CURRICULUM & SYLLABI
M.Sc. APPLIED MATHEMATICS
Effective from AY: 2024-25

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL
WARANGAL, TELANGANA

Table of Contents

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. Applied Mathematics

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 analyzing 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. Applied Mathematics

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 models for complex mathematics problems and find out solutions thatmeet the specified needs with appropriate consideration for the public health,safety, cultural, societal and environmental considerations.
PO3	Use of research-based knowledge and research methods including design of physical/computational experiments and evolve procedures appropriate 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 simulation modelling and interpretation of data to provide valid conclusions

CURRICULUM
M.Sc. Applied Mathematics

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	MA16005	Computer Programming in C++	**3-0-0**	**3**
4	MA16007	Numerical Analysis	**3-0-0**	**3**
5	MA160xx	Professional Elective – I	**3-0-0**	**3**
6	MA16009	C++ Lab	**0-1-2**	**2**
7	MA16011	Numerical Computing 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	MA16006	Topology	**3-0-0**	**3**
4	MA160xx	Professional Elective – II	**3-0-0**	**3**
5	MA160xx	Professional Elective – III	**3-0-0**	**3**
6	MA16008	Probability and Statistics with R Lab	**0-1-2**	**2**
7	MA16010	Symbolic Computing Lab	**0-1-2**	**2**
			Total Credits	**20**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA170001	Operations Research	***4-0-0***	***4***
2	MA17003	Functional Analysis	**3-0-0**	**3**
3	MA170xx	Professional Elective – IV	**3-0-0**	**3**
4	MA170xx	Professional Elective – V	**3-0-0**	**3**
5	MA17005	Operations Research Lab	**0-1-2**	**2**
6	MA17007	Software Lab	**0-1-2**	**2**
7	MA17091	Seminar and Technical writing	**0-0-4**	**2**
8	MA17093	Short Term Industrial / Research Experience	**0-0-4**	**2**
			Total Credits	**21**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA170xx	Professional Elective–VI	**3-0-0**	**3**
2	MA170xx	Professional Elective–VII	**3-0-0**	**3**
3	MA17094	Comprehensive Viva-Voce	**0-0-4**	**2**
4	MA17098	Dissertation	**0-0-16**	**8**
			Total Credits	**16**

Professional Electives

Professional Elective-I		
S.No.	**Code**	**Course Title**
1	MA16021	Advanced Linear Algebra
2	MA16023	Classical Mechanics
3	MA16025	Mathematical Modelling

Professional Elective-II		
S.No.	**Code**	**Course Title**
1	MA16022	Algebra
2	MA16024	Integral Transforms and Integral Equations
3	MA16026	Differential Geometry and Tensor analysis

Professional Elective-III		
S.No.	**Code**	**Course Title**
1	MA16028	Complex Analysis
2	MA16030	Lie Group Methods for Differential Equations
3	MA16032	Iterative Methods

Professional Elective-IV		
S.No.	**Code**	**Course Title**
1	MA17021	Discrete Mathematics
2	MA17023	Distribution Theory
3	MA17025	Multivariate Data Analysis

Professional Elective-V		
S.No.	**Code**	**Course Title**
1	MA17027	Numerical Solutions of Differential Equations
2	MA17029	Dynamical Systems
3	MA17031	Analysis of Differential Equations

Professional Elective-VI		
S.No.	**Code**	**Course Title**
1	MA17022	Measure and Integration
2	MA17024	Finite Element Method
3	MA17026	Inventory, Queueing Theory and Non-Linear Programming

Professional Elective-VII		
S.No.	**Code**	**Course Title**
1	MA17028	Fluid Dynamics
2	MA17030	Graph Theory and Algorithms
3	MA17032	Finite Volume Methods

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. Applied Mathematics

1st Semester

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

Real Analysis

Pre-Requisites: 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, β and Γ 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, Elementary Real Analysis, Prentice Hall International, 2008, Second Edition.

Reference Books:

1. William F. Trench, Introduction to Real Analysis, Library of Congress Cataloging-in-Publication Data, 2010, Second Edition.
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

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 Greens functions, 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.

MA16005 **3-0-0 (3)**

Computer Programming in 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	3	3	3	2	–	2
CO-2	1	–	1	2	–	–
CO-3	2	–	2	–	–	–
CO-4	3	2	3	–	–	–
CO-5	2	–	2	–	–	–

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

Syllabus:

Problem solving techniques: Algorithmic approach, characteristics of algorithm, Problem solving strategies: Top-down approach, Bottom-up approach, Time and space complexities of algorithms.

Number systems and data representation: Basics of C++, Basic data types, Numbers, Digit separation, Reverse order, writing in words, Development of Elementary School Arithmetic Testing System, Problems on Date and factorials, Solutions using flow of control constructs

Conditional statements: If-else, Switch-case constructs, Loops - while, do-while, for.

Functions: Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, Recursion,

Introduction to Pointers and Arrays: Sorting and searching algorithms, Large integer arithmetic, Single and Multi-Dimensional Arrays, passing arrays as parameters to functions, Magic square and matrix operations using Pointers and Dynamic Arrays, Multidimensional Dynamic Arrays String processing, File operations.

Structures and Classes: Declaration, member variables, member functions, access modifiers, function over loading, Problems on Complex numbers, Date, Time, Large Numbers.

Learning Resources:

Text Books:

1. Walter Savitch, Problem Solving with C++, Pearson, 2014, tenth Edition.

2. Cay Horstmann, Big C++, Wiley, 2009, Second Edition.

Reference Books:

1. R.G. Dromey, How to Solve it by Computer, Pearson, 2008.

Other Suggested Readings:

1. https://nptel.ac.in/courses/106/105/106105151/
2. https://onlinecourses.nptel.ac.in/noc21_cs38/preview

MA16007 **3-0-0 (3)**

Numerical Analysis

Pre-Requisites: None

Course Outcomes:

CO-1	Construct the Polynomial to the given data.
CO-2	Evaluate the integrals numerically.
CO-3	Find the roots of nonlinear equations.
CO-4	Approximate the function by a polynomial.
CO-5	Solve Initial value problems numerically.

Course Articulation Matrix:

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

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

Syllabus:

Numerical solution of nonlinear equations: Method of false postion, Newton method, Muller's method, Birga-Vita method, Bairstow's method, Graffe's root squaring method, finding the complex roots, system of non-linear simultaneous equations.

Approximation: Norms, Least square (using monomials and orthogonal polynomials), Uniform and Chebyshev approximations.

Interpolation: Existence, Uniqueness of interpolating polynomial - finite differences, finite difference operators and their properties, Inverse interpolation, Hermite interpolation, spline interpolation.

