# CURRICULUM & SYLLABI

# M.Sc. MATHEMATICS & SCIENTIFIC COMPUTING

**Effective from AY: 2024-25**

## NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

## WARANGAL, TELANGANA

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## Vision and Mission of the Institute
## National Institute of Technology Warangal

### VISION
Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship, and Technological services to society

### MISSION
- Imparting total quality education to develop innovative, entrepreneurial, and ethical future professionals fit for a globally competitive environment.
- Allow stakeholders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research to establish a self-sustaining and wealth-creating center to serve societal needs.

## Vision and Mission of the Department
## MATHEMATICS

### VISION

To be among the best mathematics departments in the country, to build an international reputation as a center of excellence in mathematics and computational research, training, and education, and to inculcate Mathematical thinking to meet the challenges and growth of science and technology as well as the needs of industry and society, with moral and ethical responsibility.

### MISSION
- ❖ To attract motivated and talented students by providing a learning environment where they can learn and develop the mathematical and computational skills needed to formulate and solve real-world problems.
- ❖ To foster an environment conducive to quality research and to train principled and highly skilled researchers with clear thinking and determination to meet the dynamic challenges of science and engineering.
- ❖ To keep up with the rapid advancements of technology while improving academic standards through innovative teaching and learning processes.
- ❖ To satisfy the country's human resource and scientific manpower requirements in mathematics through learner-centered contemporary education and research.

## Program: M.Sc. Mathematics & Scientific Computing

### Program Educational Objectives

| | |
|---|---|
| **PEO-1** | Provide sufficient understanding of the fundamentals of mathematics with computational techniques and program core to address challenges faced in mathematics and other related interdisciplinary fields. |
| **PEO-2** | Facilitate as a deep learner and progressive career in teaching, academia, research organizations, national/international laboratories, and industry. |
| **PEO-3** | Develop models and simulation tools for real-life problems by analysing and applying mathematical and computational tools and techniques. |
| **PEO-4** | Demonstrate effective communication and interpersonal, management and leadership skills to fulfil professional responsibilities, retaining scientific favour in day-to-day affairs. |
| **PEO-5** | Engage in lifelong learning and adapt to changing professional and societal needs. |

### Program Articulation Matrix

| PEO / Mission Statements | **PEO-1** | **PEO-2** | **PEO-3** | **PEO-4** | **PEO-5** |
|---|---|---|---|---|---|
| To attract motivated and talented students by providing a learning environment where they can learn and develop the mathematical and computational skills needed to formulate and solve real-world problems. | 2 | 3 | 2 | 3 | 2 |
| To foster an environment conducive to quality research and to train principled and highly skilled researchers with clear thinking and determination capable of meeting the dynamic challenges of science and engineering. | 3 | 3 | 3 | 2 | 2 |
| To keep up with the rapid advancements of technology while improving academic standards through innovative teaching and learning processes. | 2 | 3 | 2 | 2 | 2 |
| To satisfy the country's human resource and scientific manpower requirements in mathematics through learner-centered contemporary education and research. | 3 | 2 | 3 | 3 | 3 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Program: M.Sc. Mathematics & Scientific Computing

## Program Outcomes

| | |
|---|---|
| **PO1** | Gain and apply the knowledge of basic scientific and mathematical fundamentals to understand the Nature and apply it to develop new theories and models. |
| **PO2** | Design algorithms and derive solutions for complex mathematics problems to meet the specified needs with appropriate consideration for the public health and safety, cultural, societal, and environmental considerations. |
| **PO3** | Use of research-based knowledge and research methods including design of physical/computational experiments and evolve appropriate procedures to a given problem. |
| **PO4** | Create, select, and apply appropriate techniques, resources, and modern IT tools including prediction and modelling to complex real-life problems with an understanding of the limitations. |
| **PO5** | Function effectively as an individual, and as a member or leader in diverse teams to manage projects in multidisciplinary environments |
| **PO6** | Use Numerical analysis and statistical modelling and interpretation of data, to provide valid conclusions |

# CURRICULUM

## M.Sc. Mathematics & Scientific Computing

### 1st Semester

| S.No. | Code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | MA16001 | Real Analysis | 4-0-0 | 4 |
| 2 | MA16003 | Ordinary Differential Equations | 3-0-0 | 3 |
| 3 | MA26001 | Algorithmic Approach to Computational Methods | 3-0-0 | 3 |
| 4 | MA26003 | Computer Programming & Data Structures in Python | 3-0-0 | 3 |
| 5 | MA260XX | Professional Elective – I | 3-0-0 | 3 |
| 6 | MA26005 | CPDS with Python Lab | 0-1-2 | 2 |
| 7 | MA26007 | Computational Methods using MATLAB Lab | 0-1-2 | 2 |
| **Total Credits** | | | | **20** |

### 2nd Semester

| S.No. | Code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | MA16002 | Probability and Statistics | 4-0-0 | 4 |
| 2 | MA16004 | Partial Differential Equations | 3-0-0 | 3 |
| 3 | MA26002 | Object Oriented Programming with C ++ | 3-0-0 | 3 |
| 4 | MA260XX | Professional Elective – II | 3-0-0 | 3 |
| 5 | MA260XX | Professional Elective – III | 3-0-0 | 3 |
| 6 | MA26004 | Statistics with R Lab | 0-1-2 | 2 |
| 7 | MA26006 | OOP WITH C ++ LAB | 0-1-2 | 2 |
| **Total Credits** | | | | **20** |

## 3rd Semester

| S.No. | Code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | MA27001 | Database Management Systems | **4-0-0** | **4** |
| 2 | MA27003 | Numerical Optimization | **3-0-0** | **3** |
| 3 | MA270XX | Professional Elective – IV | **3-0-0** | **3** |
| 4 | MA270XX | Professional Elective – V | **3-0-0** | **3** |
| 5 | MA27005 | DBMS Lab | **0-1-2** | **2** |
| 6 | MA27007 | Numerical Optimization lab | **0-1-2** | **2** |
| 7 | MA27091 | Seminar and Technical writing | **0-0-0** | **2** |
| 8 | MA27093 | Short-term Industrial / Research Experience | **0-0-0** | **2** |
| **Total Credits** | | | | **21** |

## 4th Semester

| S.No. | Code | Course Title | L-T-P | Credits |
|---|---|---|---|---|
| 1 | MA270XX | Professional Elective – VI | **3-0-0** | **3** |
| 2 | MA270XX | Professional Elective – VII | **3-0-0** | **3** |
| 3 | MA27094 | Comprehensive Viva-Voce | **0-0-0** | **2** |
| 4 | MA27098 | Dissertation | **0-0-0** | **8** |
| **Total Credits** | | | | **16** |

# Professional Elective Courses

| Professional Elective– I | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA26021 | Numerical Linear Algebra |
| 2 | MA26023 | Java Programming |
| 3 | MA26025 | Elements of Data Science |

| Professional Elective– II | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA26022 | Mathematical Foundations of Computer Science |
| 2 | MA26024 | Perturbation Methods |
| 3 | MA26026 | Wavelet Analysis |

| Professional Elective– III | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA26028 | Theory of Complex Variables |
| 2 | MA26030 | Transformation Techniques |
| 3 | MA26032 | Computer Graphics |

| Professional Elective– IV | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA27021 | Design and Analysis of Algorithms |
| 2 | MA27023 | Advanced Data Structures |
| 3 | MA27025 | Advanced Abstract Algebra |

| Professional Elective– V | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA27027 | Cryptography |
| 2 | MA27029 | Finite Element and Finite Volume Methods |
| 3 | MA27031 | Graph Theory |

| Professional Elective– VI | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA27022 | Computational Number Theory |
| 2 | MA27024 | Evolutionary Optimization Techniques |
| 3 | MA27026 | Neural Networks |
| 4 | MA27028 | Parallel Computing |

| Professional Elective– VII | | |
|---|---|---|
| **S.No.** | **Code** | **Course Title** |
| 1 | MA27030 | Theory of Automata |
| 2 | MA27032 | Mathematics of Machine Learning |
| 3 | MA27034 | Data Mining |
| 4 | MA27036 | Algebraic Coding Theory |

## The Overall Credit Structure

| Course Category | Credits |
|---|---|
| Program Core | 42 |
| Professional Elective | 21 |
| Seminar and Technical Writing | 2 |
| Short Term Industrial / Research Experience | 2 |
| Comprehensive Viva-Voce | 2 |
| Dissertation | 8 |
| **Total Graded Credit Requirement** | 77 |

# SYLLABI

## M.Sc. Mathematics & Scientific Computing

# 1st Semester

**MA16001** **4-0-0 (4)**

# Real Analysis

**Pre-requisite: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Find whether a given function can be Riemann integrable |
| **CO-2** | Test whether a given improper integral can be convergent |
| **CO-3** | Examine uniform convergence of a given sequence of functions |
| **CO-4** | Examine uniform convergence of a given series of functions |
| **CO-5** | Expand a given function into a Fourier series |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO-2** | 3 | 2 | 2 | 3 | 3 | 2 |
| **CO-3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO-4** | 3 | 3 | 3 | 3 | 2 | 3 |
| **CO-5** | 2 | 3 | 1 | 3 | 1 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction:** Real number system, Elementary topology, continuous functions, Continuity and Compactness, Continuity and connectedness, Differentiation

**Riemann Stieltje's integral:** Definition and existence of the integral, Properties of the integral, Integration and differentiation of integral with variable limits.

**Improper integrals:** Definitions and their convergence, Tests of convergence, $\beta$ and $\Gamma$ functions.

**Uniform convergence:** Tests for uniform convergence, Theorems on limit and continuity of sum functions, Term by term differentiation and integration of series of functions.

**Power series:** Convergence and their properties.

**Fourier Series:** Dirichlet conditions, Existence, Problems, Half range sine and cosine series.

### Learning Resources:

Text Books:

1. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill, 2017, Third Edition.
2. Brian S.Thomson, Andrew M.Bruckner, Judith B.Bruner, Real Analysis, Prentice Hall International, 2008.

Reference Books:

1. William F. Trench, Introduction to Real Analysis, Library of Congress Cataloging-in-Publication Data, Free Edition 1.04, 2010
2. Tom M. Apostol, Mathematical Analysis, Addison Wesley, 1974, Second Edition

**MA16003** **3-0-0 (3)**

# Ordinary Differential Equations

**Pre-Requisite**: **None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Determine linearly independent solutions and general solution of a non-homogeneous differential equations |
| **CO-2** | Find power series solution to a differential equation containing variable coefficients |
| **CO-3** | Analyse the stability of Autonomous Systems. |
| **CO-4** | Discuss the existence and uniqueness of solution for an initial value problem |
| **CO-5** | Use Green's function to solve a non-homogeneous boundary value problem |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO-2** | 3 | 2 | 2 | 3 | 3 | 2 |
| **CO-3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO-4** | 3 | 3 | 3 | 3 | 2 | 3 |
| **CO-5** | 3 | 3 | 3 | 3 | 2 | 3 |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

## Syllabus:

**First Order Equations**: Picard's theorem, Non-Local existence theorem.

**Second Order Equations**: Linear dependence and independence, A formula for the Wronskian, the non-homogeneous equations, linear equations with variable coefficients, reduction of the order of the homogeneous equation, Sturm comparison theorem, Sturm separation theorem.

**Stability**: Autonomous Systems. The Phase Plane and Its Phenomena, Types of Critical Points. Stability, Critical Points, and Stability for Linear Systems.

**Systems of Differential Equations**: Existence theorems, homogeneous linear systems, non-homogeneous linear systems, linear systems with constant coefficients, eigenvalues and eigenvectors, diagonal and Jordan matrices.

**Boundary Value Problems**: Two-point boundary value problems, Green's functions, construction of Green's functions, and non-homogeneous boundary conditions.

### Learning Resources:

Text Books:

1. G.F. Simmons, Differential Equations with Applications and Historical Notes, McGraw Hill, 2017, Second Edition.
2. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications, 1989, First Edition.

