Program Outcomes (POs)

PO 1 Science knowledge Apply mathematics knowledge and mathematics specialties to the solution of challenging scientific issues.
PO 2 Problem Analysis Analyze and understand the theoretical and practical data at various workplaces.
PO 3 Design/ Development of solutions Design a system, component, or process to meet the desired needs within realistic constraints such as economic, environmental, health and safety, and sustainability.
PO 4 Conduct investigations of complex problems Develop the capacity to analyze complicated issues and offer workable answers by applying applied research knowledge.
PO 5 Modern tool usage Identifying, formulating, and resolving scientific issues with contemporary methods and technologies.
PO 6 Mathematics and Society Obtain the wide education required to comprehend how scientific solutions impact the local, national, international, economic, environmental, and societal contexts.
PO 7 Environment and Sustainability Understand the environmental damage and develop environmental friendly and sustainable scientific practices using the solutions in the societal and environmental context.
PO 8 Ethics Develop an ethical-moral value system and cater to the community needs in a voluntary manner by the judicious use of scientific principles
PO 9 Multidisciplinary Approach Develop a multidisciplinary approach and function on multidisciplinary teams.
PO 10 Communication Develop various communication skills such as listening, speaking, writing, etc. which will help in the effective expression of ideas and views. PO 11 Project Management and Finance Apply scientific knowledge and management skills to manage projects in industries, research and development institutions, public sector units, higher education and in academia.
PO 12 Life-long Learning Demonstrate effective usage of existing resources at workplaces and raise awareness of the importance of life-long learning

Program Specific Outcomes (PSOs)

PSO 1 Understand the mathematical concepts and explore a variety of applications having interdisciplinary dimensions. Build both analytical as well as innovative approach in solving problems of mathematical sciences.
PSO 2 Apply, analyze, and interpret basic and advanced computational laboratory concepts to develop necessary computing skills in scientific community.
PSO 3 Earn research experience within a specific field of mathematical sciences, through a supervised project to enhance the ability of the students in successfully carrying out multidisciplinary projects, in collaboration with other departments.

Program Educational Objectives (PEOs)

PEO 1 Develop students with sound mathematical knowledge and technical skills to identify, analyze and solve real-world problems.
PEO 2 Prepare students with strong foundation in all areas of mathematics for successful careers in research and innovation in various fields including academia, industries, etc.
PEO 3 Integrate comprehensive knowledge, teamwork, leadership qualities, teaching and communication skills for lifelong learning.
PEO 4 Provide students with guidance, practical training and hands-on project experience to meet the employment needs.

DETAILED SYLLABUS
Semester-I

MMAT-101: Real Analysis

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The course will develop a deep and rigorous understanding of real line $\mathbb{R}$ and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Understand many properties of the real line, especially axiomatic theory and point set topology on $\mathbb{R}$.

CO2. Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.

CO3. Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers

Contents:

Unit I: Interval and its different kinds, Bounded and unbounded sets, Supremum and infimum, Field axioms, Order axioms and Completeness axioms on $\mathbb{R}$, Nested interval property, Basic properties of natural numbers, integers and rational numbers, Archimedean property of real numbers, Denseness property of rational numbers in $\mathbb{R}$.

Unit II: Concept of sequence, Limit points of a sequence, Bolzano Weierstrass theorem for sequence, Limit inferior and superior, Convergent, divergent and oscillate sequences, Bounded and unbounded sequences, Cauchy's general principle of convergence, Algebra of sequences, Subsequences, Monotonic increasing and decreasing sequences.

Unit III: Introduction to series of real numbers, Sequence of partial sums and convergence of infinite series, Necessary condition for the convergence of an infinite series, Positive term series, Comparison tests (first type and limit form), Cauchy root test, D'Alembert's ratio test with their applications

Unit IV: Neighbourhood of a point, Interior, exterior and boundary points, Open sets, Limits points and derived set, Bolzano-Weierstrass Theorem, Adherent point and Closure of a set, Closed sets and their sequential characterization, Compact sets and their sequential characterization, Heine-Borel Theorem, Connected sets, Dense sets, Perfect sets, Cantor sets, Borel se.

