamics and statics of a body and apply the knowledge to solve different problems in Mechanics.*

***Prerequisite:*** *Before learning the course, students must have the undergraduate knowledge in definite integrals and calculus.*

***SYLLABUS OUTLINE:***

**Module I (10L)**

Co-planar forces. Astatic equilibrium. Friction. Equilibrium of a particle on a rough curve. Virtual work

**Module II (10L)**

Forces in three dimensions. General conditions of equilibrium. Centre of gravity for different bodies. Stable and unstable equilibrium.

**Module III (16L)**

Simple Harmonic Motion. Velocities and accelerations in Cartesian, polar, and intrinsic coordinates. Equations of motion referred to a set of rotating axes. Central forces. Stability of nearly circular orbits. Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone, and on any surface of revolution.

**Module IV (12L)**

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

**Text & Reference books:**

**Text Books:**

1. F. Chorlton, Textbook of Dynamics.

2. S. L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies

**Reference Books:**

1. S. L. Loney, Elements of Statics and Dynamics I and II.

2. I. H. Shames and G. Krishna Mohan Rao, Engineering Mechanics: Statics and Dynamics, ($4^{th}$ Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.

3. R. C. Hibbeler and Ashok Gupta, Engineering Mechanics: Statics and Dynamics, 11th Ed., Dorling

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:** understand analytical conditions of equilibrium of Coplanar forces.

**XX.CO2:** understand the general condition of equilibrium: analytical method, principal of virtual work.

**XX.CO3:** Understand motion of a rigid body, linear dynamical systems.

**XX.CO4:** Apply the knowledge of projectile of a path to solve the problems in a resisting medium.

**XX.CO5:** Formulate the problems of rigid body motion of a medium.

**XX.CO6:** Formulate the different types of simple harmonic motions.

**Course MC14: Financial Mathematics and Biomathematics**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to acquire the basic knowledge of the financial markets and ecology of pray predator models.*

***Prerequisite:*** *Before learning the course, students must have the undergraduate knowledge in probability theory, differential calculus.*

**Module I Financial Mathematics (20L)**

Brownian motion, Geometric Brownian motion, interest rates and present Value analysis ; rate of return ; pricing via arbitrage, risk-natural probabilities, multi-period binomial theorem, Arbitrage theorem .

Black-Scholes formula, properties of Black-Scholes option cost, Delta-Hedging arbitrage Strategy.

Pricing for American put options, Valuing investment by expected utility, risk-averse, risk-neutral, log utility function, portfolio selection problem, value and conditional value at risk, capital assets pricing model, mean Variance analysis of risk-neutral-priced call option, Conditional value at risks.

**Module II Biomathematics (28L)**

**Basic Concepts of Ecology:** Some fundamental concepts, Mathematical modelling, types of models, limitation of the models, Discrete-Time and Continuous-Time Dynamical Models.

**Single species models (Non-age Structured):** Exponential and logistic growth models and their solution.

**Single species models (Age Structured):** Continuous- time model, Lotka Integral equation, Solution

**Mathematical models in Epidemiology**: Basic concepts, SI model, formulation, solutions, SIS model with constant coefficient, formulation and solution, Some examples.

**Text & Reference books:**

**Text Books:**

1. An Elementary Introduction to Mathematical Finance –S.M. Ross

2. An Introduction to Mathematics of Financial Derivatives –S.N. Neftchi

3. Mathematics of Financial Markets –R.J. Elliot and P.E. Kopp

**Reference Books:**

4. J.D. Murray (2001). Mathematical Biology, Vol.I& II, Springer-Verlag.
5. Mark Kot (2001). Elements of Mathematical Ecology, Cambridge University Press.
6. Bhupendra Singh and N. Agrawal (2008), Bio-Mathematics, Krishna Prakash Media (P) Ltd.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Solve the problems for both discrete and continuous ecological system

**XX.CO2:** For Single-Species non-age structure population models both Exponential growth model and logistic growth model they learn how to formulate the problem and what will be the interpretation and limitation for models.

**XX.CO3:** Formulate different ecological model with the fundamental knowledge of different bio-mathematical theories.

**XX.CO4:** Understand the call option and put option exercise price and exercise time.

**XX.CO5:** Apply the knowledge of European option and American option, Geometric Brownian Motion, present value, interest rate, effective interest rate, risk neutral probabilities, Black Sholes formula , hedging , Valuing investment by expected utility etc in the financial market.

