**SYLLABUS**

**FOR**

**TWO-YEAR M.Sc. PROGRAMME**

**IN**

**MATHEMATICS & COMPUTING**



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| **NAAC – A Grade** |

**DEPARTMENT OF MATHEMATICS**

**COLLEGE OF ENGINEERING & TECHNOLOGY**

**(An Autonomous and Constituent College of BPUT, Odisha)**

**Techno Campus, Mahalaxmi Vihar, Ghatikia,**

**Bhubaneswar-751029, Odisha, INDIA**

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**Semester-1**

**Core 1: Real Analysis (PPCMH101)**

**Course Objectives:**

* 1. The students will learn about measure theory random variables, independence, expectations and conditional expectations, product measures.
  2. Explain the concept of length, area, volume using Lebesgue’s theory.
  3. Apply the general principles of measure theory and integration in such concrete subjects as the theory of probability or financial mathematics.
  4. They will develop a perspective on the broader impact of measure theory.

**Prerequisites:** Point set theory, Sequence, Series, Limit, Continuity, Differentiation.

**Syllabus:**

**Module – I:**

Introduction to Metric spaces, compact set, connected set, Weierstrass Approximation Theorem, Sequence and series of function, Uniform convergence. Lebesgue measure: Introduction, outer measure, measurable sets and Lebesgue measure, A non-measurable set, measurable function. The Lebesgue Integral: The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, The integral of a non-negative function, The general Lebesgue integral.

**Module –II:**

Measure and Integration: measure spaces, measurable functions, Integration, General convergence theorem, Signed measures, The Random-Nikodyn theorem, The Lp-spaces.

Measure and Outer measure: Outer measure and measurability, The extension theorem, The Lebesgue-Stieltjes integral, Product measures, Integral operators, Inner measure, Extension by sets measure zero.

**Module –III:**

Introduction - Properties of monotonic functions - Functions of bounded variation - Total variation - Additive property of total variation - Total variation on [a, x] as a function of x - Functions of bounded variation expressed as the difference of two increasing functions - Continuous functions of bounded variation.

The Riemann Stieltjes Integrals: Introduction, Notation, The definition of Riemann Stieltjes Integral, Linear operators, Integration by parts, Change of variable in Riemann Stieltjes integrals, Reduction to a Riemann Integral, Euler’s summation formula, Monotonically increasing integrals.

**Text Books:**

* 1. Real Analysis by H.L. Royden & P.M. Fitzpatrick (4th edition) Pearson. Chapter 2(2.1 to 2.6), Chapter 4(4.1 to 4.4), Chapter 7, Chapter 17(17.1 to 17.6), Chapter 18(18.1 to 18.4).
  2. Measure theory and integration by G. De. Barra (Wiley Eastern Limited)
  3. Mathematical analysis by Tom M. Apostol, 2nd Edition, Addison-Wesley publication company Inc. New york, 1974. Chapter 6(6.1 to 6.8), Chapter 7(7.1 to 7.11)

**Reference Books:**

1. Bartle, R.G. Real Analysis, Wiley.
2. Rudin, W. Principles of Mathematical Analysis, 3rd Edition. McGraw Hill Company, New York, 1976.
3. Malik, S.C. and Savita Arora. Mathematical Analysis, Wiley Eastern Limited, New Delhi, 1991.
4. Sanjay Arora and Bansi Lal, Introduction to Real Analysis, Satya Prakashan, New Delhi, 1991.
5. Gelbaum, B.R. and J. Olmsted, Counter Examples in Analysis, Holden day, San Francisco, 1964.
6. A.L. Gupta and N.R. Gupta, Principles of Real Analysis, Pearson Education, (Indian print) 2003.

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. Demonstrate understanding of the basic concepts underlying the definition of the general Lebesgue integral.
  2. Demonstrate understanding of the statements of the main results on integration on product spaces and an ability to apply these in examples.
  3. Apply the theory of the course to solve a variety of problems at an appropriate level of difficulty.
  4. Demonstrate skills in communicating mathematics orally and in writing.

**Core 2: Differential Equation (PPCMH102)**

**Course Objectives:**

* 1. Identify classes of linear and non-linear ordinary differential equations.
  2. Apply an appropriate method for the solution of linear and non-linear ordinary differential equations
  3. Analyse qualitative properties of systems of ordinary differential equations.
  4. Apply both analytic and numerical methods to the solution of hyperbolic, parabolic and elliptic partial differential equations.

**Prerequisites:** First order Ordinary Differential Equation, Higher order Differential Equation with constant coefficients, Partial Differentiation.

**Syllabus:**

**Module - I:**

Existence and Uniqueness of Solutions: Picard’s method of successive approximation, An existence and uniqueness theorem, Dependence of solutions on initial conditions.

Series Solutions and Special Functions: Some basic concepts and facts about power series, series solution about an ordinary point, Legendre equation and Legendre polynomial, Hermite equation and Hermite polynomial, power series solution about singular points, Frobenius method, Bessels equation and Bessel function, properties of Bessel function.

Systems of Linear Differential Equations: Basic theory of linear systems, Trail solution method for linear systems with constant coefficient, operator method for linear systems with constant coefficients.

**Module – II:**

Boundary Value Problems for Ordinary Differential Equations: Sturm-Liouville problem, Orthogonality of Eigen functions, Green’s function.

Elliptic Differential Equations: Derivation of Laplace and Poisson equation - BVP - Separation of Variables - Dirichlet’s Problem and Newmann Problem for a rectangle - Solution of Laplace equation in Cylindrical and spherical coordinates - Examples.

**Module – III:**

Parabolic Differential Equations: Formation and solution of Diffusion equation - Dirac-Delta function - Separation of variables method - Solution of Diffusion Equation in Cylindrical and spherical coordinates - Examples.

Hyperbolic Differential Equations: Formation and solution of one-dimensional wave equation - canonical reduction – IVP D’Alembert’s solution - IVP and BVP for two-dimensional wave equation – Periodic solution of one-dimensional wave equation in cylindrical and spherical coordinate systems - Uniqueness of the solution for the wave equation - Duhamel’s Principle -Examples.

**Text Books:**

1. J Sinha Roy and S Padhy, A Course On Ordinary and Partial Differential Equations, 4th Edition, Kalyani publisher. Ch 6, 7(7.1-7.4.2), 8(8.1-8.4), 10(10.1-10.3)
2. K. Sankar Rao, Introduction to Partial Differential Equations, 2nd Edition, Prentice Hall of India, New Delhi. 2005.

**Reference Books:**

1. R.C. McOwen, Partial Differential Equations, 2nd Edn. Pearson Education, New Delhi,2005.
2. I.N. Sneddon, Elements of Partial Differential Equations, McGraw Hill, New Delhi,1983.
3. R. Dennemeyer, Introduction to Partial Differential Equations and Boundary Value Problems, McGraw Hill, New York, 1968.
4. S. Balachandra Rao,H.R. Anuradha, Differential Equations with applications and programs, Universe Press.
5. C. Henry, Edwards, David E. Peney, Differential Equation and Boundary Value Problems, Pearson.
6. Wiliam E., Boyee, Richard C. Diprima. Elementary Differential Equations and Boundary Value Problems, Wiley.

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. Identify and apply initial and boundary values to find solutions to first-order, second-order, and higher order homogeneous and non-homogeneous differential equations by manual and technology-based methods and analyse and interpret the results.
  2. Select and apply numerical analysis techniques to solve differential equations.
  3. Select and apply series techniques to solve differential equations.
  4. Select and apply appropriate methods to solve differential equations.

**Core 3: Discrete Mathematical Structures (PPCMH103)**

**Course Objectives:**

* 1. Introduce different proof techniques and certain discrete structures and their theory
  2. Introduce the role of discrete structure in Modelling applications.
  3. Introduce the applications of discrete structures in computing.
  4. Introduce computer representations of these discrete structures and designing algorithms on these structures.

**Prerequisites:** None.

**Syllabus:**

**Module-I:**

Propositional Logic: propositions, connectives, well-formed formula, truth tables, logically equivalent formulas, tautology, contrdiction, contingency, concept of proof, inference rules and natural deduction, completeness and soundness, predicate logic: existencetial and universal quantifiers, laws of inference and natural deduction Proof techniques: Introduction to different standard proof techniques such as trivial proofs, Vacuous proofs, Direct proofs, Proof by Contrapositive (indirect proof), Proof by Contradiction (indirect proof, aka refutation) , Proof by Cases (sometimes using WLOG), Proofs of equivalence, Existence Proofs (Constructive & Non-constructive), Uniqueness Proofs, Mathematical Induction, Recursive definition and structural induction.

**Module-II:**

Set Theory: Review of Basic Set Operations, representation of set, finite and infinite set, countabality and uncountability, countabality of rationals, uncountability of reals,

Relations: Relation and their properties, Partitions, Closure of Relations, Warshall’s Algorithm, Equivalence relations, Partial orderings, lattice, topological ordering

Counting: sum and product rules, permutations and combinations, number of non-negative integral solutions of a linear equation

Advanced counting techniques: Recurrence relation, Solution to recurrence relation, Generating functions, pigeonhole principle and their applications, Principle of Inclusion and exclusion and its application

**Module-III:**

Introduction to graph theory, Graph terminology, Representation of graphs: adjancy matrix, incidence matrix, adjancy list, modeling applications using graphs, graph isomorphism, connectivity, Eulerian graphs and their characterization, Hamiltonian graphs and sufficient conditions for hamiltonicity, Shortest path problems, Planar graph, Graph coloring,

Introduction to trees, various characterizations of trees, Application of trees, Depth first search, breadth first search, testing connectedness and acyclicity, Minimum Spanning tree: Kruskal’s Algorithm, Prim’s Algorithm

**Text Books:**

1. Kenneth H. Rosen, “Discrete Mathematics and its Applications”, Sixth Edition, 2008, Tata McGraw Hill Education, New Delhi. Chapters: 1, 2(2.4), 4, 6(6.1, 6.2, 6.4-6.6), 7, 8, 9
2. C. L. Liu and D. Mohapatra, “Elements of Discrete Mathematics”, Third Edition, 2008, Tata McGraw Hill Education, New Delhi Chapters: 10 (10.1- 10.10), 11(11.1 – 11.7)
3. Douglas B. West, “Introduction to Graph Theory” 2e, PHI

**Reference Books:**

1. J. L. Mott, A. Kandel, T. P. Baker, “Discrete mathematics for Computer Scientists & Mathematicians”, Second Edition, PHI.
2. Gosset “Discrete Mathematics “Second Edition, Wiley
3. NarsinghDeo, “Graph Theory with applications to engineering and computer science”, PHI

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. Write an argument using logical notation and determine if the argument is or is not valid.
  2. Apply counting principles to determine probabilities.
  3. Demonstrate an understanding of relations and functions and be able to determine their properties.
  4. Model problems in Computer Science using graphs and trees.