Numerical differentiation: The value of derivative at a tabulated and non-tabulated point

Numerical integration: Gaussian Quadrature methods (Gauss-Legendre, Gauss-Chebyshev, Gauss-Laguerre and Gauss-Hermite integration methods), Romberg integration, Method of undetermined coefficients,

Numerical solution of ordinary differential equations: Initial value problems: Single step methods; Taylor's, Higher Order Taylors methods, Runge-Kutta methods, Error analysis; Multi-step methods: Adam- Bashforth, Nystorm's, Adams- Moulton's methods, Milne's predictor-corrector methods; System of IVP's and higher orders IVP's., Shooting method, Cubic spline method, solution of a nonlinear differential equation by Quasilinearization method, Collocation method.

Learning Resources:

Text Books:

1. MK Jain, SRK Iyengar and RK Jain, Numerical Methods for Engineers and Scientists, New Age International Private Limited, 2022, Eighth Edition.
2. C.F.Gerald and P.O.Wheatley, Applied Numerical Analysis, Pearson Education India, 2007, Seventh Edition.

Reference Books:

1. K. Atkinson, An Introduction to Numerical Analysis, John Wiley,1989, Second Edition
2. F.B. Hildebrand, Introduction to Numerical Analysis, Dover Publisher Inc., 2003, Second Edition.
3. Richard L.Burden and J.Douglas Faires, Numerical Analysis, 9th Edition, Brooks/Cole, Cengage Learnin

MA16009 **0-1-2 (2)**

C++ Lab

Pre-Requisites: **NIL**

Course Outcomes:

CO-1	Design and test programs to solve mathematical and scientific problems.
CO-2	Develop and test programs using control structures.
CO-3	Implement modular programs using functions.
CO-4	Develop program using arrays and matrices.
CO-5	Develop program using pointers and structures.

Course Articulation Matrix:

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

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

Syllabus:

Programs using
1. conditional control constructs.
2. loops (while, do-while, for).
3. user defined functions and library functions.
4. arrays, matrices (single and multi-dimensional arrays).
5. pointers (int pointers, char pointers).
6. Programs on structures.

MA16011 **0-1-2 (2)**

Numerical Computing Lab

Pre-Requisites: None

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:

Programs Based on Numerical methods:
1. Programs for solution of quadratic equation
2. Solution of algebraic and transcendental equations
3. Solution of system of linear equations by Gauss-Seidel method
4. Solution of system of linear equations by Gaussian elimination method
5. Finding the Inverse of a matrix
6. Solution of Tridiagonal system by Thomas algorithm
7. Formulation of finite differences table for a given data
8. Finding the value of a function using Lagrange interpolation
9. Numerical integration
10. Euler's and modified Euler's methods, Runge-Kutta methods

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, Twelfth Edition.
2. V.K. Rohatgi and A.K. Md. Ehsanes Saleh, An Introduction to Probability theory and Mathematical Sciences, Wiley, 2001, Third Edition.

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, Bostan, 2007, Fourth Edition.

Reference Books:

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

MA16006 **3-0-0 (3)**

Topology

Pre-Requisites: None

Course Outcomes:

CO-1	Compare nature of spaces with different topologies
CO-2	Understand connectedness and compactness in spaces with different topologies
CO-3	Categorize spaces based on countability and separation axioms
CO-4	Combine results in proving results such as Urysohn Lemma and Urysohnmetrization theorem
CO-5	Understand the notion of completeness with its importance in Baire's Categorytheorem

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Topological Spaces and Continuous Functions: Definition; Order topology, Product topology, Subspace topology; Closed sets; T_1 axiom and Hausdorff spaces;Continuous functions, Homeomorphisms; Product and box topologies; Metric topology.

Connectedness and Compactness in Topological Spaces: Connected spaces, Components of a space, Compact spaces.

Countability and Separation Axioms: Countability axioms, Separation axioms, Normal spaces, Urysohn Lemma, Urysohn Metrization Theorem; Brief introduction to: Tietze Extension Theorem, Tychonoff theorem, Stone-Cech Compactification.

Completeness: Complete metric spaces, Baire's Category Theorem.

Learning Resources:

Text Books:

1. James R. Munkres, Topology, Prentice Hall of India, 2007, Second Edition
2. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Inc., 2004, Eighth Edition.

Reference Books:

1. Fred H. Croom, Principles of Topology, Cengage Learning, 2016, First Edition
2. John L. Kelley, General Topology, Springer, 1991, Second Edition.

MA16008 **0-1-2 (2)**

Probability and Statistics with R Lab

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze discrete and continuous random variables using PMF, CDF, and PDF.
CO-2	Explore mean, variance, and mathematical expectation for independent random variables.
CO-3	Apply Binomial, Negative Binomial, Geometric, and Poisson distributions in statistical analysis.
CO-4	Understand and utilize Normal, Rectangular, Exponential, Gaussian, Beta, and Gamma distributions.
CO-5	Conduct hypothesis tests including Z-test, t-test, F-test, and Chi-square test, and apply ANOVA techniques for one-way and two-way classifications.

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	1	3	–	–	1

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

Syllabus:

1. Random Variables - Working with discrete and continuous random variables - Understanding probability mass function, cumulative distribution function, probability density function.
2. Mean and Variance: Exploring independent random variables and mathematical expectation.
3. Working with Binomial, Negative Binomial, Geometric, and Poisson distributions
4. Understanding Normal, Rectangular, Exponential, Gaussian, Beta, and Gamma distributions
5. Application of moment generating functions
6. Sampling and Testing of Hypothesis: Conducting Z-test, t, F, and Chi-square tests.
7. Understanding and applying ANOVA - one-way and two-way classifications
8. Applying the method of maximum likelihood estimation
9. Correlation and Regression

MA16010 **0-1-2 (2)**

Symbolic Computing Lab

Pre-Requisites: None

Course Outcomes:

CO-1	Acquire proficiency in using matlab and Mathematica to study Matrices
CO-2	Demonstrate the use of matlab and Mathematica to understand and interpret the core concepts inlinear algebra
CO-3	Find general solution of system of linear equations
CO-4	Apply matlab and Mathematica to decompose the matrices, finding eigen values and eigen vectors
CO-5	Apply matlab and Mathematica to find orthogonal basis

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

1. Introduction to matlab and Mathematica - The Scilab Environment – manipulating the command line, working directory, comments, variables, the Scilab menu bar.
2. Scalars and Vectors – introduction, initializing vectors in Scilab, mathematical operationson vectors, relational operations on vectors, logical operations on vectors, built-in logical functions.
3. Mathematical functions on scalars and complex numbers.
4. Arithmetic operators for Vectors, Matrices, basic matrix processing.
5. Finding inverse, determinant, transpose, and exponentiation of a Matrix.
6. Reducing to Row/Column echelon form.
7. Linear combination and Solving linear equations.
8. Matrix factorization (for example, Cholesky, LU, SVD).
9. Eigen values and eigen vectors.
10. Finding the orthogonal basis.
11. Subspace intersection, sum and intersection of subspaces.