Suggested Readings:

[1] *R. G. Bartle and D. R. Sherbert: Introduction to Real Analysis, John Wiley and Sons, Singapore, 3rd Ed, 2003.*

[2] *S. C. Malik and S. Arora: Mathematical Analysis, New Academic Science Ltd, 5th Ed, 2017.*

[3] *W. Rudin: Principles of Mathematical Analysis, Third Edition, McGraw Hill, New York, 3rd Ed, 1976, 2005.*

[4] *S. K. Mappa*

MMAT-102: Complex Analysis

Total Marks: 100 (70 End Semester Examination + 40 Internal Assessment)

Course Objectives: This course aims to provide knowledge about the analytical aspects of complex functions in complex variables with visualization through relevant practicals. Particular emphasis has been laid on Cauchy's theorems, series expansions and calculation of residues.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equation.

CO2. Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.

CO3. Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities

CO4. Find residues and apply Cauchy Residue theorem to evaluate integrals.

Contents:

Unit I: Limits, Continuity and differentiability of functions of a complex variable, Cauchy-Riemann (CR) equations, Sufficient conditions for differentiability, Polar form of CR equations, Analytic functions, Harmonic functions, Harmonic conjugate, Polar form of Laplace equation

Unit II: Definite integral of a complex valued function of a real variable, Contour integrals, Cauchy-Goursat theorem,Consequences of Cauchy-Goursat theorem, Cauchy's integral formula, Cauchy's integral formula for higher order derivatives

Unit III: Morera's theorem, Cauchy's inequality, Liouville's theorem, Fundamental theorem of algebra, Gauss' mean value theorem.

Unit IV: Sequence and series of complex functions and their convergences, Power series and its convergence (Absolute/Uniform), Taylor's series, Laurent's series (without proof), Singular points and its classifications, Zeros and poles of order m, Residues, Calculation of residues, Residue theorem.

Suggested Readings:

[1] R. V. Churchill and J. W. Brown: Complex Variables and Applications, New York *McGraw Hill, 9th Ed, 2013.

[2] 2. H. S. Kasana: Complex Variables -Theory and Applications, Prentice Hall of India, New Delhi, 2nd Ed, 2008.Society, 2008.

[3] S. Ponnusamy: Foundations of Complex Analysis, 2nd Ed, Narosa Publishing House, 2005.

MMAT-104: Ordinary Differential Equations

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The objective of this course is to study the solutions of first order ODE's, linear second order ODE's, boundary value problems, eigen values and eigen functions of Sturm Lioville systems, stability of systems of ODEs and PDEs.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Know about existence, uniqueness and continuity of solutions of first order ODE's, properties of zeros of solutions of linear second order ODE's, boundary value problems.

CO2. Understand with Eigen values and Eigen functions of Sturm–Liouville systems, and thesolutions of initial and boundary value problems.

CO3. Be well equipped to undertake any advanced course on ordinary as well as partialdifferential equations.

Unit I: Well posed problems, Existence, uniqueness and continuity of solution of ODEs of first order, Picard's method, Existence and uniqueness of solution of simultaneous differential equations of first order and ODEs of higher order, Sturm separation and comparison theorems, Homogeneous linear systems, Non-homogeneous linear systems, Linear systems with constant coefficients.

Unit II: Two point boundary value problems, Green's function, Construction of Green's function, Sturm–Lioville systems, Eigen values and eigen functions, Stability of autonomous system of differential equations, Critical point of an autonomous system and their classification as stable, Asymptotically stable, Strictly stable and unstable, Stability of linear systems with constant coefficients, Linear plane autonomous systems, Perturbed systems, Method of Lyapunov for nonlinear systems.

Unit III: Fourier transform and its application to solution of PDEs, Boundary value problems, Maximum and minimum principles, Uniqueness and continuous dependence on boundary data, Solution of the Dirichlet and Neumann problem for a half plane by Fourier transform method, Solution of Dirichlet problem for a circle in form of Poisson integral formula, Theory of Green's function for Laplace equation in two dimension and application in solution of Dirichlet and Neumann problem for half plane and circle, Theory of Green's function for Laplace equation in three dimension and application in solution of Dirichlet and Neumann problem for semi-infinite spaces and spheres.

Unit IV: Wave equation, Helmholtz's first and second theorems, Green's function for wave equation, Duhamel's principles for wave equation, Diffusion equation, Solution of initial

boundary value problems for diffusion equation, Green's function for diffusion equation, Duhamel's principles for heat equation.

Suggested Readings:

[1] E.A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications,2012.
[2] T. Myint-U, *Ordinary Differential Equations*, Elsevier, North-Holland, 1978.
[3] S.L. Ross, *Differential Equation*s, Second Edition, John Wiley & Sons, India, 2007.
[4] I.N. Sneddon, *Elements of Partial*
[5] *Differential Equations*, Dover Publications, 2006.

