Rayat Shikshan Sanstha's

YASHAVANTRAO CHAVAN INSTITUTE OF SCIENCE, SATARA

(An Autonomous College)

Reaccredited by NAAC with 'A+' Grade

New Syllabus For

Master of Science

Part - II

MATHEMATICS

Syllabus

to be Implemented from June, 2022 onward

M.Sc. Part I Semester I

Course Code	Course Type	Name of the course	Credits
MMT 301	Core	Algebra-II	05
MMT 302	Core	Partial Differential Equations	05
Select any three courses from Electives			
MMT 303	Elective	Number Theory	05
MMT 304	Elective	Integral Equations	05
MMT 305	Elective	Fuzzy Mathematics I	05
MMT 306	Elective	Lattice Theory I	05
MMT 307	Elective	Graph Theory I	05
MMT 308	Elective	Operations Research I	05
		Total Credits	**25**

Semester II

Course Code	Course Type	Name of the course	Credits
MMT 401	Core	Functional Analysis	05
MMT 402	Core	Advanced Discrete Mathematics	05
Select any three courses from Electives			
MMT 403	Elective	Algebraic Number Theory	05
MMT 404	Elective	Fractional Differential Equations	05
MMT 405	Elective	Combinatorics	05
MMT 406	Elective	Fuzzy Mathematics-II	05
MMT 407	Elective	Graph Theory-II	05
		Total Credits	**25**

SEMESTER III
MMT 301: Algebra II

Course Objectives: **S**tudent will be able to:

1. understand Galois theory of polynomial equations.
2. study the structure of finite field.
3. understand the formula for general polynomial of degree five or higher.
4. study computations in specific examples of finite fields.

Credits=5	**SEMESTER-III** **MMT 301: Algebra II**	**No. of hours per unit/ credits**
UNIT I	**Field Extension**	**(15)**
	Extension of a field, Algebraic extensions, Algebraically closed fields, Derivatives and multiple roots, Finite Fields.	
UNIT II	**Galois Theory**	**(15)**
	Separable and normal extensions, Automorphism groups and fixed fields, Fundamental theorem of Galois Theory.	
UNIT III	**Cyclic and Cyclotomic extensions**	**(15)**
	Prime fields, Fundamental theorem of Algebra, Cyclic extensions, Cyclotomic extensions.	
UNIT IV	**Algebra with geometry**	**(15)**
	Constructions by ruler and compass, Solvable groups, Polynomials solvable by radicals.	

Course Outcomes: Student should be able to:

1. understand the basis and degree of a field over its subfield.
2. determine splitting field for the given polynomial over the given field.
3. illustrate primitive nth roots of unity and nth cyclotomic polynomial.
4. create constructions with straight edge and compass with the help of Galois theory.

References:

1. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract

Algebra, 2nd edition, Cambridge University Press, UK. (Asian edition) 2005 (Unit I, II, III, IV)

2. Nathan Jacobson, Basic Algebra I, second edition, W. H. Freeman and company, New York (Unit I, II, III, IV)
3. I. N. Herstein, Topics in Algebra, 2nd Edition Reprint, Wiley India Pvt.Ltd,2006 (Unit I, II, III, IV)
4. U. M. Swamy, A. V. S. N. Murthy, Algebra: Abstract and Modern, Pearson Education, 2012 (Unit I, II, III, IV)
5. John B. Fraleigh, A first course in Abstract Algebra 6th Edition Narosa Publishing House, New Delhi (Unit I, II, III, IV)
6. I. T. Adamson, Introduction to Field Theory, second edition, Cambridge University Press, 1982 (Unit I, II, III, IV)
7. M. Artin, Algebra, PHI, 1996 (Unit I, II, III, IV)
8. Ian Stewart, Galois Theory,4th Edition, CRC Publication,2015 (Unit I, II, III, IV)

MMT 302: Partial Differential Equations

Course Objectives: **S**tudent will able to:

1. study classification of partial differential equations and its solutions.
2. study partial differential equations of first order with various methods.
3. understand second order partial differential equations and its applications.
4. study various boundary value problems and its solutions.