3rd Semester

MA17001 **4-0-0 (4)**

Operations Research

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
CO-6	2	2	3	2	2	2

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 and Sons, 2013, Third Edition.

3. M. S. Bazaraa, J. J. Jarvis, & H. D. Sherali, Linear programming and network flows, John Wiley and 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.

MA17003 **3-0-0 (3)**

Functional Analysis

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the nature of Banach spaces.
CO-2	Understand the nature of Hilbert spaces.
CO-3	Prove the open mapping theorem, closed graph theorem and uniformboundedness principle.
CO-4	Apply results of this course in solving operator equations.
CO-5	Understand the dual of a Hilbert space, including the adjoint of an operator, and apply projection theorems.

Course Articulation Matrix:

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

Syllabus:

Banach spaces: Normed linear spaces - Banach spaces, Definition and some examples -Incomplete normed linear spaces - Bounded linear operators - Hahn-Banach theorem.

Dual Spaces: Conjugate (or dual) spaces - Natural imbedding of normed linear space N in itssecond conjugate N^{**} - the open mapping theorem - Closed graph theorem - the conjugate of an operator - The Uniform boundedness principle

Hilbert spaces: Definition and basic properties - Orthogonal complements - orthonormal sets - Bessel's inequality - Riesz representation theorem.

Dual of a Hilbert space: The dual of a Hilbert space - adjoint of an operator - projections and projection theorem

Learning Resources:

Text Books:

1. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Inc.,2004, Eighth Edition.
2. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 2007, Third Reprint of First Edition.

Reference Books:

1. J. Conway, A Course in Functional Analysis, Springer, 2007, Second Edition.
2. Casper Goffman and George Pedrick, A First Course in Functional Analysis, AMSChelsea Publishing, 1983, Second Edition.

MA17005 **0-1-2 (2)**

Operations Research Lab

Pre-Requisites: None

Course Outcomes:

CO-1	Write a program to solve an Linear Programming Problem (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

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

MA17007 **0-1-2 (2)**

Software Lab

Pre-Requisites: MA17027

Course Outcomes:

CO-1	Recall the fundamental concepts of C/CPP/Fortran
CO-2	Write a program for second order linear boundary value problem (BVP) using finite difference
CO-3	Write a program for second order nonlinear BVP using finite difference schemes
CO-4	Adapt the finite difference schemes to write a program for Schmidt's two level, Crank-Nicolson's two level for heat conduction problem
CO-5	Develop programs for wave equation using explicit and implicit methods

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Revision: Write a program for Tridiagonal Matrix Algorithm (TDMA) - Thomas Algorithm

Ordinary Differential Equations - Finite Difference Methods:

(1) Write a program using finite difference schemes for

- Second order linear BVP with both Dirichlet boundary conditions
- Second order linear BVP with both Neumann boundary conditions
- Second order linear BVP with right Neumann and left Dirichlet boundary conditions
- Second order linear BVP with left Neumann and right Dirichlet boundary conditions

(2) Write a program for second order non-linear BVP using finite difference schemes

Partial Differential Equations - Finite Difference Methods:

(1) Write a program using finite difference schemes for

- One dimensional heat conduction problem: Schmidt's Scheme (two level)
- One dimensional heat conduction problem: Crank- Nicolson's Scheme (two level)

(2) Write a program using finite difference schemes for

- One-dimensional wave equation

Laplace equation: Explicit and Implicit Methods

MA17091 **0-0-4 (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	2	3	3
CO-2	2		2	2	3	3
CO-3	2		2	2	3	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

MA17093 **0-0-4 (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

MA17094 **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.

MA17098 **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.

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 midterm review, end sem evaluation, template for report preparation and plagiarism

Professional Elective – I

MA16021 **3-0-0 (3)**

Advanced Linear Algebra

Pre-Requisites: None

Course Outcomes:

CO-1	Test the consistency of system of linear algebraic equations
CO-2	Verify rank nullity theorem for a given linear transformation
CO-3	Find eigenvalues and canonical forms of a linear operator
CO-4	Identify the importance of orthogonal property in the spectral theory
CO-5	Demonstrate the knowledge of bilinear form and its nature

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Review of Vector Spaces-Subspaces- Bases and Dimension-Coordinates. Linear Transformations-The algebra of Linear Transformations – Isomorphism - Representation of Transformations by Matrices - Linear Functionals.

Annihilating polynomial, Invariant subspaces. Simultaneous triangularization, Simultaneous diagonalization, Jordan form.

Direct-sum Decompositions - Invariant Direct sums - The primary Decomposition theorem- Cyclic Subspaces and Annihilators, Companion matrix of the monic polynomial.

Inner Product Spaces: Orthogonality: Inner product, Inner product Spaces, Cauchy – Schwarz inequality, Norm, Orthogonality, Gram – Schmidt orthonormalization, Orthonormal basis, Expansion in terms of orthonormal basis, Orthogonal complement, Decomposition of a vector with respect to a subspace and its orthogonal complement.,

Bilinear forms - Symmetric Bilinear Forms - Skew Symmetric Bilinear Forms - Groups preserving Bilinear Forms

Learning Resources:

Text Books:

1. K.Hoffman and R.Kunze, Linear Algebra, Prentice Hall of India, New Delhi, 2003, Second Edition.
2. Sheldon Axler, Linear Algebra Done Right, Springer Nature, 2015, Third Edition
3. David C. Lay, Steven R. Lay, Judi J. McDonald, Linear algebra and its applications, Pearson, 2016, Fifth edition.

Reference Books:

1. Lipschitz, Linear Algebra, Schaum Series
2. H.Friedberg etal, Linear Algebra, PHI(2007).
3. P.Halmos,D Vanostrand, Finite Dimensional Vector Spaces, Princeton.

MA16023 **3-0-0 (3)**

Classical Mechanics

Pre-Requisites: None

Course Outcomes:

CO-1	Develop equations of motion for a system of particles
CO-2	Analyze the motion of a rigid body under translation
CO-3	Explain Euler's theorems for the motions of rigid bodies
CO-4	Analyze the motion of a rigid body under rotation about a fixed point
CO-5	Develop Lagrange's and Hamiltonian equations for body

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Systems of Particles: Linear and angular momentum; Rate of change of angular momentumof a system of particles with respect to the fixed and moving frames of reference; Effect of impulsive forces on the systems of particles.

