# Programme

# Master of Technology

# in

# Mathematics and Computing

# (M. Tech., Mathematics and Computing)

**Department of Applied Sciences (Division of Mathematics)**

राष्ट्रीय प्रौद्योगिकी संस्थान दिल्ली

**NATIONAL INSTITUTE OF TECHNOLOGY DELHI**

# Vision

To emerge as a center of excellence and eminence by imparting futuristic technical education with solid mathematical background in keeping with global standards, making our students technologically and mathematically competent and ethically strong so that they can readily contribute to the rapid advancement of society and mankind.

# Mission

- To achieve academic excellence through innovative teaching and learning practices.
- To improve the research competence to address social needs.
- To inculcate a culture that supports and reinforces ethical, professional behaviors for a harmonious and prosperous society.
- Strive to make students to understand, appreciate and gain mathematical skills and develop logic, so that they are able to contribute intelligently in decision making which characterizes our scientific and technological age.

# Program Objective

- M.Tech. (Mathematics & Computing) or Master of Technology in Mathematics & Computing is a two-year postgraduate program based on Mathematics and Computer Sciences. The course is designed to provide students with an in-depth theoretical background and practical training in computer science, numerical computing, and mathematical finance.

| | |
|---|---|
| **PO1** | To prepare graduates with a solid foundation in Engineering, Mathematical Science, and technology for a successful career in Mathematics & Computing/ Finance/Computer Engineering fields. |
| **PO2** | To prepare graduates to become effective collaborators/ innovators, who could ably address tomorrow's social, technical, and engineering challenges. |
| **PO3** | To enrich graduates with integrity and ethical values so that they become responsible engineers. |
| **PO4** | To apply mathematics, numerical computation, and applications of systems-oriented ideas to the physical, biological, social, and behavioural sciences, |
| **PO5** | To develop computational approaches for new algorithms, their analysis, and numerical results. |

**M.Tech. (Mathematics & Computing) Eligibility**

- Candidates should have passed a B.E./ B.Tech. or M.Sc. (Mathematics/Applied Mathematics/Computer Sciences) or equivalent degree from a recognized University.
- Must possess at least 60% aggregate marks or equivalent at the Graduation level
- Candidate must have qualified valid GATE score
- Admission through CCMT

**M.Tech. (Mathematics & Computing) Course Suitability**

- The course is suitable for acquiring knowledge and understanding of financial mathematics and computational techniques for finance.
- They should be able to formulate problems from finance in mathematical terms, select and develop an appropriate numerical method, write a computer program to numerically approximate the problem, and present and interpret these results for a potential client.

**How is M.Tech. (Mathematics & Computing) Course Beneficial?**

- The course is beneficial for those who want a bit of exposure to everything-maths, computer science, programming, etc.
- It will give you many varied options afterward. It provides a broad range of employment opportunities in mathematics, computing, operations research, and secondary teaching.

**Semester-wise structure**

| SN | Courses | Credits | | | | Total |
|---|---|---|---|---|---|---|
| | | 1st sem | 2nd sem | 3rd sem | 4th sem | |
| | **Program Core** | **14** | **14** | **-** | **-** | **28** |
| | **Program Electives** | **6** | **6** | **-** | **-** | **12** |
| | **Seminars/Independent Study** | **--** | **--** | **4** | **4** | **8** |
| | **Project work (Thesis)** | **--** | **--** | **16** | **16** | **32** |
| | **total** | **20** | **20** | **20** | **20** | **80** |

**M. Tech. (Mathematics & Computing) Scheme**

Scheme of **M. Tech.** (Mathematics & Computing) are prescribed as

| **Semester-I** | | | **Credits hours** | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Course Name** | **Course code** | **L** | **T** | **P** | **Credit** |
| 1 | Discrete Mathematical Structures | MACM501 | 3 | 1 | 0 | 4 |
| 2 | Numerical Methods and Computation | MACM502 | 3 | 1 | 0 | 4 |
| 3 | Probability and Statistics | MACM503 | 3 | 1 | 0 | 4 |
| 4 | Elective- I (bouquet I) | MACM5XX | 3 | 0 | 0 | 3 |
| 5. | Elective-II (bouquet II) | MACM5XX | 3 | 0 | 0 | 3 |
| 6 | Programming Languages Laboratory | MACM504 | 0 | 0 | 4 | 2 |
| **Total Credit hours (Semester-I)** | | | **15** | **3** | **4** | **20** |
| **Semester-II** | | | | | | |
| 1 | Data Structures and Algorithms | MACM551 | 3 | 0 | 2 | 4 |
| 2 | Computational Methods for Differential Equations | MACM552 | 3 | 1 | 0 | 4 |
| 3 | Numerical Optimization | MACM553 | 3 | 1 | 0 | 4 |
| 4 | Elective-III (Bouquet I) | MACM5XX | 3 | 0 | 0 | 3 |
| 5 | Elective-IV (Bouquet II) | MACM5XX | 3 | 0 | 0 | 3 |
| 6 | Computational Simulation Lab | MACM554 | 0 | 0 | 4 | 2 |
| **Total Credit hours (Semester-II)** | | | **15** | **2** | **6** | **20** |

| Semester-III | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Seminar- I | MACM598 | 0 | 0 | 2 | 1 |
| 2 | Independent Study/MOOC course | MACM5XX | 3 | 0 | 0 | 3 |
| 3 | Dissertation-Part 1 | MACM599 | 0 | 0 | -- | 16 |
| **Total** | | | **0** | **0** | **40** | **20** |
| **Semester-IV** | | | | | | |
| 1 | Seminar-II | MACM698 | 0 | 0 | 2 | 1 |
| 2 | Independent Study/MOOC course | MACM5XX | 3 | 0 | 0 | 3 |
| 3 | Dissertation-Part II | MACM699 | 0 | 0 | -- | 16 |
| **Total** | | | | | **40** | **20** |

**List of Electives (Bouquet-I: Computer Science Courses)**

| SN | Course Code | Course Name | L-T-P |
|---|---|---|---|
| 1 | MACM531 | Introduction to Cyber Security | 3-0-0 |
| 2 | MACM532 | Introduction to Machine Learning | 3-0-0 |
| 3 | MACM533 | Graph Theory and Combinatorics | 3-0-0 |
| 4 | MACM534 | Randomized Algorithms | 3-0-0 |
| 5 | MACM535 | Parallel Algorithms | 3-0-0 |
| 6 | MACM536 | Computer Networks | 3-0-0 |
| 7 | MACM537 | Pattern Recognition and Rule-Based Computing | 3-0-0 |
| 8 | MACM538 | Big Data Analysis | 3-0-0 |
| 9 | MACM539 | Data Mining | 3-0-0 |

**List of Electives (Bouquet-II: Mathematics Courses)**

| SN | Course Code | Course Name | L-T-P |
|---|---|---|---|
| 1 | MACM521 | Mathematical Modeling and Simulation | 3-0-0 |
| 2 | MACM522 | Computational Method for Partial Differential Equations | 3-0-0 |
| 3 | MACM523 | Applied Regression Analysis | 3-0-0 |
| 4 | MACM524 | Financial Mathematics | 3-0-0 |
| 5 | MACM525 | Stochastic of Finance | 3-0-0 |
| 6 | MACM526 | Boundary Elements Methods with Computer Implementation | 3-0-0 |
| 7 | MACM527 | Boundary Value Problems | 3-0-0 |

| | | | |
|---|---|---|---|
| 8 | MACM528 | Finite Element Method and Applications | 3-0-0 |
| 9 | MACM529 | Computational Linear Algebra | 3-0-0 |
| 10 | MACM5XX | Introduction to Dynamical Systems | 3-0-0 |
| 11 | MACM5XX | Data Analysis & Visualization | 3-0-0 |
| 12 | MACM5XX | Statistical Inference | 3-0-0 |
| 13 | MACM5XX | Introduction to Stochastic Processes | 3-0-0 |

**List of MOOCS Courses:**

| S.No. | Course Code | Course Name | L-T-P-C |
|---|---|---|---|
| 1 | MACM571 | An Introduction to Climate Dynamics | 3-0-0-3 |
| 2 | MACM572 | Computational Fluid Dynamics and Heat Transfer | 3-0-0-3 |
| 3 | MACM573 | Computational Fluid Dynamics using Finite Volume Method | 3-0-0-3 |
| 4 | MACM574 | Data Science | 3-0-0-3 |
| 5 | MACM575 | Deep Learning | 3-0-0-3 |
| 6 | MACM576 | Finite Element Methods | 3-0-0-3 |
| 7 | MACM577 | Introduction To Machine Learning | 3-0-0-3 |
| 8 | MACM578 | Matrix Computation and its Applications | 3-0-0-3 |
| 9 | MACM579 | Modelling and Simulation | 3-0-0-3 |
| 10 | MACM580 | Nanotechnology | 3-0-0-3 |
| 11 | MACM581 | Numerical Methods | 3-0-0-3 |
| 12 | MACM582 | Ordinary Differential Equations | 3-0-0-3 |
| 13 | MACM583 | Partial Differential Equations | 3-0-0-3 |
| 14 | MACM584 | Programming in C | 3-0-0-3 |
| 15 | MACM585 | Programming in MATLAB | 3-0-0-3 |

**M.Tech.(Mathematics & Computing) Employment Areas**

Fields such as **finance, software, IT sector, telecom, pharmaceutical, consulting engineering, and even in public sectors**.