Credits=5	SEMESTER-III **MMT 302: Partial Differential Equations**	No. of hours per unit/ credits
UNIT I	**First order Partial differential equations**	**(15)**
	Curves and surfaces, First order Partial Differential Equations, classification of first order Partial differential equations, classifications of Integrals, Linear equations of first order, Pfaffian Differential equations, Criteria of Integrability of a Pfaffian differential equation, Compatible Systems of first order partial differential equations.	
UNIT II	**Methods for solution of first order partial differential equations**	**(15)**
	Charpits method, Jacobi method of solving partial differential equations, Cauchy Problem, Integral surfaces through a given curve for a linear partial differential equation, for a non-linear partial differential equations, Method of characteristics to find the integral surface of a quasi linear partial differential equations and nonlinear first order partial differential equations.	
UNIT III	**Second order partial differential equations**	**(15)**
	Second order Partial Differential Equations. Origin of Partial differential equation, wave equations, Heat equation. Classification of second order partial differential equation. Vibration of an infinite string (both ends are not fixed) Physical Meaning of the solution of the wave equation. Vibration of a semi infinite string, Vibration of a string of finite length, Method of separation of variables, Uniqueness of solution of wave equation. Heat conduction Problems with finite rod and infinite rod, Cauchy problems.	

UNIT IV	**Boundary Value Problems**	**(15)**
	Families to equipotential surfaces, Laplace equation, Solution of Laplace equation, Laplace Equation in polar form, Laplace equation in spherical polar coordinates. Kelvin's inversion Theorem. Boundary Value Problems: Dirichlet's problems and Neumann problems, Maximum and Minimum principles, Stability theorem, Dirichlet Problems and Neumann problems for a circle, for a rectangle and for an upper half plane, Riemann's Method of solution of Linear Hyperbolic equations, Harnacks theorem.	

Course Outcome: Student should able to

1) understand first order partial differential equations and its classifications.
2) use various methods to solve partial differential equations of first order.
3) analyze second order partial differential equations and its applications.
4) evaluate boundary value problems.

REFERENCE BOOKS:

1. T. Amaranth, An elementary course in Partial differential equations, Narosa publication,1987(Unit I, II, III, IV)
2. Fritz John, Partial Differential Equations 4thEdition, Springer Science & Business Media, 1991(Unit I, II, III, IV)
3. I.N. Sneddon, Elements of Partial Differential Equations, Dover Publication 2013 (Unit I, II, III, IV)

MMT 303: Number Theory

Course Objectives: Student will be able to-

1. study Fundamental theorem of Arithmetic and The Goldbach Conjecture.
2. understand Fermat’s theorem, Little theorem and Wilson’s theorem.
3. understand Euler’s Generalization of Fermat’s theorem.
4. study quadratic reciprocity, Legendre symbol and its properties.

Credits=5	**SEMESTER-III** **MMT 303: Number Theory**	**No. of hours per unit/ credits**
UNIT I	**Fundamental Theorem of Arithmetic**	**(15)**
	Review of divisibility: The division algorithm, G.C.D. Euclidean algorithm, Diophantine equation ax + by = c. Primes and their distribution: Fundamental theorem of Arithmetic, The Goldbach Conjecture.	
UNIT II	**Fermat’s theorem and number theoretic functions**	**(15)**
	Congruence, Properties of Congruence’s, Linear Congruence, Special divisibility tests. Fermat’s theorem, Fermat’s factorization method, Little theorem, Wilson’s theorem, Number Theoretic functions: The functions τ and σ. The Mobius Inversion formula, The greatest integer function.	
UNIT III	**Eulers theorem and primitive roots**	**(15)**
	Euler’s Generalization of Fermat’s theorem: Euler's phi function, Euler's theorem, properties of phi function, An application to Cryptography. Primitive roots, The order of an integer modulo n.	
UNIT IV	**The Quadratic reciprocity law and Legendre symbol**	**(15)**
	Primitive roots for primes, composite numbers having primitive roots, The theory of Indices. The Quadratic reciprocity law Eulerian criteria, the Legendre symbol and its properties, Quadratic reciprocity, quadratic reciprocity with composite moduli.	

Course Outcomes: Student should be able to: -

1. understand the fundamental theorem of arithmetic and the Goldbach conjecture.
2. solve linear congruence relations using various theorems.
3. evaluate primitive roots and the order of integer modulo n.
4. derive the quadratic reciprocity law and properties of Legendre symbol.