Rigid Body: Moments of inertia; Kinetic energy and angular momentum of a rigid body rotating about a fixed point and about a fixed axis; General motion of a rigid body; Motion of a rigid body parallel to a fixed plane under finite and impulsive forces.

Rotational Motion: Euler's motion under no forces, Effects of earth's rotation, Eulerian angles.

Lagrangian Mechanics: Generalized coordinates, Velocities and forces; Motion of a top - Lagrange's equations of motion.

Learning Resources:

Text Books:

1. F. Chorlton, Textbook on Dynamics, CBS Publication, 2002, Second Edition
2. J. L. Synge and B. A. Griffith, Principles of Mechanics, McGraw Hill, 1987, Third Edition.

Reference Books:

1. G. R. Fowles and G. L. Cassiday, Analytical Mechanics, Cengage Learning, 2004, Seventh Edition.
2. Murray R. Spiegel, Theory & Problems of Theoretical Mechanics, Schaum's Outline Series, McGraw Hill, 2017, Reprint of First Edition.

MA16025 **3-0-0 (3)**

Mathematical Modelling

Pre-Requisites: None

Course Outcomes:

CO-1	Learn modelling through Ordinary Differential Equations of the first-order.
CO-2	Modelling through a system of ordinary differential equations of the first order
CO-3	Modelling through ordinary differential equations of the second order
CO-4	Learn modelling through partial differential equations.
CO-5	Learn modelling through partial differential equations.

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	2	2	–	–	–	–
CO-4	3	2	–	–	–	–
CO-5	3	2	–	–	–	–

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

Syllabus:

Introduction: Mathematical Modelling: Need, Techniques, Classifications and Simple Illustrations.

Mathematical Modelling through Ordinary Differential Equations of the first order: Linear Growth and Decay Models. Non-linear growth and decay models, Compartment models.

Mathematical Modelling, through a system of Ordinary differential equations of the first order: Prey-predator models, Competition models, Epidemics: simple epidemic model, Susceptible-infected-susceptible (SIS) model, SIS model with constant number of carriers. Medicine: Model for Diabetes Mellitus. Models with removal, and models with immigration.

Mathematical Modelling through Ordinary Differential Equations of the Second order: Mathematical Modelling of the Planetary Motions, Circular Motion, and Motion of Satellite Order, Electric Circuits.

Introduction to difference equations, Mathematical Modelling through difference equations: In Economics and Finance, In Population Dynamics and Genetics, In Probability Theory.

Mathematical Modelling through Partial Differential Equations: Situation giving rise to partial differential equation models, Mass Balance Equations: First Method of Getting PDE Models, Momentum Balance Equations.

Learning Resources:

Text Books:

1. W.J. Meyer, Concepts of Mathematical Modelling, Dover Publications Inc, 2004, First Edition.

2. Brian P. Ingalls, Mathematical Modeling in Systems Biology: An Introduction, MIT Press, 2022, First Edition.

Reference Books:

1. B. Barnes, and G. R. Fulford, Mathematical Modelling with Case Studies, CRC press, 2009, Third Edition
2. Seyed M. Moghadas, Majid Jaberi-Douraki, Mathematical Modelling: A Graduate Textbook, Wiley, 2018, First Edition.

Professional Elective – II

MA16022 **3-0-0 (3)**

Algebra

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze the structure of groups
CO-2	Distinguish the properties among ring structures
CO-3	Understand extension of fields and their constructions
CO-4	Apply the concepts and results to solve problems of Modern 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	1	2	2	2	2
CO-2	3	2	2	2	2	2
CO-3	3	2	2	2	2	2
CO-4	3	3	2	3	2	2
CO-5	3	1	2	3	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Groups: Group actions; Cayley's theorem; Class equation, Automorphisms; Sylow theorems and applications;

Rings: Ring homomorphisms and quotient rings; Quadratic integer rings; Properties of ideals; Ring of fractions; The Chinese Remainder Theorem;

Classes of Rings: Euclidean domains – norm, division algorithm, field norm on quadratic integer rings, results; Principal ideal domains – properties and results, Dedekind-Hasse norm; Unique factorization domains – irreducible elements, prime elements, associates, properties and results; Polynomial rings over fields, polynomial rings that are UFDs, irreducibility criteria;

Fields: Brief introduction to fields, 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. I. N. Herstein, Topics in Algebra, John Wiley & Sons, 1975, Second Edition.

Reference Books:

1. Michael Artin, Algebra, Pearson, 2016, Second Edition.
2. Joseph A. Gallian, Contemporary Abstract Algebra, Cengage Learning, 2013, Eighth Edition.

MA16024 **3-0-0 (3)**

Integral Transforms and Integral Equations

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 of BVP's using Fourier transforms
CO-4	Solve finite difference equations by using Z transforms
CO-5	Solve an integral equation
CO-6	Find the Greens function to a differential equation/integral equation

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	1	2	–	–	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Laplace Transform: Definition; Functions of exponential order and examples; Transforms of elementary, transcendental and special functions; Transforms of derivatives and integrals; Transforms of periodic, unit-step and impulse functions; The inverse transform –Properties, Partial fraction, Convolution theorem; Solution of differential equations by the use of the transform - Laplace inverse integral, Solution of Laplace equation (in two dimensions), One-dimensional heat and wave equations. Demonstrations with simple examples.
Fourier Transform: The 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. Demonstrations with simple examples.

Z-transform: Z-transform, Inverse Z-transform, Z-transform properties, Solution of linear difference equations by using Z-transform. Discrete Fourier Transform - Fourier transform of sequences, Discrete Fourier transform, transfer function.

Integral equations: Classification of integral equations, Connection with differential equations, Integral equations of the convolution type, Method of successive approximations, the resolvent, Fredholm theory, Laplace and Fourier transforms with applications to integral equations. Green's functions: Non-homogeneous boundary value problems, one-dimensional Green's function.

Learning Resources:

Text Books:

1. R.V. Churchill, Operational Mathematics, McGraw Hill, 1972.

2. F. B. Hildebrand, Methods of Applied Mathematics PHI, New Jercy, 1960.
3. E. I. Jury, Theory and applications of Z-Transform method, John Wiley, 1964.