Reference Books:

1. M. Braun, Differential Equations and Their Applications, Springer-Verlag, 1983, Third Edition
2. P.J. Collins, Differential and Integral Equations, Oxford University Press, 2006, First Edition.

**MA26001** **3-0-0 (3)**

# Algorithmic Approach to Computational Methods

**Pre-Requisites**: **None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Find the roots of nonlinear equations numerically. |
| **CO-2** | Solve the system of equations numerically. |
| **CO-3** | Interpolate the given data. |
| **CO-4** | Find the derivative of a function and definite integrals numerically. |
| **CO-5** | Solve the initial value problems. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | – | 2 | – | 1 |
| **CO-2** | 3 | 2 | – | 3 | – | 2 |
| **CO-3** | 2 | – | – | 2 | – | 3 |
| **CO-4** | 2 | – | – | 2 | – | – |
| **CO-5** | 3 | 2 | – | 3 | – | 2 |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

**Syllabus:**

**Representation of integers and fractions:** Fixed point and floating-point arithmetic, error propagation, loss of significance, condition, and instability, computational error propagation method.

**Root finding:** bisection method, secant method, regular-falsi method, Newton-Raphson method.

**Solution of a system of linear equations:** Gauss elimination with and without pivoting, LU decomposition, Ill-conditioned equations, Gauss- Jacobi method, Gauss-Seidel method, Jacobi method to find eigenvalues.

**Interpolation:** Lagrange's interpolation, Newton's divided difference interpolation (forward, backward), Newton-Gregory formulae, Sterling's formula.

**Numerical Differentiation:** Numerical differentiation with forward, backward, and central differences.

**Numerical integration:** Newton-Cotes (closed type formulae)-trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. Gaussian Quadrature (Legendre and Chebyshev cases)

**Solution of Ordinary differential equations:** Initial value problems: Single step methods; Taylor's, Euler's, Runge-Kutta methods, error analysis; System of IVPs and higher order IVPs.

**Learning Resources:**

Text Books:

1. M.K. Jain, SRK Iyengar and R.K Jain, Numerical Methods for Engineers and Scientists, New Age International, 2018.
2. F.B.Hildebrand, Introduction to Numerical Analysis, Dover Publications Inc, 2003.

Reference Books:

1. S.S.Sastry, Introductory Methods of Numerical Analysis, Prentice Hall of India, 2012.
2. S.D. Conte and C. de Boor, Elementary Numerical Analysis: An Algorithmic Approach, Mc-GrawHill, 2005.

**MA26003** **3-0-0 (3)**

# Computer Programming & Data Structures in Python

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| CO-1 | Introduce the fundamental concepts of Python. |
| CO-2 | provides a foundation for using the basic building blocks of Python. |
| CO-3 | Learn to write Python Scripts. |
| CO-4 | Explore various exception-handling mechanisms. |
| CO-5 | Develop Python packages. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | 1 | – | – | – | – |
| **CO-2** | 2 | 2 | – | – | – | – |
| **CO-3** | 2 | 2 | | 1 | – | – |
| **CO-4** | 3 | 2 | 2 | 2 | – | – |
| **CO-5** | 2 | 3 | 2 | 3 | 1 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction to Python:** Python variables, Python basic Operators, Python Data Types, variables, Declaring and using Numeric data types: int, float etc., Basic Input-Output Operations, Basic Operators.

**Conditionals and loops:** Boolean Values, if, else, and else if, Simple for loops in Python, for loop using ranges, string, lists, and dictionaries. Use while loops in Python, Loop manipulation using pass, continue, break and else.

**Strings:** Assigning values in strings, String manipulations, String special operators, String formatting operators, Triple Quotes, Raw String, Unicode String, Build-in-String methods.

**Lists:** Lists Introduction, accessing values in a list, List manipulations, List Operations, Indexing, slicing & matrices, use of tuple data type. string, list, and Dictionary, string manipulation methods, programming using string, list, and dictionary in-built functions.

**Functions:** Built–in Functions and methods, Functions, writing functions in Python, returning a result from a function, Pass by value & pass by reference, function arguments & their types, recursive functions.

**Python packages:** Simple programs using the built-in functions of packages: matplotlib, numpy, pandas etc.

**Learning Resources:**

Text Books:


1. William Mitchell, Povel Solin, Martin Novak etal., Introduction to Python Programming, NCLab Public Computing, 2012.
2. Introduction to Python Programming, C. Jacob Fredslund, 2007.


Reference Books:


1. John C. Lusth, An Introduction to Python, The University of Alabama, 2011.
2. Introduction to Python, Dave Kuhlman, 2008.

**MA26005** **0-1-2 (2)**

# CPDS with Python Lab

**Pre-Requisites: MA26003**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the basics of Python programming. |
| **CO-2** | Design and test programs to solve mathematical and scientific problems |
| **CO-3** | Develop and test programs using control structures |
| **CO-4** | Implement modular programs using functions |
| **CO-5** | Develop packages |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | – | – | – | 1 |
| **CO-2** | 3 | 3 | 2 | 3 | 3 | 3 |
| **CO-3** | 3 | 3 | 2 | 3 | 2 | 3 |
| **CO-4** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO-5** | 3 | 3 | 2 | 3 | – | – |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

## Syllabus:

Programs using

1. Conditional control constructs
2. loops
3. Strings
4. Lists
5. user defined functions and library functions
6. built-in functions of packages matplotlib
7. numpy
8. pandas

## Learning Resources:

### Text Books:

1. William Mitchell, Povel Solin, Martin Novak et al., Introduction to Python Programming, NCLab Public Computing, 2012.
2. Introduction to Python Programming, ©Jacob Fredslund, 2007.

### Reference Books:

1. John C. Lusth, An Introduction to Python, The University of Alabama, 2011.
2. Introduction to Python, ©Dave Kuhlman, 2008.

**MA26007** **0-1-2 (2)**

# Computational Methods using MATLAB Lab

**Pre-Requisites**: **MA26001**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Develop programs for computational problems |
| **CO-2** | Write programs for algebraic and transcendental equations |
| **CO-3** | Write the programs to solve a system of linear equations |
| **CO-4** | Write programs for the numerical approximation of a definite integral |
| **CO-5** | Write programs for the solution of initial value problems |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 1 | 3 | 2 | 2 | 2 | 2 |
| **CO-2** | 2 | 3 | 2 | 3 | 2 | 1 |
| **CO-3** | 2 | 3 | 2 | 3 | 2 | – |
| **CO-4** | 3 | 2 | 2 | 2 | 1 | – |
| **CO-5** | 2 | 3 | 2 | 3 | 1 | – |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

## Syllabus:

Write programs for the following using MATLAB

1. Method of successive bisection
2. Method of false position
3. Newton-Raphson iterative method
4. Secant method
5. Gauss elimination method
6. Gauss-Seidel iterative method
7. Lagrange interpolation
8. Linear regression
9. Polynomial regression
10. Simpson’s rule
11. Euler’s method
12. Taylor series method
13. Runge-Kutta method of second and fourth order formulae

**Learning Resources:**

Text Books:
1. M.K. Jain, SRK Iyengar and R.K Jain, Numerical Methods for Engineers and Scientists, New Age International, 2018.
2. Cleve Moler, Numerical Computing with MATLAB, SIAM, 2004.

Reference Books:
1. Steven Chapra, Applied Numerical Methods W/Matlab, McGraw Hill Education, 2017, Third edition.
2. Tadeusz StyŚ, Lecture Notes in Numerical Analysis with Mathematica, Bentham Science Publishers, 2018.

# $2^{nd}$ Semester

**MA16002** **4-0-0 (4)**

# Probability and Statistics

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Determine the mean, standard deviation and $m^{th}$ moment of a probability |
| **CO-2** | Apply theoretical model to fit the empirical data |
| **CO-3** | Differentiate between Large and small sample tests |
| **CO-4** | Use the method of testing of hypothesis for examining the validity of a hypothesis |
| **CO-5** | Estimate the parameters of a population from knowledge of statistics of a sample |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | 3 | 3 | 1 | 1 | 2 |
| **CO-2** | 2 | 3 | 3 | 1 | 1 | 2 |
| **CO-3** | 2 | 3 | 3 | – | – | 2 |
| **CO-4** | 3 | 3 | 2 | – | – | 1 |
| **CO-5** | 2 | 3 | 1 | – | 2 | 3 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Random variables**: Review of probability; Probability distributions with discrete and continuous random variables - Joint probability mass function, Marginal distribution function, Joint density function - Independent random variables - Mathematical Expectation - Moment generating function - Chebyshev's inequality - Weak law of large numbers - Bernoulli trials

**Theoretical Probability Distributions:** Binomial, Negative Binomial, Geometric, Poisson, Normal, Rectangular, Exponential, Gaussian, Beta and Gamma distributions and their moment generating functions; Fit of a given theoretical model to an empirical data.

**Sampling and Testing of Hypothesis:** Introduction to testing of hypothesis - Tests of significance for large samples - t, F and Chi-square tests; ANOVA - one-way and two-way classifications.

**Correlation and Regression:** Scatter diagram - Linear and polynomial fitting by the method of least squares - Linear correlation and linear regression - Rank correlation - Correlation of bivariate frequency distribution.

## Learning Resources:

Text Books:


1. S.C. Gupta and V.K. Kapur, Fundamentals of Mathematical Statistics, S.Chand & Sons, New Delhi, 2008.
2. V.K. Rohatgi and A.K. Md. Ehsanes Saleh, An Introduction to Probability theory and Mathematical Sciences, Wiley, 2001.


Reference Books:


1. Richard A. Johnson, Miller and Freund's Probability and Statistics for Engineers, Pearson, 2018, Ninth Edition.
2. J. S. Milton and J. C. Arnold, Introduction to Probability and Statistics, McGraw Hill, 2017, Fourth edition.

**MA16004** **3-0-0 (3)**

# Partial Differential Equations

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Solve linear and nonlinear first order partial differential equations |
| **CO-2** | Demonstrate the concept of characteristic curves and characteristic strips |
| **CO-3** | Solve higher order partial differential equations with constant coefficients |
| **CO-4** | Find canonical forms of second order partial differential equations |
| **CO-5** | Utilize the knowledge of PDES in solving various physical problems |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 3 | – | – | 2 |
| **CO-2** | 3 | 2 | 2 | – | – | 1 |
| **CO-3** | 3 | 3 | 3 | – | – | 2 |
| **CO-4** | 3 | 1 | 2 | – | – | – |
| **CO-5** | 3 | 3 | 3 | – | – | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Equations of the First Order**: Formulation; Classification of first order partial differential equations (PDEs); Lagrange's method, Cauchy problem, and method of characteristics for linear and quasilinear PDEs; Paffian equation, Condition for integrability; First order non-linear equations, Complete integrals, Envelopes and singular solutions, Method of Charpit and Method of characteristics.

**Equations of higher order**: Method of solution for the case of constant coefficients; Classification of second order equations; Reduction to canonical forms; Method of solution by separation of variables.

**Wave equation**: d'Alembert solution of the wave equation, Domain of dependence and range of influence; Method of separation of variables; Inhomogeneous wave equation, Duhamel's principle.

**Diffusion equation**: Fundamental solution of heat equation, Method of separation of variables, Solutions of heat equation with homogeneous and non-homogeneous boundary conditions; Inhomogeneous heat equation, Duhamel's principle.

**Laplace's equation**: Basic concepts; Types of boundary value problems; The maximum and minimum principles; Boundary value problems; Method of separation of variables, green function solution.

**Learning Resources:**

Text Books:

1. I. Sneddon, Elements of Partial Differential Equations, Dover Publications, 2006, First Edition.
2. Tyn Myint-U and Lokenath Debnath, Birkhauser, Linear Partial Differential Equations for Scientists and Engineers, Birkhäuser Boston, MA, 2007, Fourth Edition.