MMAT-105: Group Theory

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: To define the foundational concepts of abstract algebra, including binary operations and groups, and to explore the basic properties and proofs related to groups and subgroups. This course will delve into different types of subgroups, cyclic groups, and cosets, culminating with an understanding of Lagrange's theorem and its applications.

Course Outcomes: After studying this course the student will be able to

CO1. Prove fundamental structural properties of groups and subgroups, and apply group axioms to a variety of problems.

CO2. Verify and demonstrate properties of subgroups, cosets, and apply Lagrange's theorem and its corollaries to solve related problems.

CO3. Analyze and differentiate between types of groups, including isomorphic groups, normal subgroups, and simple groups, and explore the properties of cyclic groups.

CO4. Apply abstract algebra concepts to compute the direct products of groups and analyze groups of permutations, including the alternating groups**.**

Unit I: Binary relation, Function, Binary Operation; Groups, its examples and basic properties, Order of an element in a group, Subgroup its examples and some basic properties, Cyclic groups, Generators, its examples.

Unit II: Cosets, Lagrange's theorem and its related results, Index of subgroup of a group, Euler's theorem, Fermat's theorem, Isomorphism and homomorphism of groups, Normal subgroups, Cayley's theorem, Cauchy's theorem.

Unit III: Commutator subgroup and some basic properties, Quotient groups with examples, First, second and third isomorphism theorems and their related results, Internal and External direct product of groups and their related results.

Unit IV: Permutations, even and odd permutations, Order of a permutation, Transposition, Cycle and its length, Disjoint cycles and their examples, Permutation groups, Alternating groups and their related results, Signature of a permutation.

Suggested Readings:

[1] N. S. Gopalakrishnan: University Algebra
[2] Joseph A. Gallian: Contemporary Abstract Algebra

MMAT-106: LaTeX -I

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The objective of this course is to introduce latex for research paper preparation, project, book etc and beamer for beautiful presentations.

Course Outcomes: Upon successful completion, students will have the knowledge and skills to:

CO1. Install Latex and execute small documents
CO2. Typeset any type of document which involve more math
CO3.Prepare presentation using beamer class and create handouts from it.

Unit I: Introduction to LaTeX, Installation of LaTeX, Layout Design, LaTeX input files, Input file structure, document classes, packages, environments, page styles, Typesetting texts, Fancy Header, tables.

Unit II: Inline math formulas and displayed equations, Math symbols and fonts, Delimiters, matrices, arrays, Typesetting Mathematical formulae: fractions, Integrals, sums, products, etc. Producing Mathematical Graphics.

Unit III: Document classes for paper writing, thesis, books, etc. Table of contents, index, bibliography management, hypertext, pdfpages, geometry, fancy header and footer, Verbatim, itemize, and enumerate, boxes, equation number. Beamer class, beamer theme, frames, slides, pause, overlay, transparent, handouts and presentation mode.

Suggested Readings:

1. LATEX Tutorials A Primer, Indian TEX Users Group, Trivandrum, India, 2003 September.
2. Learning LATEX by Doing, Andre Heck, 2002.
3. Latex beginners guide, Stefan Kottiwitz
4. The Latex companion, M. Carter, B.vanBrunt, second edition, Addison wisely, Pearson Education.

Semester-II

MMAT- 201: Metric Space

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objective: To introduce students to the concept of distance between elements in a set and to extend this idea through related topics such as open and closed sets, convergence of sequences, compactness, and continuity of functions.

Course Outcomes: Upon successful completion of this course, students will be able to:
CO1. Demonstrate understanding of fundamental concepts in metric spaces, including open sets, closed sets, and convergence.
CO2. Apply methods and techniques to prove basic theorems concerning metric spaces and continuous mappings.
CO3. Utilize equivalent approaches for defining and introducing a metric on a set.
CO4. Analyze and apply concepts of compactness, completeness, and continuity in metric spaces.

Unit I: Definition and examples of metric spaces, Bounded and unbounded metric spaces, Distance between sets, Diameter of a set, Open and closed balls, Interior points and interior of a set, Open set.

Unit II : Neighbourhood of a point, Limit point of a set, Closure of a set, Closed set, Boundary points and boundary of a set, Exterior points and exterior of a set, Subspace of a metric space.

Unit III: Sequences and subsequences in a metric space, Convergent and Cauchy sequences, Complete metric spaces, Relation between completeness and closednes, Dense sets.