Reference Books:

1. I.N. Snedden, The use of Integral Transforms, Tata Mc-Grawhill, 1979
2. John W. Dettman, Mathematical methods in Physics & Engineering, McGraw Hill, NewYork, 1962

MA16026 **3-0-0 (3)**

Differential Geometry and Tensor Analysis

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the directions of tangent, normal and binormal at point on the given
CO-2	Find the geodesic curve on a given surface
CO-3	Find surfaces of constant curvature
CO-4	Form tensor quantities and find the corresponding metric tensors
CO-5	Expose students to mathematical applications of tensor algebra to handle diverse

Course Articulation Matrix:

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

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

Syllabus:

Local curve theory: Serret-Frenet formulation, Fundamental existence theorem of space curves.

Plane curves and their global theory: Rotation index, Convex curves, Isoperimetric inequality, Four vertex theorem.

Local surface theory: First fundamental form and arc length, Normal curvature, Geodesic curvature and Gauss formulae, Geodesics, Parallel vector fields along a curve and parallelism, the second fundamental form and the Weingarten map, Principal, Gaussian, Mean and normal curvatures, Riemannian curvature and Gauss's theorem Egregium, Isometrics and fundamental theorem of surfaces.

Global theory of surfaces: Geodesic coordinate patches, Gauss-Bonnet formula andEuler characteristic, Index of a vector field, Surfaces of constant curvature.

Tensor Analysis: N-dimensional space, Covariant and contravariant vectors, Contraction, Second & higher order tensors, Quotient law, Fundamental tensor, Associate tensor, Angle between the vectors, Principal directions, Christoffel symbols, Covariant and intrinsic derivatives.

Learning Resources:

Text Books:

1. R. S. Millman and G. D. Parker, Elements of Differential Geometry, Prentice Hall Inc.,1977, First Edition.
2. Barry Spain, Tensor Calculus, Dover Publications, 2003, Reprint of First Edition.

Reference Books:

1. S. Kumaresan, A Course in Differential Geometry and Lie Groups, Texts and Readings in Mathematics, 22, Hindustan Book Agency, New Delhi, 2002, First Edition.
2. I. N. Snedden, The Use of Integral Transforms, Tata McGraw-Hill, 1974, First Edition.

Professional Elective – III

MA16028 **3-0-0 (3)**

Complex Analysis

Pre-Requisites: **None**

Course Outcomes:

CO-1	Introduce the analyticity of complex functions and study their applications.
CO-2	Evaluate complex integrals and expand complex functions.
CO-3	Determine and classify the zeros and singularities of the complex functions.
CO-4	Evaluate improper integrals by residue theorem.
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	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:

Functions of Complex Variables: Complex variable - Functions of a complex variable - Continuity - Differentiability – Analytic functions.

Complex Integration: Cauchy's theorem - Cauchy's integral formula - Morera's theorem - Cauchy's inequality - Liouville's theorem. Series Expansions: Taylor's theorem - Laurent's theorem - Zeros of an analytic function - Singularities

Contour Integration: Residues - Cauchy's residue theorem – contour integration - the fundamental theorem of algebra - Poisson's integral formula. Analytic continuation - branches of a many-valued function - contour integration with branch, Riemann surface. The maximum modulus theorem - mean values of f(z). Rouche's theorem and its applications.

Geometry aspects of Analytical functions: Conformal mapping– Bilinear transformation - Transformation by elementary functions-uniqueness of conformal transformation - representation of any region on a circle.

Learning Resources:

Text Books:

1. R.V. Churchill and J.W. Brown, Complex Variables and Applications, McGraw Hill, Tokyo, 2013, Ninth Edition.
2. John B. Conway, Functions of One Complex Variable, Springer, India, 1995, Second Edition.

Reference Books:

1. S. Ponnusamy and Herb Silverman, Complex Variables with Applications, Birkhauser, Boston, Birkhauser Boston Incorporation publishers, 2006, First Edition.
2. Murray Spiegel, Seymour Lipschutz, John Schiller, and Dennis Spellman, Complex Variable, Schaum's Outlines Series, McGraw Hill, 2017, Revised Second Edition.

MA16030 **3-0-0 (3)**

Lie Group Methods for Differential Equations

Pre-Requisites: None

Course Outcomes:

CO-1	Show competence in the field of ordinary and partial differential equations
CO-2	Show analytic skills and working knowledge in Lie's integration methods
CO-3	Solve linear and non-linear differential equations
CO-4	Reduce a vast amount of nonlinear second-order ordinary equations used in applications to four
CO-5	Know the terminology in group analysis of differential equations

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	3	2	3	–	–	1
CO-4	3	2	2	–	–	2
CO-5	3	2	2	–	–	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Lie group analysis: Lie group of transformations – Groups, Group oftransformations; One parameter Lie groups of transformations - Infinitesimal transformations -First order theorem of Lie - Infinitesimal generators - Invariant functions - Canonical coordinates - Invariants of points - Curves and surfaces - Extended infinitesimal - Extended transformations (Prolongations) - Symmetry reductions - Multi parameter Lie groups of transformations.

Group analysis of ordinary differential equations: Invariance of ordinary differential equations - Prolongation techniques - Calculation of Lie symmetry groups - Differential equations admitting a given group - Invariant solutions - Group classification for ordinary differential equations - Symmetry analysis for systems of ordinary differential equations.

Group analysis of partial differential equations: Invariance of partial differential equations-Prolongation formulae - Determining equations - Infinitesimal of partial differential equations - Invariant solutions - Group classification for partial differential equations - Lie symmetries for systems of partial differential equations.

Learning Resources:

Text Books:

1. G.W. Bluman, S. Kumei, Symmetries and Differential Equations, Springer-Verlag, NewYork, 1989, First Edition.
2. L.V. Ovsiannikov, Group Analysis of Differential Equations, Academic Press, New York,1982 (Moscow, Nauka, 1978, in Russian), First Edition.

Reference Books:

1. P. Olver, Applications of Lie groups to Differential Equations, Springer-Verlag, Berlin,1993, Second Edition.
2. P. E. Hydon, Symmetry Methods for Differential Equations: A Beginner's Guide, Cambridge University Press, 2010.

MA16032 **3-0-0 (3)**

Iterative Methods

Pre-Requisites: None

Course Outcomes:

CO-1	Solve differential equations using ADM.
CO-2	Get solutions of differential equations by HPM.
CO-3	Find solutions of fluid dynamics problems using HAM.
CO-4	Apply VIM for ODEs.

Course Articulation Matrix:

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

Syllabus:

Adomian Decomposition Method (ADM): The ADM for solving differential equations, Convergence of ADM, ADM in several dimensions, Solving boundary value problems using ADM, Modified ADM, Mathematica code of ADM.

Homotopy Perturbation Method (HPM): The HPM algorithm, Convergence analysis, Applications.