Reference Books:

1. P. Prasad and R. Ravindran, Partial Differential Equations, New Age International (P) Ltd., New Delhi, 2010.
2. T. Amaranath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2003, Second Edition.

**MA26002** **3-0-0 (3)**

# Object Oriented Programming with C ++

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Implement programs using classes and objects |
| **CO-2** | Able to understand the overloading concept |
| **CO-3** | Specify the forms of inheritance and use them in programs |
| **CO-4** | Analyze polymorphic behavior of objects |
| **CO-5** | Understand virtual functions and polymorphism |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | – | 2 | 2 | – | 2 | – |
| **CO-2** | 1 | – | 2 | – | 2 | 1 |
| **CO-3** | 1 | – | 2 | – | 2 | 1 |
| **CO-4** | 1 | 2 | 2 | 1 | 2 | 1 |
| **CO-5** | 1 | 2 | 1 | 1 | 2 | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Basic concepts:** Concept of C++; Object oriented languages – Applications of OOP.

**Classes and Objects:** C++ Program with class-Nesting of member functions-private member functions-Arrays within a class- memory allocation for objects-Static data members-Arrays of objects-objects as Function arguments - Friend functions, inline function, Returning objects.

**Constructors and Destructors** - Multiple constructors in class-Constructors with default arguments copy constructor-Dynamic constructors.

**Overloading:** Overloading unary operators-overloading binary operators-overloading binary operators using Friends - Rules for overloading operators – function overloading, Type conversions.

**Inheritance:** Defining derived classes-Single inheritance - Multilevel inheritance - Multiple inheritance - Hierarchical inheritance -Virtual base classes – Abstract classes, Pointers, Virtual functions and Polymorphism.

**Learning Resources:**

Text Books:

1. Robert Lafore, Object-Oriented Programming in C++, Sams, 2001, Fourth Edition.
2. E. Balaguruswamy, Object oriented programming with C++, Tata McGraw Hill, 2008, Fourth Edition

Reference Books:

1. Barkakati Nabajyoti, Object-Oriented programming in C++, PHI, 1991.
2. Stroustroup Bjarne, The C++ Programming Language, Addison-Wesley,1991.

**MA26004** **0-1-2 (2)**

# Statistics with R Lab

**Pre-Requisites: MA1602**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | To determine the probabilities of sample mean using central limit theorem and to estimate confidence interval. |
| **CO-2** | To perform z-test for sampling distribution |
| **CO-3** | To analyze t-test and F-test for sampling distribution |
| **CO-4** | To perform -test and Analysis of variance (ANOVA) |
| **CO-5** | To calculate correlation and regression for given data |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-2** | 2 | 3 | 3 | 3 | 2 | 2 |
| **CO-3** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-4** | 2 | 3 | 2 | 3 | 2 | 2 |
| **CO-5** | 3 | 3 | 3 | 2 | 2 | 2 |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

## Syllabus:

Write a **R** program to

1. find measures of central tendency
2. perform different operations on Matrices
3. store data into a List and perform different operations
4. store data into Data frame and perform different operations
5. find sum of elements of vector
6. find factorial of a number using recursion
7. find mean, variance, standard deviation for the given discrete probability distribution
8. find mean, variance, standard deviation for the given continuous probability distribution
9. represent the given data in the form of graphs using built in functions
10. fit Binomial distribution to the given data
11. fit Poisson distribution to the given data
12. $Z$ test, $t$ test
13. F test
14. perform ANOVA of one way and two way classifications to test on the basis of sample observations whether the means of 3 or more populations are equal or not.
15. fit a linear regression and multiple linear regression

## Learning Resources:

### Text Books:


1. K.G. Srinivasa, G.M. Siddesh, Chetan Shetty, B.J. Sowmya, Statistical Programming in R, Oxford University Press, 2017, First Edition
2. Jenine K. Harris, Statistics With R, Solving Problems Using Real-World Data, SAGE Publications, 2020.

**MA26006** **0-1-2 (2)**

# OOP WITH C ++ LAB

**Pre-Requisites: MA26002**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Ability to develop applications for physical applications using OOP techniques |
| **CO-2** | Able to understand the overloading concept |
| **CO-3** | Specify the forms of inheritance and use them in programs |
| **CO-4** | Analyze polymorphic behaviour of objects |
| **CO-5** | Understand virtual functions and polymorphism |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-2** | 2 | 3 | 3 | 3 | 2 | 2 |
| **CO-3** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-4** | 2 | 3 | 2 | 3 | 2 | 2 |
| **CO-5** | 3 | 3 | 3 | 2 | 2 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

Write a C++ program to illustrate

1. nesting of member functions
2. memory allocation for objects
3. objects as function arguments
4. friend functions, inline functions
5. constructors with default arguments
6. copy and dynamic constructors.
7. overloading unary and binary operator, friend functions
8. Function overloading
9. type conversions
10. single, multilevel, multiple and hierarchical inheritance
11. virtual base and abstract classes.

## Learning Resources:

Text Books:

1. Michael H. Goldwasser, Michael T. Goodrich, Roberto Tamassia, Data structures and algorithms in Python, Wiley, 2013.
2. Narasimha Karumanchi, Data Structures and Algorithmic Thinking with Python, CareerMonk Publications, 2015.

Reference Books:

1. Adam Drozdek Thomson, Data Structures and Algorithm in C++, VikasPublications, 2013.
2. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Data Structures & Algorithms, Pearson, 2002.

# 3rd Semester

**MA27001** **4-0-0 (4)**

# Database Management Systems

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Identify the functional components of database management system with the development of E-R model for real world applications |
| **CO-2** | Construct the queries using Relational Algebra, Relational Calculus and SQL |
| **CO-3** | Apply the concepts of SQL and its use to construct the databases |
| **CO-4** | Design the relational databases using various normal forms and integrity constraints |
| **CO-5** | Interpret the concepts of authorization, transfer of privileges, and query processing |

**Course Articulation Matrix:**

| | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** | **PO-6** |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | – | 2 | – | – |
| **CO-2** | 3 | 3 | 1 | 3 | 3 | 1 |
| **CO-3** | 3 | 3 | 1 | 3 | – | 1 |
| **CO-4** | 2 | 3 | 3 | 2 | – | – |
| **CO-5** | – | – | 3 | 2 | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction**: Purpose of Database systems, Data independence, Data models, Database languages, Data storage, Querying and Time management, Database users, and administrators.

**Entity-Relation Model**: Entities, Entities and relationships, Mapping constraints, E-R diagrams; Extended entity-relationship features: Specialization, Generalization, and Aggregation; Design of E-R database scheme.

**Relational Model**: Structure of relational database, Relational algebra; Extended relational-algebra operations; Modifying the database and views; Tuple relational calculus; Domain relational calculus.

**Relational Commercial Languages**: SQL, QBE, and QUEL.

**Integrity Constraints**: Domain constraints, Referential integrity, Assertions, Triggers, Functional dependencies.

**Relational Database Design**: Pitfalls in relational database design, First, Second, Boyce-Codd, Third, Fourth and Fifth normal forms.

**Security and Integrity**: Security and integrity violations, Transfer of privileges, Authorization on views and schema.

**Query Processing**: Overview of query processing, Structure of query optimizer.

## Learning Resources:

Text Books:

1. A. Silberschatz, H.F. Korth, and S. Sudarshan, Database System concepts, McGraw Hill, NewYork, Seventh Edition, 2021.
2. R. Ramakrishnan, and J. Gehrke, Database Management Systems, McGraw Hill, Third Edition, 2014.

Reference Books:

1. Jeffery D. Ullman, Galgotia, Principles of Database Systems, Third Edition, 1994.
2. E. Ramez, N. Shamkant, Fundamentals of Database System, Pearson, Seventh Edition, 2017.

Online Resources:

1. https://www.youtube.com/watch?v=IoL9Ve2SRwQ&list=PL3pGy4HtqwD3Ov1J2UBTfsLgxUzUktTAM
2. https://www.youtube.com/watch?v=bGyHqvQW6JY&list=PLwZJjHGjgrZqJ9yQZ-WJb5gBJcKMr9iXP

**MA27003** **3-0-0 (3)**

# Numerical Optimization

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Formulate a LPP and understand graphical solution |
| **CO-2** | Determine the solution of a LPP by simplex methods |
| **CO-3** | Application of post optimality analysis |
| **CO-4** | Solution of transportation and assignment problems |
| **CO-5** | Determine the solution of I LPP |
| **CO-6** | Apply search techniques to unconstrained optimization problems. |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | 3 | – | – | 2 |
| **CO-2** | 2 | 2 | 3 | – | – | 1 |
| **CO-3** | 2 | 2 | 3 | 2 | 2 | 2 |
| **CO-4** | 3 | 2 | 2 | 1 | – | 1 |
| **CO-5** | 3 | 2 | 3 | – | – | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Linear Programming**: Lines and hyperplanes - convex sets, convex hull - Formulation of a Linear Programming Problem - Theorems dealing with vertices of feasible regions and optimality - Graphical solution - Simplex method (including Big-M method and two-phase method) - Revised simplex method - Dual problem - Duality theory - Dual simplex method – Post optimality analysis.

**Transportation problem:** Existence of solution - Degeneracy - MODI method (including the theory). Assignment problem, Travelling Salesman Problem.

**Integer Programming**: Gomory's cutting plane method for an all integer linear programming problem and a mixed integer linear programming problem.

**Dynamic programming:** Principle of optimality, Recursive relations, Solution of LPP, Simple examples.

**One-dimensional search methods:** Sequential search, Fibonacci search and Golden section search.

**Multi-dimensional search methods:** Gradient methods (Steepest descent/ascent methods), Conjugate gradient method (Fletcher-Reeves's method).

## Learning Resources:

Text Books:

1. H. A. Taha, Operations research: an introduction, Pearson Education Limited, 2017, Tenth Edition.
2. M. S. Bazaraa, H. D. Sherali, & C. M. Shetty, Nonlinear programming: theory and algorithms, John Wiley & Sons, 2013, Third Edition.
3. M. S. Bazaraa, J. J. Jarvis, & H. D. Sherali, Linear programming and network flows, John Wiley & Sons, 2009, Fourth Edition.

Reference Books:


1. J.C. Pant, Introduction to Optimization: Operations Research, Jain Brothers, 2007, Seventh Edition.
2. E. K. Chong, & S. H. Zak, An introduction to optimization, John Wiley & Sons, 2004, Second Edition.
3. S. S. Rao, Engineering optimization: theory and practice, John Wiley & Sons, 2019, Fifth Edition.

**MA27005** **0-1-2 (2)**

# DBMS Lab

Pre-Requisites: MA27001

Course Outcomes:

| | |
|---|---|
| **CO-1** | Create the queries using DDL and DML commands |
| **CO-2** | Construct the queries using the relational constraints, joins, set operations, and aggregate functions |
| **CO-3** | Implement the integrity constraints on various databases |
| **CO-4** | Create queries using various data types |
| **CO-5** | Develop the queries using triggers and assertions |

Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-2** | 2 | 3 | 3 | 3 | 2 | 2 |
| **CO-3** | 3 | 2 | 2 | 3 | 2 | 2 |
| **CO-4** | 2 | 3 | 2 | 3 | 2 | 2 |
| **CO-5** | 3 | 3 | 3 | 2 | 2 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction to SQL**: DDL, DML, DCL Statements, Built-in Functions and Aggregate Functions, Sub Query, Nested Sub Queries, Modification of the Database.

**Intermediate SQL**: Join Expressions, Views, Integrity Constraints, SQL Data Types and Schemes, Authorization.

**Advanced SQL**: Triggers and Assertions.

PL/SQL, Data types, Control Structures, Error handling mechanism, Subprograms (procedures and functions), Stored procedures, Data base triggers and exception.

## Learning Resources:

Text Books:

1. Silberschatz, H.F. Korth, and S. Sudarshan, Database System concepts, McGraw Hill, NewYork, Seventh Edition, 2021.
2. R. Ramakrishnan, and J. Gehrke, Database Management Systems, McGraw Hill, Third Edition, 2014.