References: -

1. D. M. Burton, Elementary Number Theory,7th Edition, Universal book stall, New Delhi,2015 (Unit I, II, III, IV)
2. S. B. Malik, Basic Number theory 2nd Revised Edition, Vikas Publishing House,2005 (Unit I, II, III, IV)
3. George E. Andrews, Number theory, Hindusthan Pub. Corp,1972 (Unit I, II, III, IV)
4. I. Niven, H. S. Zuckerman, H. L. Montgomery, An Introduction to Theory of Numbers,5th Edition. John Wiley & Sons,1991 (Unit I, II, III, IV)
5. S. G. Telang, M. Nadkarni, J. Dani, Number Theory, Tata McGraw-Hill Publishing Co. New Delhi, 2001(Unit I, II, III, IV)

MMT 304 Integral Equations

Course Objectives: Student will be able to: -

1. understand fundamental mathematical ideas and techniques that lie at the core of integral equation approach of problem solving.
2. study numerical solutions of integral equations as well as on solving elliptical boundary value problems.
3. study the solutions of Fredholm integral equations and its various methods.
4. understand Applications of Laplace and Fourier transforms to solutions of Volterra integral equations.

Credits=5	**SEMESTER-III** **MMT 304: Integral Equations**	**No. of hours per unit/ credits**
UNIT I	**Linear integral Equations**	**(15)**
	Classification of linear integral equations, Conversion of initial value problem to Volterra integral equation, Conversion of boundary value problem to Fredholm integral equation, Separable kernel, Fredholm integral equation with separable kernel, Fredholm alternative, Homogeneous Fredholm Equations and Eigen functions.	
UNIT II	**Solutions to Linear integral Equations**	**(15)**
	Solutions of Fredholm integral equations by: Successive approximations Method, Successive substitution Method, Adomain decomposition method, Modified decomposition method, Resolvent kernel of Fredholm equations and its properties, Solutions of Volterra integral Equations, Successive approximations method, Neumann series, Successive substitution Method.	
UNIT III	**Applications of Laplace and Fourier transforms**	**(15)**
	Solution of Volterra integral equations by Adomian decomposition method, and the Modified decomposition method, Resolvent kernel of Volterra equations and its properties, Convolution type kernels, Applications of Laplace and Fourier transforms to solutions of	

	Volterra integral equations, Symmetric Kernels**:** Fundamental properties of eigenvalues and eigenfunctions for Symmetric kernels, expansion in eigenfunctions and bilinear form.	
UNIT IV	**Hilbert Schmidt Theorem and its consequences**	**(15)**
	Hilbert Schmidt Theorem and its consequences, Solution of symmetric integral equations, Operator method in the theory of integral equations, Solution of Volterra and Fredholm integrodifferential equations by Adomian decomposition method, Green's function: Definition, Construction of Green's function and its use in solving boundary value problems.	

Course Outcomes: Student should be able to:

1. understand Fredholm and Volterra integral equations.
2. solve Fredholm and Volterra integral equations with various methods.
3. analyze the applications of Laplace and Fourier transforms to solutions of integral Equations
4. evaluate Volterra and Fredholm integrodifferential equations by Adomian decomposition method.

References: -

1. R. P. Kanwal, Linear Integral Equation- Theory and Technique, Academic Press, 1971 (Unit I, II, III, IV)
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations-Methods and Applications. Springer, 2011 (Unit I, II, III, IV)
3. L. G. Chambers, Integral Equations- A Short Course, International Text Book Company, 1976 (Unit I, II, III, IV)
4. M. A. Krasnov, et.al. Problems and exercises in Integral equations, Mir Publishers, 1971 (Unit I, II, III, IV)
5. C. D. Green, Integral Equation Methods, Thomas Nelson and sons, 1969 (Unit I, II, III, IV)
6. J. A. Cochran, The Analysis of Linear Integral Equations, McGraw Hill Publications,1972 (Unit I, II, III, IV)

MMT 305 Fuzzy Mathematics I

Course Objectives: Student will be able to: -

1. understand the basic structure of fuzzy sets and classical sets.
2. study Decomposition theorems, Extension principle of fuzzy sets.
3. study the need of fuzzy sets, fuzzy relations and its applications.
4. understand the appropriate fuzzy theory corresponding to uncertain and imprecise collected data

Credits=5	**SEMESTER-III** **MMT 305: Fuzzy Mathematics I**	**No. of hours per unit/ credits**
UNIT I	**Fuzzy Sets**	**(15)**
	Fuzzy sets and crisp sets, Examples of fuzzy sets, Basic types and basic concepts, Standard operations, Cardinality, degree of subsethood, Level cuts.	
UNIT II	**Representation of Fuzzy sets**	**(15)**
	Representation of Fuzzy sets, Properties of level cuts, Decomposition theorems, Extension principle, Direct and inverse image of a fuzzy set. Properties of direct and inverse images.	
UNIT III	**Operations on fuzzy sets**	**(15)**
	Operations on fuzzy sets, Types of operations, Fuzzy complement, Equilibrium and dual point, Increasing and decreasing generators, Fuzzy intersection: t-norms, Fuzzy union: t-conorms, Combination of operators, Aggregation operations.	
UNIT IV	**Fuzzy numbers**	**(15)**
	Fuzzy numbers, Characterization theorem, Linguistic variables, Arithmetic operations on Intervals, Arithmetic operations on fuzzy numbers, Lattice of fuzzy numbers, Fuzzy equations.	