Homotopy Analysis Method (HAM): The HAM algorithm, Convergence analysis, The role of auxiliary parameter, Control of convergence, Relation to ADM and HPM, Applications of HAM to solve nonlinear equations.

Variational Iteration Method (VIM): The VIM algorithm, Convergence of VIM, Applications to solve ordinary differential equations, Solving system of fractional differential equations using ADM.

Learning Resources:

Text Books:

1. G. Adomian, Solving frontier problems in Physics: The decomposition method, Kluwer Academic Publishers, London, 1994.
2. S. Liao, Beyond perturbation: introduction to the homotopy analysis method, , CRC press, 2003.
3. Belal Batiha, Variational Iteration Method and its applications, LAP Lambert Academic Publishing, 2012.

Professional Elective – IV

MA17021 **3-0-0 (3)**

Discrete Methematics

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

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

Syllabus:

Mathematical Logic: Connectives, Tautologies, Equivalence of formulas, Duality law, Tautological implications, Normal forms, Theory of inference for statement calculus, Methods of proof.

Predicates: Predicative logic, Statement functions, Variables and quantifiers, Free and bound variables, 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 its 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, Lattices.

Boolean Algebra: Chains, Lattices, 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, Second Edition
2. C. L. Liu, and O. P. Mohapatra Elements of Discrete Mathematics, McGraw Hill, 2017, Fourth Edition

Reference Books:

1. K. H. Rosen, Discrete Mathematics and its Applications with Combinatorics and Graph Theory, Tata McGraw Hill, 2015, Seventh Edition.
2. Bernand Kolman, Robert C. Busby and Sharon Cutler Ross, Discrete Mathematical Structures, PHI, 2009, Sixth Edition.

MA17023 **3-0-0 (3)**

Distribution Theory

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the weak solutions for differential equations
CO-2	Understand support and singular support of distributions
CO-3	Derive fundamental solutions of partial differential equations
CO-4	Prove approximations theorems

Course Articulation Matrix:

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

Syllabus:

The calculus of distributions: Test functions and distributions, Some operations with distributions, Adjoint identities, Consistency of derivatives, Distributional solutions of differential equations. Support and singular support of distributions, Convolution of functions, Convolution of distributions, Fundamental solutions.

The Fourier transforms: From Fourier series to Fourier integrals, The Schwartz space, The Fourier inversion formula, Tempered distributions. Convolution with tempered distributions.

Solving partial differential equations: The Laplace equation, The heat equation, The wave equation.

The structure of distributions: Structure theorems, Distributions with point support, Positive distributions, Continuity of distributions, Approximation theory of distributions, Local theory of distributions, Distributions on spheres.

Learning Resources:

Text Books:

1. S. Kesavan, Topics in Functional Analysis and Applications, , New Age International Publishers, 2015.
2. R. S. Strichartz, A Guide to Distribution Theory and Fourier Transforms, World Scientific, 2008, Third Edition

Reference Books:

1. I. M. Gelfand and G. E. Shilov, Generalized Functions, Academic Press, 1964, Vol.1.
2. Gerald B. Folland, Introduction to Partial Differential Equations, Princeton University Press, 1995

MA17025 **3-0-0 (3)**

Multivariate Data Analysis

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze Multivariate Distributions and their characteristics
CO-2	Perform Multivariate Analysis of variance
CO-3	Perform Conjoint analysis
CO-4	Analyze Cluster analysis and canonical correlation
CO-5	Interpret Multidimensional scaling

Course Articulation Matrix:

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

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

Syllabus:

Multivariate analysis of variance: Introduction -- Differences between MANOVA and discriminant analysis – A hypothetical illustration of MANOVA – A decision process for MANOVA

Conjoint analysis: Comparing conjoint analysis with other multivariate methods – Designing a conjoint analysis experiment – Managerial applications of conjoint analysis – Alternate conjoint methodologies – An illustration of conjoint analysis

Canonical correlation analysis: Analysing relationships with canonical correlation – interpreting the canonical variate – Validation and diagnosis

Cluster analysis: Cluster analysis decision process – Multidimensional scaling – Comparing MDS to other interdependence techniques – A decision framework for perceptual mapping – Correspondence analysis.

Learning Resources:

Text Books:

1. Joseph F. Hair, Multivariate Data Analysis, CENGAGE, 2018, Eighth Edition.
2. M. G. Kendall, Charles Griffith, A Course in Multivariate Analysis, 1968, First Edition.

Reference Books:

1. Trever Cox, An Introduction of Multivariate Data Analysis, Holder Education, 2005, First Edition.
2. Kohei Adachi, Matrix Based Introduction to Multivariate Data Analysis, Springer, 2021, Second Edition.

Professional Elective – V

MA17027 3-0-0 (3)

Numerical Solutions of Differential Equations

Pre-Requisites: **MA16007**

Course Outcomes:

CO-1	Apply the explicit and implicit multistep methods to solve the linear and non-linear initial value problems in ordinary differential equations
CO-2	Apply the cubic splines method to solve the two-point boundary value problems in ordinary differential equations
CO-3	Apply the iterative schemes to finite difference equations.
CO-4	Find the numerical solution of the heat equation, wave equation and the Laplace equation in one dimensional and 2-dimensional space using the finite difference
CO-5	Analyse the stability, convergence and the error analysis of the finite difference methods

Course Articulation Matrix:

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

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

Syllabus:

Ordinary Differential Equations: Multistep (explicit and implicit) methods for initial value problems, Linear and nonlinear boundary value problems, Quasi-linearization and Shooting methods.

Finite Difference Methods: Finite difference approximations for derivatives, Boundary value problems with explicit and implicit boundary conditions, Error analysis, Stability analysis, Convergence analysis.

Partial Differential Equations: Finite difference approximations for partial derivatives and finite difference schemes for parabolic equations: Schmidt's two level, Multi-level explicit methods, Crank-Nicolson's two level, Multi-level implicit methods, Dirichlet's problem, Neumann problem, Mixed boundary value problem. Hyperbolic Equations: Explicit methods, Implicit methods, One space dimension. Elliptic equations: Laplace equation, Poisson equation, Iterative schemes, Dirichlet's problem, Neumann problem, Mixed boundary value problem, ADI methods.

Learning Resources:

Text Books:

1. M. K. Jain, Numerical Solution of Differential Equations, Wiley Eastern, Delhi, 2018, Fourth Edition.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Computational Methods for Partial Differential Equations, Wiley Eastern, 2016, Second Edition.

Reference Books:

1. G. D. Smith, Numerical Solution of Partial Differential Equations, Oxford University Press, 2004, Reprint of Third Edition.
2. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, 2012, Fifth Edition.