**XX.CO6:** Understand the log utility function, portfolio selection problem, value and conditional value at risk, capital assets pricing model, mean Variance analysis of risk-neutral-priced call option, Conditional value at risks.

**Course MC15: Partial differential equations and Differential Geometry**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to acquire the basic knowledge of the partial differential equation and differential geometry which will help the candidate to formulate and solve different problems of physics.*

***Prerequisite:*** *Before learning the course, students must have the undergraduate knowledge in differential calculus of one and two variables and the fundamental concepts of differential equations.*

***SYLLABUS OUTLINE:***

**Module I: Partial Differential Equations [18L]**

Order and degree. Linear and nonlinear PDE, Lagrange method. Charpit method, First order PDE. Laplace, wave diffusion equations, D'alembert method of solution, Green' function.

**Module II: Application to vector calculus [12L]**

Derivative of sum and product, Velocity and acceleration. , Green's theorem. Stokes' theorem. Gauss Divergence theorem.

**Module III: Differential Geometry [18L]**

Tensor. Riemannian space, Space curves. Planar curves. Serret-frenet formula. Osculating circles, Evolutes and involutes. Theory of surfaces. Conjugate and Asymptotic lines. Minimal surfaces. Developable. Geodesics. Gauss Bonnet theorem

**Text & Reference books:**

**Text Books:**

1. Sneddon I.N. : Elements of Partial Differential Equations, Mcgraw Hill.
2. Rao, K. S.: Partial differential equations.
3. An Introduction to Differential Geometry (with the use of tensor Calculus), L. P. Eisenhart, Princeton University Press, 1940.
4. S. Lang, Fundamentals of Differential Geometry, Springer, 1999.

**Reference Books:**

5. Williams W.E. : Partial Differential Equations.
6. Miller F.H. : Partial Differential Equations
7. Petrovsky. I.G : Lectures on Partial differential equations.
8. T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
9. B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:** Understand the basic properties of PDEs and to the basic analytical techniques to solve complex problems.

**XX.CO2:** Solve different types of second order partial differential equations, Laplace equation and wave equation and diffusion equation.

**XX.CO3:** Apply the concept of the curved line and surface with vectors, direction derivative.

Gradient, Divergence, curl, Laplacian significance to solve practical problems.

XX**.CO4:** Evaluate practical problems using the integral theorems (Green's theorem, Stokes'

theorem and Divergence theorem) of vector field.

**XX.CO5:** Understand the role of tensors in differential geometry, the interpretation of the

curvature tensor, Geodesic curvature, Gauss, and Weingarten formulae.

**XX.CO6:** Solve the problems of differential geometry to diverse situations.

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

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

***Prerequisite:*** Before learning the course of continuum mechanics, it is recommended to have a strong foundation in calculus, differential equations, and solid mechanics. Familiarity with concepts such as

stress, strain, equilibrium, Newton's laws of motion and basic principles of mechanics is essential. A background in physics and engineering mechanics will also be beneficial.

***SYLLABUS OUTLINE:***

**Module I (8L):** Deformation of Continuum: Lagrangian and Eulerian methods of describing deformation, finite strain deformation, infinitesimal strain tensor, infinitesimal stretch, and rotation, change in volume.

**Module I (8L):** Analysis of Strain: Relative displacement, strain quadratic, principal strains, strain invariants, compatibility conditions.

**Module I (8L):** Analysis of Stress: Body forces, and surface forces, stress tensor, normal and shearing stresses, principal stress, stress invariants. Stress equations of equilibrium and motion, Symmetry of stress tensor.

**Module I (4L):** Generalized Hooke's Law: Strain energy, Generalized Hooke's Law, Isotropic elastic solid, Elastic moduli for isotropic media, Beltrami-Michel compatibility equations.

**Module I (6L):** Fluid: Basic concept of fluid, classification of fluids, constitutive equations, equations of motion of fluid , stream lines, path line and vortex lines, circulation, and vorticity.

**Module I (10L):** Inviscid Incompressible Fluid: Equation of continuity, constitutive equation of perfect fluid and viscous fluid, Euler's equation of motion, integrals of Euler's equation of motion, Bernoulli's equation, Kelvin's minimum energy theorem, Sources and sinks and doublets.

**Module I (4L):** Viscous Incompressible Fluid: Governing equations, Navier Stroke's equations, flow between parallel plates.