Course Outcomes: Student should be able to:

1. understand fuzzy sets and describe the properties.
2. solve examples on direct and inverse images of fuzzy sets.
3. analyze operations on fuzzy sets.
4. evaluate arithmetic operations on fuzzy numbers and fuzzy equations.

References: -

1. George J. Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and Applications, PHI.Ltd.2000 (Unit I, II, III, IV)
2. M. Grabish, Sugeno, Murofushi Fuzzy Measures and Integrals theory and Applications, PHI, 1999 (Unit I, II, III, IV)
3. H.J. Zimmerermann, Fuzzy set Theory and its Applications, Kluwer, 1984 (Unit I, II, III, IV)
4. M. Hanss, Applied Fuzzy Arithmetic, An Introduction with Engineering Aplications, Springer- Verlag Berlin Heidelberg 2005 (Unit I, II, III, IV)
5. M. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic, PHI Learning Private Limited, New Delhi 2006 (Unit I, II, III, IV)
6. Timothy J. Ross, Fuzzy Logic with Engineering Applications, 3rd Edition, John Wiley and Sons, 2011 (Unit I, II, III, IV)

MMT 306 Lattice theory I

Course Objectives: Student will be able to: -

1. understand basic theories of lattices and their equivalence.
2. study the methods for characterizing distributive lattices.
3. study Pseudo complemented lattices and its special subsets of pseudo complemented lattices.
4. understand ideas from lattice theory can be used in the implementation of a knowledge representation language.

Credits=5	**SEMESTER-III** **MMT 306: Lattice Theory I**	**No. of hours per unit/ credits**
UNIT I	**Lattices**	**(15)**
	Posets, Definition and examples of posets, definitions of lattices and their equivalence, examples of lattices, description of Lattices, some algebraic concepts, duality principle, Special elements, homomorphism, Isomorphism and isotone maps.	
UNIT II	**Distributive Lattices and Boolean Algebra**	**(15)**
	Distributive lattices – Properties and characterizations, Modular lattices – Properties and Characterizations, Congruence relations, Boolean algebras – Properties and characterizations.	
UNIT III	**Ideals and filters in lattices**	**(15)**
	Ideals and filters in lattices, Lattice of all ideals I(L), Properties and characterizations of I(L), Stone's theorem and its consequences of operators, Aggregation operations.	
UNIT IV	**Pseudo Complemented Lattices**	**(15)**
	Pseudo complemented lattices, S(L) and D(L) – special subsets of pseudo complemented lattices, Distributive pseudo complemented lattice, Stone lattices – properties and Characterizations.	

Course Outcomes: Student should be able to:

1. understand the relation between Posets and Lattice.
2. understand the basic Properties and characterizations of Lattice.
3. apply the ideals and filters in lattices to solve the examples.
4. construct pseudo complemented lattices.

References: -

1. George Gratzer, W. H. Freeman, First concepts and distributive lattices by and company, San Francisco 1971 (Unit I, II, III, IV)
2. G. Birkhoff, Amer, Lattice Theory Math. Soc. Coll. Publications, 3rd Edition ,1973 (Unit I, II, III, IV)

MMT 307 Graph theory I

Course Objectives: Student will be able to: -

1. understand and apply fundamental concepts in Graph theory.
2. study the methods for characterizing distributive lattices.
3. study graph theory based tools in solving practical problems
4. understand applications of graph theory to practical problems and other branches of Mathematics.