- Asset Allocation Companies
- Colleges / Universities
- Financial Risk Management Firms
- Hedging Firms
- Investment Management Companies
- Modeling and Forecasting Financial Markets

M.**Tech (Mathematics & Computing) Job Types**

- Actuary
- Banker
- Business Data Analyst
- Commodities or Futures Trader
- Computational Engineer
- Consultant
- Data Analyst
- Economic Researcher
- Financial Analyst
- Internet Commerce Worker
- Meteorologist
- Statistician
- Telecommunications Analyst
- Information and Communications Technologist
- Computer Scientist
- Computer Programmer
- Database Coordinator
- Systems Analyst

# Core Course Contents

1. **Course Title:** Discrete Mathematical Structures
   **Course Code:** MACM501
   **L-T-P: 3-1-0**
   **Credits: 4**

   **Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of discrete mathematical structures. |
| **CO-2** | Solving problems on discrete structures. |
| **CO-3** | Analyzing the discrete mathematical structures. |
| **CO-4** | Creating discrete mathematical structures. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | 1 | 3 | 2 |
| **CO-2** | 3 | 2 | 1 | 3 | 3 |
| **CO-3** | 2 | 2 | 1 | 3 | 3 |
| **CO-4** | 2 | 3 | 1 | 2 | 3 |
| **Average** | **2.50** | **2.00** | **1.00** | **2.75** | **2.75** |

1 - Slightly  2 - Moderately  3 - Substantially

**Syllabus:**

**Module I:**
Relations, recursion, recurrence relations, linear homogeneous recurrence relations, solution of recurrence relations.

**Module II:**
Partially ordered sets, different types of lattices, Boolean algebra, Boolean expressions, logic, networks, Karnaugh maps, and application of Boolean algebra to switching theory.

**Module III:**
Directed graphs, undirected graphs, matrices, relations and graphs, paths and circuits, Eulerian and Hamiltonian graphs.

**Module IV:**
Planar, connected graphs. Trees, properties of trees, rooted trees, spanning trees,

minimum spanning trees, binary tree, tree traversals.

**Module V:**

Linear codes, error detection and correction, Hamming distance, and Hamming weights, maximum-likelihood decoding, syndrome decoding, perfect code, the sphere Packing bound, cyclic codes.

**Reference Books:**


1. K A Ross and G R Wright, "Discrete Mathematics", Prentice Hall of India, 2003.
2. C L Liu," Elements of Discrete Mathematics", McGraw-Hill Publishing Co., 1985.
3. Narsingh Deo, "Graph theory with applications to Engineering & Computer Science", Prentice Hall of India, 1994.

2. **Course Title: Numerical Methods and Computations**
**Course Code:** MACM502
**L-T-P: 3-1-0**
**Credits: 4**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of numerical methods. |
| **CO-2** | Solving problems by numerical methods and computation. |
| **CO-3** | Deriving the numerical techniques. |
| **CO-4** | Implementation of numerical techniques. |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | 1 | 3 | 2 |
| **CO-2** | 3 | 2 | 1 | 3 | 3 |
| **CO-3** | 3 | 2 | 1 | 2 | 3 |
| **CO-4** | 2 | 3 | 1 | 2 | 3 |
| **Average** | **2.75** | **2.00** | **1.00** | **2.50** | **2.75** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Numerical Algorithms and errors, Floating point systems, Roundoff error accumulations. Interpolation: Lagrange Interpolation, Newton's divided difference interpolation. Finite differences. Hermite Interpolation. Cubic splines.

**Module II:**
Numerical differentiation. Numerical Integration: Newton cotes formulas, Gaussian Quadrature composite quadrature formulas.

**Module III:**
Approximation: Least squares approximation, minimum maximum error techniques. Legendre and Chebyshev polynomials.

**Module IV:**

Solution of Nonlinear equations: Fixed point iteration, bisection, Secant, Regula-Falsi, Newton-Raphson methods. Solution of linear systems: Direct methods, Gauss elimination, LU and Cholesky factorizations. Iterative methods – Jacobi, Gauss-Seidel and SOR methods. System of nonlinear equations.

**Module V:**

Eigen-Value problems: Power and Inverse power method. Numerical Solution of ODE. Taylor series, Euler and Runge-Kutta methods.

**References Books:**


a. Gerald & Wheatley, Applied Numerical Analysis, Pearson, 2004.
b. M. K. Jain, S.R.K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computations, New Age Int., New Delhi, 2010.
c. D. Kincaid and W Cheney, Numerical Analysis: Mathematics of Scientific Computing (3e), Thomson Brooks/ Cole, 2002.
d. S.D. Conte & Carl De Boor, Elementary Numerical Analysis, McGraw Hill, 2005.
e. Naseem Ahmad, Fundamentals of Numerical Analysis with Error Estimation, Anamaya Publishers, 2010.
f. J Stoer and R. Bullirsce, An introduction to Numerical Analysis (2e), Academic Press, 1996

3. **Course name: Probability and Statistics**
**Course Code:** MACM503
**L-T-P: 3-1-0**
**Credits: 4**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of probability and statistics. |
| **CO-2** | Solving problems using concepts of probability theory and statistics. |
| **CO-3** | Analyzing the concept of probability in real-life problems. |
| **CO-4** | Creating models based on probability and statistics. |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | - | 3 | 2 |
| **CO-2** | 3 | 1 | - | 3 | 3 |
| **CO-3** | 2 | 2 | - | 3 | 3 |
| **CO-4** | 2 | 3 | - | 3 | 3 |
| **Average** | **2.50** | **1.75** | **-** | **3** | **2.75** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Probability definition, conditional probability, Bayes theorem, random variables, expectation and variance, moment generating function.

**Module II:**
Specific discrete and continuous distributions, e.g., uniform, Binomial, Poisson, geometric, Pascal, hypergeometric, exponential, normal, gamma, beta.

**Module III:**
Poisson process, Chebyshev’s inequality, bivariate and multivariate distributions, joint, marginal, and conditional distributions.

**Module IV:**
Order statistics, law of large numbers, central limit theorem, sampling distributions –

Chi-sq, Student’s t-test, F-distribution.

**Module V:**

Theory of estimation, maximum likelihood test, testing of hypotheses, nonparametric analysis, test of goodness of fit.

**Reference Books:**


**a.** **S.**C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics (A Modern Approach), 10th Edition, Sultan Chand & Sons, 2002

b. Sheldon M. Ross, First Course in Probability, A, 9th Edition, Pearson, Boston, 2014.

c. V.K. Rohatgi and A.K. Md. Ehsanes Saleh, An Introduction to Probability and Statistics, John Wiley & Sons, 3rd Edition, 201

4. **Course name: Programming Languages Laboratory**
**Course Code:** MACM504
**L-T-P: 0-0-4**
**Credits: 2**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the basic programming language. |
| **CO-2** | Solving problems using programming languages. |
| **CO-3** | Developing programs based on high-level languages. |
| **CO-4** | Application of programming languages in real problems. |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | - | 2 | 2 |
| **CO-2** | 3 | 2 | - | 2 | 3 |
| **CO-3** | 3 | 2 | - | 2 | 3 |
| **CO-4** | 2 | 3 | 1 | 3 | 3 |
| **Average** | **2.75** | **2.00** | **0.25** | **2.25** | **2.75** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Introduction to Computers - CPU, ALU, I/O devices.

**Module II:**
Introduction to C Programming - Data types, Looping Statements, Arrays.

**Module III:**
Structure, Functions (Both simple and Recursive functions), Call by Value and Call by Reference, Pointers, File Handling in C.

**Module IV:**
Introduction to C++ Programming, Looping Statements, arrays and Structures in C++, Functions in C++.

**Module V:**
Basic Python programming.

**Reference Books:**


a. M. Morris Mano, Computer System Architecture, Prentice Hall of India, 1982.
b. William Stalling, Computer Organization and Architecture, Pearson Education, 2015.
c. P. K. Sinha & Sinha, Priti, Computer Fundamentals, BPB, 2007.
d. V. Rajaraman, Fundamentals of Computers, PHI, 2010.
e. S. Lipshutz, Data Structures, Schaum outline series, McGraw-Hill, 2011.
f. Cay Horstmann, Computing Concepts with Java Essentials, 2nd Edition, Wiley India, 2006.