**Text & Reference books:**

**Text Books:**

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

**Reference Books:**

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

11. L.I. Sedov :Introduction to the Mechanics of a Continuous Medium, Addison Wesley Publishing Company, INC.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX. CO1:** Understand and apply both Lagrangian and Eulerian methods for describing deformation in continuum mechanics, including finite strain deformation, infinitesimal strain tensor, infinitesimal stretch, rotation, and change in volume.

**XX. CO2:** Develop idea to analyze strain in deformable bodies, including relative displacement, quadratic strain, principal strains, strain invariants, and compatibility conditions**.**

**XX. CO3:** Analyze stress in deformable bodies, including body forces, surface forces, stress tensor, normal and shearing stresses, principal stress, stress invariants, equations of stress equilibrium and motion, and the symmetry of the stress tensor.

**XX. CO4:** Understand the generalized Hooke's Law, strain energy, and its application in isotropic elastic solids. They will learn about elastic moduli for isotropic media and the Beltrami-Michel compatibility equations.

**XX. CO5:** Develop idea of fundamentals of fluids, including their classification, constitutive equations, equations of motion for fluid flow, concepts of streamlines, path lines, vortex lines, circulation, and vorticity.

**XX. CO6:** Apply the knowledge of equations of continuity and motion for inviscid and viscous incompressible fluids, Euler's equation, Bernoulli's equation, Navier-Stokes equations, and flow between parallel plates.

**Course MC17: Supervised learning with regression and classification technique I and II**
**Credit 4: (3L-0T-2P)**

***Learning objectives:*** *On completion of the course, student will be able to:*

Develop the ability to train and apply models that can make accurate predictions or classifications using labeled training data.

***Prerequisite:*** *Before learning the course*

Familiarity with basic programming concepts and understanding of fundamental mathematical concepts such as linear algebra and theory of probability and statistics.

***SYLLABUS OUTLINE:***

**Module-I: NLP [8L]**

Word Sense Disambiguation, Machine Translation, Pronoun Resolution, Regular Expressions, Tokenization, Lemmatization, Stemming

**Module-II: Evaluation Metrics [10L]**

Precision, AUC, Recall, Mean Absolute Percentage Error, Specificity, Root Mean Square Error

**Module-III: Deep Learning [14L]**

Bayesian Neural Nets, Neural Networks, Deep Boltzmann Machine (DBM), Convolutional Neural Networks, Deep Belief Networks (DBN)

**Module-IV: Algorithms [16L]**

Logistic Regression, Linear regression: Usually performed through OLS, Naive Bayes, K Means Clustering, K-Nearest Neighbours, Classification and Regression Trees (CARTs), AdaBoost, Support Vector machines, Random Forest, Decision Trees, ARIMA, ID3, C4.5, C5.0, CHAID, Hierarchical Clustering

**Supervised Learning Lab:**

1. Write a python program to compute: Central Tendency Measures: Mean, Median, Mode

Measure of Dispersion: Variance, Standard Deviation.

2. Study of Python Basic Libraries such as Statistics, Math, Numpy and Scipy.

3. Study of Python Libraries for Supervised Learning applications such as Pandas and Matplotlib.

4. Write a Python program to implement Simple Linear Regression.

5. Implementation of Multiple Linear Regression for House Price Prediction using sklearn.

6. Implementation of Decision tree using sklearn and its parameter tuning.

7. Implementation of KNN using sklearn.

8. Implementation of Logistic Regression using sklearn.

9. Implement Naïve Baye's theorem.

10. Implementation of K-Means Clustering.

11. Write a program to demonstrate the working of the decision tree based ID3 algorithm. Use an appropriate data set for building the decision tree and apply this knowledge to classify a new sample.

12. Performance analysis of Classification Algorithms on a specific dataset (Mini Project)

13. Construct a .csv dataset and implement any one of the following using python:

Linear Regression, Logistic Regression, Navie Bayes, K Means Clustering, , Decision Tree, Random Forest, KNN, SVM.

14. Write a program for: Word sense disambiguation, tokenization, lemmatization, stemming, calculation of mean absolute percentage error, calculation of root mean square error.

**Text & Reference books:**

**Text Books:**

1. "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville
2. "The Art of Data Science — A Guide for Anyone Who Works With Data"- by Roger D. Peng and Elizabeth Matsui
3. Understanding Machine Learning: From Theory to Algorithms" – By ShaiShalev-Shwartz and Shai Ben-David
4. "The Art of Data Science — A Guide for Anyone Who Works with Data"- by Roger D. Peng and Elizabeth Matsui
5.