**Core 4: Linear Algebra (PPCMH104)**

**Course Objectives:**

* 1. Use computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization.
  2. Use visualization, spatial reasoning, as well as geometric properties and strategies to model, solve problems, and view solutions, especially in R2 and R3, as well as conceptually extend these results to higher dimensions.
  3. Critically analyze and construct mathematical arguments that relate to the study of introductory linear algebra.
  4. Work collaboratively with peers and instructors to acquire mathematical understanding and to formulate and solve problems and present solutions.

**Prerequisites:** None

**Syllabus:**

**Module-I:**

Geometric interpretation of solution of system of equations in two and three variables; matrix notation; solution by elimination and back substitution; interpretation in terms of matrices, elimination using matrices; elementary matrices, properties of operations on matrices. Definition and uniqueness; non-existence in general: singular matrices; calculation of inverse using Gauss-Jordan elimination; existence of one sided inverse implies invertibility; decomposition of a matrix as product of upper and lower triangular matrices. Vector spaces and Subspaces, Solving Ax=0 and Ax=b, Linear Independence, Basis and Dimension, The four fundamental Subspaces, graph and networks, Linear Transformations.

**Module-II:**

Orthogonal Vectors and Subspaces, Cosines and Projections onto Lines, Projections and Least Squares, orthogonal Bases and Gram-Schmidt, The Faster Fourier Transform, Properties of the determinant, formulas for the determinant, Expansion of determinant of a matrix in Cofactors, Applications of Determinants.

**Module-III:**

Eigen values and eigenvectors, Diagonalisation of a Matrix, Difference equations and powers A^k, Markov Matrices, complex Matrices, unitary Matrices, similarity transformations, Jordan Form, minima, maxima and saddle points, tests for positive definiteness, Test for positive definiteness, singular value decomposition, minimum principles.

**Text Book:**

* 1. Strang, Introduction to Linear Algebra, 4th ed., Wellesley Cambridge Press., Chapters-1-5, 6.1,6.2,6.3,6.4.

**Reference Books:**

1. An introduction to Linear Algebra by V. Krishnamurthy, V. P. Mainra and J. L. Arora, East West Publication
2. M. Artin, Algebra, Prentice-Hall of India.
3. Hoffman and Kunze, Linear Algebra, 2nd ed., PHI.
4. S. Kumaresan, Linear Algebra, a geometric approach, PHI.

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. solve systems of linear equations and to compute the inverse of an invertible matrix.
  2. Use the basic concepts of vector and matrix algebra, including linear dependence / independence, basis and dimension of a subspace, rank and nullity, for analysis of matrices and systems of linear equations.
  3. Evaluate determinants and use them to discriminate between invertible and non-invertible matrices.
  4. Orthogonally diagonalize symmetric matrices and quadratic forms.

**OE 1: Data Structure Using C++ (POECS101)**

**Course Objectives:**

* 1. To impart the basic concepts of data structures and algorithms.
  2. To understand concepts about searching and sorting techniques.
  3. To understand basic concepts about stacks, queues, lists, trees and graphs.
  4. To understanding about writing algorithms and step by step approach in solving problems with the help of fundamental data structures.

**Prerequisites:** Basic knowledge of C

**Syllabus:**

**Module I:**

Mathematical Background, Running Time calculations, Abstract data types (ADTs), The List ADT, The Stack ADT, and The Queue ADT.

**Module II:**

Trees: Basic concepts and implementation of Trees, Tree traversals, Binary trees, Binary search trees, AVL trees, Splay Trees, Tree traversals revisited, B-Trees.

Hashing: General Idea, Hash Function, Open Hashing, Closed Hashing.

**Module III:**

Priority Queues: The Model, Simple Implementations, Binary Heap, Application of Priority Queues.

Sorting: Insertion Sort, Heap Sort, Merge Sort, Quick Sort, Sorting large objects.

**Text Book:**

* 1. Data Structure and Algorithm Analysis in C++, Mark Allen Weiss, Addison Wesley, ISE 1999, Chapter 2 (2.4.1, 2.4.2, 2.4.4), 3, 4, 5 (5.1-5.4), 6 (6.1-6.4), 7(7.1-7.2 ,7.5-7.7)

**Reference Book:**

* 1. Fundamentals of Data Structures in C++, E. Horowitz, S. Sahani, D Mehta, Galgotia Publications, 2003.

**Course Outcomes:** After the successful completion of this course the students will be able to

1. choose appropriate data structure as applied to specified problem definition.
2. handle operations like searching, insertion, deletion, traversing mechanism etc. on various data structures.
3. apply concepts learned in various domains like DBMS, compiler construction etc.
4. use linear and non-linear data structures like stacks, queues, linked list etc.

**OE 2: Fundamentals of Computer Systems (POECS102)**

**Course Objectives:**

* 1. To understand the main components of an OS & their functions and process management and scheduling.
  2. To understand various issues in Inter Process Communication (IPC) and the role of OS in IPC.
  3. To describe a sound introduction to the discipline of database management systems.
  4. Gain core knowledge of Network layer routing protocols and IP addressing.

**Syllabus:**

**Module I:**

***OPERATING SYSTEM:*** Computer hardware, operating system structure; Process management (Process scheduling, Process state, scheduling algorithms, process attributes); Interprocess communication and synchronization, deadlock; Memory management (Partitioning, paging, segmentation, swapping); Virtual memory; File system management (Directories and names, File system objects and functions); Device management (hardware I/O organization, software organization, devices)

**Module II:**

***RELATIONAL DATABASE SYSTEM:*** Data models, Database system architecture, Relational database, Concepts (RDBMS, Relation, types of keys, relational operators, set operations on relations); Functional Dependencies (Definition, function dependencies and keys, Inference axioms for functional dependencies, redundant functional dependencies, equivalence of functional dependencies); Normalization (First, second, and third normal forms, Data anomalies in 1nf,2nf,3nf relations, Boyce-Codd normal form); The entity-Relationship model (entities and attributes, one-one, many-one, many-many relationships, normalizing the model.

**Module III:**

***COMPUTER NETWORKING:*** Data Communications (multiplexing, signaling, encoding and decoding, error detection and recovery, flow control, sliding window, congestion window); Communications networks (Int. to networking, network components and topologies); Network technologies (LAN, WAN, and wireless networks); Switching (circuit and packet switching, brigges and switches, integrating switches with hubs and routers),Naming and addressing, Routing( information, protocol, hierarchical and multicast routing), Services and Applications (FTP, TFTP, Domain name system, e-mail, WWW, HTML, HTTP)

**Text Book:**

1. J. Archer Harris, Operating Systems, (Schaum’s Outline) TMH.
2. Ramon A. Mata-toledo, P.K.. Cushman, Fundamentals of Relational Databases (Schaum’s Outline), TMH.
3. Ed Tittel, Computer Networking, (Schaum’s Outline) TMH.

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. Describe and analyze the memory management and its allocation policies.
  2. Identify use and evaluate the storage management policies with respect to different storage management technologies.
  3. Create and populate a RDBMS for a real-life application, with constraints and keys, using SQL.
  4. Explain the function computational of Application layer and Presentation layer paradigms and Protocols.

**Lab 1: Data Structure Using C++ Lab (PLCCS107)**

**(Minimum 10 experiments to be done)**

***List of Experiments:***

1. Simple Programs using C++
2. Implementation of Array (Insertion, Deletion, Find)
3. Implementation of Linked List (Insertion, Deletion, Find)
4. Polynomial Representation, Addition, and Multiplication using Linked List
5. Implementation of Stack (Using Array and Linked List)
6. Application of Stack (Conversion of Infix Arithmetic expression to Postfix expression, Prefix expression, Evaluation of Prefix and Postfix expression)
7. Implementation of Queue (Enque and Deque Operation) using array and Linked List
8. Implementation of Tree traversal (Inorder, Preorder, Post order) in binary tree. Implementation of BST (Insertion, Deletion, FinMin, FindMax, Find Depth of the tree)
9. Implementation of Priority Queue
10. Implementation of Insertion Sort, Merge Sort.
11. Implementation of Quick Sort, Heap Sort.

**Lab 2: Systems Lab (PLCCS108)**

***List of Experiments:***

1. Use of SQL syntax: insertion, deletion, join, updation using SQL.
2. Programs on join statements and SQL queries including where clause.
3. Programs on procedures, functions, database triggers and packages.
4. Programs on data recovery using check point technique.
5. Concurrency control problem using lock operations.
6. Basic UNIX Commands and UNIX Shell Programming.
7. Programs on process creation and synchronization, inter process communication including shared memory, pipes and messages. (Dinning Philosopher problem / Cigarette Smoker problem / Sleeping barber problem)
8. Programs on UNIX System calls.
9. Simulation of CPU Scheduling Algorithms. (FCFS, RR, SJF, Priority, Multilevel Queuing)
10. Simulation of Banker’s Algorithm for Deadlock Avoidance, Prevention.
11. Program for FIFO, LRU, and OPTIMAL page replacement algorithm.

**Semester-2**

**Core 5: Topology (PPCMH201)**

**Course Objectives:**

1. Introduce students to the concepts of open and closed sets abstractly, not necessarily only on the real line approach.
2. Introduce students how to generate new topologies from a given set with bases.
3. They would be familiar with separation axioms, compactness and completeness.
4. They would be able to determine whether a function defined on a metric or topological space is continuous or not and what homeomorphisms are.

**Prerequisites:** Real Analysis.

**Syllabus:**

**Module –I:**

Countable and uncountable set, Infinite sets and the Axiom of choice, Well-ordered sets. Topological spaces, Basis and sub basis for a topology, the order, product and subspace topology, closed sets and limit points. Continues function and homeomorphism, Metric topology, Connected spaces, connected subspaces of the real line, Components and local connectedness.

**Module –II:**

Compact spaces, Basic properties of compactness, Compactness and finite intersection property, Compact subspaces of the real line, Compactness in metric spaces, Limit point compactness, Sequential compactness and their equivalence in metric spaces, Local compactness and one-point compactification.

**Module –III:**

First and second countable spaces, Product spaces, Lindelo’’f space, Separable spaces, separable axioms, Hausdorff, Regular and normal spaces. The Urysohn lemma, completely regular spaces, The Urysohn metrization theorem, Imbedding theorem, Tietn extension Theorem, Tychonoff theorem, Stone-Cech compactification.

**Text Book:**

1. Topology, J.R. Munkres, 2e, Pearson Education, 2000.

Chapter: 1(7,9,10),2(excluding section 22), 3, 4 (excluding section 36), 5.