5. **Course Title: Data Structures and Algorithms**
**Course Code:** MACM551
**L-T-P: 3-0-2**
**Credits: 4**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of data structures. |
| **CO-2** | Solving problems using data structures. |
| **CO-3** | Analyzing problems based on data structures. |
| **CO-4** | Creating algorithms based on data structures. |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | - | 2 | 3 |
| **CO-2** | 3 | 3 | - | 2 | 3 |
| **CO-3** | 3 | 3 | - | 2 | 3 |
| **CO-4** | 3 | 3 | - | 2 | 3 |
| **Average** | **3.00** | **2.50** | **0** | **2.00** | **3.00** |

1 - Slightly 2 - Moderately 3 – Substantially

**Syllabus:**

**Module I:**
Preliminaries: Growth of functions, recurrence relation, generating functions, solution of difference equations, Master's theorem (without proof).

**Module II:**
Sorting and Order Statistics: Bubblesort, mergesort, heapsort, quicksort, sorting in linear time, median and order statistics.

**Module III:**
Elementary Data Structures: Stacks, queues, linked lists, implementing pointers, rooted trees, direct-address tables, hash tables, open addressing, perfect hashing, binary search trees, red-black trees, dynamic programming, optimal binary search trees, greedy algorithms.

**Module IV:**

Graph Algorithms: Breadth-first search, depth-first search, topological sort, Minimum spanning trees, Krushkal's and Prim's algorithms, shortest path, Bellman-Ford algorithm, Dijkstra's algorithm.

**Module V:**

Floyd-Warshall algorithm, Johnson's algorithm, Maximum flow, Ford-Fulkerson method, maximum bipartite matching.

**List of Experiments:**

1. 1-Dimensional Arrays and its various operations like insertion, deletion, searching, sorting etc.
2. 2-Dimensional Arrays and its various operations like inserting or deleting a particular row or column.
3. Finding solutions of a given equation using Gauss Jordan Method.
4. Finding solutions of a given equation using Gauss Elimination Method.
5. Singly Linked List and its various operations like insertion, deletion and reversing.
6. Doubly Linked List and its various operations like insertion, deletion and reversing.
7. Circular Linked List and its various operations like insertion, deletion and reversing.
8. Doubly Circular Linked list and its various operations like insertion, deletion and reversing.
9. Implementation of Stacks and its various operations using arrays (Push, Pop and Peek).
10. Implementation of Stacks and its various operations using linked list (Push, Pop and Peek).
11. Implementation of Queues using Arrays and perform operations like enqueue, dequeue etc.
12. Implementation of Queues using Linked List and perform operations like enqueue, dequeue etc.
13. Implementation of Circular Queues using arrays and perform operations like enqueue, dequeue etc.
14. Implementation of Circular Queues using Linked List and perform operations like enqueue, dequeue etc.
15. Implementation of Binary Trees and perform operations for traversals and to find the height of the tree.
16. Implementation of Binary Search Trees and perform operations for traversals and to find the height of the tree.
17. Implementation of AVL Trees and perform operations of searching, insertion, deletion and to get the height of the tree.
18. Implementation of Various Sorting Algorithms on Arrays
    a) Bubble Sort
    b) Optimized Bubble Sort
    c) Insertion Sort
    d) Selection Sort
    e) Quick Sort
    f) Merge Sort

**Reference Books:**


i. Elmasri, Navathe, Fundamentals of Database Systems, Pearson Education, 2008.
ii. Henry F. Korth, Abraham Silberschatz, S. Sudarshan, Database System Concepts, McGraw-Hill, 2005.
iii. C. J. Date, An Introduction to Database Systems, Pearson, 2006.
iv. Ramakrishna, Gehrke, Database Management Systems, McGraw-Hill, 2014.
v. S.K. Singh, Database Systems Concepts, Design and Applications, Pearson, 2011. 6. Jeffrey D. Ullman, Jennifer Widom, A First Course in Database Systems, Pearson, 2014.

6. **Course name: Computational Methods for Differential Equations**
**Course Code:** MACM552
**L-T-P: 3-1-0**
**Credits: 4**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of differential equations. |
| **CO-2** | Solving problems on differential equations. |
| **CO-3** | Analyzing the computational methods for differential equations. |
| **CO-4** | Implementing computational methods on differential equations. |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | - | 3 | 2 |
| **CO-2** | 3 | 2 | - | 3 | 3 |
| **CO-3** | 3 | 3 | - | 3 | 3 |
| **CO-4** | 2 | 3 | - | 2 | 3 |
| **Average** | **2.75** | **2.25** | **0** | **2.75** | **2.75** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Numerical methods for solving IVPs for ODEs: Difference equations, Routh-Hurwitz criterion, Test Equation.

**Module II:**
Single step methods: Taylor series method, explicit Runge-Kutta methods, convergence, order, relative and absolute stability

**Module III:**
Multistep methods: Development of linear multistep method using interpolation and undetermined parameter approach, convergence, order, relative and absolute stability, Predictor-Corrector methods.

**Module IV:**
Solution of initial value problems of systems of ODES.

**Module V:**

BVP: Finite difference methods for second-order ODEs, Eigenvalue problems.

**Reference Books:**


i. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications, INC., 2012.
ii. Henrice, P., Discrete variable methods in ordinary differential equations, Wiley, New York, 1962.
iii. Atkinsen, K.E. Han, W. Stewark, D.E., numerical solution of ordinary differential equations, John Wiley and Sons, 2009.
iv. Boyce and Diprime, Elementary Differential Equations and Boundary Value Problems, Wiley, 2008.
v. H. F. Weinberger, A First Course in Partial Differential Equations: with Complex Variables and Transform Methods (Dover Books on Mathematics), Dover Publications, 1995.

7. **Course name: Numerical Optimization**
**Course Code:** MACM553
**L-T-P: 3-1-0**
**Credits: 4**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of optimization. |
| **CO-2** | Solving problems using numerical optimization. |
| **CO-3** | Analyzing the numerical techniques of optimization. |
| **CO-4** | Implementing the optimization techniques on real applications. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | - | 3 | 2 |
| **CO-2** | 3 | 2 | - | 3 | 3 |
| **CO-3** | 3 | 2 | - | 3 | 3 |
| **CO-4** | 3 | 3 | 2 | 3 | 3 |
| **Average** | **3** | **2.25** | **0.5** | **3** | **2.75** |

1 - Slightly 2 - Moderately 3 – Substantially

**Syllabus:**

**Module I:**
Introduction, Background, and Classification of Optimization Problems.

**Module II:**
Unconstrained optimization, Line Search methods, Trust region methods, Gradient descent, Exact and Quasi-Newton Methods.

**Module III:**
Non-linear least squares, Nonlinear equations.

**Module IV:**
Constrained optimization, Linear programming: Simplex method, Nonlinear constrained optimization, Farkas' lemma, Karushâ“Kuhnâ“Tucker(KKT) conditions, Quadratic programming.

**Module V:**

Penalty, Barrier, and Augmented Lagrangian methods, Sequential Quadratic Programming, Large-scale optimization: Algorithms and Software.

**Reference Books:**


a. P. E. Gill, W. Murray and M. H. Wright, Numerical Methods for Linear Algebra and Optimization: Volume 1, Addison-Wesley.
b. P. E. Gill and W. Murray, Numerical Methods for Constrained Optimization, Academic Press. 3. P. E. Gill, W. Murray, and M. H. Wright, Practical Optimization, Academic Press.

8. **Course name: Computational Simulation Lab**
**Course Code:** MACM554
**L-T-P: 0-0-4**
**Credits: 2**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Gain a comprehensive understanding of the working, operation, and testing of different types of transformers. |
| **CO-2** | Explain and apply the concepts of electromechanical energy conversion. |
| **CO-3** | Gain a comprehensive understanding of the working, operation, testing, and control of DC Motors and DC Generators |
| **CO-4** | Comprehend the practical knowledge of transformers and DC machines |

**Course Articulation Matrix:**

| **CO/PO** | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | - | 3 | 3 |
| **CO-2** | 3 | 2 | - | 3 | 3 |
| **CO-3** | 3 | 3 | 2 | 3 | 3 |
| **CO-4** | 3 | 3 | 3 | 3 | 3 |
| **Average** | **3** | **2.50** | **1.25** | **3** | **3** |

1 - Slightly 2 - Moderately 3 -Substantially

**Syllabus:**

**Module I:**
Numerical Optimization, Linear programming: Simplex method, Nonlinear constrained optimization, Quadratic programming.

**Module II:**
Large-scale optimization: Algorithms and Software.

**Module III:**
Errors - Rounding off error - Solution of Algebraic and Transcendental equations - Bisection method - Regula-Falsi Method - Newton-Rephson's Method - Muller's Method

**Module IV:**
Interpolation formulae using differences - Difference Schemes - Lagrange's interpolation formula.

**Module V:**
Taylor's series method for linear ODE, $2^{nd}$ and $4^{th}$ order Runge Kutta(RK) method, Multistep method.