**Reference Books:**

1. The Hundred-Page Machine Learning Book – Andriy Burkov
2. Pattern Recognition and Machine Learning - Christopher M. Bishop
3. Python Machine Learning - Sebastian Raschka and VahidMirjalili
4. Machine Learning - Tom M. Mitchell

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Apply Data pre-processing techniques and illustrate Machine Learning concepts and basics of supervised learning concepts.

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**XX.CO2:** Describe dimensionality reduction techniques and supervised learning concepts (NLP , Evaluation Metrics, Deep Learning, regression, linear classification)

**XX.CO3:** Solve real life problems using appropriate supervised machine learning models and evaluate the performance measures and Illustrate the concepts of Multilayer neural network.

**XX.CO4:** Analyze the deep learning algorithms for various types of learning tasks in various domains.

**XX.CO5:** Applying supervised learning methods to construct a Machine Learning model.

**XX.CO6:** Apply the algorithms to a real-world problem related to supervised learning concepts.

**Course MC18: Integral transforms**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to: develop the knowledge of different integral transforms to solve complex differential equations and solve real life problems.*

***Prerequisite:*** *Before learning the course learners should have a basic knowledge about integration, differentiation, differential calculus, convergency and ordinary and partial differential equations.*

***SYLLABUS OUTLINE:***

**Integral transform**:

**Module I The Fourier Transform (10L):**

Fourier series, Algebraic properties of Fourier transform, Convolution, Translation, Modulation. Analytical properties of Fourier transforms, Transform of derivatives and derivatives of transform, Perseval formula, Inversion theorem, Plancherel's theorem, Application to solving ordinary and partial differential equation.

**Module II The Laplace transform (8L):**

Algebraic properties of Laplace transform, Transform of derivatives and derivatives of transform. The inversion theorem, Evaluation of inverse transforms by residue. Asymptotic expansion of inverse transform, Application to solving P.D.E., Integral equation, etc.

**Module III The Z-Transform (8L):**

Z- Transform, Properties of the region convergence of the Z-transform. Inverse Z-transform for discrete-time systems and signals, Applications.

**Module IV The Hankel transform (8L):**

Elementary properties; Inversion theorem; transform of derivatives of functions; Perseval relation; Relation between Fourier and Hankel transform; use of Hankel transform in the solution of PDE.

**Module V The Mellin transform (6L):**

Definition; properties and evaluation of transforms; Convolution theorem for Mellin transforms; applications to integral equations.

**Module VI Wavelet Transform: (8L)**
Definition of wavelet, Examples, Window function, Windowed Fourier transform, Continuous wavelet transform, Discrete wavelet transform, Multiresolution analysis, Application to signal and image processing

**Text & Reference books:**

**Text Books:**

1. L. Debnath, Integral transforms and their applications, CRC press, New York-London-Tokyo, 1995.

2. I.N. Sneddon, Fourier Transform, McGraw Hill, 1951.

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

**Reference Books:**

1. F.C. Titchmash, Introduction to the theory of Fourier Integrals, Oxford Press, 1937.
2. Peter, K.F. Kahfitting, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
3. E.J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.
4. E.I. Jury, Theory and Application of Z-Transform, John Wiley and Sons, N.Y.
5. R.V. Churchill, Operational Mathematics, McGraw Hill, 1958.
6. D. Loknath, Integral Transforms and their Application, C.R.C. Press, 1995.
7. Introduction to Wavelet Transforms – Narasimhan, Basumallik and Veena
8. Ram P. Kanwal, Linear Integral Equation – Theory and Technique, Academic Press, Inc.
9. W.V. Lovitt, Linear Integral Equations, Dover, New York.
10. S.G. Mikhlin, Integral Equations, Pergamon Press, Oxford.
11. N.I. Mushkhelishvili, Noordhoff, Singular Integral Equations, Gronignen, Holland.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcomes:**