Unit IV: Compact metric spaces, Compact sets and their criterion, Continuous functions between two metric spaces, Characterizations of Continuous functions, Continuous functions on compact spaces

Suggested Readings:

[1] Q. H. Ansari: Metric Spaces Including Fixed Point Theory and Set-valued Maps, Narosa Publishing House, New Delhi. 2010.

[2] M. O. Searcoid: Metric spaces, Springer, 2007.

[3] S. Kumaresan: Topology of Metric Spaces, Narosa Publishing House, 2nd Ed, 2011.

MMAT-202: Functional Analysis

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: To study commutative rings with unity and modules over the same that helps in developing basic foundation in other areas of mathematics such as algebraic geometry, homological algebra and algebraic number theory.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Verify the requirements of a norm, completeness with respect to a norm, relation between compactness and dimension of a space, check boundedness of a linear operator.

CO2. Distinguish between Banach spaces and Hilbert spaces, decompose a Hilbert space in terms of orthogonal complements

CO3. Extend a linear functional under suitable conditions, check reflexivity of a space, ability to apply uniform boundedness theorem.

Unit I: Normed spaces, Banach spaces and their examples, Examples of incomplete normed spaces, Subspace of normed spaces, Isometry on normed spaces, Completion of normed linear spaces, Quotient spaces,

Unit II: Bounded linear operators and bounded linear functionals with their norms and properties, Unbounded linear operators, Space of bounded linear operators, Dual basis, Algebraic and topological duals and relevant results

Unit III: Inner product spaces and examples, Parallelogram law, Polarization identity and related results, Schwartz and triangle inequalities, Separability and reflexivity of Hilbert spaces, Orthonormal sets and sequences, Bessel inequality.

Unit IV: Hahn-Banach theorem and its extended forms, Open and closed maps, Graph of linear operators and closedness property, Open mapping and closed graph theorems, their consequences and applications.

Suggested Readings:

[1] E. Kreyszig: Introductory Functional Analysis with Applications, John Willey, 1978

[2] P. K. Jain and O. P. Ahuja: Functional Analysis, New Age International Publishers, 2nd Ed, 2010

[3] W. Rudin: Functional Analysis, Mc Graw Hill Education, 2nd Ed, 1991.

[4] B.V. Limaye: Functional Analysis, New Age International Publishers, 3rd Ed, 2014.

MMAT-203: Optimization Techniques

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: his course begins with applications and scope of O.R. Formulation of linear programming problem and then different methods to solve them will be discussed. Duality in LPP will be introduced. Introduction to NLPP and some solving methods will be covered. At the end KKT Conditions and convex optimization techniques.

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

CO1. Formulate, interpret, and solve linear programming problems (LPP) using graphical methods, canonical forms.
CO2. Apply simplex, two-phase, and Big M methods to solve linear programming problems; analyze duality in LPP through theorems like weak and strong duality.
CO3. Formulate nonlinear programming problems (NLPP) and solve them using methods such as Lagrange multipliers and the steepest descent method.
CO4. Apply KKT conditions and Wolfe's method for optimization in convex and quadratic programming problems.

UNIT I: Linear programming problem, Formulation of linear programming problem, Graphical solution of L.P.P, General L.P.P. and some definitions, Canonical and standard form of L.P.P, Hyperplanes, Convex sets and their properties

UNIT II: Fundamental theorem of linear programming, Simplex method, Two-phase method, Big M method, Duality in L.P.P., General Primal-Dual pair , Weak duality theorem, Strong duality theorem.

UNIT III: Convex functions and their properties, General NLPP, Formulation of NLPP, Methods for solving NLPP: Graphical method, Method of Lagrange's multipliers, The Steepest Descent method.

UNIT IV: KKT necessary/sufficient optimality conditions, Solution of NLPP using KKT conditions, Quadratic programming, Wolfe's method for quadratic programming, Convex programming problem.

Suggested Readings:

[1] Kanti Swarup, P.K. Gupta, Man Mohan, Operations Research, Sultan Chand & Sons, 2009
[2] S. Chandra, Jayadeva, Aparna Mehra, Numerical Optimization with Applications, Narosa.Edition, John Wiley & Sons, India, 2007.
[3] Hamdy A. Taha, Operations Research, An Introduction, 9th Edition, Pearson.
[4] M.S. Bazarra, H.D. Sheral and C.M. Shetty, Nonlinear Programming theory and Algorithms

MMAT-204: Ring Theory

Total Marks: 50 (30 End Semester Examination +20 Internal Assessment)