**Reference Books :**

1. Introduction to general Topology, by K.D. Joshi, Wiley Eastern Ltd., 1983.
2. Foundation of General Topology, by W.J. Pervin, Academic Press, 1964.
3. General Topology, by S. Nanda and S. Nanda, Macmillan India.

**Course Outcomes:** After the successful completion of this course the students will be able to

1. familiar with methods and techniques of proving basic theorems on topological spaces and continuous mappings.
2. check if a given function is metric, continuous.
3. check if a given set is open, closed, dense, compact, connected.
4. apply his or her knowledge of general topology to formulate and solve problems of a topological nature in mathematics and other fields where topological issues arise.

**Core 6: Numerical Analysis (PPCMH202)**

**Course objectives:**

1. Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.
2. Apply numerical methods to obtain approximate solutions to mathematical problems.
3. Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.
4. Analyse and evaluate the accuracy of common numerical methods.

**Prerequisites:** Differentiation, Integration, Differential Equation, Interpolation.

**Syllabus:**

**Module –I:**

Solution of Equations: Zeros of Polynomials, Horner’s method, Muller’s method, Interpolation & Polynomial Approximation: Lagrange polynomial, Data approximation Hermite, cubic, spline and piecewise interpolation (Natural cubic splines, clamped Splines)

Numerical differentiation: Numerical differentiation, Richardson Extrapolation.

Numerical Integration & Composite Integration (Newton Cotes & Gaussian Quadrature), Romberg Integration, brief idea of Adaptive quadrature method, Improper Integral, Asymptotic error formula.

**Module -II:**

Multiple Integrals,

Initial value problems for ODE: Taylor’s series method Runge-Kutta method, predictor-corrector method, Convergence & stability

Numerical solution to ODE; Taylor’s series methods, Adaptive Runge - Kutta method, predictor- corrector method, convergence and stability, multistep methods.

Boundary value problem for ODE: Shooting method for linear & non-linear problems, finite difference methods for linear & non-linear problems, The Rayleigh Ritz Method.

**Module –III:**

Approximating Eigen value: power method, shifted power method, inverse power, Householder’s method, QR-method, error and stability.

Numerical solution to partial differential equations: Solution of parabolic, elliptic, Hyperbolic differential equations using finite difference method and stability considerations.

**Text Book:**

1. Numerical Analysis:Richard L. Burden & J.D. Faires. Cengage Learning 9th Edition Chapter – 2 (2.6), Chapter-3 (3.1, 3.2, 3.4-3.6), Chapter 4 (4.1-4.9), Chapter-5(5.1-5.8, 5.10), Chapter 9(9.1-9.5), Chapter-11(11.1-11.5), Chapter 12(12.1-12.3)

**Reference Books:**

1. Advanced numerical methods, L.V. Fusset
2. Numerical methods for Scientific and Engineering Computation, M.K. ain, S.R.K.Iyengar.
3. Numerical methods for Engineers by Chapra & Canale, TMH
4. An introduction to Numerical Analysis: by Kendall E. Atkinson, Wiley

**Course Outcomes:** After the successful completion of this course the students will be able to

1. solve an algebraic or transcendental equation and differential equation using an appropriate numerical method.
2. approximate a function using an appropriate numerical method.
3. evaluate a derivative at a value and a definite integral using an appropriate numerical method.
4. solve a linear system of equations using an appropriate numerical method.

**Core 7: Complex Analysis (PPCMH203)**

**Course objectives:**

1. Determine whether a given function is differentiable, and if so find its derivative.
2. Find parametrizations of curves, and compute complex line integrals directly.
3. Identify the isolated singularities of a function and determine whether they are removable, poles, or essential.
4. Use the residue theorem to compute complex line integrals and real integrals.

**Prerequisites:** Basic Real Analysis.

**Syllabus:**

**Module-I:**

The complex number system: The real numbers, The field of complex numbers, the complex plane, polar representation and roots of complex numbers, Line and half planes in the complex plane. Power series and radius of convergence, analytic function, Power series representation of analytic functions, Cauchy- Riemann equation, analytic function as mapping and its Mobius transformation.

**Module-II:**

Complex integration: Zeros of analytic function, entire function, Liouville’s theorem, fundamental theorem of algebra, maximum modulus theorem, Index of a closed curve, Cauchy’s theorem and Cauchy’s integral formula, Morera’s theorem.

**Module-III:**

Classification of singularity, Poles, absolute convergence, Laurent series development, Residue theorems, evaluation of integrals by using residue theorem, Argument principle, Rouche’s theorem, Maximum Modulus theorem, Schwarz’s Lemma.

**Text Book:**

1. Functions of one Complex variable- J. B. Conway (Springer Verlag, International student edition, Narosa Publishing house, Chapter-1(1.1-1.5), Chapter-3(3.1- 3.3), Chapter-4(4.2 - 4.5), Chapter-5(5.1-5.3), Chapter-6(6.1 - 6.2).

**Reference Books:**

1. Complex Analysis by Alhfors, TMH.
2. Complex Variable; Theory & Application: Kasana, PHI

**Course Outcomes:** After the successful completion of this course the students will be able to

1. Explain the fundamental concepts of complex analysis and their role in modern mathematics and applied contexts.
2. Demonstrate accurate and efficient use of complex analysis techniques.
3. Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis.
4. Apply problem-solving using complex analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.

**Core 8: Abstract Algebra (PPCMH204)**

**Course objectives:**

1. Understanding of group and rings and its properties.
2. To understand the concept of sylow p-subgroups, algebraic extension of fields, algebraically closed fields, normal extension, separable extension.
3. Demonstrate knowledge and understanding of finite fields, Galois theory, cyclic extensions, symmetric functions.
4. To use the method of ruler and compass constructions.

**Prerequisites:** Set, Relation, Mapping, Group, Ring, Field.

**Syllabus:**

**Module-I:**

Normal subgroup, Isomorphism theorem, Automorphisms, Permutation group: Cyclic decomposition and Alternating group Structure theorems for groups: Direct Product, finitely generated abelian group. Structure theorem for groups: Invariants of a finite abelian group, Sylows theorem. Unique factorization domain, Principal ideal domain, Euclidean domains, polynomial rings over UFD.

**Module-II:**

Algebraic extension of fields: Irreducible polynomials and Einstein criterion, Adjunction of roots, Algebraic extension. Algebraically closed fields, Normal separable extensions: splitting fields, normal extensions. Normal separable extension: Multiple roots, Finite fields, Separable extensions.

**Module-III:**

Galois Theory: Automorphism groups and fixed fields, Fundamental theorem of Galois theory. Application of Galois theory to classical problems: Roots of unity and Cyclotomic polynomials, Cyclic extensions, Polynomials solvable by radicals, Symmetric functions, Ruler and compass constructions.

**Text Book:**

1. P.B. Bhattacharya, S. K Jain and S.R.Nagpaul: Basic Abstact Algebra, Cambridge University Press. Chapters: 5 (Art 2,3), 7(Art 1,2), 8(Art 1-4), 11 (Art 1-4), 15(Art 1-3), 16(Art 1,2), 18(1-5).

**Reference Books:**

1. Vivek Sahai and Vikas Bist: Algebra (Narosa publication House).
2. I.S. Luthar and I.B.S. Passi: Algebra Vol. 1 Groups (Narosa publication House).
3. I.N. Herstein**:** Topics in Algebra (Wiley Eastern Ltd.).
4. Surjit Singh and Quazi Zameeruddin: Modern Algebra (Vikas Publishing House).
5. S.K. Jain & S.R. Nagpal: Basic Abstract Algebra (Cambridge University Press 1995).
6. Dummit: Abstract Algebra, Wiley
7. Modern Algebra by A. R. Vasishtha, Krishna Prakashan Mandir, Meerut.

**Course Outcomes:** After the successful completion of this course the students will be able to

1. apply algebraic ways of thinking.
2. demonstrate knowledge and understanding of fundamental concepts including groups, subgroups, normal subgroups, homomorphisms and isomorphism.
3. demonstrate knowledge and understanding of rings, fields and their properties.
4. understand and prove fundamental results and solve algebraic problems using appropriate techniques.

**Core 9: Probability and Stochastic Processes (PPCMH205)**

**Course Objectives:**

1. To provide the students with knowledge about the random variable, random process and how to model the random processes in the communication system such as receiver performance, interference, thermal noise, and multipath phenomenon.
2. To introduce the idea of a stochastic process, and to show how simple probability and matrix theory can be used to build this notion into a beautiful and useful piece of applied mathematics.
3. To understand the notion of a Markov chain, and how simple ideas of conditional probability and matrices can be used to give a thorough and effective account of discrete-time Markov chains;
4. To be able to apply these ideas to answer basic questions in several applied situations including genetics, branching processes and random walks.

**Prerequisites:** Probability Distribution and Expectation of single random variable.

**Syllabus:**

**Module-I:**

Multiple random variables, Functions of several random variables, Covariance, Correlation and Moments, Conditional expectation. Modes of convergence of a sequence of random variables, Weak law of large numbers, Strong law of large numbers, Central limit theorem.

**Module-II:**

Introduction to Stochastic process, Specification of stochastic process, Markov chain, Transition probability, Classification of states and chains, Determination of higher transition probability, , Markov chain with discrete and continuous space.

**Module-III:**

Poisson process with related distribution, Generalization of Poisson process: Pure birth process, Birth and death process.

**Text book**

1. An Introduction of Probability and Statistics by V. K. Rohatgi and A. K. Md.E. Saleh, 2nd Edition, Wiley Publication. (Chapter 4 and Chapter 6)
2. Stochastic Process by J. Medhi, New Age International Publication (2nd edition}
3. A first course in Stochastic process, S. Karlin & H. Taylor, 2nd Edition, Academic Press.

**Reference book**

1. Fundamentals of Mathematical Statistics by S.C. Gupta & V.K. Kapoor, S Chand & Sons.
2. Stochastic Process by Sheldon M. Ross, Wiley & sons, (2nd edition)
3. Stochastic Process by D N Shanbhag, C R Rao, Gulf Publishing.
4. Stochastic Methods by Crispin Gardiner, Springer.
5. Probability, Random Variables and Stochastic Processes, 4thEdn., A. Papoulis and S. U. Pillai, TMH Publication.

**Course outcomes:** After the successful completion of this course the students will be able to

1. Have a general overview of discrete and continuous random variables and their statistical properties
2. Understand how random variables and stochastic processes can be described and analyzed
3. Know the law of large numbers and their application
4. Overview of Markov process and applications;

**OE 3: Design and Analysis of Algorithm (POECS201)**

**Course Objectives:**

1. Analyse the asymptotic performance of algorithms.
2. Demonstrate a familiarity with major algorithms and data structures.
3. Apply important algorithmic design paradigms and methods of analysis.
4. Synthesize efficient algorithms in common engineering design situations.