After attending this course the students will be able to

**XX.CO1: Understand** the basic properties of different integral transforms (Laplace transform, Fourier transform).

**XX.CO2: Apply** different integral transforms to the real life problems of Physics, Biology, and Engineering etc.

**XX.CO3: Formulate** and **solve** complex engineering boundary value problems.

**XX.CO4: Discuss** the properties of Z transform and Wavelet transform and its applications.

**XX.CO5: Identify** the Fredholm and Volterra integral equations with different kind for different kernels.

**XX.CO6: Solve** the problems of mechanics with the help of integral equations with different methods.

**Course MC19: Advanced ODE and dynamical system**
**Credit 4: (4L-0T-0P)**

**Module I: Advanced ODE (24L):**
Existence and Uniqueness of solutions of initial value problems for first order ordinary differential equations, Singular solutions of first order ODEs. Linear homogeneous differential equation: Ordinary and singular points, Series solution, Method of Frobenius, Fuch's theorem, Equations of Fuchsian type. Linear non-homogeneous differential equation: Solution by variation of parameters, Strum-Liouville's equation. Eigen value problem and the variational method. Completeness of eigen-functions. Integral representation and Green's function. System of ODE's Flow diagram, Phase portrait, Isocline. Fixed points and their nature. stability, asymptotic stability, Liapunov function, Linearization at a critical point.

**Module II Dynamical system (24L):**
Linear dynamical systems, preliminary notions: solutions, phase portraits, fixed or critical points. Plane autonomous systems. Concept of Poincare phase plane. Simple examples of damped oscillator and a simple pendulum. The two-variable case of a linear plane autonomous system. Characteristic polynomial. Focal, nodal and saddle points.

**Text & Reference books:**

**Text Books:**

1.G.F.Simmons, Differential Equations, Tata McGraw Hill 14
2.S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004
3. H Strogatz- Nonlinear Dynamics.

**Reference Books:**

1.D.A. Murray, Introductory course in Differential Equations, Orient and Longman
2.H.T. H.Piaggio, Elementary Treaties on Differential Equations and their applications, C.B.S Publisher & Distributors, Delhi,1985.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:** understand the existence and uniqueness theorem for the initial value problems

**XX.CO2:** solve the initial value problems using Green's function technique

**XX.CO3:** understand different types of bifurcations of the dynamical system.

**XX.CO4:** understand the focal point, nodal point and saddle point of a dynamical system.

**XX.CO5:** apply the knowledge of phase portrait and flow diagram to solve complex problem.

**XX.CO6:** understand the asymptotic stability and Liapunov function.

**Course MC20: Generalized functions and special functions**

**Credit 4: (4L-0T-0P)**
***Learning objectives:*** *On completion of the course, student will be able to: develop the knowledge of different generalized functions and special function and solve real life problems.*

***Prerequisite:*** *Before learning the course learners should have a basic knowledge about integration, differentiation, differential calculus and the convergence criteria.*

**SYLLABUS OUTLINE:**

**Module I Generalized Functions (20L):**
The Dirac Delta function and Delta sequences. Test functions. Linear functionals. Regular and singular distributions. Sokhotski-Plemelj equation. Operations on distributions. Properties of the generalized of the generalized derivatives. Some transformation properties of the delta function. Convergence of distributions.

**Module II Special functions (28L)**

Legendre function. Rodrigues formula. Orthogonal property. Recurrence relations.
Bessel function. Orthogonal property. Recurrence relations. Gauss hypergeometric function and its properties, Integral representation. Linear transformation formulas, Contiguous function relations. Differentiation formulae, Linear relation between the solutions of Gauss hypergeometric equation, Kunlmer's confluent hyper geometric function and its properties'; Integral representation, Kummer's first transformation. Legendre polynomials and functions and ; Bessel functions ; Hermite polynomials ; Laguerre polynomials.

**Text & Reference books:**

**Text Books:**

1. L. Debnath, Integral transforms and their applications, CRC press, New York-London-Tokyo, 1995.

2. I.N. Sneddon, Fourier Transform, McGraw Hill, 1951.

3. D. Porter and D.S.G. Stirling, Integral Equations, Cambridge University Press, 2004.
4. H. Hochstadt, Integral equations, Wiley-Interscience, 1989.
5. A. Wazwaz, A first course in integral equations, World Scientific, 1997.
6. F.G. Tricomi, Integral Equations, Dover, 1985.
7. V. Vladimirov, Equations of mathematical physics. Dekker, New York, 1971.
8. I. Stakgold, Green's functions and boundary value problems, Wiley, New York, 1979.

**Reference Books:**

1. R.V. Churchill, Operational Mathematics, McGraw Hill, 1958.

2. D. Loknath, Integral Transforms and their Application, C.R.C. Press, 1995.
3. Introduction to Wavelet Transforms – Narasimhan, Basumallik and Veena
4. Ram P. Kanwal, Linear Integral Equation – Theory and Technique, Academic Press, Inc.
5. W.V. Lovitt, Linear Integral Equations, Dover, New York.
6. S.G. Mikhlin, Integral Equations, Pergamon Press, Oxford.
7. N.I. Mushkhelishvili, Noordhoff, Singular Integral Equations, Gronignen, Holland.