Credits=5	**SEMESTER-III** **MMT 307: Graph Theory I**	**No. of hours per unit/ credits**
UNIT I	**Trees and Connectivity**	**(15)**
	Trees and connectivity: Definitions and simple properties, Bridges, spanning trees, cut vertices and Connectivity. Euler Tours: Euler graphs, Properties of Euler graph, The Chinese postman problem.	
UNIT II	**Hamiltonian Cycles**	**(15)**
	Hamiltonian Cycles, Hamiltonian graphs, The travelling salesman problem, Matching's and Augmenting path, The marriage problem, The Personal Assignment problem.	
UNIT III	**Plane and Planar Graphs**	**(15)**
	The Optimal Assignment problem, A Chinese postman Problem, Postscript, Planer Graphs: Plane and Planar graphs, Euler's formula, Platonic bodies Kurotowskis theorem, non-Hamiltonian plane Graphs, The dual of a plane graph.	
UNIT IV	**Vertex Coloring**	**(15)**
	Colouring: Vertex coloring, vertex coloring algorithms, critical graphs, cliques, Edge coloring, Map coloring, Directed graphs: Definition, Indegree and outdegree, Tournaments, traffic flow. Networks: Flows and Cuts, The Ford and Fulkerson Algorithm, Separating seen.	

Course Outcomes: Student should be able to:

1. understand trees and connectivity and its properties.
2. determine whether graph is Hamiltonian or planar.
3. solve problems using vertex and edge Colouring.
4. construct models of real word problem using graph theory.

References: -

1. John Clark and Derek Holton, A first look at graph theory, World Scientific Publishing Co Pt Ltd, 1991 (Unit I, II, III, IV)
2. Douglas B. West, Introduction to Graph Theory,2nd Edition, Pearson Education Asia,2001 (Unit I, II, III, IV)
3. F. Harary, Graph Theory, Narosa Publishing House 1989 (Unit I, II, III, IV)
4. K. R. Parthsarthy, Basic Graph Theory, Tata McGraw Hill publishing Co. Ltd. New Delhi,1994 (Unit I, II, III, IV)

MMT 308 Operations Research I

Course Objectives: Student will be able to: -

1. understand complex mathematical models in management science, and transportation problem.
2. study advanced methods for large-scale transportation.
3. understand some applications of graph theory to practical problems and other branches of Mathematics.
4. study Kuhn Tucker, Wolfe's method and Beale's method for solving Non-linear programming.

Credits=5	**SEMESTER-III** **MMT 308: Operations Research I**	**No. of hours per unit/ credits**
UNIT I	**Convex sets and their properties**	**(15)**
	Convex sets and their properties. Lines and hyper planes convex set Important Theorems, polyhedral convex set Convex combination of vectors, convex hull, Convex polyhedron, convex cone, simplex and convex function, General formulation of linear programming Matrix form of LP Problem, definitions of standard LPP, Fundamental Theorem of linear programming. Simplex method, computational procedure of simplex method, problem of degeneracy and method to Resolve degeneracy.	
UNIT II	**Linear Programming**	**(15)**
	Revised simplex method in standard form I, Duality in linear programming duality theorem, Integer linear programming, Gomory's cutting plane method, Branch and Bound and linear Programming.	
UNIT III	**Dynamic Programming**	**(15)**
	Dynamic programming. Bellman's principle of optimality, solution of problems with a finite number of stages. Application of dynamic programming in production, inventory control.	

UNIT IV	Non linear programming	(15)
	Non-linear programming unconstrained problems of maximum and minimum Lagrangian method Kuhn Tucker necessary and sufficient conditions, Wolfe's method, Beale's method. Directed graphs: Definition, Indegree and outdegree, Tournaments, traffic flow. Networks: Flows and Cuts, The Ford and Fulkerson Algorithm, Separating seen.	

Course Outcomes: Student should be able to:

1. understand linear programming (LP) models for shortest path, maximum flow, minimal spanning tree, critical path.
2. use some solution methods for solving the nonlinear and linear optimization problems.
3. analyze the general nonlinear programing models.
4. derive the Khun-Tucker optimality conditions.

References: -

1. S.D. Sharma, Himanshu Sharma, Operations Research Theory, Methods and Applications, Kedar Nath Ram Noth,2010 (Unit I, II, III, IV)
2. KantiSwarup, P.K. Gupta and Manmohan, Operations research, S. Chand & Sons, New Delhi 2001 (Unit I, II, III, IV)
3. Hamady. A. Taha, Operations Research10th Edition, Pearson 2017 (Unit I, II, III, IV)
4. P. K. Gupta, D. S. Hira, Operations Research 7th Edition, S. Chand Publication 1976 (Unit I, II, III, IV)

MMT 401 Functional Analysis

Course Objectives: Student will be able to: -

1. study of the main properties of bounded operators between Banach and Hilbert spaces.
2. study basic result associated to different types of converges in normed spaces.
3. understand Banach and Hilbert spaces and self-adjoint operators.
4. understand use contractions of Banach spaces.