**Prerequisites:** Discrete Mathematics. Data Structure.

**Syllabus:**

**Module- I:**

Introduction to design and analysis of algorithms, Growth of Functions (Asymptotic notations, standard notations and common functions), Recurrences, solution of recurrences by substitution, recursion tree and Master methods, worst case analysis of Merge sort, Quick sort and Binary search, Design & Analysis of Divide and conquer algorithms.

Heapsort: Heaps, Building a heap, The heapsort algorithm, Priority Queue, Lower bounds for sorting.

**Module – II:**

Dynamic programming algorithms (Matrix-chain multiplication, Elements of dynamic programming, Longest common subsequence)

Greedy Algorithms - (Assembly-line scheduling, Achivity- selection Problem, Elements of

Greedy strategy, Fractional knapsac problem, Huffman codes).

Data structure for disjoint sets: - Disjoint set operations, Linked list representation, Disjoint set forests.

**Module – III:**

Graph Algorithms: Breadth first and depth-first search, Minimum Spanning Trees, Kruskal and Prim's algorithms, single- source shortest paths (Bellman-ford and Dijkstra's algorithms), All- pairs shortest paths (Floyd – Warshall Algorithm). Back tracking, Branch and Bound.

Fast Fourier Transform, string matching (Rabin-Karp algorithm), NP - Completeness (Polynomial time, Polynomial time verification, NP - Completeness and reducibility, NP-Complete problems (without Proofs), Approximation algorithms (Vertex-Cover Problem, Traveling Salesman Problem).

**Text Book:**

1. T.H. Cormen, C.E. Leiserson, R.L. Rivest, C.Stein : Introduction to algorithms -2nd edition, PHI,2002. Chapters: 1,2,3,4 (excluding 4.4), 6, 7, (7.4.1), 8 (8.1) 15 (15.1 to 15.4), 16 (16.1, 16.2, 16.3), 21 (21.1,21.2,21.3), 22(22.2,22.3), 23, 24(24.1,24.2,24.3), 25 (25.2), 30,32 (32.1, 32.2) 34, 35(35.1, 35.2)

**Reference Books:**

1. Algorithms – Berman, Cengage Learning
2. Computer Algorithms: Introduction to Design & Analysis, 3rd edition-by Sara Baase, Allen Van Gelder, Pearson Education
3. Fundamentals of Algorithm-by Horowitz & Sahani, 2nd Edition, Universities Press.
4. Algorithms by Sanjay Dasgupta, Umesh Vazirani – McGraw-Hill Education
5. Algorithm Design – Goodrich, Tamassia, Wiley India.

**Course Outcomes:** After the successful completion of this course the students will be able to

1. analyze worst-case running times of algorithms using asymptotic analysis,
2. describe the dynamic-programming paradigm and explain when an algorithmic design situation calls for it. Recite algorithms that employ this paradigm. Synthesize dynamic-programming algorithms, and analyse them.
3. Explain what competitive analysis is and to which situations it applies. Perform competitive analysis.
4. Compare between different data structures. Pick an appropriate data structure for a design situation.

**Lab 3: Numerical Analysis Lab (PLCMH201)**

***List of Experiments:***

1. Write a computer-oriented algorithm & the corresponding C Program to fit a st. line of the form y = a x + b, for a given data, using the method of least square.
2. Write a computer-oriented algorithm & the corresponding C Program to fit a nth degree polynomial of the form for a given data by the method of least square.
3. Write a computer oriented algorithm & the corresponding C Program to find the smallest positive root using fixed point iteration method.
4. Write a computer oriented algorithm & the corresponding C Program to find the smallest positive root using Newton- Raphson method.
5. Write a computer oriented algorithm & the corresponding C Program to find the solution of the system of linear equations using Gauss Seidel Method.
6. Write a computer oriented algorithm & the corresponding C Program to interpolate y using the given pair of values of x and y by Lagrange’s interpolation.
7. Write a computer oriented algorithm & the corresponding C Program to find the derivative at the initial point using Newton ‘s Forward Difference Method.
8. Write a computer oriented algorithm & the corresponding C Program to find the derivative at the final point using Newton ‘s Backward Difference Method.
9. Write a computer oriented algorithm & the corresponding C Program to integrate Numerically using Trapezoidal & Simpson’s Rule.
10. Write a computer oriented algorithm & the corresponding C Program to integrate Numerically using Gauss Quadrature Rule.
11. Write a computer oriented algorithm & the corresponding C Program to solve the Differential Equation. at the specified pivotal points by using the Runge-Kutta Method of 4th order.

**Lab 4: Design and Analysis of Algorithm Lab (PLCCS208)**

***List of Experiments:***

1. Using a stack of characters, convert an infix string to postfix string.
2. Implement insertion, deletion, searching of a BST.
3. (a) Implement binary search and linear search in a program (b) Implement a heap sort using a max heap.
4. (a) Implement DFS/ BFS for a connected graph. (b) Implement Dijkstra’s shortest path algorithm using BFS.
5. (a) Write a program to implement Huffman’s algorithm. (b) Implement MST using Kruskal/Prim algorithm.
6. (a) Write a program on Quick sort algorithm. (b) Write a program on merge sort algorithm. Take different input instances for both the algorithm and show the running time. 7. Implement Strassen’s matrix multiplication algorithm.
7. Write down a program to find out a solution for 0 / 1 Knapsack problem.
8. Using dynamic programming implement LCS.
9. (a) Find out the solution to the N-Queen problem. (b) Implement back tracking using game trees.

**Semester-3**

**Core 10: Functional Analysis (PPCMH301)**

**Course Objectives:**

* 1. Explain the fundamental concepts of functional analysis and their role in modern mathematics and applied contexts.
  2. Demonstrate accurate and efficient use of functional analysis techniques.
  3. Demonstrate capacity for mathematical reasoning through analyzing proving and explaining concepts from functional analysis.
  4. Apply problem-solving using functional analysis technique applied to diverse situations in physics, engineering and another mathematical context.

**Prerequisites:** Real Analysis.

**Syllabus:**

**Module -I:**

Normed spaces, continuity of linear maps, Hahn-Banach theorems, Banach spaces.

Uniform bounded principle, Application-Divergencce of Fourier Series of Continuous Functions, closed graph theorem, open mapping theorem, bounded inverse theorem, Spectrum bounded Operator.

**Module-II:**

Duals and transposes, duals of L^p [a,b] and C[a,b].

Inner product spaces, orthonormal sets, approximation and optimization, projections, Riesz representation theorem.

**Module-III:**

Bounded operators and adjoints on a Hilbert space, normal, unitary and self adjoint operators.

**Text book:**

* 1. B. V. Limaye : Functional Analysis (2nd Edition)- New Age International Limited., Chapter-2 (5-8), chapter-3 (9-12), chapter-4 (13,14), chapter-6 (21-24), chapter-7 (25,26)
  2. G. BACHMAN, L. NARICI, Functional Analysis, Academic Press

**Reference book:**

* 1. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons (Asia), pvt.ltd., 2006.
  2. John B. Conway, A course in Functional Analysis, 2nd edition, Springer verlag, 2006

**Course Outcomes:** After the successful completion of this course the students will be able to

* 1. define and thoroughly explain Banach and Hilbert spaces and self-adjoint operators,
  2. apply Hilbert space-theory,
  3. to work with families of applications appearing in the course,
  4. produce examples and counterexamples illustrating the mathematical concepts presented in the course.

**Core 11: Matrix Computation (PPCMH302)**

**Course Objectives:**

1. Demonstrate ability to manipulate matrices and to do matrix algebra.
2. Demonstrate ability to solve systems of linear equations.
3. Demonstrate ability to work within vector spaces and to deal with vector space properties.
4. Demonstrate ability to manipulate linear transformations and compute determinants.
5. Demonstrate ability to compute eigenvalues and eigenvectors.

**Prerequisites:** Determinant, Matrices, MATLAB.

**Syllabus:**

**Module-I:**

Gaussian Elimination and Its Variants: Matrix Multiplication Systems of Linear Equations, Triangular Systems, Positive Definite Systems; Cholesky Decomposition, Banded Positive Definite Systems, Sparse Positive Definite Systems, Gaussian Elimination and the LU Decomposition, Gaussian Elimination with Pivoting, Sparse Gaussian Elimination, Sensitivity of Linear Systems: Vector and Matrix Norms, Condition Numbers.

**Module-II:**

The Least Squares Problem, The Discrete Least Squares Problem, Orthogonal Matrices, Rotators, and Reflectors, Solution of the Least Squares Problem, The Gram-Schmidt Process, Geometric Approach, Updating the QR Decomposition, The Singular Value Decomposition, Introduction, Some Basic Applications of Singular Values.

**Module-III:**

Systems of Differential Equations, Basic Facts, The Power Method and Some Simple Extensions, Similarity Transforms, Reduction to Hessenberg and Tridiagonal Forms, The QR Algorithm, Implementation of the QR algorithm, Use of the QR Algorithm to Calculate Eigenvectors, The SVD Revisited, Eigen values and Eigen vectors, Eigen spaces and Invariant Subspaces, Subspace Iteration, Simultaneous Iteration, and the QR Algorithm, Eigen values of Large, Sparse Matrices, Eigen values of Large, Sparse Matrices, Sensitivity of Eigen values and Eigenvectors, Methods for the Symmetric Eigenvalue Problem, The Generalized Eigenvalue Problem.

**Text Book:**

* 1. Fundamentals of Matrix Computation by David S Watkins

Ch1. Ch 2.1,2.2, Ch 3, Ch 4.1,4.2, Ch 5, Ch 6.

**Reference Book:**

1. Matrix Computations by Gene H. Golub, Charles F.Van Loan The Johns Hopkins University Press, Baltimore.

**Course Outcomes:** After the successful completion of this course the students will be able to

1. use sophisticated scientific computing and visualization environments to solve application problems involving matrix computation algorithms,
2. interpret the results produced by computer implementations of numerical algorithms,
3. explain the effects of errors in computation and how such errors affect solutions,
4. demonstrate the necessary analytical background for further studies leading to research in applied mathematics or related disciplines.

**Core 12: Computational Statistics (PPCMH303)**

**Course Objectives:**

* 1. To introduce students to state-of-the-art methods and modern programming tools for data analysis.
  2. To learn the principles and methods of statistical analysis and also put them into practice using a range of real-world data sets.
  3. To provide a basic understanding of data analysis using statistics and to use computational tools on problems of applied nature.
  4. To investigate and evaluate relative efficiency of different methods.

**Prerequisites:** Probability, Statistics.

**Syllabus:**

**Module-I:**

Random variables, Expected Values, The Law of Large Numbers, Central Limit Theorem, x^2, t and F distributions, The Sample Mean and the Sample Variance, Testing of hypothesis and assessing goodness of fit, Acceptance sampling, Estimation of Parameters, Confidence Intervals.