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcomes:**

After attending this course the students will be able to

**XX.CO1: Apply** the knowledge of Legendre and Bessel functions to solve different partial different equations.

**XX.CO2: Apply** the knowledge of generalized functions to solve various complex problems of physics, mechanics etc.

**XX.CO3: Formulate** and **solve** complex engineering boundary value problems using generalized functions.

**XX.CO4: Discuss** the orthogonal properties of Legendre polynomials and its applications.

**XX.CO5: Identify** the Rodrigue's formula for Legendre polynomials.

**XX.CO6: Solve** the problems of mechanics with the help of special functions with different methods.

**Course MC21: Calculus of variations and integral equations**
**Credit 4: (4L-0T-0P)**
***Learning objectives:*** *On completion of the course, student will be able to acquire the basic knowledge of the variational calculus and dynamical system.*

***Prerequisite:*** *Before learning the course, students must have the undergraduate knowledge in probability theory, differential calculus.*

**Module I Calculus of variations (24L):**
Basic Lemma. Fundamental problem and its solution. Case of several dependent variables. Applications to geodesics on a surface. Hamilton's variational principle, brachistochrone problem.
Variable end-point conditions; Extended problem and its solution. Lagrange's problem – Holonomic and Non-holonomic constraints. Solutions of holonomic and Non-holonomic Lagrange's problems with generalizations to several dependent variables. Mixed Lagrange's problem and its solution. Application to the Principle of Least Action.
Isoperimetric problem and its solution.

Basic Lemma and fundamental problem in two and three dimensions.

**Module II Integral Equations (24L):**
Reduction of boundary value problem of an ordinary differential equation to an integral equation. Fredholm equation: Solution by the method of successive approximation. Numann series. Existence and uniqueness of the solution of Fredholm equation. Equations with degenerate kernel. Eigen values and eigen solutions. Volterra equation: Solution by the method of iterated kernel, existence and uniqueness of solution. Solution of Abel equation. Solution of Volterra equation of convolution type by Laplace transform.

**Text & Reference books:**

**Text Books:**

1. D.N. Burghes and A.M. Downs, Modern Introduction to Classical Mechanics & Control, Ellis Horwood Publisher, Chichester, 1975.
2. J.C. Pant, Introduction to Optimization, New Delhi, Jain Brothers, 1983.

**Reference Books:**

1. A.S. Gupta, Calculus of Variations with Applications, Prentice Hall, 1997.
2. G.M. Ewing, Calculus of variations with Applications, Dover Publications, 1985.
3. R. Weinstock, Calculus of Variations, Dover Publications, 1974.
4. Peter, K.F. Kahfitting, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
5. E.J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.
6. E.I. Jury, Theory and Application of Z-Transform, John Wiley and Sons, N.Y.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:** solve different kinds of Fredholm and Voltera differential equations.

**XX.CO2:** understand the existence and uniqueness theorem of the solution of Fredholm equation.

**XX.CO3:** determine the shortest path using the principle of least action.

**XX.CO4:** understand the holonomic and non-holonomic problems to solve complex engineering problems.

**XX.CO5:** formulate different engineering problems using Hamilton's variational principle.

**XX.CO6:** formulate and solve isoperimetric problems.

**Course ME1: Unsupervised learning and challenges for big data analytics**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to:*

understand and apply techniques such as clustering and dimensionality reduction to uncover patterns and structures in data without labeled or pre-defined target variables. This involves gaining knowledge of algorithms like k-means clustering, hierarchical clustering, and principal component analysis (PCA). Challenges for big data analytics in unsupervised learning involve handling the vast volume, velocity, and variety of data. These challenges include scalability of algorithms, efficient processing and storage techniques, and addressing issues related to data quality, noise, and high-dimensional data representations.

***Prerequisite:*** *Before learning the course*

Familiarity with basic programming concepts and understanding of fundamental mathematical concepts such as linear algebra and theory of probability and statistics.

***SYLLABUS OUTLINE:***

**Module-I:** Big Data Essentials: Introduction, Hadoop, and Analysis **[7L]**

Introduction to Big Data. What is Big Data. Why Big Data is Important. Meet Hadoop. Data.Data Storage and Analysis. Comparison with other systems. Grid Computing. A brief history of Hadoop. Apache hadoop and the Hadoop EcoSystem. Linux refresher; VMWare Installation of Hadoop.