Reference Books:

1. Jeffery D. Ullman, Galgotia, Principles of Database Systems, Third Edition, 1994.
2. E. Ramez, N. Shamkant, Fundamentals of Database System, Pearson, Seventh Edition, 2017.

**MA27007** **0-1-2 (2)**

# Numerical Optimization Lab

**Pre-Requisites: MA1703**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Write a program to solve an LPP by simplex method. |
| **CO-2** | Write a program to solve an LPP by Big-M method. |
| **CO-3** | Write a program to solve an LPP by two-phase method. |
| **CO-4** | Write a program to solve an LPP by revised simplex method. |
| **CO-5** | Write a program to solve a transportation problem and an assignment problem. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO-2** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO-3** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO-4** | 1 | 3 | 2 | 3 | 2 | 2 |
| **CO-5** | 1 | 3 | 2 | 3 | 2 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

Simple programs dealing with fundamentals of C/C++ language for

1. Simplex method
2. Big-M method
3. Two-phase method
4. Revised simplex method
5. Dual simplex method
6. Solution of a transportation problem by north west corner rule
7. Initial basic feasible solution for a transportation problem by Vogel's approximation method
8. Assignment problem

**Learning Resources:**

References:


1. Kenneth Lange, Optimization, Springer, 2013, 2nd Edition.
2. Richard Bellman, Mathematical Optimization Techniques, University of California Press, 2022.

**MA27091** **0-0-0 (2)**

# Seminar and Technical Writing

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Consolidate ideas based on expert talks attended |
| **CO-2** | Prepare a well-organized report employing elements of critical thinking and technical writing |
| **CO-3** | Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | 2 | – | – | 3 |
| **CO-2** | 2 | – | 2 | – | – | 3 |
| **CO-3** | 2 | – | 2 | – | – | 3 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

**Description:**

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

**Evaluation Criteria:**

**The student will be evaluated by the panel based on the below criteria.**

| Criteria | Description | Weightages |
|---|---|---|
| I | Clarity on the topic | |
| II | List of lectures attended | |
| III | Report | |
| IV | Presentation | |
| V | Response to questions | |

**Evaluation Criteria-CO Mapping**

| Criteria \ CO | CO1 | CO2 | CO3 |
|---|---|---|---|
| I | X | | |
| II | X | | |
| III | | X | |
| IV | | | X |
| V | | | X |

**MA27093** **0-0-0 (2)**

# Short-term Industrial/ Research Experience

**Pre-Requisites:** None

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Apply engineering principles to real-world problems, gaining practical experience |
| **CO-2** | Plan, manage and execute the work with ethical consideration |
| **CO-3** | Review the social and environmental impact of the work |
| **CO-4** | Communicate the learnings through report and presentation |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 3 | 3 | 3 | -- |
| **CO-2** | 2 | 2 | 2 | 2 | 2 | -- |
| **CO-3** | -- | -- | -- | -- | -- | 3 |
| **CO-4** | -- | -- | -- | -- | -- | |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

**Description:**

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

**Evaluation Criteria:**

**The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.**

| Criteria | Description | Weightages |
|---|---|---|
| I | Relevance of the area of work | |
| II | Performance of the Task | |
| III | Crucial learnings from the work | |
| IV | Report Preparation | |
| V | Presentation and Response to questions | |

**Evaluation Criteria-CO Mapping**

| Criteria \ CO | CO1 | CO2 | CO3 | CO4 |
|---|---|---|---|---|
| I | X | | | |
| II | | X | | |
| III | | | X | |
| IV | | | | X |
| V | | | | X |

# 4th Semester

**MA27094** **0-0-4 (2)**

# Comprehensive Viva-Voce

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Comprehend the knowledge gained in the course work |
| **CO-2** | Demonstrate the ability in problem solving |
| **CO-3** | Communicate effectively using engineering terminology |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 3 | 3 | - | - |
| **CO-2** | 3 | 3 | 3 | 3 | - | - |
| **CO-3** | 2 | 2 | 2 | 2 | - | - |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

### Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

**MA27098** **0-0-16 (8)**

# Dissertation

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Identify the materials and methods for carrying out experiments/develop a code. |
| **CO-2** | Execute the research methodology with a concern for society, environment and ethics |
| **CO-3** | Analyse, discuss and justify the results/trends and draw valid conclusions. |
| **CO-4** | Prepare the report as per recommended format and present the work orally adhering to stipulated time. |
| **CO-5** | Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism. |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | - | 3 | 3 | 2 | 3 |
| **CO-2** | 2 | - | 3 | 3 | 2 | 3 |
| **CO-3** | 3 | - | 3 | 3 | 2 | 3 |
| **CO-4** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO-5** | 3 | 3 | 3 | - | - | 3 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

**Description:**

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

**Dissertation Evaluation:**

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation will be evaluated for 100 marks, with the following weightages:

| **Sub-component** | **Weightage** |
|---|---|
| a) Periodic evaluation by Guide | 40 marks |
| b) Mid-term review | 20 marks |
| c) End Semester viva-voce examination | 40 marks |

The midterm review will be conducted by a committee constituted by the Head of the Department. The end semester examination will be conducted by an External Examiner along with the evaluation committee constituted by the Head of the Department.

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## Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

| Task | Description | Weightages |
|---|---|---|
| IV | Performance of the Task | |
| V | Dissertation Preparation | |
| VI | Review (Presentation & Understanding) | |
| VII | Viva-Voce | |
| VIII | Publications /Possibility of publication | |

## Evaluation Criteria-CO Mapping:

| Criteria \ CO | CO1 | CO2 | CO3 | CO4 | CO5 |
|---|---|---|---|---|---|
| IV | X | X | | | |
| V | | | | X | |
| VI | | | X | | |
| VII | | | | X | |
| VIII | | | | | X |

Refer to PG – regulations for any further information regarding Mid-Term review, End-Sem evaluation, template for report preparation and Plagiarism.

# Professional Elective – I

**MA26021** **3-0-0 (3)**

# Numerical Linear Algebra

**Pre-Requisites**: **None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the basic concepts of linear algebra related to stability, accuracy, etc., |
| **CO-2** | Find the QR factorization of a matrix using Householder transformation and study its applications. |
| **CO-3** | Write various algorithms to solve a system of linear equations to understand computational issues. |
| **CO-4** | Describe the numerical procedure of the eigenvalue problem. |
| **CO-5** | Apply the SVD of a matrix in solving real-life problems. |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | – | 2 | – | – | 1 |
| **CO-2** | 3 | – | 2 | – | – | 1 |
| **CO-3** | 3 | 3 | 2 | – | – | 1 |
| **CO-4** | 3 | – | 2 | – | – | 2 |
| **CO-5** | 3 | – | 2 | – | – | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Review of linear algebra concepts**: Vector and Matrix norms and norm-preserving properties of orthogonal matrices; Linear transformations, rank, basis.

**Transformations in numerical linear algebra and their applications**: Elementary matrices, Householder transformation with applications to LU, QR factorizations, and Hessenberg-reduction. Orthonormal bases and orthogonal projections.

**Numerical Solutions of Linear Systems**: QR factorizations with growth factors and stability; estimation of the condition numbers; iterative methods: Jacobi and Gauss-Seidel methods and their convergence; Least-squares Solutions to Linear Systems: existence and uniqueness, Normal equations; Pseudo Inverse; QR factorization methods for overdetermined systems.

**Numerical Matrix Eigenvalue Problems**: Gershgorin disk theorem, the Power method, the Inverse Power methods & Rayleigh Quotient Iteration; Basic and Hessenberg QR iterations.

**The Singular Value Decomposition**: Properties and applications of SVD.

**Learning Resources**:

Text Books:

1. Biswa Nath Datta**,** Numerical Linear Algebra and Applications, Prentice Hall India/SIAM, 2010/2013, Second Edition.
2. Carl D. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2000.

Reference Books:

1. David Kincaid and Ward Cheney,Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Society, 2002.
2. V. Sundarapandian, Numerical Linear Algebra, Prentice Hall India, 2014.

**MA26023** **3-0-0 (3)**

# Java Programming

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Introduce the fundamental concepts of Java |
| **CO-2** | Provides a foundation for using basic concepts in Java |
| **CO-3** | Learn to write Java Scripts |
| **CO-4** | Explore various Exception-handling mechanisms |
| **CO-5** | Provide the basic knowledge of using Java with OOP terminology |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | – | 2 | – | – |
| **CO-2** | 3 | 2 | – | 2 | – | – |
| **CO-3** | 2 | 2 | 2 | 2 | – | – |
| **CO-4** | 2 | 2 | 1 | 2 | 1 | – |
| **CO-5** | 2 | 1 | 1 | 1 | 1 | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Java Basics**: History of Java, Java buzzwords, comments, data types, variables, constants, scope and lifetime of variables, operators, operator hierarchy, expressions, type conversion and casting, enumerated types, control flow-block scope, conditional statements, loops, break and continue statements, simple java program, arrays, input and output, formatting output.

**Inheritance:** The inheritance concept, benefits of inheritance, Super classes, and subclasses, Member access rules, Inheritance hierarchies, super use, preventing inheritance: final classes and methods, casting, polymorphism—dynamic binding, method overriding, abstract classes and methods, and the Object class and its methods.

**Interfaces**: Interfaces vs. Abstract classes, defining an interface, implementing interfaces, accessing implementations through interface references, extending interface.

**Files: Files:** streams- byte streams, character streams, text Input/output, binary input/output, random access file operations, File management using File class, Using java.io.

**Networking:** Networking in Java – Introduction, Manipulating URLs, Ex. Client/Server Interaction with Stream Socket Connections, Connectionless Client/Server Interaction with Datagrams, Using java.net.

**Exception handling:** Dealing with errors, benefits of exception handling, the classification of exceptions-exception hierarchy, checked exceptions and unchecked exceptions, usage of try, catch, throw, throws, and finally, rethrowing exceptions, exception specification, built-in exceptions, creating own exception subclasses, Guidelines for proper use of exceptions.

**Learning Resources:**

Text Books:

1. Cay S. Horstmann and G. Cornell, Core Java, Volume 1-Fundamentals, Pearson, 2013, Ninth Edition.
2. H. Schildt, Java: the complete reference, McGraw Hill, 2022, 12th Edition.

Reference Books:

1. D.S. Malik, Java Programming, Cengage Learning, 2009.
2. E. Balagurusamy, Programming with Java, Mc Graw Hill, 2023, Seventh Edition.

**MA26025** **3-0-0 (3)**

# Elements of Data Science

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Analyze the basics of data science |
| **CO-2** | Apply Principal Component Analysis |
| **CO-3** | Analyze spectral clustering |
| **CO-4** | Compute dimension reduction and clustering of random graphs |
| **CO-5** | Apply approximation algorithms |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | – | 2 | 3 | – | 2 |
| **CO-2** | 3 | – | 2 | 2 | – | 1 |
| **CO-3** | 2 | – | 2 | 2 | – | – |
| **CO-4** | 2 | – | 2 | 3 | – | 1 |
| **CO-5** | 3 | – | 2 | 2 | – | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction and Algebra:** Introduction of Data Science, Visualization of data, Resampling, Distributions, Linear Model & Bayesian Model, Simple examples, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients, Backpropagation and Automatic Differentiation.

**Statistics:** Parameter Estimation, Bayesian Linear Regression, Maximum Likelihood as Orthogonal Projection, Principal Component Analysis (PCA), Spectral Clustering, Cheeger's inequality, Concentration of measure and tail bounds in probability. Dimension reduction through Johnson-Lindelstrauss Lemma and Gordon's Escape through a Mesh Theorem.

**Graph Theory:** Approximation algorithms in Theoretical Computer science and the Max-cut problem, Clustering of random graphs: Stochastic Block model, Synchronization, Inverse problems on graphs.