Course Objectives: To introduce fundamental concepts in ring theory, including rings, subrings, ideals, ring homomorphisms, and their properties. This course will explore key applications of ring theory through examples of important rings, define concepts such as ideals, nil ideals, quotient rings, prime and maximal ideals, and delve into the homomorphisms of rings and related theorems.
Course Learning Outcomes: After studying this course the student will

CO1. Understand and perform standard computations in ring theory, demonstrating knowledge of basic structures such as rings, subrings, and ideals.
CO2. Apply and prove elementary theorems of ring theory, utilizing proof techniques

effectively.
CO3. Analyze polynomial rings and associated properties, including deriving and applying Gauss' lemma and Eisenstein's criterion for irreducibility over the rationals.
CO4. Explore factorization and ideal theory within polynomial rings and investigate structures such as primitive polynomials, unique factorization domains (UFD), Euclidean domains (ED), and principal ideal domains (PID) to solve related problems

Contents:

Unit I: Rings, Zero divisors, Integral domains, Division rings, Fields, Subrings and Ideals, Congruence modulo a subring relation in a ring, Simple ring, Algebra of ideals, Ideal generated by a subset.

Unit II: Homomorphism in rings, Natural homomorphism, Kernel of a homomorphism, Fundamental theorem of homomorphism, First and second isomorphism theorems.

Unit-III: Prime and irreducible elements, H.C.F. and L.C.M. of two elements of a ring, Principal ideals domains, Euclidean domains, Unique factorisation domains. Relations between Principal ideal domains, Euclidean domains and Unique factorization domain.

Unit-III: Polynomials rings, Algebraic and transcendental elements over a ring, Factorization in polynomial ring R[x], Division algorithm in R[x], where R is a commutative rings with identity, Properties of polynomial ring R[x] if R is a field or a U.F.D.

Suggested Readings:

[1] Surjeet Singh and QuaziZameeruddin: Modern Algebra.
[2] J. B. Fraleigh: A first Course in Abstract Algebra.
[3] Joseph A Gallian: Contemporary Abstract Algebra

MMAT-205: LaTeX -II

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The objective of this course is to develop advanced LaTeX skills for preparing research articles, books, and project reports, as well as mastering the Beamer package for professional presentations.

Course Outcomes: Upon successful completion, students will have the knowledge and skills to:

CO1. Organize and typeset large documents with advanced formatting, cross-references, and indexing.
CO2. Create complex diagrams, plots, and custom graphics using TikZ and pgfplots packages.
CO3. Manage bibliographies using BibTeX and BibLaTeX for scholarly articles.
Customize presentations with Beamer themes, animations, and handouts for effective communication.

Unit I: Document Layout and Organization: Document class – Page style – Parts of the document – Table of contents.

Unit II: Typesetting matrices and arrays using matrix, pmatrix, bmatrix, etc, Alignment of columns and rows for complex matrix expressions, Formatting block matrices and partitioned matrices

.

Unit III: Introduction to the graphicx package for inserting external images,Working with graphics using the eps and pdf formats, Basic of the TikZ package for creating diagrams and plots, Using TikZ for mathematical diagrams (Venn diagrams, flowcharts, trees).

Suggested Readings:

1. LATEX Tutorials A Primer, Indian TEX Users Group, Trivandrum, India, 2003 September.
2. Learning LATEX by Doing, Andre Heck, 2002.
3. Latex beginners guide, Stefan Kottiwitz
4. The Latex companion, M. Carter, B.vanBrunt, second edition, Addison wisely, Pearson Education

Semester-III

MMAT-301: Advanced Real Analysis

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives : To understand the uniform convergence, sequence and series of real valued functions, the properties of certain real-valued functions, the generalization of Riemann integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration.

Course Learning Outcomes: After studying this course the student will be able to

CO1. The valid situations for the inter-changeability of differentiability and integrability with infinite sum, and approximation of transcendental functions in terms of power series.

CO2. Some special real functions and their properties.

CO3. Some of the families and properties of Riemann-Stieltjes integrable functions, and the applications of the fundamental theorems of integration.

Unit I: Characterizations of continuous functions via open sets and closed sets, Dini's derivative, Applications of Taylor's theorem, Bounded functions, Monotone functions, Functions of bounded variation and their properties, Variation function, Jordon theorem, Absolute continuous functions and their properties

Unit II: Sequence of Functions and Applications to Approximation Theorems

Pointwise and uniform convergence of sequence of functions, Uniform norm on a set of bounded functions, Cauchy's Criterion for uniform convergence, Interchange of the limit and continuity, interchange of the limit and derivative and interchange of the limit and integral of a sequence of functions, Bounded convergence theorem, Dini's Theorem.