Credits=5	SEMESTER-IV **MMT 401: Functional Analysis**	No. of hours per unit/ credits
UNIT I	**Normed Linear Spaces**	**(15)**
	Normed linear spaces, Banach spaces, Quotient spaces, Continuous linear transformations, Equivalent norms, Finite dimensional normed spaces and properties, Conjugate space and Separability, The Hahn-Banach theorem and its consequences.	
UNIT II	**The Open mapping theorem and uniform boundedness principle**	**(15)**
	Second conjugate space, the natural embedding of the normed linear space in its second Conjugate space, Reflexivity of normed spaces, Weak * topology on the conjugate space. The open mapping theorem, Projection on Banach space, the closed graph theorem, the conjugate of an operator, the uniform boundedness principle.	
UNIT III	**Hilbert Spaces**	**(15)**
	Hilbert spaces: examples and elementary properties, Orthogonal complements, The projection theorem, Orthogonal sets, The Bessel's inequality, Fourier expansion and Perseval's equation, separable Hilbert spaces, The conjugate of Hilbert space, Riesz's theorem, The adjoint of an operator	
UNIT IV	**Self adjoint operators**	**(15)**
	Self-adjoint operators, Normal and Unitary operators, Projections, Eigen values and eigenvectors of an operator on a Hilbert space, The determinants and spectrum of an operator, The spectral theorem on a finite dimensional Hilbert space.	

Course Outcomes: Student should be able to:

1. understand the fundamental properties of normed spaces and transformations between them.
2. use specific techniques for bounded operators over normed spaces.
3. apply the notion of dot product and Hilbert spaces to solve problems on its properties.
4. derive the spectral theorem to the resolution of integral equations

References: -

1. G. F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw Hill, 1963 (Unit I, II, III, IV)
2. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 1978 (Unit I, II, III, IV)
3. G. Bachman and L. Narici, Functional Analysis, Academic Press, 1972 (Unit I, II, III, IV)
4. A. E. Taylor, Introduction to Functional analysis, John Wiley and sons,1958 (Unit I, II, III, IV)
5. J. B. Convey, A course in Functional Analysis, Springer-Verlag, 1985 (Unit I, II, III, IV)
6. B. V. Limaye, Functioned Analysis, New age international, 1996 (Unit I, II, III, IV)

MMT 402 Advanced Discrete Mathematics

Course Objectives: Student will be able to: -

1. study simple, multigraph, directed, undirected graph, cyclic, acyclic and the connectivity of a graph.
2. understand Euler or a Hamiltonian path or circuit.
3. understand Pigeonhole principle and solve problems related to this.
4. study types of Lattice and find supremum and infimum.

Credits=5	SEMESTER-IV **MMT 402: Advanced Discrete Mathematics**	No. of hours per unit/ credits
UNIT I	**Graph theory**	**(15)**
	Graph Theory: Definition, examples and properties, Simple graph, Graph isomorphism, Bipartite graphs, Complete Bipartite graph, regular graph, sub-graphs spanning sub-graph, Edge deleted sub-graph, Vertex deleted sub-graph, Union and intersection of two graphs, complements of a graph, self-complementary graph, paths and cycles in a graph, Eccentricity, Radius and diameter of a connected graph, Peterson graph, Wheel graph. Isomorphism of Graphs, First theorem of graph theory.	
UNIT II	**Matrix representation of graph and Pigeonhole principle**	**(15)**
	The Matrix representation of a graph, Adjacency matrix and Incidence matrix of a graph, Definition and simple properties of a tree, bridges, spanning trees, Inclusion exclusion principle, Simple examples on Inclusion exclusion principle Pigeonhole principle, examples on Pigeonhole principle.	
UNIT III	**Discrete numeric functions and Linear recurrence relations**	**(15)**
	Discrete numeric functions and sum and product of two numeric functions, generating functions, Linear recurrence relations with constant coefficients Particular solutions of Linear recurrence relations, Total solutions.	
UNIT IV	**Lattices and Boolean Algebra**	**(15)**
	Ordered sets and lattices Hasse diagrams of posets, Supremum and infimum, Isomorphic ordered sets, well-ordered sets, Lattices, Bounded lattices, Distributive lattices, Complements complemented lattices, Boolean algebra, Basic definitions, Basic theorems, duality, Boolean algebras as lattices	

Course Outcomes: Student should be able to:

1. understand graphs and its different types with properties.
2. understand Pigeonhole principle and solve the examples on it.
3. use discrete numeric functions for generating functions and solve linear recurrence relations.
4. derive basic theorems on Boolean algebra and lattices.