**Optimization:** Continuous Optimization, Basics of duality in Optimization, Convex Optimization.

## Learning Resources:

Text Books:

1. Joel Grus, Data Science from scratch, O'Reilly Media, 2015.
2. Murtaza Haider, Getting Started with Data Science, IBM Press, 2016

Reference Books:

1. Lillian Pierson, Data Science for Dummies, Wiley, Second Edition, 2017.
2. J Koponen & J Hidden, Data Visualization Handbook, CRC Press, 2019.

# Professional Elective – II

## MA26022 3-0-0 (3)

# Mathematical Foundations of Computer Science

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Apply Propositional and first-order logic to determine the statement's validity |
| **CO-2** | Construct induction proofs involving summations, inequalities, and divisibility |
| **CO-3** | Implement principles of counting, permutations, and combinatory to solve real-world problems. Formulate and solve recurrence relations |
| **CO-4** | Determine whether a given relation is an equivalence relation/poset and will be able to draw a Hasse diagram. |
| **CO-5** | Develop and analyse the concepts of Boolean algebra |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | – | 2 | – | – |
| **CO-2** | 1 | 2 | 2 | – | – | – |
| **CO-3** | – | 2 | 2 | 3 | – | – |
| **CO-4** | 1 | 2 | – | 2 | – | 3 |
| **CO-5** | 2 | 1 | – | 1 | – | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Mathematical Logic:** Connectives, Tautologies, the equivalence of formulas, duality law, tautological implications, normal forms, theory of inference for statement calculus, methods of proof, predicative logic, statement functions, variables, and quantifiers, free and bound variables, and inference theory for predicate calculus.

**Counting:** Basics of counting, Permutations, and combinations - Generalized Permutations and combinations – Pascal's Identity- Vandermonde's Identity, the Principles of Inclusion–Exclusion, Pigeonhole Principle, and Application.

**Recurrence relations:** Generating functions, Generating Functions of Permutations and Combinations, Formulation as Recurrence Relations, Solving Recurrence Relations by Substitution and Generating Functions, Method of Characteristic Roots, Solving Inhomogeneous Recurrence Relations – Applications of recurrence relations.

**Relations:** Binary relations - Properties of binary relations, equivalence relations and partitions, Matrix Representation of relations, Adjacency Matrices, Incidence Matrices, Transitive closure and Warshal's algorithm, Partial and total ordering relations.

**Boolean Algebra:** Chains, Lattices, the principle of duality, basic properties of lattices, distributive and complemented lattices, Boolean lattices and algebras, uniqueness of finite Boolean algebras, Boolean expressions, and functions - Representation and Minimizations of Boolean functions.

**Learning Resources:**

Text Books:

1. J. R. Mott, A. Kandel and Baker, Discrete Mathematics for Computer Scientists, PHI, 2006, Third Edition.
2. C.L. Liu, Elements of Discrete Mathematics, McGraw Hill, 2017, Fourth Edition.

Reference Books:

1. J. P. Tremblay and R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw Hill Book Co., 2017.
2. Bernand Kolman, Robert C. Busby, Sharon Cutler Ross, Discrete Mathematical Structures, PHI, 2008, Sixth Edition.

**MA26024** **3-0-0 (3)**

# Perturbation Methods

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Solve perturbation problems in differential equations |
| **CO-2** | Understand boundary layer in fluid flow problems |
| **CO-3** | Understand regular and singular perturbation theory |
| **CO-4** | Use asymptotic expansions to solve perturbation problems |
| **CO-5** | Learn the uniqueness of conformal transformation |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 3 | – | – | 2 |
| **CO-2** | 3 | 2 | 3 | – | – | 2 |
| **CO-3** | 3 | 2 | 3 | – | – | 1 |
| **CO-4** | 3 | 1 | 2 | – | – | 2 |
| **CO-5** | 3 | 2 | 2 | – | – | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction:** Parameter perturbations, Coordinate perturbations, Order symbols, Gauge functions, Asymptotic expansions, sequences, Convergent versus asymptotic series, Nonuniform expansions, and Elementary operations on asymptotic expansions.

**Straightforward expansions and sources of nonuniformity**: Infinite domains, A small parameter multiplying the highest derivative. Type change of partial differential equations, The presence of singularities, and the role of coordinate systems.

**The method of strained coordinates**: The method of strained parameters, Lighthill's technique, Temple's technique, Renormalization technique, Limitations of the method of strained coordinates.

**The methods of Matched and Composite Asymptotic Expansions**: The methods of matched asymptotic and composite asymptotic expansions.

**Variation of Parameters and Methods of Averaging**: Variation of parameters, the method of averaging, Struble's technique, The Krylov-Bogoliubov-Mitropolski technique, the method of averaging by using canonical variables, Von-Zeipel's procedure, averaging by using the Lie series and transforms, averaging by using Lagrangians.

**The method of Multiple Scales**: Description of the method, Applications of the derivative, Expansion method, the two-variable expansion procedure, and the generalized method.

## Learning Resources:

Text Books:

1. E. J. Hinch, Perturbation Methods, Cambridge University Press, 1991.
2. A.H. Nayfeh, Introduction to Perturbation Techniques, John Wiley & Sons, 2014.

Reference Books:

1. Carl M. Bender Steven A. Orszag, Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory, Springer-Verlag New York, First Edition, 1999.
2. J. Kevorkian and J. D. Cole, Perturbation Methods in Applied Mathematics, Springer, New York, 2010.
3. Milton Van Dyke, Perturbation Methods in Fluid Dynamics, Academic Press, 2008.

**MA26026** **3-0-0 (3)**

# Wavelet Analysis

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Expand a function in Haar wavelets |
| **CO-2** | Construct Meyer wavelets to a given function |
| **CO-3** | Find Daubechies wavelet series to a given function |
| **CO-4** | Analyse two or more dimensional problems using wavelets |
| **CO-5** | Study the Convergence properties of wavelet expansions |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 2 | 2 | 2 | 3 |
| **CO-2** | 3 | 3 | 3 | 3 | 2 | 3 |
| **CO-3** | 3 | 3 | 3 | 2 | 3 | 2 |
| **CO-4** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO-5** | 3 | 3 | 3 | 2 | 3 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Haar Wavelets:** Heuristic treatment of the wavelet transform – Wavelet transform – Haar wavelet expansion: Haar functions and Haar series, Haar sums and Dyadic projections, Completeness of the Haar functions, Haar series in $C_0$ and $L^p$ spaces, Pointwise convergence of Haar series, Construction of standard Brownian motion, Haar function representation of Brownian motion.

**Multi-resolution analysis:** Orthogonal systems, Scaling functions, from scaling function to MRA, Meyer wavelets, from scaling function to ortho-normal wavelet; Wavelets with compact support - From scaling filter to scaling function, Explicit representation of compact wavelets, Daubechies recipe, Hernandez-Weiss recipe, Smoothness of wavelets.

**Convergence properties of wavelet expansions:** Wavelet series in $L^p$ spaces, large scale analysis, almost everywhere convergence, Convergence at a pre-assigned point; Wavelets in several variables – A tensor product of wavelets, a general formulation of MRA and wavelets in $R^d$, Examples of wavelets in $R^d$.

## Learning Resources:

Text Books:

1. Mark A. Pinsky, Introduction to Fourier Analysis and Wavelets, Cenage Learning India Pvt. Ltd, 2002.
2. M. V. Altaisky, Wavelets Theory: Applications Implementation, University Press, 2009

Reference Books:

1. Walnut, David F, An Introduction to Wavelet Analysis, Springer Nature Switzerland AG 2021
2. Sabrine Arfaoui, Anouar Ben Mabrouk, Carlo Cattani, Wavelet Analysis Basic Concepts and Applications, Chapman, and Hall/CRC, 2021.

# Professional Elective – III

**MA26028** **3-0-0 (3)**

# Theory of Complex Variables

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Introduce the complex number system in a plane. |
| **CO-2** | Introduce the analyticity of complex functions and study their applications |
| **CO-3** | Evaluate complex integrals and expand complex functions |
| **CO-4** | Determine and classify the zeros and singularities of the complex functions |
| **CO-5** | Learn the analytic continuation along a path |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 2 | – | – | 2 |
| **CO-2** | 3 | 1 | 2 | – | – | 1 |
| **CO-3** | 3 | 2 | 1 | – | – | 2 |
| **CO-4** | 3 | 2 | 3 | – | – | 1 |
| **CO-5** | 3 | 3 | 3 | – | – | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**The Complex Number System:** The field of complex numbers, polar representations, power, roots, complex exponential, complex logarithm, extended complex plane, Riemann sphere and stereographic projection.

**Analytic Functions:** Definitions, Cauchy-Riemann equations, harmonic functions, conformal maps and geometry of Mobius transformations.

**Complex Integration:** Riemann-Stieltjes integration, power series representation of analytic functions, zeros of an analytic function, winding number, Cauchys integral formula, Cauchy estimates and Liouville theorem, Cauchys theorem, Morera's theorem, open mapping theorem, maximum modulus theorem, Schwarzs lemma.

**Singularities:** Classification of singularities, Laurent series, Casorati-Weierstrass theorem, residues, evaluation of definite integrals using residue theorem, meromorphic functions, the argument principle, Rouchs theorem.

**Analytic Continuation:** Schwarz's reflection principle, analytic continuation along a path, Monodromy theorem, Little Picard theorem.

## Learning Resources:

Text Books:

1. R.V. Churchill and J.W. Brown, Complex Variables and Applications, McGraw Hill, Tokyo, 2009, Eighth Edition.
2. John B Conway, Functions of One Complex Variable, Springer, 1978.
3. L. V. Ahlfors, Complex Analysis (3rd Edition), McGraw-Hill, 1979.

References:


1. Rudin, W., Real and Complex Analysis (3rd Edition), McGraw-Hill, 1987..
2. Murray Spiegel, Seymour Lipschutz, John Schiller, and Dennis Spellman, Complex Variable, Schaum's Outlines Series, McGraw Hill, 2017, Revised Second Edition.

**MA26030** **3-0-0 (3)**

# Transformation Techniques

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the concepts of certain integral transforms |
| **CO-2** | Solve differential equations using Laplace transforms |
| **CO-3** | Find the solution for BVPs using Fourier transforms |
| **CO-4** | Solve partial differential equations in cylindrical coordinates using Hankel Transform |
| **CO-5** | Understand the Hilbert transforms and its properties |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | – | – | 1 | 2 |
| **CO-2** | 2 | 1 | – | 2 | – | 2 |
| **CO-3** | – | 1 | 2 | 2 | 1 | 2 |
| **CO-4** | – | – | 2 | – | – | 2 |
| **CO-5** | 2 | 2 | – | – | – | |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Laplace Transforms** Definition - Functions of exponential order and examples of elementary functions, Transcendental and special functions, Transforms of derivatives and Integrals and periodic function, Unit step function, and impulse function. The inverse transforms, Convolution theorem. Solution of ordinary differential equations by the use of the transform. Laplace inverse integral - Solution of Laplace equation (in two dimensions). One-dimensional heat equation and one-dimensional wave equation.

**Fourier transforms:** Fourier transform, Inverse Fourier transform, Fourier transform properties, Convolution integral, convolution theorem, Correlation, correlation theorem, Parseval's theorem, Wave from sampling, sampling theorem, frequency sampling theorem. Solution of ordinary differential equations using the transform.

**Hankel Transforms:** Hankel transform and its properties, Hankel transformation of Orthogonality, Parseval's theorem, Relation to the multidimensional Fourier transform, and Applications to solve partial differential equations.

**Hilbert Transforms**: Introduction, definition, basic properties, Hilbert transforms in complex plane, applications; asymptotic expansions of 1-sided Hilbert transforms.

**Learning Resources:**

Text Books:


1. Gilbert Strang, Introduction to Applied Mathematics, 1986, Wellesley-Cambridge Press.
2. F. B. Hildebrand, Methods of Applied Mathematics,1960, PHI, New Jersey.