**Module-II: HDFS Design and Operations: Concepts, Interfaces, and Replication [8L]**

The design of HDFS.HDFS concepts. Command line interface to HDFS. Hadoop File systems. Interfaces.Java Interface to Hadoop. Anatomy of a file read. Anatomy of a file write. Replica placement and Coherency Model. Parallel copying with distcp, Keeping an HDFS cluster balanced.

**Module-III: Data Analysis with Hadoop: MapReduce, Configuration, and Job Execution [11L]**

Introduction. Analyzing data with unix tools. Analyzing data with hadoop. Java MapReduce classes (new API). Data flow, combiner functions, Running a distributed MapReduce Job. Configuration API. Setting up the development environment. Managing configuration. Writing a unit test with MRUnit. Running a job in local job runner. Running on a cluster. Launching a job. The MapReduce WebUI.

**Module-IV: Classic MapReduce: Job Execution, Shuffle, and Optimization [10L]**

Classic Mapreduce. Job submission. Job Initialization. Task Assignment. Task execution .Progress and status updates. Job Completion. Shuffle and sort on Map and reducer side. Configuration tuning. MapReduce Types. Input formats. Output formats ,Sorting. Map side and Reduce side joins.

**Module-V: Hive Essentials: Shell, Services, and Data Manipulation [12L]**

The Hive Shell. Hive services. Hive clients. The meta store. Comparison with traditional databases. HiveQl. Hbasics. Concepts. Implementation. Java and Mapreduce clients. Loading data, web queries.

**Text & Reference books:**

**Text Books:**

1. Tom White, Hadoop, “The Definitive Guide”, 3rd Edition, O’Reilly Publications, 2012.
2. Dirk deRoos, Chris Eaton, George Lapis, Paul Zikopoulos, Tom Deutsch , “Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data”, McGrawHill Osborne Media; 1 edition, 2011

**Reference Books:**

1. Tom White, Hadoop, “The Definitive Guide”, 3rd Edition, O’Reilly Publications, 2012.
2. Dirk deRoos, Chris Eaton, George Lapis, Paul Zikopoulos, Tom Deutsch , “Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data”, McGrawHill Osborne Media; 1 edition, 2011

***Pedagogy for Course Delivery****: Hybrid Mode (Offline Class/Presentation/Video/MOODLE/NPTEL)*

***List of Professional Skill Development Activities (PSDA)****:NA*
***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

***Continuous assessment***: Quiz/assessment/presentation/problem solving etc.

**Course Outcome (CO):**

After attending this course the students will be able to

**XX.CO1:** Apply various pre-processing techniques on different datasets and illustrate Machine Learning concepts and basics of unsupervised learning concepts.

**XX.CO2:** Describe and analyze various Big Data platforms.

**XX.CO3:** Identify and Apply unsupervised learning concepts to solve real world problems.

**XX.CO4:** Analyze the deep learning algorithms for various types of learning tasks in various domains.

**XX.CO5:** Develop Big Data Solutions using HadoopEcoSystem.

**XX.CO6:** Apply the algorithms to a real-world problem related to unsupervised learning concepts.

**Course ME2: Advanced Computational methods**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to:*
Gather some knowledge about advanced computational techniques and solve the boundary value problems using Finite element method.

***Prerequisite:*** *Before learning the course, students must have the fundamental knowledge on calculus, matrix theory, differential equation and numerical analysis.*

***SYLLABUS OUTLINE:***

**Module I Generalized Matrix Inversion (10L):**
Conventional inverse, Improvement of elements of inverse matrix by iterative scheme, Generalized inverse of a matrix, Operations on partitioned matrices, Inversion by partitioning, Computation of g-inverse by Gauss reduction type method, Application of generalized matrix inverses, Computer implementation of the methods.

**Module II Eigen Value Problems (10L):**
Eigen pairs of real non-symmetrical matrices, Computation of eigen values and eigen vectors by (i) Danilevsky method (ii) Krylov method

**Module III Simulation (8L):**Introduction, Methodology of simulation, Generation of random numbers, Monte-Carlo simulation, Simulation of different models, Advantages and limitations of simulation.