MA17029 **3-0-0 (3)**

Dynamical Systems

Pre-Requisites: **MA16003 & MA16004**

Course Outcomes:

CO-1	Identify Autonomous and Nonautonomous Systems
CO-2	Understand Limit Cycle Motion and Periodic Attractor
CO-3	Differentiate Dissipative and Conservative Systems
CO-4	Understand different types of bifurcations
CO-5	Apply Poincare Bendixson Theory.

Course Articulation Matrix:

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

Syllabus:

Qualitative Features: Autonomous and nonautonomous Systems- Equilibrium Points - Phase space/phase plane and phase trajectories: Stability, Attractors and Repellers; Classification of equilibrium points- Limit cycle motion - Periodic attractor – Poincare - Bendixson theorem - Higher dimensional systems: Lorenz equations - Quasiperiodic attractor- Poincare map - Chaotic attractor - Dissipative and conservative systems - Hamiltonian systems.

Bifurcations and Onset of Chaos in Dissipative Systems: Saddle-node bifurcation - Pitchfork bifurcation - Transcritical bifurcation - Hopf bifurcation - Discrete dynamical systems - Logistic map - Equilibrium points and their stability- Periodic solutions or cycles - Period doubling phenomenon- Onset of chaos: Sensitive dependence on initial conditions - Lyapunov exponent- Bifurcation diagram - Logistic map- Strange attractor in the Henon map - The period doubling phenomenon - Self-similar structure - Route to chaos.

Chaos in Conservative Systems: Poincare cross section - Orbits in conservative systems - Regular and irregular trajectories - Canonical perturbation theory: Overlapping resonances and chaos - Periodically driven undamped duffing oscillator - The standard map - Linear stability and invariant curves - Numerical analysis: Regular and chaotic motions.

Characterization of Regular and Chaotic Motions: Lyapunov exponents - Numerical computation of Lyapunov exponents - One-dimensional map - Computation of Lyapunov exponents for continuous time dynamical systems- Power spectrum and dynamical motion - Autocorrelation - Criteria for chaotic motion.

Learning Resources:

Text Books:

1. M. Lakshmanan, S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer, First edition, 2010.
2. George F. Simmons, Differential Equations with Applications and Historical Notes, McGraw-Hill, Second Edition, 2003.

Reference Books:

1. Hirsch, Smale and Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, , Elsevier Academic Press, USA, 2004.
2. Lawrence Perko, Differential Equations and Dynamical Systems, Third Edition, Springer-Verlag, 2010.

MA17031 **3-0-0 (3)**

Analysis of Differential Equations

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the Poincare inequality
CO-2	Understand the concepts of approximation
CO-3	Utilization of weak derivatives
CO-4	Apply the Galerkin's method
CO-5	Study the canonical forms of partial differential equations

Course Articulation Matrix:

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

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

Syllabus:

Semigroups: Semigroups of operators, Examples, basic properties, Hille-Yosida theorem, Maximl dissipative operators, regularity, Heat equation, wave equation, Schrodinger equation, Inhomogeneous equations.

Sobolev spaces: Definition of Sobolev spaces, approximation by smooth functions, Extension theorems, Poincare inequality, Imbedding theorems, Compactness theorems, trace theory.

Boundary value problems: Variational problems in Hilbert spaces and Lax-Milgram lemma. Examples of weak formulations of elliptic boundary value problems, Regularity, Galerkin's method, Maximum principles, Eigenvalue problems, introduction to the finite element method,

Learning Resources:

Text Books:

1. S. Kesavan, Topics in Functional Analysis and Applications, John Wiley & Sons, 1989, First Edition.
2. L.C. Evans, Partial differential equations, American Mathematical Society, 2022, Second Edition.

Reference Books:

1. Walter Rudin, Real and complex analysis, McGraw-Hill, New York, 2003, Third Edition.
2. H. L. Royden, Real Analysis, Pearson, 2003, Third Edition.

Professional Elective – VI

MA17022 **3-0-0 (3)**

Measure and Integration

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the class of measurable sets
CO-2	Derive properties of Lebesgue measurable sets and functions
CO-3	Determine whether the given function is Lebesgue integrable or not
CO-4	Prove Fatou's Lemma, Lebesgue's Monotone convergence theorem and Lebesgue dominated convergence theorem
CO-5	Understand and apply product measures and Fubini's theorem to perform integration on Cartesian products.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Lebesgue Measure: Outer measure, Measurable sets, A non-measurable set, Example of measurable set which is not a Borel set, Lebesgue measure and its properties, Measurable functions.

Abstract Integration: The concept of measurability, Simple functions, Elementary properties of measures, Arithmetic in [0, ∞], integration of positive functions, Lebesgue's monotone convergence theorem, Fatou's lemma, Lebesgue's dominated convergence theorem, Integration of complex functions, the role played by sets of measure zero.

Product measures: Integration on Cartesian products, Product measures, The Fubini's theorem.

Learning Resources:

Text Books:

1. H. L. Royden, Real Analysis, Pearson, 2003, Third Edition.
2. W. Rudin, Real and Complex Analysis, Tata McGraw-Hill Edition, 2006, Third edition

Reference Books:

1. G. de Barra, Measure and Integration, New Age International Pvt. Ltd, 2013, First Edition.
2. Terence Tao, An Introduction to Measure Theory, Graduate Studies in Mathematics, AMS, 2011.

MA17024 **3-0-0 (3)**

Finite Element Method

Pre-Requisites: None

Course Outcomes:

CO-1	Determine an extremum by calculus of variations approach
CO-2	Formulate a variational problem for a boundary value problem
CO-3	Find the solution of solution of one-dimensional problems
CO-4	Find the solution of two-dimensional problems by rectangular elements
CO-5	Find the solution of two-dimensional problems by triangular elements

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Calculus of Variations: Introduction, Euler's Equation, Euler Lagrange Equations, Ostrogradsky equation.

Variational formulation: 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.

One dimensional problem: Solution of one-dimensional boundary value problems by linear, quadratic and cubic shape functions.

Two dimensional problems: Solution of two-dimensional boundary value problems by linear, quadratic and cubic rectangular, serendipity and triangular shape functions.

Time Dependent Problems: One-dimensional heat and wave equations.

Learning Resources:

Text Books:

1. J. N. Reddy**,** An Introduction to the Finite Element Method, McGraw Hill, 2020, Fourth Edition.
2. I. J. Chung**,** Finite Element Analysis in Fluid Dynamics, McGraw-Hill International Book Company, 2007, Digitized Version, First Edition.