Reference Books:

1. Sudhakar Nair, Advanced Topics in Applied Mathematics: For Engineering and the Physical Sciences, 2011, Cambridge University Press.
2. R V Churchill, *Operational Mathematics*, 1972, McGraw Hill.

**MA26032** **3-0-0 (3)**

# Computer Graphics

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the structure of an interactive computer graphics system and the separation of system |
| **CO-2** | Develop and analyses the algorithms for generation lines and polygons |
| **CO-3** | Apply the geometrical transformations to objects |
| **CO-4** | Implement the techniques for segmentation |
| **CO-5** | Differentiate different techniques for windowing and clipping |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | – | – | – | – | – |
| **CO-2** | – | 2 | – | 2 | – | – |
| **CO-3** | – | – | – | – | – | 2 |
| **CO-4** | – | – | – | – | 1 | – |
| **CO-5** | – | – | 3 | – | – | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction:** Pixels and frame buffers - Coordinate systems - vector generation - line drawing and circle generation - algorithms and initializing of lines - thick line segments - character generation - display file and its structure**.**

**Polygons:** Polygon representation - inside test - filling of polygon - 2D Transformations: Matrices - coordinate transformations - rotation about an arbitrary point - other transformations and inverse transformations.

**Segments:** Segment table - operations on segments - image transformation and other display file structures.

**Windowing and Clipping:** The viewing transformations - clipping - the cohen sutherland outcode algorithm - the sutherland Hodgman algorithm - clipping of polygons and multiple windowing.

**3D Transformations:** Rotation about an arbitrary axis - parallel projection - respective projection - Clipping in three dimensions - clipping planes and 3D viewing transformations.

**Hidden surfaces and Lines:** Back face algorithms, Z buffers - scan line algorithms - the painter's algorithms - warnock's algorithm - Franklin algorithm and hidden line methods.

**Shading:** Shading equations - smooth shading - Gouraud and phong shading methods - shadows. Curves and Fractals: Curve generation - interpolation - B-Splines - Benzier curves - fractal lines and fractal surfaces.

**Learning Resources:**

Text Books:

1. S.Harrington, Computer Graphics - A Programming Approach, McGraw Hill, New York, 1983.
2. D.F.Rogers & J.A.Adams, Mathematical Elements of Computer Graphics, McGraw Hill, New York, 1990.

Reference books:

1. Desai, Apurva A, Computer Graphics, PHI, New Delhi, 2008.
2. Samit Bhattacharya, Computer Graphics, Oxford University Press, 2018.

# Professional Elective – IV

**MA27021** **3-0-0 (3)**

# Design and Analysis of Algorithms

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basic concepts of algorithms and analysis |
| **CO-2** | Analyze time and space complexity |
| **CO-3** | Understand algorithm design methodology |
| **CO-4** | Apply important algorithm methodology to solve problems |
| **CO-5** | Understand the difference between P and NP classes of problems |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | 1 | – | – | – |
| **CO-2** | 3 | – | 2 | 2 | – | – |
| **CO-3** | 2 | – | 1 | – | – | – |
| **CO-4** | 3 | 3 | – | 3 | – | 2 |
| **CO-5** | 2 | – | 1 | – | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Analysing Algorithms:** Concepts in Algorithms Analysis, asymptotic complexity of algorithms, Growth functions Recurrences, Master Theorem.

**Divide and Conquer Method:** Expected Running Time of Randomized Quick Sort, Merge Sort, Strassen's Matrix Multiplication Algorithm.

**Data Structures for Set manipulation problems:** Binary tree traversal algorithms, disjoint-set union algorithms.

**Graph Algorithms:** Representations of graphs, Breadth-first search, Depth-first search, Minimum spanning tree, The algorithms of Kruskal and Prim, Shortest paths, Dijkstra's Algorithm

**Greedy Method:** Activity Selection Problem, Knapsack Problem, single source shortest path Problem.

**Dynamic Programming:** Solution to 0-1 Knapsack Problem, multistage graphs, TSP using Dynamic Programming Backtracking: Basic examples, N-Queen's Problem, sum of subsets Problem.

**Complexity Classes**: Example NP-complete problems.

**Learning Resources:**

Text Books:

1. T.H. Cormen, C.E. Leiserson, R.L. Rivest and C. Stein, Introduction to Algorithms, PHI, New Delhi, 2004, Third Edition.
2. E. Horowitz, S. Sahni and S. Rajasekaran, Fundamentals of Computer Algorithms, Universities Press, Second Edition, 2011.

Reference Books:


1. A. V. Aho, J. E. Hopcroft and J.D. Ullman, The Design and Analysis of Computer Algorithms, Pearson, New Delhi, Tenth Edition, 2012.
2. S. Baase and A.V. Gelder, Addison and Wesley, Computer Algorithms: Introduction to Design and Analysis, Third Edition, 2000.

**MA27023** **3-0-0 (3)**

# Advanced Data Structures

**Pre-Requisites: MA26003**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand and implementation of symbol table using hashing techniques |
| **CO-2** | Apply the concept of Skip Lists for Data Structures and Algorithms. |
| **CO-3** | Develop and analyze algorithms for red-black trees, B-trees and Splay trees |
| **CO-4** | Develop algorithms for text processing applications |
| **CO-5** | Identity suitable data structures and develop algorithms for computational geometry |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | 1 | – | – | – |
| **CO-2** | 3 | – | 2 | 2 | – | – |
| **CO-3** | 2 | – | 1 | – | – | – |
| **CO-4** | 3 | 3 | – | 3 | – | 2 |
| **CO-5** | 2 | – | 1 | – | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Dictionaries**: Definition, Dictionary Abstract Data Type, Implementation of Dictionaries.

**Hashing**: Review of Hashing, Hash Function, Collision Resolution Techniques in Hashing, Separate Chaining, Open Addressing, Linear Probing, Quadratic Probing, Double Hashing, Rehashing, Extendible Hashing.

**Skip Lists:** Need for Randomizing Data Structures and Algorithms, Search and Update Operations on Skip Lists, Probabilistic Analysis of Skip Lists, Deterministic Skip Lists

**Trees:** Binary Search Trees (BST), AVL Trees

**Red Black Trees:** Height of a Red Black Tree, Red Black Trees Bottom-Up Insertion, Top-Down Red Black Trees, Top-Down Deletion in Red Black Trees, Analysis of Operations.

**2-3 Trees:** Advantage of 2-3 trees over Binary Search Trees, Search and Update Operations on 2-3 Trees, Analysis of Operations.

**B-Trees:** Advantage of B- trees over BSTs, Height of B-Tree, Search and Update Operations on 2-3 Trees, Analysis of Operations.

**Splay Trees:** Splaying, Search and Update Operations on Splay Trees, Amortized Analysis of Splaying.

**Text Processing:** String Operations, Brute-Force Pattern Matching, The Boyer-Moore Algorithm, The Knuth-Morris-Pratt Algorithm, Standard Tries, Compressed Tries, Suffix Tries, The Huffman Coding Algorithm, The Longest Common Subsequence Problem (LCS), Applying Dynamic Programming to the LCS Problem.

**Computational Geometry:** One Dimensional Range Searching, Two Dimensional Range Searching, Constructing a Priority Search Tree, Searching a Priority Search Tree, Priority Range Trees, Quadtrees, k-D Trees.

**Learning Resources:**

Text Books:

1. Mark Allen Weiss, "Data Structures and Algorithm Analysis in C++", 2nd Edition, Pearson, 2004.

Reference Books:

1. Michael T. Goodrich, Roberto Tamassia, "Algorithm Design", 1st Edition, Wiley, 2006.

**MA27025** **3-0-0 (3)**

# Advanced Abstract Algebra

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Analyze the structure of groups |
| **CO-2** | Distinguish the properties among ring structures |
| **CO-3** | Understand the extension of fields and their constructions |
| **CO-4** | Apply the concepts and results to solve problems of Abstract Algebra |
| **CO-5** | Construct proofs that arise in various algebraic structures |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | – | 2 | – | – | – |
| **CO-2** | 3 | – | 2 | – | – | – |
| **CO-3** | 3 | – | 2 | – | – | – |
| **CO-4** | 3 | – | 2 | 1 | – | – |
| **CO-5** | 3 | – | 2 | 1 | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Groups**: Actions on a group; Conjugacy classes, class equation, Sylow Theorems, and applications

**Rings**: Examples; Quadratic integer rings; ideals, prime and maximal ideals, rings of fractions; Chinese Remainder theorem.

**Classes of Rings**: Euclidean Domains – norms, division algorithm, field norm on Quadratic integer rings, properties; Principal Ideal Domains – properties and results; Unique Factorizations Domains – prime elements, irreducible elements, associates, properties; Polynomial rings over fields, polynomial rings that are UFDs, irreducibility criteria.

**Fields**: Algebraic and transcendental elements; Brief introduction to Field extensions, Finite fields.

### Learning Resources:

Text Books:


1. David S. Dummit, and Richard M. Foote, Abstract Algebra, John Wiley & Sons, 2004, Third Edition.
2. Michael Artin, Algebra, Pearson, 2016, Second Edition.


Reference Books:


1. Joseph A. Gallian, Contemporary Abstract Algebra, Cengage Learning, 2013, Eighth Edition.
2. I. N. Herstein, Topics in Algebra, John Wiley & Sons, 1975, Second Edition.

# Professional Elective – V

**MA27027** **4-0-0 (4)**

# Cryptography

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the structure of stream ciphers, DES, AES |
| **CO-2** | Analyse RSA and ElGamal public key cryptosystems |
| **CO-3** | Learn algorithms for integer factorization and discrete log problems. |
| **CO-4** | Learn elliptic curve cryptosystems. |
| **CO-5** | Know the concepts of hash functions and digital signature schemes. |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | – | 3 | 1 | 2 | 1 | – |
| **CO-2** | – | 3 | 1 | 2 | 1 | – |
| **CO-3** | 1 | 2 | – | 3 | 2 | – |
| **CO-4** | – | 3 | – | 2 | 2 | – |
| **CO-5** | – | 3 | 2 | 2 | 2 | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction**: Review basic group theory and basic number theory, Historical ciphers and their cryptanalysis, modern cryptography principles, perfect secrecy, and one-time pad.

**Private-key Cryptography**: Stream ciphers, Block ciphers - SPN, Feistel design, DES, AES. Introduction to differential and linear cryptanalysis.

**Public-key Cryptography**: RSA Cryptosystem, Primality testing, Algorithms for factoring, Diffie-Hellman key-exchange protocol, Discrete-Logarithm Problem (DLP), ElGamal Cryptosystem, Algorithms for DLP.

**Elliptic curves**: Basic facts, elliptic-curve cryptosystem.

**Discussion** on Hash functions, Digital signatures, and other relevant cryptography topics.

### Learning Resources:

Text Books:

1. Douglas R. Stinson, Cryptography: Theory and Practice, Chapman & Hall/CRC, 2006, Third Edition.
2. William Stallings, Cryptography and Network Security: Principles and Practice, Pearson, 2017, Seventh Edition.

Reference Books:

1. Christof Paar and Jan Pelzl, Understanding Cryptography, Springer, 2010.
2. Jonathan Katz and Yehuda Lindell, Introduction to Modern Cryptography, CRC Press, Taylor & Francis Group, 2015, Second Edition.

**MA27029** **3-0-0 (3)**

# Finite Element and Finite Volume Methods

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Formulate a variational problem for a boundary value problem |
| **CO-2** | Find the solution of solution of boundary value problems using FEM |
| **CO-3** | Identify the properties of discretization schemes. |
| **CO-4** | Solve convective problems using upwind, QUICK and hybrid schemes |
| **CO-5** | Solve convective problems using upwind, QUICK and hybrid schemes |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | – | 3 | 1 | 2 | 1 | – |
| **CO-2** | – | 3 | 1 | 2 | 1 | – |
| **CO-3** | 1 | 2 | – | 3 | 2 | – |
| **CO-4** | – | 3 | – | 2 | 2 | – |
| **CO-5** | – | 3 | 2 | 2 | 2 | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

Variational Formulation for a boundary value problem with homogeneous and non-homogeneous boundary conditions, Rayleigh- Ritz minimization, Weighted residuals - Collocation, Least squares method, Galerkin, Petrov-Galerkin methods for boundary value problems. Finite Element Solution of boundary value problems.