**Module-II:**

Linear methods for Regression and Classification: Overview of supervised Learning, Linear regression models and least squares, Multiple Regression, Subset selection, Ridge regression, least angle regression and Lasso, Linear discriminant analysis, Logistic regression.

Additive Models, Trees and Boosting: Generalized additive models, Regression and Classification trees, Boosting Methods- exponential loss and AdaBoost, Random forests and analysis.

**Module-III:**

Support Vector Machines (SVM), and K-nearest Neighbour: Basis expansion and regularization, Kernel smoothing methods, SVM for classification, Reproducing Kernels, SVM for regression, K-nearest Neighbour classifiers.

Unsupervised Learning: Cluster analysis, Principal Components, Gaussian mixtures and selection.

**Text Books**

1. 1.Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning-Data Mining Inference and Prediction, Second Edition, Springer Verlag, 2009.
2. 2 John A. Rice, “Mathematical Statistics and Data Analysis” third edition, Cengage Learning.

**References**

1. C.M. Bishop- Pattern Recognition and Machine Learning, Springer,2006.
2. L. Wasserman- All of statistics

**Course Outcomes: -** After the successful completion of this course the students will be able to

* 1. understand concepts of Large Numbers and different distributions in statistics and their limitations;
  2. understand modern notions in data analysis-oriented computing;
  3. be capable of confidently applying common Supervised & Unsupervised Learning algorithms in practice and implementing their own;
  4. be capable of performing distributed computations;

**Core 13: Optimization Theory (PPCMH304)**

**Course Objectives:**

* 1. To understand the theory of optimization methods and algorithms developed for solving various types of optimization problems
  2. To develop and promote research interest in applying optimization techniques in problems of Engineering and Technology
  3. To apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.
  4. The focus of the course is on convex optimization though some techniques will be covered for non-convex function optimization too.

**Prerequisites:** Operation Research.

**Syllabus**

**Module-I**

Calculus on R and Rn, Convex Analysis, One Dimensional Optimization: Function Comparison Methods, Polynomial Interpolation Methods, Iterative Methods, Two Point Equal Interval Search, Method of Bisection, Fibonacci Method, Golden Section Search Method, Quadratic Interpolation, Cubic Interpolation, Iterative Methods: Newton’s Method, Secant Method.

**Module-II**

Unconstraint Optimization: Optimization without constraints, Conjugate Gradient method, Steepest Descent Method, Newton’s, Quasi-Newton’s Method. Linear programming: Introduction to LPP, Simplex method, Big M method, Two Phase method, Revised simplex method, Duality theory and Dual simplex method.

**Module-III**

Constraint Optimization: Lagrange Multiplier, Kuhn-Tucker conditions, Convex Optimization, Penalty Function Techniques, Method of Multipliers, Linearly Constrained Problems and Cutting Plane Method.

**Text Books**

1. Mohan C Joshi, Kannan M Moudgalya, “Optimization Theory and Practice”, Narosa Publishing House Pvt. Ltd.

**Reference Books**

1. A. Ravindran, K.m.Rasdell, G.V. Reklaitis, “Engineering optimization” 2nd edition, Wiley India Pvt. Ltd.
2. Kalyamoy Deb, “Optimization for Engineering Design”, PHI Learning Pvt Ltd
3. Stephen G. Nash, A. Sofer,” Linear and Non-Linear Programming”, McGraw Hill
4. Ashok D Belegundu, A R Chandrupatla, Second Edition Cambridge University Press.

**Course Outcomes:** After successful completion of the course, students will be able to

* 1. understand importance of optimization of industrial process management,
  2. apply basic concepts of mathematics to formulate an optimization problem,
  3. analyze and appreciate variety of performance measures for various optimization problems,
  4. apply optimization algorithms to model problems in engineering and natural sciences.

**PE 1: Numerical Optimization (PPEMH301)**

**Course Objectives:**

1. To find acceptable approximate solutions when exact solutions are either impossible or so arduous and time-consuming as to be impractical;
2. To devise alternate methods of solution better suited to the capabilities of computers;
3. To formulate problems in their fields of research as optimization problems by defining the underlying independent variables, the proper cost function, and the governing constraint functions;
4. To understand how to assess and check the feasibility and optimality of a particular solution to a general constrained optimization problem.

**Prerequisites:** Optimization Theory

**Syllabus:**

**Module-I**

***Trust-Region Methods:*** The Cauchy Point and Related Algorithms, The Cauchy Point, Improving on the Cauchy Point, The Dogleg Method, Two-Dimensional Subspace Minimization, Steinhaug’s Approach,

***Newton Methods:*** Inexact Newton Steps, Line Search Newton Methods, Line Search Newton–CG Method, Modified Newton’s Method, Hessian Modifications, Eigenvalue Modification, Adding a Multiple of the Identity,

Modified Cholesky Factorization. Gershgorin Modification, Modified Symmetric Indefinite Factorization, Trust-Region Newton Methods, Newton–Dogleg and Subspace-Minimization Methods, Accurate Solution of the Trust-Region Problem, Trust-Region Newton–CG Method, Preconditioning the Newton–CG Method, Local Convergence of Trust-Region Newton Methods

**Module-II**

***Quasi-Newton Methods:*** The BFGS Method, Properties of the BFGS Method, Implementation, The SR1 Method, Properties of SR1 Updating, The Broyden Class, Properties of the Broyden Class, Convergence Analysis, Global Convergence of the BFGS Method, Super linear Convergence of BFGS, Convergence Analysis of the SR1Method,

***Large-Scale Quasi-Newton and Partially Separable Optimization:*** Limited-Memory BFGS Relationship with Conjugate Gradient Methods ,General Limited-Memory Updating ,Compact Representation of BFGS Updating ,SR1Matrices ,Unrolling the Update ,Sparse Quasi-Newton Updates, Partially Separable Functions, Internal Variables ,Invariant Subspaces and Partial Separability, Sparsity vs. Partial Separability ,Group Partial Separability ,Algorithms for Partially Separable Functions ,Exploiting Partial Separability in Newton’s Method ,Quasi-Newton Methods for Partially Separable Functions.

**Module-III**

***Fundamentals of Algorithms for Nonlinear Constrained Optimization***

Initial Study of a Problem, Categorizing Optimization Algorithms, Elimination of Variables, Simple Elimination for Linear Constraints, General Reduction Strategies for Linear Constraints, The Effect of Inequality Constraints, Measuring Progress: Merit Functions

***Quadratic Programming:*** Portfolio Optimization ,Equality–Constrained Quadratic Programs, Properties of Equality-Constrained QPs, Solving the KKT System, Direct Solution of the KKT System, Range-Space Method, Null-Space Method ,Method Based on Conjugacy, Inequality-Constrained Problems, Optimality Conditions for Inequality-Constrained Problems, Degeneracy, Active-Set Methods for Convex QP, Specification of the Active-Set Method for Convex QP, Finite Termination of the Convex QP Algorithm, Updating Factorizations, Active-Set Methods for Indefinite QP, Choice of Starting Point.

**Text books:**

1. Numerical Optimization, Jorge Nocedal & Stephen J. Wright, Springer.

**Reference books:**

1. Linear and Nonlinear Programming, David G. Luenberger & Yinyu Ye, Springer
2. Numerical Optimization: Theoretical and Practical Approach, J.Frederic Bonnans, J. Charles Gilbert, Claude Lemarechal, Claudia A. Sagas

**Course Outcomes:** After successful completion of the course, students will be able to

1. use sophisticated scientific computing and visualization environments to solve application problems involving matrix computation algorithms,
2. analyse numerical algorithms, and understand the relationships between the computational effort and the accuracy of these algorithms,
3. interpret the results produced by computer implementations of numerical algorithms,
4. explain the effects of errors in computation and how such errors affect solutions.

**PE 1: Numerical Solution of Differential Equation (PPEMH302)**

**Course Objectives:**

1. Learn basic scientific computing for solving differential equations.
2. Understand mathematics–numeric interaction, and how to match numerical method to mathematical properties.
3. Understand correspondence between principles in physics and mathematical equations.

**Prerequisites:** Differential Equation. Numerical Analysis.

**Syllabus:**

**Module-I:**

***Finite Difference Methods for Parabolic Equations:*** stability, consistence and convergence, 1-D parabolic equations, 2-D and 3-D parabolic equations.

***Finite Difference Methods for Hyperbolic Equations:*** some basic difference scheme, dissipation and dispersion errors, extensions to conservation laws, the second-order hyperbolic PDEs.

***Finite Difference Methods for Elliptic Equations:*** numerical solution of linear systems, error analysis with a maximum principle.

**Module-II:**

***Finite Element Methods:*** ***Basic Theory:*** introduction to one-dimensional problems, introduction to two-dimensional problems, abstract finite element theory, examples of conforming finite element spaces, examples of nonconforming finite elements, finite element interpolation theory, finite element analysis of elliptic problems, finite element analysis of time-dependent problems.

**Module- III:**

***Finite Element Methods: Programming:*** FEM mesh generation. Forming FEM equations, calculation of element matrices, assembly and implementation of boundary conditions, the MATLAB code for element, the MATLAB code for element.

**Text Book:**

1. Computational Partial Differential Equations using MATLAB by J. Li and Y-T Chen *CRC Press Chapman & Hall.* Chapters: 2, 3, 4, 6, 7

**Course Outcomes:** After successful completion of the course, students will be able to

1. apply numerical methods to obtain approximate solutions to mathematical problems,
2. derive numerical methods for various mathematical operations and tasks,
3. analyse and evaluate the accuracy of common numerical methods,
4. write efficient, well-documented MATLAB code and present numerical results in an informative way.

**PE 1: Differential Geometry (PPEMH303)**

**Course Objectives:**

* 1. Find the osculating surface and the osculating curve at any point of a given curve.
  2. Calculate the first and the second fundamental forms of a surface.
  3. Calculate the Gaussian curvature, the mean curvature, the curvature lines, the asymptotic lines, the geodesics of a surface.
  4. Use efficiently the mathematical tool of tensor calculus in the study of surfaces.

**Prerequisites:** Differential Calculus.

**Syllabus:**

**Module-I:**

Review of Calculus on Rn.

Differentiable Manifolds: Differentiable structures defined on sets, Differentiable Functions on a manifold, tangent Spaces: Tangent vector as an equivalent class of curves, Tangent vector as a directional derivative operator, Algebraic Approach of Tangent vectors, Differentials of smooth maps Vector fields on differentiable manifolds: Vector fields and Lie Brackets; f-related vector fields. Integral curves and flows: Integral curves; One parameter group of transformations of a manifold.