References: -

1. Seymon Lipschutz and Mark Lipson, Discrete Mathematics 2nd by. Tata Mc Graw Hill Publishing Company Ltd. New Delhi (Unit I, II, III, IV)
2. John Clark and Derek Holton, A first book at Graph Theory Applied Publishers Ltd (Unit I, II, III, IV)
3. S. G. Telang, M. Nadkarni, J. Dani, Number Theory, Tata McGraw-Hill Publishing Co. New Delhi, 2001. (Unit I, II, III, IV)

MMT 403 Algebraic Number Theory

Course Objectives: Student will be able to: -

1. understand algebraic numbers and algebraic integers and find its integral basis.
2. study the existence of factorization and norms.
3. study the relationship between factorization of numbers and of ideals.
4. understand the class number and fitness of class group.

Credits=5	**SEMESTER-IV** **MMT 403: Algebraic Number Theory**	**No. of hours per unit/ credits**
UNIT I	**Field Extensions and Free Abelian Groups**	**(15)**
	Revision of rings, polynomial rings and fields, Field extensions, Symmetric polynomials, Modules, Free Abelian groups.	
UNIT II	**Ring of integers**	**(15)**
	Algebraic Numbers, Algebraic number fields, Conjugates and Discriminants, Algebraic integers, Integral Bases, Norms and Traces, Ring of integers, Quadratic fields, Cyclotomic fields.	
UNIT III	**Prime Factorization**	**(15)**
	Factorization into irreducible, Noetherian rings, Dedekind rings, Examples of Non- Unique factorization into irreducible, Prime factorization, Euclidean Domains, Euclidean quadratic fields.	
UNIT IV	**Class groups and Class numbers**	**(15)**
	Ideals, Prime factorization of ideals, Norm of an ideal, Nonunique factorization in cyclotomic fields, Two-squares theorem, Four-squares theorem, class groups and class numbers, Finiteness of the Class groups.	

Course Outcomes: Student should be able to:

1. identify properties of number fields.
2. understand the arithmetic of algebraic number fields.
3. use theorem about integral bases, and about unique factorization in to ideals.
4. analyze class numbers and find the relationship between factorization of numbers as well as of ideals.

References: -

1. Stewart and D. Tall, Algebraic Number Theory and Fermat's last theorem, 3rd Edition 2002 (Unit I, II, III, IV)
2. N. Jacobson, Basic Algebra - I, Dover Publications, Second edition 2012 (Unit I, II, III, IV)
3. Murty, M. Ram, Esmonde, Jody Indigo, Problems in Algebraic Number Theory, Springer 2008 (Unit I, II, III, IV)
4. J. Neukirch, Algebraic Number Theory, Grundlehren der mathematischen Wissenschaften 1999 (Unit I, II, III, IV)

MMT 404 Fractional Differential Equations

Course Objectives: Student will be able to: -

1. study types of Fractional Differential Equations.
2. understand Mellin transforms of fractional derivatives-Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative.
3. study the solution of FDE by using Laplace transform method.
4. understand mathematical models using fractional derivatives to solve application problems such as harmonic oscillators and circuits.

Credits=5	**SEMESTER-IV** **MMT 404: Fractional Differential Equations**	**No. of hours per unit/ credits**
UNIT I	**GL and RL Fractional order**	**(15)**
	Brief review of Special Functions of the Fractional Calculus: Gamma Function, Mittag-Leffler Function, Wright Function, Fractional Derivative and Integrals: Grünwald-Letnikov (GL) Fractional Derivatives-Unification of integer order derivatives and integrals, GL Derivatives of arbitrary order, GL fractional derivative of $(t-\alpha)^{\beta}$, Composition of GL derivative with integer order derivatives, Composition of two GL derivatives of different orders. Riemann- Liouville (RL) fractional derivatives-Unification of integer order derivatives and integrals, Integrals of arbitrary order, RL derivatives of arbitrary order, RL fractional derivative of $(t-\alpha)^{\beta}$	
UNIT II	**Caputo's fractional derivative**	**(15)**
	Composition of RL derivative with integer order derivatives and fractional derivatives, Link of RL derivative to Grünwald-Letnikov approach, Caputo's fractional derivative, generalized functions approach, Left and right fractional derivatives. Properties of fractional derivatives: Linearity, The Leibnitz rule for fractional derivatives, Fractional derivative for composite function, Riemann-Liouville fractional differentiation of an integral depending on a parameter, Behavior near the lower terminal, Behavior far from the lower terminal.	