**Module IV Fast Fourier Transform (8L):**
Discrete Fourier transforms and its basic properties. Fast Fourier Transforms (FFT), Computation of FFT, Fast Sine and Cosine Transforms, Some applications.

**Module V Finite Element Method (12L):**
Applications of FEM for ODE and PDE.

**Text & Reference books:**

**Text Books:**

1. M.J. Maron. Numerical Analysis – A Practical Appraoch, McMillan Pub. Co., New York.

2. E. Bodewig. Matrix Calculus. Amsterdam, North Holland Pub. Co., 1959.

3. E.V. Krishnamurthy and S.K. Sen. Numerical Algorithms : Computations in Science and Engineering, New Delhi, Affiliated East-West Press, 1991.

**Reference Books:**

1.H.M. Antia. Numerical Methods for Scientists and Engineers – McGraw Hill Pub. Co. Ltd., New Delhi, 1991.

2. S.S. Rao, Optimization Theory with Applications, New Age International (P) Pvt. Ltd.

3. C.R. Rao and S.K. Mitra, Generalized Inverse of Matrices and its Applications, Wiley, 1971.

4. R.M. Pringle and A.A. Rayner, Generalized Inverse Matrices with Application to Statistics, Hanfer Pub. Co., 1971.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:**understand the g-inverse of a matrix.

**XX.CO2:**understand the Eigen value problems using Danilevsky method and Krylov method.

**XX.CO3:**Generate the random numbers using the simulation technique.

**XX.CO4:**apply the knowledge of Fast Fourier transform to the problems of Mechanics.

**XX.CO5:**understand the Monte-Carlo simulation.

**XX.CO6:**Formulate and solve complex problems of physics and Mechanics using Finite element method.

**Course ME3: Automata theory**
**Credit 4: (4L-0T-0P)**

***Learning objectives:*** *On completion of the course, student will be able to understand and apply techniques based on the theories of Automata and apply it to various real life problems.*

***Prerequisite:*** *Basic knowledge of Matrices, Propositional Logics, Discrete mathematics and Graph theory.*

***SYLLABUS OUTLINE:***

**Module I Automata and Languages (14L):**
Finite Automata, regular languages, regular expressions, closure properties, equivalence of deterministic and non-deterministic finite automata, pumping lemma, minimization of finite automata.

**Module II Context-free languages (10L):**
Context-free grammars, closure properties, pumping lemma for CFL, push down automata.

**Module III Computability (12L):**
Turing machines and computable functions. Universality, halting problems, recursive and recursively enumerable sets.

**Module IV Complexity (12L):**
Time complexity of deterministic and nondeterministic Turing machines, basic idea of the classes P and NP; notion of NP completeness and brief idea of reducibility among NP complete problems.

**Text & Reference books:**

**Text Books:**

1. M.A. Harrison, Introduction to Switching and Automata Theory, McGraw Hill, New York.
2. S. Ginsburg, An Introduction to Mathematical Machine Theory (Addison-Wesley).
3. J. Hartmanis and R.E. Stearns, Algebraic Structure Theory of Sequential Machines (Prentice-Hall).
4. L. Taylor, Booth, Sequential Machines and Automata Theory (John Wiley and Sons).

**Reference Books:**

1. M. Davis, Computability and Unsolvability (McGraw-Hill, New York).
2. A. Paz, Introduction to Probabilistic Automata (Academic Press).
3. A. Gill, Introduction to the Theory of Finite State Machines (McGraw Hill, New York).
4. Hopcroft and Ullman, Formal Languages and Their Relation to Automata (Addison-Wesley).
5. J.E. Hopcroft and J.D. Ulman, Introduction to Automata Theory, Languages and computation (Addison-Wesley).
6. H.R. Lewis and C.H. Papadimitriou, Elements of the Theory of Computation (Prentice-Hall).
7. D. Kelly, Automataand Formal Languages: An Introduction, Prentice-Hall.
8. P. Linz, An Introduction to Formal Languages and Automata, 6th ed.

Course Outcome (CO):

After attending this course the students will be able to

**XX.CO1:** understand the basic properties of formal languages and grammars

**XX.CO2:** differentiate regular, context-free and recursively enumerable languages

**XX.CO3:** make grammars to produce strings from a specific language

**XX.CO4:** acquire concepts relating to the theory of computation and computational models including decidability and intractability.

**XX.CO5:** Design automata, regular expressions and context free grammars for accepting or generating a certain language.

**XX.CO6:** Describe the language accepted by an automata or generated by a regular expression or a context free grammar.