Unit III: Series of Functions Pointwise and uniform convergence of series of functions, Cauchy's Criterion for uniform convergence, Weierstrass M-test, Abel's test, Dirichlet's test for uniform convergence, Continuity, Derivability and integrability of the sum function of a series of functions.

UNIT IV: Riemann-Stieltjes Integrals Concept and properties of Riemann-Stieltjes integral, Integration by parts, Change of variables, Concept of Riemann integrals, Reduction of Riemann-Stieltjes integration into Riemann integration, Riemann condition of integrability, Integral as a limit of sums, Existence of Reimann-Stieltjes integrals, Mean value theorems.

Suggested Readings:

[1] R. G. Bartle and D. R. Sherbert: Introduction to Real Analysis, John Wiley and Sons, Singapore, 3rd Ed, 2003.

[2] Rudin: Principles of Mathematical Analysis, Third Edition, McGraw Hill, New York, 3rd Ed, 1976.

[3] S. C. Malik and Savita Arora: Mathematical Analysis, New Age International, 2017

[4] H. L. Royden: Real Analysis, Macmillan, 1993.

MMAT-302: General Topology

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives :To introduce basic concepts of point set topology, basis and subbasis for a topology and order topology. Further, to study continuity, homeomorphisms, open and closed maps, product and box topologies and introduce notions of connectedness, path connectedness, local connectedness, local path connectedness

Course Learning Outcomes: After studying this course the student will be able to

CO1. Determine interior, closure, boundary, limit points of subsets and basis and subbasis of topological spaces.

CO2. Check whether a collection of subsets is a basis for a given topological space or not, and determine the topology generated by a given basis.

CO3. Identify the continuous maps between two spaces and maps from a space into product space and determine common topological property of given two spaces..

CO4. Determine the connectedness and path connectedness of the product of an arbitrary family of spaces

Unit I: Definitions of topology and topological spaces, Examples of topology including discrete topology, indiscrete topology, standard topology on IR, co-finite topology and co-countable topology, Topology induced by a metric, Basis for

topology, Subspace topology.

Unit II: Continuous functions, Pasting lemma, Homeomorphisms, Convergence in topological spaces, Connected spaces, Connected sets in the real line, Intermediate value theorem, Components and Local connectedness, Path connected, Path components, Locally path connected spaces.

Unit III: First and second countable spaces, Lindelof spaces, T-1, T-2 (Hausdorff), T-3 (Regular), T-4 (Normal), T-3.5 (Completely regular) spaces and their characterizations.

UNIT IV: Product Spaces and Quotient Spaces Product topology (finite and infinite number of spaces), Tychonoff product, Projection maps, Stone Cech Compactification, Comparison of the Box and Product topologies.

Suggested Readings:

[3] James R. Munkres: Topology, A first course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000

[4] Martin D. Crossley.: Essential Topology, Springer Undergraduate Mathematics Series.

[5] M. A. Armstrong: Basic Topology, Undergraduate Text in Mathematics, 1983.

[4] Mohammed Hichem Mortad: Introductory Topology, Second Edition, World Scientific.

MMAT-303: Partial Differential Equations

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives : The objective of this course is to form partial differential equations occurring in the various fields of science and engineering and to provide their analytic solutions.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Classify the second order linear partial differential equations.

CO2. Transform linear partial differential equations of hyperbolic type into canonical form and solve it by Riemann's method.

CO3. formulate and solve heat, Laplace and wave equations into Cartesian, polar, cylindrical and spherical coordinates.

Contents:

UNIT I: Classification of second order linear PDE, Canonical form of hyperbolic type linear PDE, Riemann's method and Goursat problem for linear hyperbolic equations, Derivations of heat equation and wave equation in one/two/three dimensions, .

UNIT II: Occurrence of Laplace equation in Physics, Cauchy's problems for second order linear PDE, One-dimensional Initial BVP Semi-infinite string with a fixed end as well as a free end, Nonhomogeneous boundary conditions.

UNIT III: Finite string with fixed ends, Cauchy problem for nonhomogeneous wave equations; Revisit to method of separation of variables and Fourier method.

UNIT IV: Higher-dimensional Initial BVP Double and triple Fourier series, Fourier

series solutions of Initial BVP in vibrating membrane, vibrating cuboid, heat-conducting plate and heat-conducting cuboid; Dirichlet, Neumann and Robin problems.