**Module-II:**

***Exterior Algebra and Exterior Derivative:*** Tensor Products, Tensor Algebra, Exterior Algebra, Exterior Derivative.

***Lie Group and Lie Algebras:*** The Lie algebra of a Lie group; Lie groups homomorphism and Isomorphism, One parameter subgroups and Exponential map, Lie Transformation Groups, Lie Derivative.

***Fibre Bundles:*** Principal Fibre Bundle, Definition of Cross Section, Linear Frame Bundle, Associated Principal Bundle, Vector Bundles, Bundle Homomorphism, Tangent Bundle, Fundamental Vector Field.

***Linear Connections:*** Affine Connections, Torsion Tensor of an Affine connection, Curvature Tensor of an Affine connection.

**Module -III**

Riemannian Manifolds: Riemannian Connection, Riemannian Curvature Tensor, Riemannian Manifold as a metric space, Some Connections on a Riemannian manifold, Sectional Curvature of a Riemannian manifold, Some transformations on Riemannian manifold.

Submanifolds: Submanifolds of a Riemannian manifold, Induced connection and Second Fundamental Form, Equations of Gauss, Codazzi and Ricci Mean Curvature.

**Text Book:**

1. U. C. De, A. A. Shaikh; Differential Geometry of Manifolds, Narosa Publishing House Pvt. Ltd., New Delhi, Chennai, Mumbai, Kolkata, 2007 Reprinted 2009.

The course is covered by Chapters II, III, IV, V, VI, VII and VIII.

**Reference Book:**

1. William Boothby; An Introduction to Differentiable manifolds and Riemannian Geometry, Academic Press, New York.
2. Loring W. Tu; An Introduction to Differentiable manifolds, Second Edition, Springer International Edition, First Indian Reprint 2012.
3. Wilmore- Differential and Riemannian geometry, Oxford University Press, 1996.
4. Warner-Foundations of differential geometry and Lie groups Springer, 1983.

**Course Outcomes:** After successful completion of the course, students will be able to

* 1. explain the concepts and language of differential geometry and its role in modern mathematics,
  2. analyse and solve complex problems using appropriate techniques from differential geometry,
  3. apply problem-solving with differential geometry to diverse situations in physics, engineering or other mathematical contexts,
  4. apply differential geometry techniques to specific research problems in mathematics or other fields.

**PE 2: Parallel & Distributed Computing (PPECS301)**

**Course Objectives:**

1. To develop and apply knowledge of parallel and distributed computing techniques and methodologies,
2. gain experience in the design, development, and performance analysis of parallel and distributed applications,
3. gain experience in the application of fundamental Computer Science methods and algorithms in the development of parallel applications
4. gain experience in the design, testing, and performance analysis of a software system and to be able to communicate that design to others.

**Syllabus:**

**Module – I**

***Introduction to parallel computing.***

***Parallel programming platforms:*** Trends in microprocessor Architectures, Limitations of memory system performance, Dichotomy of parallel computing platforms, physical organization of parallel platforms, communication costs in parallel machines, Routing mechanisms for interconnection network, Impact of process processors mapping and mapping techniques.

**Module – II**

***Principles of parallel algorithm design:*** Preliminaries, Decomposition techniques, Characteristics of tasks and interactions, Mapping techniques for load balancing, Methods for containing. Interactions overheads, Parallel algorithm models. Basic communication operations: One-to-All Broadcast and All-to-One Reduction, All-to-All broadcast and reduction All-Reduce and prefix sum operations, scatter and gather, All-to-All personalized communication, circular shift, Improving the speed of some communication operation.

**Module – III**

***Analytical modeling of parallel programs:*** Performance metrics for parallel systems, Effect of granularity of performance, scalability of parallel system, Minimum execution time and minimum cost-optimal execution time, Asymptotic analysis of parallel programs, other scalability metrics. ***Programming using the message passing paradigm:***

Principle of message – Passing programming, Send and receive operations, the message passing interface, Topologies and embedding, Overlapping communication with computation, collective communication and computation operations, Groups and communicators.

Dense matrix algorithm: Matrix-vector multiplication, Matrix-matrix algorithm, Solving a system of linear equations.

**Text Book:**

1. Introduction to Parallel Computing, Second Edition, Ananth Gram, Anshul Gupta, George Karypis, Vipin Kumar Person Education.
2. Parallel computing Theory and Practice, Second Edition, Michael J. Quinn, TMH.

**Course Outcomes:** After successful completion of the course, students will be able to:

1. develop and apply knowledge of parallel and distributed computing techniques and methodologies.
2. apply design, development, and performance analysis of parallel and distributed applications.
3. Use the application of fundamental Computer Science methods and algorithms in the development of parallel applications.
4. Explain the design, testing, and performance analysis of a software system, and to be able to communicate that design to others.

**PE 2: Cloud Computing (PPECS302)**

**Course Objectives:**

1. To learn how to use Cloud Services.
2. To implement Virtualization and Task Scheduling algorithms
3. Apply Map-Reduce concept to applications.
4. Broadly educate to know the impact of engineering on legal and societal issues involved and to build Private Cloud.

**Syllabus:**

**Module I:**

Business and IT perspective, Cloud and virtualization, Cloud services requirements, cloud and dynamic infrastructure, cloud computing characteristics, cloud adoption. Cloud characteristics, Measured Service.

**Module II:**

Cloud models, security in a public cloud, public verses private clouds, cloud infrastructure self-service. Gamut of cloud solutions, principal technologies, cloud strategy, cloud design and implementation using SOA, Conceptual cloud model, cloud service demand. Cloud ecosystem, cloud business process management, cloud service management, cloud stack, computing on demand, cloud sourcing.

**Module III:**

Cloud analytics, Testing under cloud, information security, virtual desktop infrastructure, Storage cloud. Resiliency, Provisioning, Asset management, cloud governance, high availability and disaster recovery, charging models, usage reporting, billing and metering. Virtualization defined, virtualization benefits, server virtualization, virtualization for x86 architecture, Hypervisor management software, Logical partitioning, VIO server, Virtual infrastructure requirements. Storage virtualization, storage area networks, network attached storage, cloud server virtualization, virtualized data center. SOA journey to infrastructure, SOA and cloud, SOA defined, SOA defined, SOA and IAAS, SOA based cloud infrastructure steps, SOA business and IT services.

**TEXTS:**

1. Cloud Computing by Dr. Kumar Saurabh, Wiley India, 2011.

**References**

1. Michael Miller, Cloud Computing: Web based applications that change the way you work and collaborate online, Que publishing, August 2009
2. Haley Beard, Cloud Computing Best Practices for Managing and Measuring Processes for On Demand computing applications and data Centres in the Cloud with SLAs, Emereo Pty Limited, July 2008.

**Course Outcomes:** After successful completion of the course, students will be able to:

1. design different workflows according to requirements and apply map reduce programming model
2. apply and design suitable Virtualization concept, Cloud Resource Management and design scheduling algorithms
3. create combinatorial auctions for cloud resources and design scheduling algorithms for computing clouds
4. assess cloud Storage systems and Cloud security, the risks involved, its impact and develop cloud application

**PE 2: Machine Learning (PPECS303)**

**Course Objectives:**

1. To understand the fundamental issues and challenges of machine learning: data, model selection, model complexity, etc.
2. To understand the strengths and weaknesses of many popular machine learning approaches.
3. To appreciate the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised and un-supervised learning.
4. To design and implement various machine learning algorithms in a range of real-world applications.

**Prerequisites:** Statistics, Linear Algebra, Probability

**Syllabus:**

**Module –I**

Introduction: generative models for discrete data (Bayesian concept learning, Naïve Bayes classifier), Gaussian discriminant analysis, Inference in jointly Gaussian distributions, Bayesian statistics, Bayesian linear and logistic regression, General linear models and exponential family, Mixture models and EM algorithm, Gaussian Processes.

**Module -II**

Review of SVM, Multiclass SVM, kernels for building generative models, kernels for strings. Neural Networks- Perceptron, MLP and back propagation, Methods of acceleration of convergence of BPA, Introduction to Deep Learning.

**Module –III**

Dimensionality Reduction (Factor Analysis, Kernel PCA, Independent Component Analysis, ISOMAP, LLE), feature selection, Spectral Clustering, Markov and Hidden Markov Models, Performance Analysis, Model Assessment, Bias Variance Trade-off, Training error, Test error, Model Complexity, Cross Validation and Boot Strap Method.

**Text Books:**

1. Machine Learning: A Perspective Tom Mitchell. First Edition, McGraw- Hill, 1997.
2. Introduction to Machine Learning Edition 2, by Ethem Alpaydin.

**Course Outcomes:** Upon successful completion, students will be able to:

1. understand the fundamental issues and challenges of machine learning: data, model selection, model complexity, etc
2. understand the strengths and weaknesses of many popular machine learning approaches,
3. appreciate the underlying mathematical relationships within and across Machine Learning algorithms and the paradigms of supervised and un-supervised learning,
4. design and implement various machine learning algorithms in a range of real-world applications.

**PE 2: Soft Computing (PPECS304)**

**Course Objectives:**

* 1. Develop the skills to gain a basic understanding of neural network theory and fuzzy logic theory.
  2. Introduce students to artificial neural networks and fuzzy theory from an engineering perspective

**Module – I**

***NEURAL NETWORK:*** Models of a Neuron, Neural Networks viewed as Directed Graph, Least Mean Square Algorithm, Perceptron, Perceptron Convergence Theorem, Some Preliminaries Multilayer Perceptron, Back Propagation Algorithm, XOR Problem, Heuristics for making the Back Propagation Algorithm Perform Better, Virtues and Limitation of Back Propagation Learning, Accelerated Convergence of Back Propagation Learning, Supervised Learning viewed as an Optimization Problem, Introduction to Deep Learning.

**Module – II**

***Fuzzy Logic and Neuro Fuzzy System***

Fuzzy sets: Introduction, Basic Definitions and Terminology, Set theoretic Operations, MF Formulation and Parameterization, MF’s of One and Two Dimensions, Derivatives of Parameterized MF’s, Fuzzy Complement, Fuzzy Intersection and Union, Parameterized T-norm and T- conorm

Fuzzy Rules and Fuzzy Reasoning: Extension Principle and Fuzzy Relations, Linguistic Variables, Fuzzy If-Then Rules, Compositional Rule of Inference and Fuzzy Reasoning

Fuzzy Inference Systems: Mamdani Fuzzy Models, Sugeno Fuzzy Models, Tsukamoto Fuzzy Models, Input Space Partitioning, Fuzzy Modeling

ANFIS: Adaptive Neuro-Fuzzy Inference Systems: - ANFIS Architecture, Hybrid Learning Algorithm, Learning Method that Cross-fertilize ANFIS and RBFN, ANFIS as a Universal Approximator, Simulation Example of Modeling a Two-Input Sinc Function.