**List of Experiments:**

**Reference Books:**


i. Gerald & Wheatley, Applied Numerical Analysis, Pearson, 2004.
ii. G.D. Smith, Numerical Solutions of Partial Differential Equations, Clarendon Press, Oxford, 1985.
iii. S.D. Conte & Carl De Boor, Elementary Numerical Analysis, McGraw Hill, 2005.
iv. Naseem Ahmad, Fundamentals Numerical Analysis with error estimation, Anamaya Publishers, 2010.

# Bouquet-I: Computer Science Courses

1. **Course name: Introduction to Cyber Security**
   **Course Code:** MACM531
   **L-T-P: 3-0-0**
   **Credits: 3**

   **Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand the fundamental concepts of cybersecurity |
| **CO2** | To analyze and apply cryptographic protocols, key distribution techniques, and security frameworks |
| **CO3** | To evaluate the security challenges and solutions in emerging technologies |
| **CO4** | To enable the students to handle cyber incidents through effective investigation, response, and recovery strategies |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 2 | 1 | 1 |
| CO-2 | 3 | 3 | 2 | 2 | 3 |
| CO-3 | 2 | 3 | 2 | 2 | 2 |
| CO-4 | 2 | 3 | 3 | 2 | 2 |
| Average | 2.50 | 2.75 | 2.25 | 1.75 | 2.00 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Introduction to Cybersecurity, Network Security, Key Distribution, Transport Layer Security, Internet Protocol Security

**Module II:**
Wireless security, Email security, Network monitoring, Intrusion detection system, Virtual private network, and firewall

**Module III:**
Systems Security, Malware, Program analysis, Penetration testing, Embedded system and hardware security, Mobile security, Secure storage management

**Module IV:**
Evolving Security Techniques, IoT security, Cyber-physical system security, Adversarial ML, Blockchains

**Module V:**
Cyber Forensics & Incident Management, Security Audit and Compliance

**Reference Books:**


i. Kevin Clark · Narrated by Jim D Johnston, Cybersecurity for Beginners: Learn the Fundamentals of Cybersecurity in an Easy, Step-by-Step Guide, 2022
ii. Ajay Singh, Introduction to Cyber Security Concepts, Principles, Technologies, and Practices, Universities Press (India) Pvt. Ltd.

2. **Course name: Introduction to Machine Learning**
   **Course Code:** MACM532
   **L-T-P: 3-0-0**
   **Credits: 3**

   **Course Outcomes:**

| | |
|---|---|
| **CO1** | To apply algorithmic models of learning to analyze and design classifiers and predictive systems for varied data types |
| **CO2** | To develop and apply machine learning algorithms for real-world applications |
| **CO3** | To analyze theoretical aspects of Machine learning using concepts from computational learning theory |
| **CO4** | To implement and evaluate modern unsupervised and deep learning techniques |

   **Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 3 |
| CO-2 | 3 | 3 | 1 | 2 | 2 |
| CO-3 | 3 | 2 | 1 | 2 | 3 |
| CO-4 | 3 | 3 | 1 | 2 | 1 |
| Average | 3 | 2.5 | 1 | 2 | 2.25 |

1 - Slightly    2 - Moderately    3 - Substantially

**Syllabus:**

**Module I:**
Algorithmic models of learning. Learning classifiers, functions, relations, grammars, probabilistic models, value functions, behaviors, and programs from experience. Bayesian, maximum a-posteriori, and minimum description length frameworks, Parameter estimation, sufficient statistics

**Module II:**
Decision trees, neural networks, support vector machines, Bayesian networks, bag of words classifiers, N-gram models, Markov and Hidden Markov models, Probabilistic relational models, Association rules

**Module III:**
Nearest neighbor classifiers, locally weighted regression, ensemble classifiers, Accuracy and confidence boosting, Occam learning

**Module IV:**
Computational learning theory, mistake bound analysis, sample complexity analysis, VC dimension, Dimensionality reduction, feature selection, and visualization

**Module V:**
Clustering, mixture models, k-means clustering, hierarchical clustering, distributional clustering, Introduction to Deep Learning, Deep Learning for Computer Vision, and NLP (natural language processing)

**Reference Books:**


i. Bishop, C., Pattern Recognition and Machine Learning, Berlin: Springer-Verlag, 2006.
ii. Tom Mitchell, Machine Learning, McGraw-Hill, 1997.
iii. Hastie, Tibshirani, Friedman, The Elements of Statistical Learning, Springer, 2001.
iv. Sergios Theodoridis, Konstantinos Koutroumbas, Pattern Recognition, Academic Press, 2009.

3. **Course name: Graph Theory and Combinatorics**
**Course Code:** MACM533
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand graph-theoretic structures and representations for modeling and analyzing complex systems in computing and engineering. |
| **CO2** | To analyze and implement advanced algorithms for connectivity, shortest paths, and spanning trees in large-scale and weighted networks |
| **CO3** | To apply advanced graph algorithms to solve problems related to connectivity, shortest paths, and spanning trees |
| **CO4** | To evaluate and implement graph optimization strategies |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 2 |
| CO-2 | 3 | 2 | 1 | 2 | 3 |
| CO-3 | 3 | 2 | 1 | 2 | 3 |
| CO-4 | 3 | 3 | 1 | 2 | 3 |
| Average | 3 | 2.25 | 1 | 2 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Definitions, pictorial representation of a graph, isomorphic graphs, subgraphs, matrix representations of graphs, degree of a vertex, special graphs, complements, larger graphs from smaller graphs

**Module II:**
Connected graphs and shortest paths, walks, trails, paths, cycles, cut-vertices and cut-edges, blocks, connectivity, weighted graphs and shortest paths, weighted graphs, Dijkstra's shortest path algorithm, Floyd-Warshall shortest path algorithm

**Module III:**
Trees: definitions and characterizations, number of trees, Cayley's formula, minimum spanning trees, Kruskal's algorithm, Prim's algorithm, bipartite graphs, Eulerian graphs, Fleury's algorithm, Chinese Postman problem

**Module IV:**
Hamilton Graphs, necessary conditions and sufficient conditions, independent sets, coverings and matchings, matchings in bipartite graphs, Hall's theorem, Konig's theorem, perfect matchings in graphs, vertex Colorings, basic definitions, cliques and chromatic number, greedy coloring algorithm. Edge colorings, Gupta-Vizing theorem, class-1 and class-2 graphs, edge-coloring of bipartite graphs

**Module V:**
Planar graphs, basic concepts, Euler's formula and its consequences, characterizations of planar graphs, 5-color theorem, directed graphs, directed walks, paths and cycles, Eulerian and Hamiltonian graphs, planarity (duality, Euler's formula, characterization, 4-color theorem); Advanced topics (perfect graphs, matroids, Ramsay theory, extremal graphs, random graphs); Applications.

**Reference Books:**


i. D. B. West, Introduction to Graph Theory, 2nd edition, Prentice Hall, 2000.
ii. R. Diestel, Graph Theory (Graduate Texts in Mathematics), 2nd edition, Springer-Verlag, 2000.
iii. J.A. Bondy and U.S.R. Murty, Graph Theory (Graduate Texts in Mathematics), Springer, 2011.
iv. R. P. Grimaldi, Discrete and Combinatorial Mathematics: An Applied Introduction, 5th edition, Pearson Education, Asia, 2003.
v. N. Alon and J. Spencer, The Probabilistic Method, 3rd edition, John Wiley and Sons, 2008.

4. **Course name: Randomized Algorithms**
   **Course Code:** MACM534
   **L-T-P: 3-0-0**
   **Credits: 3**

   **Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand and apply foundational principles of probability |
| **CO2** | To analyze and interpret discrete and continuous random variables, their distributions, and statistical properties |
| **CO3** | To apply and distinguish between various theoretical probability distributions and their use |
| **CO4** | To design and conduct statistical inference using sampling theory and hypothesis testing |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 2 |
| CO-2 | 3 | 2 | 1 | 3 | 2 |
| CO-3 | 3 | 2 | 1 | 3 | 2 |
| CO-4 | 3 | 3 | 1 | 3 | 2 |
| Average | 3 | 2.25 | 1 | 2.75 | 2 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
The concept of probability, The axioms of probability, Some important theorems on Probability, Conditional Probability, Theorems on conditional probability, Independent Events, Bayes ' Theorem.

**Module II:**
Random Variables Random variables, discrete probability distributions, Distribution functions for Discrete random variables, Continuous probability distribution, Distributions for Continuous random variables, joint distributions, Independent random variables.

**Module III:**
Mathematical Expectation Definition, Functions of random variables, some theorems on Expectation, the variance and Standard Deviation, Moments, Moment Generating Functions, Covariance, Correlation Coefficient.