Suggested Readings:

[1] K. S. Rao: Introduction to Partial Differential Equations, PHI Learning Pvt Ltd, New Delhi, 3rd Ed, 2011.

[2] T. Amaranath: An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2nd Ed, 2003.

[3] Tyn Myint U and Lokenath Debnath: Linear Partial Differential Equations for Scientists and Engineers, Birkhäuser Boston, 4th Ed, 2007.

[4] N. Sneddon: Elements of Partial Differential Equations, McGraw Hill Book Company, 1957.

MMAT-304: Advanced Linear Algebra

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: To provide students with a good understanding of the concepts and methods of Linear Algebra described in details in the syllabus and to develop critical reasoning by studying the logical proofs and axiomatic methods as applied to prove various theorems.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Apply the concepts and methods described in syllabus, will be able to solve problems using methods in Linear algebra, and will know the application of Linear Algebra to follow complex logical arguments and develop modest logical argument.

CO2. Understand and compute transition matrices, dual basis, dual vector spaces and dual linear transformations.

CO3. Deal with the inner product spaces, orthonormal basis, Bessel's inequality and Riesz Representation theorem with applications.

CO4. Understand three dimensional motions, Weiss's and Butler's sphere theorems and Kelvin's inversion theorem.

Contents:

Unit I: Recall of vector space, basis, dimension and related properties, Algebra of Linear transformations, Vector space of Linear transformations L(U,V), Dimension of space of linear transformations, Change of basis and transition matrices,

Unit II: Linear functional, Dual basis, Computing of a dual basis, Dual vector spaces, Annihilator, Second dual space, Dual transformations.

Unit III: Inner-product spaces, Normed space, Cauchy-Schwartz inequality, Pythagorean Theorem, Projections, Orthogonal Projections, Orthogonal complements, Orthonormality, Matrix Representation of Inner-products.

Unit IV: Gram-Schmidt Orthonormalization Process, Bessel's Inequality, Riesz Representation theorem and orthogonal Transformation, Inner product space isomorphism

Suggested Readings:

[1] V. Krishnamurty, V. P. Mainra and J. L. Arora: An introduction to Linear Algebra, East West Press, New Delhi, 2002.
[2] Kenneth Hoffman and Ray Kunze: Linear Algebra, 2nd Ed.
[3] Sheldon Alexer: Linear Algebra Done Right, Springer, 3rd Ed

MMAT-305: Matlab

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The objective of this course is to provide students with a strong foundation in programming and data analysis using MATLAB. Students will learn to solve mathematical problems, visualize data, and develop algorithms with practical applications in engineering, science, and mathematics.

Course Learning Outcomes: After studying this course the student will be able to

CO1. Ability to express programming & simulation.

CO2. Ability to find importance of this software for Lab Experimentation.

CO3. Articulate importance of software's in research by simulation work.

CO4. Ability to write basic mathematical problems in MATLAB.

Contents:

Unit I: MATLAB Windows and Mathematical Operations with Arrays, Standard MATLAB windows (Command Window, Figure Window, Editor Window, help window), The semicolon (;), The clc command, Using MATLAB as calculator, Display formats, Elementary math built in functions, The zeroes, ones and eye commands, The transpose operators, Using a colon, Adding elements to existing variables, Deleting elements**.**

Unit II: Creating arrays (one dimensional & two dimensional), Built in functions for handling arrays, Array multiplication, Inverse of a matrix, Solving three linear equations (array division), Element by element operations, Built in function for analysing arrays, Generation of random numbers, Creating and saving a script files, output commands.

Unit III: User-Defined Functions and Function Files User-defined functions and function files, Creating a Function File, Structure of a function file, Function definition, Input and output arguments, Function body, Local and global variables, Saving a function file, Using a user-defined function, Examples of simple user-defined Functions, Comparison between script files and function files, Anonymous and inline functions, Anonymous functions.

Unit IV: Programming in MATLAB and Plots with Special Graphics Programming in MATLAB, Relational and logical operators, Conditional statements: The If-End structure, The If-Else-End structure, The If-Elseif-Else-End structure, The switch Case statement, Loops: For-End Loops, While-End Loops, Nested Loops And Nested Conditional statements, The break and continue commands, Two dimension and three dimensional plots, Line plots.

Suggested Readings:

[1] Amos Gilat: MATLAB-An Introduction and its Applications, Wiley India Edition.Kenneth Hoffman and Ray Kunze: Linear Algebra, 2nd Ed.
[2] E. Balagurusamy: Programming in ANSI C, McGraw Hill Education.
[3] Steven C Chapra: Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw-Hill.