Central differencing scheme, Upwind differencing scheme, Hybrid differencing scheme, Power-law scheme. Properties of discretisation schemes: Conservativeness - Boundedness – Transportiveness. Quadratic upwind differencing scheme: the QUICK scheme - Stability problems of the QUICK scheme and remedies - Generalisation of upwind- biased discretisation schemes - Total variation and TVD schemes - Criteria for TVD schemes - Flux limiter functions - Implementation and Evaluation of TVD schemes. Finite Volume solution of 1-D and 2-D problems

### Learning Resources:

Text Books:

1. H. Versteeg and W. Malalasekera, An introduction to CFD: The Finite Volume Method, Pearson, 2007, Second Edition.
2. I. J. Chung, Finite Element Analysis in Fluid Dynamics, McGraw-Hill International Book Company, 2007, Digitized Version, First Edition.
3. J. N. Reddy, An Introduction to the Finite Element Method, McGraw Hill, 2020, Fourth Edition.

Reference Books:

1. P. E. Lewis and J. P. Ward, The Finite Element Method - Principles and Applications, Addison Wesley, 1991, First Edition.
2. F. Moukalled, L. Mangani, M. Darwish, The Finite Volume Method in Computational Fluid Dynamics An Advanced Introduction with OpenFOAM® and Matlab, Springer, 2015, First Edition.

**MA27031** **4-0-0 (4)**

# Graph Theory

**Pre-Requisites: None**

**Course Outcomes:**

At the end of the course, the student will be able to:

| | |
|---|---|
| **CO1** | Examine whether the graphs are isomorphic or not |
| **CO2** | Determine whether graphs are Hamiltonian and/or Eulerian |
| **CO3** | Construct minimal spanning trees and shortest paths |
| **CO4** | Determine the matching in a graph and solve the assignment problem |
| **CO5** | Construct planar graphs, colouring of graphs and their applications |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 1 | - | - | - | 1 | - |
| **CO-2** | 1 | - | - | - | 1 | - |
| **CO-3** | 3 | 2 | 2 | 3 | - | 1 |
| **CO-4** | 2 | 1 | 2 | 2 | - | - |
| **CO-5** | 3 | 2 | 3 | 3 | 2 | 1 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

**Syllabus:**

**Preliminary Concepts**: Graph definition, various kinds of graphs; Incidence matrix; Isomorphism; Decomposition; Special graphs; Paths, cycles and trails - connection in graphs, bipartite graphs, Eulerian Circuits; Vertex degree and counting, Hamiltonian Cycles - necessary and sufficient conditions; Review of digraphs.

**Trees:** Trees and distance - properties; Spanning trees; Kruskal and Prim algorithms with proofs of correctness; Shortest paths - Dijkstra's algorithm, BFS and DFS algorithms, Application to Chinese postman problem; Trees in Computer science - rooted trees, binary trees, Huffman's Algorithm.

**Matchings**: Matching in a graph and maximum matchings; Hall's matching theorem; Maximum bipartite matching - Augmenting path algorithm;

**Connectivity**: Connectivity; Characterizing 2-connected graphs; Menger's theorem; Network flow problems-Ford-Fulkerson labeling algorithm, Max-flow Min-cut Theorem.

**Coloring**: Chromatic number; Greedy coloring algorithm; Brooks' theorem; Graphs with large chromatic number; Turan's theorem.

**Planar Graphs**: Planar graphs; Euler's formula, dual of a plane graph; Kuratowski's Theorem; Five Color Theorem; Four Colour Problem.

**Learning Resources:**

Text Books:

1. Douglas B. West, Introduction to Graph Theory, Pearson, 2015, Second Edition.
2. R. Diestel, Graph Theory, Springer, 2017, Fifth Edition.

Reference Books:


1. Narsingh Deo,Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall, 1979.
2. J. A. Bondy and U. S. R. Murty, Graph Theory, Springer, 2008.

# Professional Elective – VI

**MA27022** **3-0-0 (3)**

# Computational Number Theory

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | solve the system of congruences |
| **CO-2** | know the basic arithmetic of finite fields |
| **CO-3** | test the primality of integers |
| **CO-4** | factor integers |
| **CO-5** | compute discrete logarithms over finite fields |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | – | – | – | – |
| **CO-2** | 2 | – | 1 | – | – | – |
| **CO-3** | 3 | 3 | 2 | - | – | – |
| **CO-4** | 3 | 3 | 2 | 3 | – | – |
| **CO-5** | 3 | 3 | 2 | 3 | – | – |

**1 - Slightly;** **2 - Moderately;** **3 - Substantially**

## Syllabus:

**Algorithms for integer arithmetic:** Divisibility, gcd, prime number theorem, modular arithmetic, modular exponentiation, congruence, Chinese remainder theorem (CRT), Hensel lifting, orders and primitive roots, quadratic residues, modular square roots and continued fractions.

**Representation of finite fields:** Prime and extension fields, representation of extension fields, polynomial basis, finite field arithmetic, primitive elements, normal basis, optimal normal basis, irreducible polynomials.

**Algorithms for polynomials:** Root-finding and factorization.

**Primality testing algorithms:** Fermat test and Miller-Rabin test.

**Integer factoring algorithms:** Trial division, Pollard rho method and $p$-1 method.

**Computing discrete logarithms over finite fields:** Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method and index calculus methods.

**Elliptic curves:** The elliptic curve group, elliptic curves over finite fields and elliptic curve method for integer factorization.

**Learning Resources:**

Text Books:

1. Abhijit Das, Computational number theory: CRC press, 2015.
2. Victor Shoup, A Computational Introduction to Number Theory and Algebra, Version 2, Cambridge University Press, 2008. (Available at https://www.shoup.net/ntb/)

## Reference Books:


1. Kenneth H. Rosen, Elementary Number Theory & Its Applications: Pearson, 2011, Sixth Edition.
2. Joseph H. Silverman, The Arithmetic of Elliptic Curves, Springer, 2009, Second Edition.

**MA27024** **3-0-0 (3)**

# Evolutionary Optimization Techniques

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Differentiate and classify traditional and non-traditional optimization methods |
| **CO-2** | Formulate an optimization problem to solve complex problems |
| **CO-3** | Design GA for various optimization problems |
| **CO-4** | Utilize Ant colony optimization algorithms for various optimization problems |
| **CO-5** | Apply Particle swarm optimization for various optimization problems |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | 2 | 1 | 2 | – | – |
| **CO-2** | 2 | 2 | 1 | 2 | – | – |
| **CO-3** | 3 | 2 | 2 | 2 | – | – |
| **CO-4** | 3 | 2 | 2 | 2 | – | – |
| **CO-5** | 3 | 2 | 2 | 2 | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Problem-Solving Methods:** Problem Space, Problem-solving, State space, Algorithm's performance and Complexity, Search Algorithms, Depth first search method, Breadth first search method, Branch and Bound search method, Introduction to P-type, NP-complete and NP-Hard problems. Classical methods versus Non-traditional methods.

**Evolutionary Methods:** Principles of Evolutionary Processes and genetics, Introduction to evolutionary algorithms, Evolutionary strategy, Evolutionary programming.

**Genetic Algorithm:** Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, Genetic programming, and Simple applications.

**Swarm Optimization:** Introduction to Swarm Intelligence, Ant colony optimization (ACO), Metaheuristic, Algorithm for Travelling Salesman Problem, Particle swarm optimization (PSO), Other variants of swarm intelligence algorithms, Simple problems and applications.

**Learning Resources:**

Text Books:


1. K. Deb, Multi-objective Optimization using Evolutionary Algorithms, John Wiley and Sons, First Edition, 2001.
2. B. Chopard & M. Tomassini, An introduction to metaheuristics for optimization, Springer International Publishing, 2018.


Reference books:


1. J. Dreo, A. Petrowski, P. Siarry & E. Taillard, Metaheuristics for hard optimization: methods and case studies, Springer Science & Business Media, First Edition, 2006.
2. S. S. Rao, Engineering optimization: theory and practice, John Wiley & Sons, Fifth Edition, 2019.

**MA27026** **3-0-0 (3)**

# Neural Networks

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Construct prediction models for statistical data |
| **CO-2** | Design Multi-Layer neural network to solve Supervised Learning problems |
| **CO-3** | Classify non-linear data like face recognition and disease prediction |
| **CO-4** | Apply Genetic Algorithm for optimization problems |
| **CO-5** | Design applications like games and agent-based controllers |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO-2** | 3 | 3 | 2 | 3 | 3 | 1 |
| **CO-3** | 3 | 2 | 3 | 3 | 3 | 2 |
| **CO-4** | 3 | 2 | 3 | 2 | 2 | 1 |
| **CO-5** | 3 | 3 | 3 | 1 | 3 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction to machine learning, issues related to machine learning**: pre-processing, inductive bias, variance, feature extraction, and feature selection techniques. Different types of learning, training, and testing, hypothesis, and cost function.

**Mathematics for machine learning**: Regression techniques: linear, logistic, regularization, and generalization.

**Classification techniques**: DECISION TREES (DT)-construction of decision trees using different algorithms, Regression tree, tree pruning, rule extraction from trees, and multivariate trees. Ensemble learning: Bagging and boosting and different techniques of bagging and boosting. **Artificial neural networks (ANN):** different learning rules, single-layer perceptron, multi-layer neural nets, backpropagation algorithm, feed-forward networks, network training, radial basis function networks, recurrent neural networks. Bayesian learning: probabilistic reasoning: prior, likelihood, and posterior, belief networks: modeling independence, Markov equivalence in belief networks, hidden Markov models (HMM). Naïve Bayes classifier, learning with hidden variables, Expectation Maximisation (EM). - GENETIC ALGORITHMS – an illustrative example, Hypothesis space search, Genetic Programming, Models of Evolution and Learning. Instance-based learning: Nearest-Neighbour classification, condensed-neighbour classification. Unsupervised linear dimensionality reduction: principal component analysis(PCA), PCA vs singular value decomposition, working on high-dimensional data, latent-semantic analysis: information retrieval. Supervised linear dimensionality reduction: Fisher's linear discriminant. Kernel methods: dual representations, kernel construction, learning with hyperparameters, support vector machines (maximum margin classifier), linear and multiclass SVM.

**Reinforcement learning** - The Learning Task, Q Learning, Nondeterministic rewards and actions, Temporal difference learning, Generalizing from examples, and relationship to Dynamic Programming.

**Learning Resources:**

Textbooks:

1. Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2016.
2. Tom M. Mitchell, Machine Learning, McGraw Hill, 2017.

Reference Books:

1. Ethem Alpaydin, Introduction to machine learning, MIT Press, 2020.
2. Sebastian Raschka, Python Machine Learning, Packt Publishing,2017, Second Edition.

**MA27028** **3-0-0 (3)**

# Parallel Computing

**Pre-Requisites: None**

## Course Outcomes:

| | |
|---|---|
| **CO-1** | Understand the fundamentals of parallel computing. |
| **CO-2** | Design and analyse the parallel algorithms for solving linear systems of equations. |
| **CO-3** | Design parallel algorithms for eigenvalue problems. |
| **CO-4** | Develop parallel algorithm code for iterative methods. |
| **CO-5** | Apply parallel computing method for solving simple differential equations. |

## Course Articulation Matrix:

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 1 | – | – | – | – |
| **CO-2** | – | 2 | 2 | – | – | – |
| **CO-3** | – | – | – | – | – | – |
| **CO-4** | – | – | – | 2 | – | 2 |
| **CO-5** | 3 | – | – | – | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction to parallel programming**: Data parallelism, functional parallelism, pipelining, Flynn's taxonomy, parallel algorithm design, task/channel model, Foster's design methodology, case studies: boundary value problem, finding the maximum, *n*-body problem, Speedup and efficiency, Amdahl's law, Gustafson-Barsis's Law, Karp-Flatt Metric, Iso efficiency metric.