**Module IV:**
Special Probability Distributions: The Binomial Distribution, The Normal Distribution, The Poisson Distribution, Uniform distribution, Chi-square Distribution, Exponential distribution, Relations between different distributions, Central limit theorem.

**Module V:**
Sampling Theory: Population and Sample, Sampling with and without replacement, the sample mean, Sampling distribution of means, proportions, differences, and sums, the sample variance, the sample distribution of variances, Tests of Hypotheses and Significance Statistical Decisions, Statistical hypotheses, Null Hypotheses, Tests of hypotheses and significance, Type I and Type II errors, level of significance, Tests involving the Normal distribution, One-Tailed and Two-Tailed tests, Special tests of significance for large and small samples.

**Reference Books:**


iii. Robert V Hogg, Joseph McKean, Allen T Craig, Introduction to Mathematical Statistics, Pearson Edition, 7th Edition

iv. Sheldon M Ross, Introduction to Probability and Statistics for Engineers and Scientists, Publisher Elsevier, 5th Edition

5. **Course name: Parallel Algorithms**
**Course Code:** MACM535
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand and compare various models of parallel computation and analyze their computational capabilities |
| **CO2** | To design and analyze parallel algorithms for fundamental problems |
| **CO3** | To implement efficient parallel algorithms for different types of problems |
| **CO4** | To evaluate the performance and scalability of parallel algorithms using different approaches |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 3 |
| CO-2 | 3 | 2 | 1 | 2 | 3 |
| CO-3 | 3 | 2 | 1 | 2 | 3 |
| CO-4 | 3 | 3 | 1 | 2 | 3 |
| Average | 3 | 2.75 | 1 | 2 | 3 |

1 - Slightly 2 - Moderately 3 – Substantially

**Syllabus:**

**Module I:**
Need for Parallel Processing - Data and Temporal Parallelism - Models of Computation - RAM and PRAM Model – Shared Memory and Message Passing Models- Processor Organisations - PRAM Algorithm – Analysis of PRAM Algorithms- Parallel Programming Languages.

**Module II:**
Parallel Algorithms for: Reduction, Prefix Sum, List Ranking, Preorder Tree Traversal, Searching, Sorting, Merging Two Sorted Lists, Matrix Multiplication, Graph Coloring, Graph Searching.

**Module III:**
2D Mesh SIMD Model, Parallel Algorithms for: Reduction, Prefix Computation, Selection, Odd-Even Merge Sorting, Matrix Multiplication

**Module IV:**
Hypercube SIMD Model - Parallel Algorithms for Selection- Odd-Even Merge Sort- Bitonic Sort- Matrix Multiplication Shuffle Exchange SIMD Model - Parallel Algorithms for Reduction-Bitonic Merge Sort - Matrix Multiplication - Minimum Cost Spanning Tree.

**Module V:**
UMA Multiprocessor Model -Parallel Summing on Multiprocessor- Matrix Multiplication on Multiprocessors and Multicomputer - Parallel Quick Sort - Mapping Data to Processors.

**Reference Books:**


i. Michael J. Quinn, "Parallel Computing: Theory & Practice", Tata McGraw-Hill Edition, Second edition, 2017.
ii. Ellis Horowitz, Sartaj Sahni and Sanguthevar Rajasekaran, "Fundamentals of Computer Algorithms", University Press, Second edition, 2011.
iii. V Rajaraman, C Siva Ram Murthy, "Parallel computers- Architecture and Programming ", PHI learning, 2016.
iv. Ananth Grame, George Karpis, Vipin Kumar, and Anshul Gupta, "Introduction to Parallel Computing", 2nd Edition, Addison Wesley, 2003.
v. M Sasikumar, Dinesh Shikhare, and P Ravi Prakash, " Introduction to Parallel Processing", PHI learning, 2013.
vi. S.G.Akl, "The Design and Analysis of Parallel Algorithms", PHI, 1989.

6. **Course name: Computer Networks**
   **Course Code:** MACM536
   **L-T-P: 3-0-0**
   **Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand the fundamental concepts of computer networks |
| **CO2** | To analyze data transmission techniques at the physical and data link layers |
| **CO3** | To design and evaluate addressing schemes and routing strategies for reliable internetworking |
| **CO4** | To implement and assess transport and application layer protocols |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 2 |
| CO-2 | 3 | 2 | 1 | 2 | 3 |
| CO-3 | 3 | 3 | 1 | 2 | 3 |
| CO-4 | 3 | 2 | 1 | 2 | 3 |
| Average | 3 | 2.25 | 1 | 2 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Introduction: history and development of computer networks, Basic Network Architectures: OSI reference model, TCP/IP reference model, and Network topologies, types of networks (LAN, MAN, WAN, circuit switched, packet switched, message switched, extranet, intranet, Internet, wired, wireless)

**Module II:**
Physical layer: line encoding, block encoding, scrambling, modulation, demodulation (both analog and digital), errors in transmission, multiplexing (FDM, TDM, WDM, OFDM, DSSS), Different types of transmission media. Data Link Layer services: framing, error control, flow control, medium access control. Error & Flow control mechanisms: stop and wait, Go back N, and selective repeat, MAC protocols: Aloha, slotted aloha, CSMA, CSMA/CD, CSMA/CA, polling, token passing, scheduling.

**Module III:**
Local Area Network Technology: Token Ring. Error detection (Parity, CRC), Ethernet, Fast Ethernet, Gigabit Ethernet, Personal Area Network: Bluetooth and Wireless Communications Standard: Wi-Fi (802.11) and WiMAX

**Module IV:**
Network layer: Internet Protocol, IPv6, ARP, DHCP, ICMP, Routing algorithms: Distance vector, Link state, Metrics, Inter-domain routing. Sub-netting, Super-netting, Classless addressing, Network Address Translation

**Module V:**
Transport layer: UDP, TCP. Connection establishment and termination, sliding window, flow and congestion control, timers, retransmission, TCP extensions, Queuing theory, Single and multiple server queuing models, Little’s formula. Application Layer. Network Application services and protocols include e-mail, www, DNS, SMTP, IMAP, FTP, TFTP, Telnet, BOOTP, HTTP, IPSec, and Firewalls.

**Reference Books:**


i. Computer Networks, AS Tanenbaum, DJ Wetherall, Prentice-Hall, 5th Edition, 2010
ii. Computer Networks: A Systems Approach, LL Peterson, BS Davie, Morgan-Kauffman, 5th Edition, 2011
iii. Computer Networking: A Top-Down Approach 81, JF Kurose, KW Ross, Addison-Wesley, 5th Edition, 2009

7. **Course Name: Pattern Recognition and Rule-Based Computing**
**Course Code:** MACM537
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand the theoretical foundations of pattern recognition |
| **CO2** | To analyze and apply statistical and linear discriminant techniques |
| **CO3** | To implement and compare learning algorithms for pattern recognition |
| **CO4** | To design and evaluate advanced recognition systems using various techniques |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 2 |
| CO-2 | 3 | 2 | 1 | 2 | 3 |
| CO-3 | 3 | 2 | 1 | 2 | 3 |
| CO-4 | 3 | 3 | 1 | 2 | 3 |
| Average | 3 | 2.25 | 1 | 2 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Introduction to Pattern Recognition, Feature Detection, Classification, Review of Probability Theory, Conditional Probability and Bayes Rule, Random Vectors, Expectation, Correlation, Covariance, Review of Linear Algebra, Linear Transformations

**Module II:**
Decision Theory, ROC Curves, Likelihood Ratio Test, Linear and Quadratic Discriminants, Fisher Discriminant, Sufficient Statistics, Coping with Missing or Noisy Features

**Module III:**
Template-based Recognition, Feature Extraction, Eigenvector, and Multilinear Analysis

**Module IV:**
Training Methods, Maximum Likelihood and Bayesian Parameter Estimation, Linear Discriminant/Perceptron Learning, Optimization by Gradient Descent, Support Vector Machines, Bayesian Networks

**Module V:**
Decision Trees, Multi-layer Perceptron, Reinforcement Learning with Human Interaction, Genetic Algorithms, Combination of Multiple Classifiers "Committee Machines"

**Reference Books:**


**a.** Duda, Richard O., Peter E. Hart, and David G. Stork. *Pattern Classification*. New York, NY: John Wiley & Sons, 2000. ISBN: 9780471056690.