Semester-IV

MMAT-401: Research Project

MMAT-402(A) Geometry of Curves and Surfaces

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The primary objective of this course is to understand the notions of space curve, surfaces, geodesics, Weingarten maps, parametrization of surfaces, areas, volumes and Coddazi equation and Gauss theorem.

Course Learning Outcomes: After studying this course the student will be able to
CO1. Understand the concepts of graphs, level sets as solutions of smooth real valued functions, tangent space and normal **.**
CO2. Learn about linear self-adjoint Weingarten map and curvature of a plane curve with applications in geometry and physics**.**
CO3. Deal with parametrization and be familiar with well-known surfaces as equations in multiple variables, able to find area and volumes.
CO4: Study surfaces with boundary and be able to solve various problems and the Gauss theorem.

Contents:

Unit I: Space curves, Examples, Plane curves, Parameterization of curves (Generalized and natural parameters), Change of parameter, regular curves and singularities,Contact of curves, Contact of a curve and a plane, Frenet- trihedron, Osculating plane, Serret-Fernet formulae, Fundamental Theorem for space curves

Unit II: Surfaces in 3, Implicit and explicit forms of the equation of a surface, Parametric curves on surfaces, Tangent plane, First fundamental form, Angle between two curves on a surface, Area of a surface, Invariance under co-ordinate transformation.

Unit III: Second fundamental form on a surface, Gauss map and Gaussian curvature, Gauss and Weingrten formulae, Christoffel symbols, Some co-ordinate transformations, Coddazi equation and Gauss theorem, Fundamental theorem of surface Theory.

Unit IV: Curvature of a curve on a surface, Geodesic curvature and normal curvature, Geodesics, Principal directions and lines of curvature, Rodrigue formula, Asymptotic lines, Conjugate directions.

Suggested Readings:

[1] A. Goetz: Differential Geometry, Springer Verlag *DifferentialEquations*, Second Edition, Oxford University Press, 2011.
[2] W. Kühnel, Differential Geometry, Curves-Surfaces-Manifolds, Third Edition, American Mathematical Society, 2013.
[3] A. Mishchenko and A. Formentko, A Course of Differential Geometry and

Topology, Mir Publishers Moscow, 1988.
[4] A. Pressley, Elementary Differential Geometry, Springer, India, 2004.

MMAT-402(B): Advanced Group Theory

Total Marks: 100 (70 End Semester Examination + 30 Internal Assessment)

Course Objectives: The course aims to introduce the learner to the concepts of normal series,composition series and Zessenhaus lemma. A study of solvable groups, nilpotent group and fitting and Frattini subgroup will be conducted and the students will be introduced to free group, presentation of a group and properties of a free group.

Course Learning Outcomes: After doing this course student will be able to

CO1. Prove Schreier's refinement theorem and Jordan-Holder theorem and also to prove**e**fundamental theorem of arithmetic using Jordan-Holder theorem.

CO2. Prove Hall's theorem, Schur's theorem and Burnside basis theorem**.**

CO3. Identify indecomposable spaces and to prove Krull-Schmidt theorem**.**

CO4. Determine distinct presentations of a group.

Contents:

Unit I: Relation of conjugacy, conjugate classes of a group, Number of elements in a conjugate class of an element of a finite group, Class equation in a finite group and related results

Unit II: Partition of a positive integer, Conjugate classes in Symmetric groups, Sylow's theorems, External and Internal direct products and related results. Series of Groups Structure theory of finite abelian groups.

Unit III: Subgroup generated by a subset of a group, Commutator subgroup of a group, Subnormal series of a group, Refinement of a subnormal series, Length of a subnormal series, Solvable groups and related results, n-th derived subgroup.

Unit IV: Upper central and lower central series of a group, Nilpotent groups, Relation between solvable and nilpotent groups, Composition series of a group, Zassenhaus theorem, Schreier refinement theorem, Jordan-Holder theorem for finite groups.

Suggested Readings:

[1] T.W. Hungerford, Algebra, Springer-Verlag, 1981.
[2] D.J.S. Robinson, A Course in the Theory of Groups, Springer-Verlag, 1996.
[3] J.S. Rose, A Course on Group Theory, Dover Publications, 2012.
[4] J.J. Rotman, An Introduction to the Theory of Groups, Springer, 1995.
[5] M. Suzuki, Group Theory-I, Springer, 2014.