**Module – III**

Introduction to Genetic Algorithms: Working Cycle of a Genetic Algorithm, Binary- Coded GA, Crossover or Mutation, Fundamental theorem of GA/ Schema Theorem, Limitations of Binary-Coded GA, GA parameters Setting, Constraints Handling in GA, Penalty Function Approach, Advantages and Dis advantages of Genetic Algorithms, Combination of Local and Global Optimum Search Algorithms, Real- Coded GA, Crossover Operators, Mutation Operators,

Combined Genetic Algorithms: Fuzzy Logic: - Fuzzy Genetic Algorithm, Brief Literature Review and Working Principle of Genetic- Fuzzy Systems,

Combined Genetic Algorithms: Neural Networks: Introduction, Working Principle of Genetic- Neural Systems, Forward Calculation and Hand Calculation.

**Text Book:**

1. Neural Network by Simon Haykin, Pearson Prentice Hall.
2. Neuro Fuzzy and Soft Computing, J. S. R. JANG, C.T. Sun, E. Mitzutani, PHI
3. Soft Computing: Fundamentals and Applications, Dilip K. Pratihar, Narosa

**Reference Book**

1. Neural Networks, Fuzzy Logic, and Genetic Algorithm (synthesis and Application) S. Rajasekaran, G.A. Vijayalakshmi Pai, PHI

**Course Outcomes:** After successful completion of the course, students will be able to:

* 1. comprehend the fuzzy logic and the concept of fuzziness involved in various systems and fuzzy set theory,
  2. understand the concepts of fuzzy sets, knowledge representation using fuzzy rules, approximate reasoning, fuzzy inference systems, and fuzzy logic,
  3. understand the fundamental theory and concepts of neural networks, Identify different neural network architectures, algorithms, applications and their limitations,

**Lab 5: Matrix Computation & Computational Statistics Lab Using R Programming (PLCMH301)**

**Course Objectives:**

1. Use of R Programming on regression analysis.
2. Use of R Programming on clustering.

**Syllabus:**

***Implementation of following methods using R Programming***

Simple and multiple linear regression, Logistic regression, Linear discriminant analysis, Ridge Regression, Cross validation and boot strap, Fitting Classification and Regression trees, K-nearest neighbours, Principal component analysis, K-means clustering.

**Reference (For R Programming)**

1. G. James, D. Witten, T. Hastie, R. Tibshirani-An introduction to statistical learning with applications in R, Springer,2013.

**Course Outcomes:** Upon successful completion of the course students will be able to

1. apply R Programming to solve statistical problems,
2. understand about statistical based computer programming,
3. apply different programming tools on various statistical problems,
4. code statistical functions.

**Lab 6: Optimization Lab (PLCMH302)**

**Course Objectives:**

1. Using MATLAB program to solve LPP by simplex method, transportation & assignment problems.
2. Modelling and simulation of optimization problems using MATLAB.
3. Using MATLAB to solve nonlinear programming problem.

**Syllabus:**

1. Introduction to linear programming problem, solving LPP by MATLAB (Introduction)
2. Solve various simplex problem using MATLAB Function
3. Solve Transportation and assignment problem using, Any suitable simulator
4. Compare. between Transportation, Assignment problem by Using MATLAB
5. Explore queuing theory for scheduling, resource allocation, and traffic flow applications using mat lab
6. Elementary concept of Modelling and Simulation using Mat-lab
7. Solve Various Decision Problem Using Matlab
8. Introduction to Nonlinear Programming by any suitable simulator
9. Iterative method for optimization problem by any suitable simulator
10. Application of nonlinear programming using Mat lab

**Course Outcomes:** After successful completion of the course, students will be able to:

1. solve various types of optimization problems using MATLAB,
2. understand the idea of simulation of optimization problems,
3. apply MATLAB program to solve various nonlinear programming problems.

**Semester-4**

**Core 14: Number Theory and Cryptography (PPCMH401)**

**Course Objectives:**

1. To learn about representation of finite fields.
2. To identify how number theory is related to and used in cryptography.
3. To classify the symmetric encryption techniques.
4. To illustrate various Public key cryptographic techniques

**Prerequisites:** Set of integers. Permutation & Combination. Programming language.

**Syllabus**

**Module-I**

Euclidean GCD Algorithm, Extended GCD Algorithm, Congruences and Modular Arithmetic: Modular Exponentiation, Fast Modular Exponentiation, Linear Congruences: Chinese Remainder Theorem, Polynomial Congruences: Hensel Lifting, Quadratic Congruences: Quadratic Residues and Non Residues, Legendre Symbol, Jacobi Symbol, Multiplicative Orders: Primitive Roots, Computing Orders, Prime Number Theorem and Riemann Hypothesis

Polynomial-Basis Representation, Fermat’s Little Theorem for Finite Fields, Multiplicative Orders of Elements in Finite Fields, Normal Elements, Minimal Polynomials,

Application to cryptography: The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, The Permutation Cipher, Stream Ciphers.

**Module-II**

Primality Testing: Fermat Test, Solovay-Strassen Test, Miller-Rabin Test, AKS Test, Integer Factorization: Trial Division, Pollard’s Rho Method, Floyd’s Variant, Block GCD Calculation, Brent’s Variant, Pollard’s p-1 Method: Large Prime Variation, Quadratic Sieve Method: Sieving, Incomplete Sieving, Large Prime Variation, Multiple- Polynomial Quadratic Sieve Method

The RSA Cryptosystem: Introduction to Public-key Cryptography, Implementing RSA Cryptosystem, Other Attacks on RSA: Computing , The Decryption Exponent, Wiener’s Low Decryption Exponent Attack, Cryptographic Hash Functions: Hash Functions and Data Integrity, Security of Hash Functions : The Random Oracle Model, Algorithms in the Random Oracle Model, Comparison of Security Criteria, Discrete Logarithms: The ElGamal Cryptosystem, Algorithms for the Discrete Logarithm Problem: Shank’s Algorithm , The Pollard Rho Discrete Logarithm Algorithm, Security of ElGamal Systems.

**Module-III**

Elliptic Curves: Elliptic Curves over the Reals, Elliptic Curves Modulo a Prime, Properties of Elliptic Curves, Point Compression and the ECIES, Computing Point Multiples on Elliptic Curves. Signature Schemes: Introduction, Security Requirements for Signature Schemes, Signatures and Hash Functions, The ElGamal Signature Schemes, Security of the ElGamal Signature Scheme, Variants of the ElGamal Signature Schemes: The Schnorr Signature Scheme, The Digital Signature Algorithm, The Elliptic Curve DSA, Elliptic Curve Primality Test.

**Text Books:**

* 1. Computational Number Theory-Abhijit Das, CRC Press (First Indian Reprint,2015) Chapter 1(1.2-1.7, 1.9), Chapter 2 (2.2.1,2.4.1,2.4.2, 2.4.3, 2.4.4), Chapter 5 (5.2.1,5.2.2, 5.2.3, 5.3.2), Chapter 6(6.1-6.6, 6.8).
  2. Cryptography Theory and Practice- Douglas R. Stinson, Chapman & Hall/ CRC (Third Edition) Chapter 1, Chapter 4 (4.1 ,4.2), Chapter 5(5.1,5.3,5.7), Chapter 6 (6.1,6.2,6.5,6.7), Chapter 7(7.1-7.4)

**Reference Books:**

1. Neal Koblitz: A Course in number theory and Cryptography, Springer Veriag, Chapter 6(section 3)

**Course Outcomes:** After successful completion of the course, students will be able to:

1. solve problems in elementary number theory,
2. develop a deeper conceptual understanding of the theoretical basis of number theory and cryptography.
3. apply elementary number theory to cryptography,
4. work effectively as part of a group to solve challenging problems in Number Theory and Cryptography.

**Core 15: Theory of Computation (PPCMH402)**

**Course Objectives:**

1. Demonstrate knowledge of basic mathematical models of computation and describe how they relate to formal languages.
2. Understand that there are limitations on what computers can do and learn examples of unsolvable problems.
3. Learn that certain problems do not have efficient algorithms and identify such problems.

**Prerequisites:** Discrete Mathematics.

**Syllabus:**

**Module – I:**

Alphabet, languages and grammars. Production rules and derivation of languages. Chomsky hierarchy of languages. Regular grammars, regular expressions and finite automata (deterministic and nondeterministic). Closure and decision properties of regular sets. Pumping lemma of regular sets. Minimization of finite automata. Left and right linear grammars.

**Module – II:**

Context free grammars and pushdown automata. Chomsky and Griebach normal forms. Parse trees, Cook, Younger, Kasami, and Early's parsing algorithms.

Ambiguity and properties of context free languages. Pumping lemma, Ogden's lemma, Parikh's theorem. Deterministic pushdown automata, closure properties of deterministic context free languages.

**Module – III:**

Turing machines and variation of Turing machine model, Turing computability, Type 0 languages. Linear bounded automata and context sensitive languages. Primitive recursive functions. Cantor and Godel numbering. Ackermann's function, mu- recursive functions, recursiveness of Ackermann and Turing computable functions.

Church Turing hypothesis. Recursive and recursively enumerable sets. Universal

Turing machine and undecidable problems. Undecidability of Post correspondence problem. Valid and invalid computations of Turing machines and some undecidable properties of context free language problems. Time complexity class P, class NP, NP completeness.

**Text Books:**

1. Introduction to Automata Theory, Languages and Computation: J.E. Hopcroft and J.D Ullman, Pearson Education, 3rd Edition.
2. Introduction to the theory of computation: Michael Sipser, Cengage Learning

**Reference Books:**

1. Introduction to Languages and the Theory of Computation: Martin, Tata McGraw Hill, 3rd Edition
2. Introduction to Formal Languages, Automata Theory and Computation: K. Kirthivasan, Rama R, Pearson Education.
3. Theory of computer Science (Automata Language & computations) K.L. Mishra N. Chandrashekhar, PHI.
4. Elements of Theory of Computation: Lewis, PHI
5. Theory of Automata and Formal Languages: Anand Sharma, Laxmi Publication
6. Automata Theory: Nasir and Srimani, Cambridge University Press.
7. Introduction to Computer Theory: Daniel I.A. Cohen, Willey India, 2nd Edition.
8. Theory of computation by Saradhi Varma, Scitech Publication

**Course Outcomes:** After successful completion of the course, students will be able to:

1. analyze and design finite automata, pushdown automata, Turing machines, formal languages, and grammars,
2. demonstrate the understanding of key notions, such as algorithm, computability, decidability, and complexity through problem solving,
3. prove the basic results of the Theory of Computation,
4. model, compare and analyze different computational models, state and explain the relevance of the Church-Turing hypothesis

**PE 3: Computational Finance (PPEMH401)**

**Course Objectives:**

1. To demonstrate knowledge and understanding of the concepts underlying computational finance, the mathematical tools and their computational implementations,
2. To demonstrate knowledge underlying the subject, theoretical foundation of Block chain technologies.
3. To provide an experience of formulating finance problems into computational problems and bring a level of confidence to students to the finance field.
4. To introduce numerical techniques for valuation, pricing and hedging of financial investment instruments such as options.