8. **Course name: Big Data Analysis**
**Course Code:** MACM538
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To understand and apply core concepts of Business Intelligence and Business Analytics frameworks, and differentiate them |
| **CO2** | To analyze big data architectures and processing models |
| **CO3** | To apply statistical techniques and exploratory data analysis |
| **CO4** | Demonstrate practical skills in using big data tools |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | 1 | 2 | 2 |
| CO-2 | 3 | 3 | 1 | 2 | 3 |
| CO-3 | 3 | 2 | 1 | 3 | 2 |
| CO-4 | 2 | 3 | 1 | 2 | 3 |
| Average | 2.75 | 2.5 | 1 | 2.25 | 2.5 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Fundamentals of Business Analytics-Business Intelligence (BI), Business Intelligence vs. Business Analytics, BI Framework, BI Roles & Responsibilities, BI DW Best Practices, Popular BI Tools, BI Applications

**Module II:**
Big Data Analytics, In-Memory Analytics, In-Database Processing, Symmetric Multiprocessor System (SMP), Massively Parallel Processing, Shared-Nothing Architecture, Parallel and Distributed Systems, CAP Theorem, NoSQL

**Module III:**
Typical enterprise application architecture, Visualizing Relationship in Data, Probability, Estimation, Outliers and Normal Distribution, Inference, Regression, Exploratory Data Analysis (EDA), Big Data, Scaling Problems, HDFS, Design Patterns, Cluster

**Module IV:**
Data analytic life cycle, Advance analytic theory and method: "Clustering", Advance analytic theory and method: "Association", Advance analytic theory and method: "Classification", Advance analytic theory and method: "Regression"

**Module V:**
Big Data Analytics Tool: Hadoop, MongoDB, Cassandra, MapReduce, Hive, Pig, Oozie

**Reference Books:**


i. Jeffery Stanton, An Introduction to Data Science Jeffery Stanton
ii. R.N. Prasad, Seema Acharya, Fundamentals of Business Analytics, Wiley

9. **Course name: Data Mining**
**Course Code:** MACM539
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | To apply data preprocessing techniques to prepare datasets for mining and machine learning tasks |
| **CO2** | To design and implement classification, prediction, and clustering algorithms for various types of data |
| **CO3** | To develop association rule mining techniques to discover interesting patterns |
| **CO4** | To analyze and interpret complex data mining scenarios and evaluate model performance |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 2 | 1 | 1 | 2 | 3 |
| CO-2 | 3 | 2 | 1 | 2 | 3 |
| CO-3 | 2 | 2 | 1 | 1 | 3 |
| CO-4 | 2 | 3 | 1 | 2 | 3 |
| Average | 2.25 | 2 | 1 | 1.75 | 3 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Data Mining Concepts, Input, Instances, Attributes and Output, Knowledge Representation & Review of Graph Theory, Lattices, Probability &Statistics. Machine learning concepts and approaches: Supervised Learning Framework, concepts & hypothesis, Training & Learning, Boolean functions and formulae, Monomials, Disjunctive Normal Form & Conjunctive Normal Form, A learning algorithm for monomials

**Module II:**
Data Preparation, Data Cleaning, Data Integration & Transformation, Data Reduction. Mining Association Rules Associations, Maximal Frequent & Closed Frequent item sets, Covering Algorithms & Association Rules, Linear Models & Instance Based Learning, Mining Association Rules from Transactional databases, and Mining Association Rules from Relational databases & Warehouses, Correlation analysis & Constraint based Association Mining

**Module III:**
Classification and Prediction Issues regarding Classification & Prediction, Classification by Decision Tree induction, Bayesian classification, Classification by Back Propagation, k Nearest Neighbor Classifiers, Genetic algorithms, Rough Set & Fuzzy Set approaches

**Module IV:**
Cluster Analysis: Types of data in Clustering Analysis, Categorization of Major Clustering methods, Hierarchical methods, Density-based methods, Grid-based methods, Model-based Clustering methods. Mining Complex Types of Data Annexure VIII 295, Multidimensional analysis & Descriptive mining of Complex data objects, Mining Spatial Databases, Mining Multimedia Databases, Mining Time series & Sequence data, Mining Text databases, Mining World Wide Web

**Module V:**
Data Mining Applications and Trends in Data Mining: Massive Datasets/Text mining, Agent-Based Mining. Variance Analysis and MLE F test, Techniques of Analysis of Variance, Analysis of Variance in Two-Way Classification Model.

**Reference Books:**


**i.** Cristianini N. and Shawe Taylor J.,An Introduction to Support Vector Machines and Other Kernel based Learning Methods,2000.

**ii.** Larose D.T., Discovering knowledge in data: an introduction to data mining, Wiley Interscience, 2005.

**iii.** Tan P. N., Steinbach M. and Kumar V. Publisher, Introduction to Data Mining, Wesley, 2006.

# Bouquet-II: Mathematics Courses

1. **Course name: Mathematical Modeling and Simulation**
   **Course Code:** MACM521
   **L-T-P: 3-0-0**
   **Credits: 3**

   **Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of modeling and simulation. |
| **CO-2** | Solving problems using modeling and simulation. |
| **CO-3** | Analyzing the models and using simulations for applications. |
| **CO-4** | Developing mathematical models. |

   **Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | - | - | 3 | - |
| CO-2 | 3 | 2 | - | 2 | 3 |
| CO-3 | 3 | 2 | - | 2 | 3 |
| CO-4 | 3 | 2 | 1 | 2 | 3 |
| Average | 3 | 1.5 | 0.25 | 2.25 | 2.25 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Introduction to Mathematical Modeling Process: Concept, Objectives, Methods, and Tools. Mathematics is the natural modeling language; Definition of mathematical models

**Module II:**
Modeling Continuous Systems: Modeling with Differential Equations: Population dynamics; Electrical Circuits; Mechanical Systems; Biological models (Lotka-Volterra systems, Predator-Prey systems).

**Module III:**
Modeling with Partial Differential Equations: Linear Temperature Diffusion; One-dimensional Hydrodynamic model. Case Studies: Heat diffusion, Wave vibration, Laplace Equation

**Module IV:**
Modeling Discrete Systems: Modeling with difference equations; Modeling with data; Discrete Velocity Models; Continuous Vs. Discrete Models

**Module V:**
Simulation: Block-Diagrams; State-Space Model; Transfer Functions, State-space Vs. transfer function. Stability and pole locations; Introduction to Matlab\Simulink (Starting Simulink, Basic Elements, Building a System, Running Simulations); Simulation of some models (case study models) and Analysis of Simulation results.

**Reference Books:**


i. Mathematical Modeling and Simulation: Introduction for Scientists and Engineers, Kai Veltn, Wiley, 2009.
ii. Introduction to Simulink® with Engineering Applications, Steven T. Karris, Orchard Publications, 2006.
iii. Simulation Modeling and Analysis with Expertfit Software, Averill Law, McGraw-Hill Science, 2007. 2. A Concrete Approach to Mathematical Modelling, M. M. Gibbons, Wiley-Interscience, 2007.

2. **Course name: Computational Methods for Partial Differential Equations**
**Course Code:** MACM522
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of partial differential equations. |
| **CO-2** | Solving problems on partial differential equations. |
| **CO-3** | Analyzing the models of PDE and finding numerical solutions. |
| **CO-4** | Implementation of numerical techniques on PDE's. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | - | - | 2 | - |
| CO-2 | 3 | - | - | 2 | 1 |
| CO-3 | 2 | 2 | - | 3 | 3 |
| CO-4 | 2 | 3 | 2 | 2 | 3 |
| Average | 2.50 | 1.25 | 0.50 | 2.25 | 1.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Two-point boundary value problem: Variational approach, Discretization and convergence of numerical schemes.

**Module II:**

Second order elliptic boundary value problem, Variational formulation and Boundary conditions, Finite element Methods, Galerkin Discretization,

**Module III:**

Implementation, Finite difference and Finite volume methods, Convergence and Accuracy.

**Module IV:**

Parabolic initial value problems, Heat equations, variational formulation, Method of lines, Convergence.

**Module V:**

Wave Equations, Method of lines, Timestepping.

**Reference Books:**


i. Haberman R. Elementary applied partial differential equations: with Fourier series and boundary value problems: Prentice-Hall, Inc.; 1998.

ii. S.S. Rao, Finite Element Methods in Engineering, Butterworth-Heinemann, 1989.

iii. G.D. Smith, Numerical Solution of Partial Differential Equations: Finite Difference Method, Clarendon Press, Oxford , 1985.

iv. Lawrence C. Evans, Partial Differential Equations, American Mathematical Society

v. An Introduction to Partial Differential Equations, Renardy M., and Rogers R., Springe

3. **Course name: Applied Regression Analysis**
**Course Code:** MACM523
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of regression analysis. |
| **CO-2** | Solving problems using regression analysis. |
| **CO-3** | Analyzing the real models using regression analysis. |
| **CO-4** | Developing mathematical models using regression. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 1 | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 2 | 3 |
| CO-3 | 3 | 2 | 2 | 3 | 3 |
| CO-4 | 2 | 3 | 1 | 2 | 3 |
| Average | 2.75 | 2 | 0.75 | 2.25 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Simple linear regression, multiple linear regression.