Reference Books:

1. O. C. Zienkiewiez and K. Morgan, Finite Elements and Approximation, John Wiley, 1983, First Edition.
2. P. E. Lewis and J. P. Ward, The Finite Element Method - Principles and Applications, Addison Wesley, 1991, First Edition.

MA17026 3-0-0 (3)

Inventory, Queuing Theory and Non-Linear Programming

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the characteristics of a queuing model
CO-2	Determine the EOQ for a deterministic inventory model
CO-3	Determine the EOQ for a stochastic inventory model
CO-4	Determine the solution of a CNLPP
CO-5	Determine the solution of a QPP

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Queuing theory: Characteristics of queueing systems - The birth and death process - Steady state solutions - Single server model (finite and infinite capacities) - Single server model (with SIRO) - Models with state dependent arrival and service rates- Waiting time distributions.

Inventory control: Inventory control for single commodity - Deterministic inventory models (without and with shortages) - Probabilistic inventory (both discrete and continuous) control models.

Nonlinear programming problem: Unconstrained NLPP, Constrained NLPP - Lagrange's multipliers method - Convex NLPP, Kuhn-Tucker conditions (including the proof) - Quadratic programming problem (Wolfe's method).

Learning Resources:

Text Books:

1. H. A. Taha, Operations Research: An Introduction, PHI, Delhi, 2014, Tenth Edition.
2. H. M. Wagner, Principles of Operations Research, PHI, Delhi, 2010, Second Edition.

Reference Books:

1. J. C. Pant, Introduction to Optimization: Operations Research, Jain Brothers, Delhi, 2015, Seventh Edition.
2. Kanti Swarup, P.K. Gupta, Man Mohan, Operations Research - Introduction to Management Science, Sultan Chand and Sons, 2019, Thirteenth Edition.

Professional Elective – VII

MA17028 **3-0-0 (3)**

Fluid Dynamics

Pre-Requisites: None

Course Outcomes:

CO-1	Draw stream lines and path lines of a velocity field of a fluid
CO-2	Find complex velocity potential for an incompressible and irrotational flow
CO-3	Set up equations of motion with boundary conditions for problems and solve them
CO-4	Analyze the flow in a tube of uniform cross section and find volumetric flow rate
CO-5	Draw streamlines and path lines of a velocity field of a fluid

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Kinematics of fluids in motion: Real fluids and ideal fluids – Velocity of a fluid at a point – Stream lines and path lines – Steady and unsteady flows – The velocity potential – The velocity vector – Local and particle rates of change – The equation of continuity – Acceleration of fluid – Conditions at a rigid boundary.

Equations of motion of fluid: Euler's equations of motion – Bernoulli's equation – Some flows involving axial symmetry – Some special two-dimensional flows. Some three-dimensional flows: Introduction – Sources, sinks and doublets – Axisymmetric flows – Stokes' stream function. The Milne-Thomson circle theorem – The theorem of Blasius – Applications.

Viscous flows: Stress analysis in fluid motion – Relations between stress and rate of strain – The coefficient of viscosity and laminar flow – the Navier-Stokes' equations of motion of viscous fluid – Steady motion between parallel planes, Through tube of uniform cross section and flow between concentric rotating cylinders. Steady viscous flow in tubes of uniform cross section – A uniqueness theorem – Tube having uniform elliptic cross section – Tube having equilateral triangular cross section – Steady flow past a fixed sphere.

Learning Resources:

Text Books:

1. Frank Chorlton, Fluid Dynamics, CBS Publishers, Delhi, 2004, Reprint of First Edition.
2. L. M. Milne Thomson, Theoretical Hydrodynamics, Macmillan Company, New York, 1960, First Edition.

Reference Books:

1. Franz Durst, Fluid Mechanics: An Introduction to the Theory of Fluid Flow, Springer Verlag Berlin Heidelberg, 2008, Second Edition
2. Stephen Whitaker, Introduction to Fluid Mechanics, Ed-Tech Press, 2018, Second Edition.

MA17030 **3-0-0 (3)**

Graph Theory and Algorithms

Pre-Requisites: None

Course Outcomes:

CO-1	Examine whether the graphs are isomorphic or not
CO-2	Determine whether graphs are Hamiltonian and/or Eulerian
CO-3	Construct minimal spanning trees and shortest paths
CO-4	Determine the matching in a graph and solve the assignment problem
CO-5	Construct planar graphs, coloring 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, Fleury’s algorithm; Vertex degree and counting, Havel-Hakimi criteria; 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; Weighted bipartite matching - Hungarian algorithm and solving the assignment problem; Tutte's theorem.

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; Cycle method for planarity testing, 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, First Edition.
2. J. A. Bondy and U. S. R. Murty, Graph Theory, Springer, 2010, First Edition.

MA17032 **3-0-0 (3)**

Finite Volume Method

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discretize steady and unsteady convection-diffusion problem
CO-2	Identify the properties of discretisation schemes.
CO-3	Solve convective problems using upwind, QUICK and hybrid schemes
CO-4	Solve the velocity and pressure coupling
CO-5	Solve discretised equations using multigrid methods

Course Articulation Matrix:

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

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

Syllabus:

Convection - Diffusion problems and discretization: Steady 1D, 2D and 3D convection and diffusion problems - Discretization schemes: Central differencing scheme, Upwind differencing scheme, Hybrid differencing scheme, Power-law scheme. Properties of discretization schemes: Conservativeness - Boundedness - Transportiveness.

Higher-order differencing schemes: Quadratic upwind differencing scheme: the QUICK scheme - Stability problems of the QUICK scheme and remedies - Generalization of upwind- biased discretization schemes - Total variation and TVD schemes - Criteria for TVD schemes - Flux limiter functions - Implementation and Evaluation of TVD schemes.

Solution algorithms for pressure—velocity coupling: The staggered grid – SIMPLE algorithm - SIMPLER algorithm.

Solution of discretized equations: Application of the TDMA to 2D and 3D problems - Point- iterative methods: Jacobi iteration method - Gauss-Seidel iteration method - Relaxation methods - Multigrid techniques: Multigrid cycles - Grid generation for the multigrid method.

Unsteady flows: Explicit scheme - Crank-Nicolson scheme - Fully implicit scheme - Transient SIMPLE.

Learning Resources:

Text Books:

1. H. Versteeg and W. Malalasekera, An introduction to CFD: The Finite Volume Method, Pearson, 2007, Second Edition.
2. S.V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, 2009, Reprint of First Edition.

Reference Books:

1. D.M. Causon, C.G. Mingham, and L. Own, Introductory Finite Volume Methods for Partial Differential Equations, Springer, 2009, Reprint of 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.