**Prerequisites:** Probability. Partial Differential Equation.

**Syllabus:**

**Module-I**

Stochastic process: Markov process, Wiener process, Geometric Brownian Motion, Ito Integral, Ito’s Lemma.

Basic concepts of financial- Stock options, Forward and Futures, Speculation, Hedging, put-call parity, Principle of non-arbitrage pricing, Computation of volatility.

**Module-II**

Derivation of blacks-scholes differential equation and Black-scholes Option Pricing formula, Greeks and Hedging strategies.

**Module-III**

Finite difference methods for partial differential equations-finite difference approximation to derivatives, Explicit and implicit and methods for parabolic equations, Iterative methods for solution of a system of linear algebraic equations, two dimensional Parabolic equations- alternating – direct implicit method, Convergence, Stability and Consistency of finite difference schemes.

**Text Book:**

1. J. Bax and G. Chacko-Financial Derivatives: Pricing, Application and Mathematics-Cambridge Univ. Press, 2004.
2. G. D. Smith: Numerical Solution of Partial Differential Equations, Oxford University Press.

**References Book:**

1. P. Wilmott: Qualitative Finance-John Wiley, 2000.
2. P. Copinsui and T. Zastawrian: Mathematics for Finance-an Introduction to Financial Engineering, Springer Verlag.
3. J. C. Hull: Options, Futures and others Derivatives-PHI, 2003

**Course Outcomes:** After successful completion of the course, students will be able to:

1. Understand the underlying concepts computational finance,
2. translate mathematical problems (well defined systems of mathematical equations) into computational tasks,
3. process numerical results into a comprehensible form (including the use of standard graphical plotting packages), for presentation in a report,
4. to be able to give a critical assessment of the integrity of numerical methods and results,
5. recall the advantages and limitations of different methods, assess / evaluate the performance of several financial models

**PE 3: Fuzzy and Rough Set Theory (PPEMH402)**

**Course Objectives:**

1. Apply soft computing techniques to solve engineering problems.
2. Handle multi-objective optimization problems.
3. Apply advanced AI techniques of swarm intelligence, particle swarm optimization, ant-colony optimization and petrinets.
4. Apply rough set theory and granular computing to solve process control applications.

**Prerequisites:** Set theory.

**Syllabus:**

**Module-I:**

Crisp sets and Fuzzy sets**:** Introduction – crisp sets an overview – the notion of fuzzy sets –basic concepts of fuzzy sets – membership functions – methods of generating membership functions – defuzzification methods- operations on fuzzy sets - fuzzy complement – fuzzy union – fuzzy intersection – combinations of operations – General aggregation operations. Fuzzy arithmetic and Fuzzy relations: Fuzzy numbers- arithmetic operations on intervals- arithmetic operations on fuzzy numbers- fuzzy equations- crisp and fuzzy relations – binary relations – binary relations on a single set – equivalence and similarity relations – compatibility or tolerance relations.

**Module-II:**

Fuzzy measures – belief and plausibility measures – probability measures – possibility and necessity measures – possibility distribution - relationship among classes of fuzzy measures.

Fuzzy Logic and Applications: Classical logic: an overview – fuzzy logic – approximate reasoning - other forms of implication operations - other forms of the composition operations – fuzzy decision making –fuzzy logic in database and information systems - fuzzy pattern recognition – fuzzy control systems.

**Module-III:**

Basic concept of rough sets: Approximation space and set approximation, rough membership function

Rough set in data analysis: Information system, Indiscernibility relation, Set approximation, rough sets and membership function, Dependency of attributes, Reduction of attributes, Reducts and core, Discernibility matrices and functions, Decision rule synthesis.

**Text Book**:

1. George J Klir and Tina A. Folger, Fuzzy sets, Uncertainty and Information, Prentice Hall of India, 1988.
2. An introduction to rough set theory and application: A tutorial, by Z. Suraj
3. Rough sets: Mathematical Foundation by L. Polkowski, Spinger-Verlag, Berlin
4. H.J. Zimmerman, Fuzzy Set theory and its Applications, 4th Edition, Kluwer Academic Publishers, 2001.

**Reference Book:**

1. Goerge J Klir and Bo Yuan, Fuzzy sets and Fuzzy logic: Theory and Applications. Prentice Hall of India, 1997.
2. Hung T Nguyen and Elbert A. Walker, First Course in Fuzzy Logic, 2nd Edition, Chapman & Hall/CRC, 1999.
3. Jerry M Mendel, Uncertain Rule – Based Fuzzy Logic Systems; Introduction and New Directions, PH PTR, 2000.
4. John Yen and Reza Langari, Fuzzy Logic: Intelligence Control and Information, Pearson Education, 1999.
5. Timothy J Ross, Fuzzy Logic with Engineering Applications, McGraw Hill International Editions, 1997.

**Course Outcomes:** After successful completion of the course, students will be able to:

1. decide the difference between crips set and fuzzy set theory
2. make calculation on fuzy set theory and gain the methods of fuzzy logic
3. recognize fuzzy logic membership function
4. recognize fuzzy logic fuzzy inference systems make applications on Fuzzy logic membership function and fuzzy inference systems

**PE 3: Graph Algorithms (PPEMH403)**

**Course Objective:**

1. The course aims at presenting a rigorous introduction to graph algorithms.
2. The course also emphasizes the role of graph theory in modeling applications in computer science solving these applications using graph algorithms.

**Prerequisites:** Permutation & Combination.

**Syllabus:**

**Module-I:**

Introduction to Graphs: Definition and basic concepts, Efficient representations of Graphs; Graph Searching: DFS and BFS; Application of Graph Searching: finding connected components, bi-connected components, testing for bipartite graphs, finding cycle in graph; Trees: Different MST algorithms, enumeration of all spanning trees of a graph;

**Module-II**

Paths and Distance in Graphs: Single source shortest path problem, all pairs shortest path problem, center and median of a graph, activity digraph and critical path; Hamiltonian Graphs: sufficient conditions for Hamiltonian graphs, traveling Salesman problem; Eulerian Graphs: characterization of Eulerian graphs, construction of Eulerian tour, The Chinese Postman problem;

**Module-III**

Planar Graphs: properties of planar graphs, a planarity testing algorithm; Graph Coloring: vertex coloring, edge coloring, planar graph coloring; Matching: maximum matching in bipartite graphs, maximum matching in general graphs, Perfect Matching; Networks: The Max-flow min-cut theorem, max-flow algorithm, NP-Complete Graph problems; Approximation algorithms for some NP-Hard graph problems; Algorithms for some NP-Hard graph problems on special graph classes;

**Text Books:**

1. G. Chatrand and O.R. Oellermann, Applied and algorithmic Graph Theory, McGraw – Hill, Inc. 1993.
2. M C Golumbic, Algorithmic Graph Theory and Perfect Graphs, North Holland, 2004.
3. T. Kloks, Advanced Graph Algorithms, 2012 , <http://books.google.com>

**Reference Books:**

* 1. R. Diestel, Graph Theory, <http://diestel-graph-theory.com/basic.html>

**Course Outcomes:** After successful completion of the course, students will be able to:

1. apply the algorithms in the areas of computer science, biology, chemistry, physics, sociology and engineering,
2. write precise and accurate mathematical definitions of objects in graph theory,
3. Use a combination of theoretical knowledge and independent mathematical thinking in creative investigation of questions in graph theory.

**PE 3: Finite Element Method (PPEMH404)**

**Course Objectives:**

1. To learn basic principles of finite element analysis procedure.
2. To learn the theory and characteristics of finite elements.
3. Learn to model complex geometry problems and solution techniques.
4. To develop proficiency in the application of the finite element method (modelling, analysis, and interpretation of results) to realistic engineering problems using a major commercial general-purpose finite element code.

**Prerequisites:** Real Analysis, Differential Equation. Linear Algebra.

**Syllabus:**

**Module – I:**

***Direct Approach for Discrete Systems:*** Describing the behavior of a single bar element, Equations for a system, Applications to other linear systems, two-dimensional truss systems, transformation law, three-dimensional truss systems.

***Strong and Weak Form in One-dimensional problems:*** The strong form in one-dimensional problems, the weak form in one-dimension, continuity, the equivalence between the weak and strong forms, one-dimensional stress analysis with arbitrary boundary conditions, one-dimensional heat conduction with arbitrary boundary conditions, two-point boundary value problems with generalized boundary conditions, advection-diffusion, minimum potential energy.

**Module – II:**

***Approximation of Trial Solutions, Weight Functions and Gauss Quadrature for One-dimensional problems:*** two-node linear element, quadratic one-dimensional element, direct construction of shape functions in one dimension, approximation of the weight functions, global approximation and continuity, Gauss quadrature.

***Finite Element Formulation for one-dimensional problems:*** development of discrete equation (simple case), element matrices for two-node element, application to heat conduction and diffusion problems, development of discrete equations for arbitrary boundary conditions, two-point boundary value problem with generalized boundary conditions, convergence of the FEM, FEM for advection-diffusion equation.

***Strong and Weak Forms for Multidimensional Scalar Field Problems:*** divergence theorem and Green’s formula, strong form, weak form, the equivalence between weak and strong forms, generalization to three-dimensional problems, Strong and weak forms of scalar steady-state advection-diffusion in two-dimensions.

**Module – III:**

***Approximations of Trial solutions, Weight Functions and Gauss quadrature for Multidimensional problems:*** completeness and continuity, three-node triangular element, four-node rectangular elements, four-node quadrilateral element, higher order quadrilateral elements, triangular coordinates, completeness of isoperimetric elements, Gauss quadrature in two-dimensions, three dimensional elements.

***Finite Element Formulation for Multidimensional Scalar Field Problems:*** finite element formulation for two-dimensional heat conduction problems, verification and validation, advection-diffusion equation.

**Text Book:**

1. A First Course in Finite Elements by J. Fish and T. Belytschko, *John Wiley & Sons,* Chapters 2, 3, 4, 5, 6, 7, 8

**Course Outcomes:** After successful completion of this course students will be able to

1. understand the concepts behind variational methods and weighted residual methods in FEM,
2. develop element characteristic equation procedure and generation of global stiffness equation will be applied,
3. apply suitable boundary conditions to a global structural equation, and reduce it to a solvable form,
4. able to identify how the finite element method expands beyond the structural domain, for problems involving dynamics, heat transfer, and fluid flow.

**Seminar: Seminar (PSEMH401)**

[Will be decided by the Department]

**Major Project: Project (PPRMH401)**

[Will be decided by the Department]