**Module II:**
Model adequacy checking, transformations, and weighting to correct model inadequacies

**Module III:**
Polynomial regression models, orthogonal polynomials

**Module IV:**
Dummy variables, variable selection and model building, multicollinearity, Nonlinear regression.

**Module V:**
Generalized linear models, autocorrelation, measurement errors, calibration problems, bootstrapping.

**Reference Books:**


i. Draper, N. R., and Smith, H. (2003), Applied Regression Analysis, New York: Wiley.
ii. Sen, A. A. and Srivastava, M. (1990). Regression Analysis Theory, Methods & Applications, Springer-Verlag, Berlin.
iii. Bowerman, B. L. and O'Connell, R. T. (1990). Linear Statistical Models: An Applied Approach, PWS-KENT Pub., Boston.

4. **Course name: Financial Mathematics**
   **Course Code:** MACM524
   **L-T-P: 3-0-0**
   **Credits: 3**
   **Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of financial mathematics. |
| **CO-2** | Solving problems using financial mathematics. |
| **CO-3** | Analyzing the financial mathematical models. |
| **CO-4** | Developing mathematical models. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 1 | - | 2 | - |
| CO-2 | 3 | 2 | - | 2 | 3 |
| CO-3 | 2 | 3 | 1 | 3 | 3 |
| CO-4 | 2 | 3 | 2 | 3 | 3 |
| Average | 2.50 | 2.25 | 0.75 | 2.50 | 2.25 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Financial markets, Interest computation, value, growth and discount factors, derivative products

**Module II:**
Basic option theory: single and multiperiod binomial pricing models

**Module III:**
Cox-Ross-Rubinstein (CRR) model, volatility, Black-Scholes formula for option pricing as a limit of the CRR model

**Module IV:**
Greeks and hedging, Mean-Variance portfolio theory: Markowitz model

**Module V:**
Capital Asset Pricing Model (CAPM), factor models, interest rates, interest rate derivatives, and Binomial tree models.

**Reference Books:**


i. Sheldon M. Ross, An elementary introduction to mathematical finance, 1999.
ii. Mark H. A. Davis, Mathematical Finance: a Very short Introduction, Oxford,2019.

5. **Course name: Stochastic of Finance**
**Course Code:** MACM525
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of Stochastic theory. |
| **CO-2** | Solving problems using stochastic theory. |
| **CO-3** | Analyzing the financial-based models using stochastic theory. |
| **CO-4** | Implementing the stochastic models in Finance. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | - | - | 3 | - |
| CO-2 | 2 | - | - | 3 | 2 |
| CO-3 | 2 | 2 | - | 3 | 3 |
| CO-4 | 2 | 2 | 1 | 2 | 3 |
| Average | 2.25 | 1 | 0.25 | 2.75 | 2 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Stochastic Processes: Brownian and Geometric Brownian Motion

**Module II:**
Levy Processes, Jump-Diffusion Processes; Conditional Expectations and Martingales

**Module III:**
Ito Integrals, Ito's Formula; Stochastic Differential Equations; Change of Measure, Girsanov Theorem

**Module IV:**
Martingale Representation Theorem and Feynman-Kac Theorem

**Module V:**
Applications of Stochastic Calculus in Finance, Option Pricing, Interest Rate Derivatives, Levy Processes in Credit Risk.

**Reference Books:**


**i.** Hans Föllmer, Alexander Schied, Stochastic Finance, 4th Edition, De Gruyter,2016.
**ii.** Nicolas Privault, Stochastic Finance: An Introduction with Market Examples**,** CRC Press,2013.

6. **Course name: Boundary Element Methods with Computer Applications**
**Course Code:** MACM526
**L-T-P: 3-0-0**
**Credits: 3**
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of boundary element methods. |
| **CO-2** | Solving problems using boundary element methods. |
| **CO-3** | Developing programs for solving boundary value problems. |
| **CO-4** | Implementing the boundary value problems in real applications. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 1 | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 3 | 3 |
| CO-3 | 2 | 2 | 1 | 2 | 3 |
| CO-4 | 2 | 3 | 2 | 3 | 3 |
| Average | 2.50 | 2 | 0.75 | 2.50 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Distributions and Sobolev spaces of fractional order. Elliptic boundary value problems on unbounded domains in $R^n$ (n=2,3), Fundamental solution of elliptic equations.

**Module II:**
Simple layer and double layer potentials Fredholm integral equations of first and second kinds. Singular and hypersingular kernels.Interior and exterior Dirichlet problems and integral representations of their solutions.

**Module III:**
Variational formulation of problems defined on boundary. Solution of some model problems by boundary element methods, approximate integrations over boundary

**Module IV:**
Solution methods of algebraic equations; computer implementation of boundary element methods for a model problem. Coupling of boundary element and finite element methods.

**Module V:**
Some advanced topics of boundary integral methods integrals with hypersingular kernel, a method of elimination of singularity, Lagrange multiplier method.

**Reference Books:**


**i.** Gernot Beer, Ian M. Smith, Christian Duenser, The Boundary Element Method with Programming For Engineers and Scientists,2008.

**ii.** Prem K. Kythe, An Introduction to Boundary Element Methods,2020.

7. **Course name: Boundary Value Problems**
**Course Code:** MACM527
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of boundary value problems. |
| **CO-2** | Solving the boundary value problems. |
| **CO-3** | Characterizing the boundary value problems. |
| **CO-4** | Developing models based on boundary value problems. |

**Course Articulation Matrix:**

| | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** |
|---|---|---|---|---|---|
| **CO-1** | 3 | - | - | 2 | - |
| **CO-2** | 3 | - | - | 2 | 3 |
| **CO-3** | 3 | - | - | 3 | 2 |
| **CO-4** | 3 | 2 | 1 | 3 | 3 |
| **Average** | **3** | **0.25** | **0.25** | **2.50** | **2** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Sturm-Liouville problem, Boundary Value Problems for nonhomogeneous ODEs, Green's Functions.

**Module II:**
Fourier Series and Integrals: Periodic Functions and Fourier Series, Arbitrary Period and Half-Range Expansions, Fourier Integral theorem and convergence of series Parabolic equations: Heat equation.
Fourier series solution, Different Boundary Conditions, Generalities on the Heat Conduction Problems on bounded and unbounded domains and applications in Option pricing.

**Module III:**
The Wave Equation: The Vibrating String, Solution of the Vibrating String Problem, d'Alembert's Solution, One-Dimensional Wave Equation
The Potential Equation: Potential Equation in a Rectangle, Fourier series method, Potential equation in Unbounded Regions, Fourier integral representations, Potential in a Disk, and Limitations

**Module IV:**

Higher Dimensions and Other Coordinates: Two-Dimensional Wave Equation: Derivation, Parabolic equation, Solution by Fourier series, Problems in Polar Coordinates, Temperature in a Cylinder, Vibrations of a Circular Membrane.

**Module V:**

Finite dimensional approximations of solutions, piecewise linear polynomials, and introduction to different methods like the Galerkin and Petrov-Galerkin methods.

**Reference Books:**


i. Anthony W. Knapp, introduction to Boundary-Value Problems,2017.

ii. David Powers,Boundary Value Problems and Partial Differential Equations,6th Edition - July 24, 2009

8. **Course name: Finite Element Method and Applications**
**Course Code:** MACM528
**L-T-P: 3-0-0**
**Credits: 3**
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the concepts of finite element methods. |
| **CO-2** | Solving problems using finite element methods. |
| **CO-3** | Developing programs using finite element methods. |
| **CO-4** | Implementing the FEM for real-life problems. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 1 | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 3 | 3 |
| CO-3 | 2 | 3 | 2 | 2 | 3 |
| CO-4 | 2 | 3 | 1 | 3 | 3 |
| Average | 2.50 | 2.25 | 0.75 | 2.50 | 2.75 |

1 - Slightly 2 - Moderately 3 – Substantially

**Syllabus:**

**Module I:**
Introduction and basic concepts, Finite element spaces.

**Module II:**
Mathematical fundamentals and computer algorithms, Variations and weighted residual techniques, Abstract formulation of FEM for elliptic equations

**Module III:**
Applications to Elastic stress analysis using linear elements, FEM for parabolic and hyperbolic equations

**Module IV:**
Unsteady heat flow analysis, Mixed-FEM, Nonlinear, Curved, Isoperimetric plate and shell elements, Fluid flow, Material nonlinearity including plasticity, Creeping viscous flow

**Module V:**
Boundary element formulation for electrostatic problems, Adaptive mesh refinement, and large problem solvers.

**Reference Books:**

i. Reddy, J. N., Introduction to the finite element method. McGraw-Hill Education, 2019.
ii. S.C. Brenner, L.R. Scott, Mathematical Theory of Finite Element Method, Springer-Verlag, 1994.
iii. Madenci, E., & Guven, I., The finite element method and applications in engineering using ANSYS®. Springer, 2015.