**Shared Memory:** Fundamentals of Shared Memory Programming, Basic OpenMP concepts, PARALLEL directive, Data scoping rules, Basic OpenMP constructs/directives/calls, Examples, parallelizing an existing code using OpenMP, more advanced OpenMP directives & functions, OpenMP Performance issues, Fundamentals of Distributed Memory Programming.

**The message-passing model**: the message-passing interface, MPI standard, basic concepts of MPI: MPI_Init, MPI_Comm_size, MPI_Comm_rank, MPI_Send, MPI_Recv, MPI_Finalize timing the MPI programs: MPI_Wtime, MPI_Wtick, collective communication: MPI_Reduce, MPI_Barrier, MPI_Bcast, MPI_Gather, MPI_Scatter, case studies: the sieve of Eratosthenes, Floyd's algorithm, Matrix-vector multiplication.

**Monte Carlo methods**: parallel random number generators, case studies, Matrix multiplication, row-wise block-stripped algorithm, Cannon's algorithm, solving linear systems, back substitution.

**Sorting algorithms**: quicksort, parallel quick sort, hyper quick sort, sorting by regular sampling, Fast Fourier transform, combinatorial search, divide and conquer, parallel backtrack search.

**Learning Resources:**

Text Books:

1. M. J. Quinn, Parallel Computing – Theory and Practice, Tata McGraw-Hill Publishing Company Ltd., 2002, Second Edition.

2. B. Wilkinson and M. Allen, Parallel Programming–Techniques and applications using networked workstations and parallel computers, Pearson Education, 2005, Second Edition.

Reference Books:

1. Michael J. Quinn, Parallel Programming in C with MPI and OpenMP, Tata McGraw-Hill Publishing Company Ltd., 2003.

# Professional Elective – VII

**MA27030** **3-0-0 (3)**

# Theory of Automata

**Pre-requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO1** | Formulate computer languages |
| **CO2** | Construct Finite automata to accept given language |
| **CO3** | Construct grammar for a given language |
| **CO4** | Classify the languages and arrange in hierarchy |
| **CO5** | Design the Turing machines |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 3 | 2 | – | – |
| **CO-2** | 3 | 3 | – | 3 | – | – |
| **CO-3** | 2 | 2 | – | 2 | – | – |
| **CO-4** | 2 | – | – | 2 | – | – |
| **CO-5** | 3 | 3 | 3 | 2 | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

**Syllabus:**

**Preliminaries**: Sets, Relations, Equivalence relation, partition, Transitive closures, Kleene' closure*, Strings, Alphabets, Languages, Recursive definitions.

**Regular Languages and Finite Automata**: Regular Expressions, Regular Languages, Finite State Machines, Deterministic finite automata (DFA), Non-deterministic finite automata (NFA), Non-deterministic finite automata with $\varepsilon$ moves (NFA- $\varepsilon$), $\varepsilon$ -closure, Equivalence of DFA, NFA and NFA- $\varepsilon$, Language accepted by Finite Automata, Kleene's Theorem

**Properties of Regular Sets**: Properties of the Languages accepted by finite automata, Regular and non-regular languages, Minimal finite automata, Pumping lemma, Myhill - Nerode theorem. Closure properties of Regular languages,

**Context Free Languages and Pushdown Automata**: Context free grammars (CFG), context free languages (CFL), closure properties of context free languages, Chomsky normal form, Greibach normal form, Pumping lemma for CFL, parsing, Pushdown automata (PDA), CFG for PDA, PDA for CFG, phrase structured grammars and languages and context sensitive grammars and languages.

**Turing Machines:** Turing machine model, example, Modification of Turing machines, Church's hypothesis and Non-deterministic Turing machines.

**Learning Resources:**

Text Books:


1. Hopcroft J. and Ullman J.D., Introduction to Automata Theory, Languages and Computation, Narosa Publishing, 1989.
2. Martin, J.C., Introduction to Languages and the Theory of Computation, Tata McGraw Hill, 2009.


Reference Books:


1. Carrel J. and Long D., Theory of finite automata with an introduction to formal languages, Prentice Hall, 1989.
2. Peter Linz, An introduction to formal languages and automata, Jones & Bartlett, 1997.

**MA27032** **3-0-0 (3)**

# Mathematics of Machine Learning

**Pre-requisites**: None

**Course Outcomes:**

| | |
|---|---|
| **CO1** | Identify problems that are amenable to solution by AI methods |
| **CO2** | Formalize a given problem in the language/framework of different AI methods |
| **CO3** | Implement basic AI algorithms |
| **CO4** | Design and carry out an empirical evaluation of different algorithms on problem formalization, |
| **CO5** | Understand the concept of various decision trees |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 2 | 3 | 2 | – | – |
| **CO-2** | 3 | 3 | – | 3 | – | 2 |
| **CO-3** | 2 | 2 | – | 2 | – | – |
| **CO-4** | 2 | – | – | 2 | – | – |
| **CO-5** | 3 | 3 | 3 | 2 | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction:** Intelligent Machines, Well posed Problems, Example of Applications in diverse fields, Data Representation, Domain Knowledge for Productive use of Machine Learning, Diversity of Data: Structured / Unstructured, Forms of Learning, Machine Learning and Data Mining, Basic Linear Algebra in Machine Learning Techniques.

**Supervised Learning**: Rationale and Basics: Learning from Observations, Bias and Why Learning Works: Computational Learning Theory, Occam's Razor Principle and Overfitting Avoidance Heuristic Search in inductive Learning, Estimating Generalization Errors, Metrics for assessing regression, Metris for assessing classification.

**Statistical Learning**: Machine Learning and Inferential Statistical Analysis, Descriptive Statistics in learning techniques, Bayesian Reasoning: A probabilistic approach to inference, K-Nearest Neighbor Classifier. Discriminant functions and regression functions, Linear Regression with Least Square Error Criterion, Logistic Regression for Classification Tasks, Fisher's Linear Discriminant and Thresholding for Classification, Minimum Description Length Principle.

**Support Vector Machines (SVM)**: Introduction, Linear Discriminant Functions for Binary Classification, Perceptron Algorithm, Large Margin Classifier for linearly seperable data, Linear Soft Margin Classifier for Overlapping Classes, Kernel Induced Feature Spaces, Nonlinear Classifier, Regression by Support vector Machines. Learning with Neural Networks: Towards Cognitive Machine, Neuron Models, Network Architectures, Perceptrons, Linear neuron and the Widrow-Hoff Learning Rule, The error correction delta rule.

**Decision Tree Learning:** Introduction, Example of classification decision tree, measures of impurity for evaluating splits in decision trees, ID3, C4.5, and CART decision trees, pruning the tree, strengths and weakness of decision tree approach.

**Learning Resources:**

Text Books:

1. M.Gopal, Applied Machine Learning, McGraw Hill Education
2. Kevin Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
3. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer 2009 .

Reference Books:

1. Christopher Bishop, Pattern Recognition and Machine Learning, Springer,2007
2. Toby Segaran, Programming Collective Intelligence: Building Smart Web 2.0 Applications.

**MA27034** **3-0-0 (3)**

# Data Mining

**Pre-Requisites: None**

**Course Outcomes:**

At the end of the course, the student will be able to

| | |
|---|---|
| **CO1** | Interpret data mining tasks and issues |
| **CO2** | Apply different techniques for data mining |
| **CO3** | Analyze multi-dimensional modelling techniques |
| **CO4** | Implement of the clustering techniques |
| **CO5** | Evaluate the performance of algorithms for association rules |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 2 | – | – | 2 | – | – |
| **CO-2** | – | – | 1 | 3 | – | – |
| **CO-3** | – | – | – | 2 | 1 | 2 |
| **CO-4** | 2 | 2 | – | 2 | – | – |
| **CO-5** | | 2 | 1 | – | – | – |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Introduction**: Basic Data Mining Tasks, Data Mining Issues, Data Mining Metrics, Data Mining from a Database Perspective.

**Data Mining Techniques**: A Statistical Perspective on Data Mining, Similarity Measures, Decision Trees, Neural Networks, Genetic Algorithms.

**Classification**: Statistical-Based Algorithms, Distance-Based Algorithms, Decision Tree-Based Algorithms, Neural Network-Based Algorithms, Rule-Based Algorithms, Combining Techniques.

**Clustering**: Similarity and Distance Measures, Hierarchical Algorithms, Partitional Algorithms, Clustering Large Databases, Clustering with Categorical Attributes.

**Association Rules**: Basic Algorithms, Incremental Rules, Advanced Association Rule Techniques, Measuring the Quality of Rules.

**Advanced Techniques**: Web Mining, Spatial Mining and Temporal Mining.

**Learning Resources:**

Text Books:

1. J. Han, M. Kamber and Jian Pei, Data Mining: Concepts and Techniques, Elsevier. 2007, Third Edition.
2. M. H. Dunham, Data Mining: Introductory and Advanced Topics, Pearson Education. 2006.

Reference Books:


1. I. H. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques, Morgan Kaufmann. 2008.
2. D. Hand, H. Mannila and P. Smyth, Principles of Data Mining, Prentice-Hall. 2009.

**MA27036** **3-0-0 (3)**

# Algebraic Coding Theory

**Pre-Requisites: None**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Use the main algebraic tools utilized in coding theory |
| **CO-2** | Classify the linear codes based on their equivalence |
| **CO-3** | Understand the geometry of linear codes |
| **CO-4** | Apply abstract algebra concepts in encoding and decoding of linear codes |
| **CO-5** | Analyze the parameters governing the codes for identification in real-life applications |

**Course Articulation Matrix:**

| | PO-1 | PO-2 | PO-3 | PO-4 | PO-5 | PO-6 |
|---|---|---|---|---|---|---|
| **CO-1** | 3 | 3 | 2 | 3 | 1 | 2 |
| **CO-2** | 3 | 3 | 2 | 3 | 1 | 2 |
| **CO-3** | 3 | 3 | 2 | 3 | 1 | 2 |
| **CO-4** | 3 | 3 | 2 | 3 | 2 | 2 |
| **CO-5** | 3 | 3 | 3 | 3 | 2 | 2 |

**1 - Slightly; 2 - Moderately; 3 - Substantially**

## Syllabus:

**Linear Codes**: Codes as a subspace of vector space over finite fields; Hamming weight; Generator and Parity-check matrices; Equivalence of linear codes; Encoding, decoding of linear codes; cosets and decoding.

**Bounds**: Sphere-covering bound; Gilbert-Varshamov bound; Hamming bound; Binary and $q$-ary Hamming codes; Perfect codes; Singleton bound and MDS codes; non-linear codes.

**Cyclic Codes**: Generator polynomial; Cyclic codes as an ideal of quotient ring; Decoding of cyclic codes.

**Special Codes**: BCH codes and their parameters; decoding of BCH codes; Reed-Solomon (RS) codes; Quadratic-residue codes.

**Goppa Codes**: Generalized Reed-Solomon codes; Alternant codes; Goppa Codes; Post-quantum cryptography - Application in McEliece Public Key Cryptosystem.

**Learning Resources:**

Text Books:

1. San Ling and Chaoping Xing, Coding Theory: A First Course, Cambridge University Press, 2004.
2. Vera Pless, Introduction to the Theory of Error-Correcting Codes, Wiley-Interscience, 1998, Third Edition.

Reference Books:

2. W. Cary Huffman and Vera Pless, Fundamentals of Error Correcting Codes, Cambridge University Press, 2010
3. Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, Springer-Verlag, 2004, Second Edition.