9. **Course name: Computational Linear Algebra**
**Course Code:** MACM529
**L-T-P: 3-0-0**
**Credits: 3**
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the numerical methods. |
| **CO-2** | Solving problems using numerical methods. |
| **CO-3** | Creating programs based on advanced numerical techniques. |
| **CO-4** | Implementing numerical techniques on real-life problems. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | - | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 3 | 3 |
| CO-3 | 3 | 2 | - | 1 | 3 |
| CO-4 | 3 | 3 | 1 | 3 | 3 |
| Average | 3 | 1.75 | 0.25 | 2.25 | 2.75 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**
Vector and matrix norms.

**Module II:**

Direct method for linear system of equations: LU decomposition, Cholesky Factorization, QR factorization; Perturbation analysis of Linear systems of equations.

**Module III:**
Iterative methods for solving linear systems: Jacobi, Gauss-Seidel and SOR methods

**Module IV:**
Singular value decomposition of a matrix and its applications. Linear least squares problem.

**Module V:**
Computational methods for the matrix eigenvalue problems: power method and its variants, Householder method, the QR algorithm.

**Reference Books:**


i. G.D. Smith, Numerical Solutions of Partial Differential Equations, Clarendon Press, Oxford, 1985.
ii. B. N. Dutta, Numerical Linear Algebra and Applications, SIAM, Prentice Hall India, 2010.
iii. S.D. Conte & Carl De Boor, Elementary Numerical Analysis, McGraw Hill, 2005.

10. **Course name: Introduction to Dynamical Systems**

**Course Code:** MACM5XX

**L-T-P: 3-0-0**

**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand and analyze the qualitative behavior of one-dimensional and two-dimensional autonomous systems |
| **CO-2** | To identify and classify bifurcations in dynamical systems |
| **CO-3** | To apply theoretical tools to study limit cycles, periodic orbits, and nonlinear flow systems |
| **CO-4** | To investigate and interpret complex dynamical behavior using classical models |

**Course Articulation Matrix:**

| | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** |
|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | - | 3 | 2 |
| **CO-2** | 3 | 2 | - | 2 | 2 |
| **CO-3** | 3 | 2 | - | 3 | 3 |
| **CO-4** | 2 | 2 | - | 2 | 3 |
| **Average** | **2.75** | **2** | **-** | **2.5** | **2.5** |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I:**

One-dimensional flows: Fixed points and stability, linear stability analysis, Impossibility of Oscillations, Potentials, Saddle-node bifurcation, Transcritical bifurcation, Pitchfork bifurcation

**Module II:**

Flows on the circle: uniform and nonuniform Oscillator, Overdamped Oscillator Two-dimensional flows: Linear systems, nonlinear autonomous systems, phase portraits, Fixed points, and linearization

**Module III:**

Conservative systems, Reversible systems, index theory, limit cycles, Poincaré-Bendixson theorem, Lienard systems,

**Module IV:**

Saddle-node, Transcritical and Pitchfork bifurcations, Hopf bifurcation, Chaos: Lorenz equation, Simple properties of Lorenz Equations,

**Module V:**

Lorenz Map, Strange attractor, Discrete dynamical systems

**Reference Books:**


a. Steven H Strogatz, Nonlinear Dynamics and Chaos, Perseus books publishing, 1994

b. James T Sandefur, Discrete dynamical systems Theory and applications, Clarendon press, 1990

## 11. Course name: Data Analysis & Visualization

**Course Code:** MACM5XX
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To apply the principles of data visualization using Python tools |
| **CO-2** | To implement and evaluate various unsupervised learning techniques |
| **CO-3** | To build and analyze regression models and assess their predictive performance on real-world datasets |
| **CO-4** | To develop and compare supervised classification algorithms and gain a foundational understanding of artificial neural networks |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 2 | 3 |
| CO-3 | 3 | 2 | - | 3 | 2 |
| CO-4 | 2 | 3 | - | 3 | 3 |
| Average | 2.75 | 2.25 | - | 2.5 | 2.5 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module I**

Data visualization: Basic principles, categorical and continuous variables; Exploratory graphical analysis – creating static graphs, animated visualizations – loops, GIFs and videos; Data visualization in Python, examples

**Module II**

Clustering techniques: K-means, Gaussian mixture models and expectation-maximization, agglomerative clustering, evaluation of clustering – Rand index, mutual information-based scores, Fowlkes-Mallows' index

**Module III**

Regression: Linear models, ordinary least squares, ridge regression, LASSO, Gaussian processes regression

**Module IV**
Supervised classification methods: K-nearest neighbor, naive Bayes, logistic regression, decision tree, support vector machine

**Module V**
Introduction to artificial neural networks (ANNs), deep NNs, and convolutional neural networks (CNNs)

**Reference Books:**


i. Hastie, T., Tibshirani, R.,, Friedman, J. (2009). The elements of statistical learning: data mining, inference and prediction. Springer.
ii. Richard O. Duda, Peter E. Hart, and David G. Stork. 2000. Pattern Classification (2nd Edition). Wiley- Interscience, New York, NY, USA.
iii. Christopher M. Bishop. 2006. Pattern Recognition and Machine Learning (Information Science and Statistics). Springer-Verlag, Berlin, Heidelberg.

## 12.Course name: Statistical Inference

**Course Code:** MACM5XX
**L-T-P: 3-0-0**
**Credits: 3**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand and evaluate the properties of estimators |
| **CO-2** | To apply theoretical results to determine sufficient statistics and efficiency bounds. |
| **CO-3** | To compute and compare point estimates and analyze their statistical properties with practical examples. |
| **CO-4** | To construct and interpret confidence intervals and perform hypothesis testing and also evaluate test performance. |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | - | 2 | 2 |
| CO-2 | 3 | 2 | - | 3 | 3 |
| CO-3 | 3 | 2 | - | 2 | 3 |
| CO-4 | 3 | 2 | - | 3 | 2 |
| Average | 3 | 2 | - | 2.5 | 2.5 |

1 - Slightly 2 - Moderately 3 - Substantially

**Syllabus:**

**Module-I**
Parameter space and sample space, point estimation, requirements of a good estimator, consistency, unbiasedness, efficiency, sufficiency, minimum variance unbiased estimators, completeness, minimal sufficiency

**Module-II**
Factorization theorem, Fisher-Neyman criterion, Cramér-Rao inequality, derivation and implications of lower bounds, use of sufficiency and completeness in deriving estimators

**Module-III**
Maximum likelihood estimation, least squares and minimum variance methods, properties of maximum likelihood estimators with illustrative examples, comparison of estimators under different criteria

**Module-IV**

Interval estimation, confidence intervals, and confidence limits for the parameters of the normal distribution, construction of confidence intervals for large samples using asymptotic properties

**Module-V**

Formulation of statistical hypotheses, null and alternative hypotheses (simple and composite), Type-I and Type-II errors, power of a test, best critical region, most powerful and uniformly most powerful tests, uniformly most powerful unbiased critical region, Neyman-Pearson Lemma, tests for goodness of fit, sequential probability ratio tests, likelihood ratio tests

**Reference Books:**


i. Rohatgi, V.K. and Saleh, A.M.E. An introduction to probability and statistics. John Wiley & Sons, 2015.

ii. Casella, G. and Berger, R.L. Statistical inference (Vol. 2). Pacific Grove, CA: Duxbury. 2002.

iii. Lehmann, E.L. and Casella, G. Theory of point estimation. Springer Science & Business Media. 2006.

iv. Lehmann, E.L. and Romano, J.P. Testing statistical hypotheses. Springer Science & Business Media. 2006.

## 13. Course name: Introduction to Stochastic Processes

**Course Code:** MACM5XX
**L-T-P: 3-0-0**
**Credits: 3**
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand and apply the foundational concepts of probability and generating functions to discrete random processes |
| **CO-2** | To model and analyze stochastic processes, including stationary, Markov, and Gaussian processes |
| **CO-3** | To examine the behavior of discrete and continuous-time Markov chains and evaluate long-term state probabilities |
| **CO-4** | To design and evaluate Poisson processes and basic queuing models |

**Course Articulation Matrix:**

| CO/PO | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 |
|---|---|---|---|---|---|
| CO-1 | 3 | 2 | - | 3 | 2 |
| CO-2 | 3 | 2 | - | 3 | 3 |
| CO-3 | 3 | 2 | - | 2 | 3 |
| CO-4 | 3 | 3 | - | 3 | 2 |
| Average | 3 | 2.25 | - | 2..75 | 2.5 |

1 - Slightly 2 - Moderately 3 – Substantially

**Syllabus:**

**Module I**
Basics of probability, generating functions, and bivariate probability generating functions

**Module II**
Stochastic process: introduction and stationary processes, Markov processes, Gaussian process

**Module III**
Discrete and continuous-time Markov chains, classification of states, limiting distribution

**Module IV**
Poisson process, steady-state, and transient distributions

**Module V**
Queuing models, M/M/1 with finite and infinite system capacity, waiting time distribution

**Reference Books:**


i. Stochastic Processes- S. M. Ross, 2nd Edition 1996
ii. Stochastic Processes- J. Medhi; 4th edition, 2019