UNIT III	**Integral transforms of fractional derivatives**	**(15)**
	Laplace transforms of fractional derivatives- Laplace transform of the Riemann- Liouville fractional derivative, Caputo derivative and Grünwald-Letnikov fractional derivative. Fourier transforms of fractional integrals and derivatives. Mellin transforms of fractional derivatives-Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative, Mellin transforms of Caputo derivative.	
UNIT IV	**Fractional Differential Equations**	**(15)**
	Existence and uniqueness theorem: Linear fractional differential equations (FDE), Fractional differential equation of a general form, Existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. Methods of solving FDE's: The Laplace transform method. The Mellin transform method, Power series method	

Course Outcomes: Student should be able to:

1. understand the concept of fractional derivatives and its forms.
2. apply properties like Linearity, The Leibnitz rule for fractional derivatives.
3. simplify Mellin transforms of fractional derivatives-Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative
4. evaluate fractional differential equations using various methods.

References: -

1. Igor Podlubny, Fractional differential equations. San Diego, Academic Press 1999 (Unit I, II, III, IV)
2. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006 (Unit I, II, III, IV)
3. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010 (Unit I, II, III, IV)
4. L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press, 2010. (Unit I, II, III, IV)

MMT 405 Combinatorics

Course Objectives: Student will be able to: -

1. understand Pigeonhole principle, Ramsey, Catalan and Stirling numbers.
2. study inclusion exclusion principle, Derangements and combinatorial number system.
3. understand Rook polynomial and recurrence relations.
4. study group theory and Polya's enumeration theorem.

Credits=5	**SEMESTER-IV** **MMT 405: Combinatorics**	**No. of hours per unit/ credits**
UNIT I	**The Pigeonhole Principle and Ramsey numbers**	**(15)**
	The sum Rule and the product Rule, Permutations and combinations, The Pigeonhole Principle, Ramsey Numbers, Catalan Numbers, Stirling Numbers.	
UNIT II	**Combinatorial Number theory**	**(15)**
	Generalized Permutations and combinations, Multinomial Theorem, The Inclusion–Exclusion principle, Sieve's formula, Derangements, System of Distinct Representatives (SDR), Combinatorial Number theory.	
UNIT III	**Rook Polynomial and Recurrence Relations**	**(15)**
	Rook- Polynomial, Ordinary and Exponential generating functions, Partitions of a positive Integer, Recurrence Relations, Fibonacci sequence.	
UNIT IV	**Group Theory in Combinatorics**	**(15)**
	Group Theory in Combinatorics, The Burnside Frobenius Theorem, Permutation Groups and Their Cycle Indices, Polya's Enumeration Theorems.	

Course Outcomes: Student should be able to:

1. understand the Pigeonhole principle and combinatorial numbers.
2. apply the inclusion exclusion principle and derangements in combinatorial problems.
3. simplify recurrence relations using ordinary and exponential generating functions.
4. derive the Burnside Frobenius theorem and Polya's Enumeration theorem.

References: -

1. Richard A. Brualdi, Introductory Combinatorics 5th Edition 2009 (Unit I, II, III, IV)
2. Alan Tucker, Applied Combinatorics 6th Edition, Wiley 2012 (Unit I, II, III, IV)
3. Mitchel T. Keller and Willian T. Trotter, Applied Combinatorics,2017 Edition (Unit I, II, III, IV)
4. V.K. Balakrishnan, Schum’s Outline of Theory and problems of combinatorics. Mc. Grew Hill Education 1994 (Unit I, II, III, IV)

MMT 406 Fuzzy Mathematics II

Course Objectives: Student will be able to: -

1. understand Fuzzy relations in different forms.
2. study Fuzzy relational equations and methods of solutions.
3. understand Fuzzy qualified and quantified propositions.
5. study Fuzzy approximate reasoning in different forms.

Credits=5	**SEMESTER-IV** **MMT 406: Fuzzy Mathematics II**	**No. of hours per unit/ credits**
UNIT I	**Fuzzy Relations**	**(15)**
	Projections and cylindrical Extensions Binary Fuzzy Relations on single set, Fuzzy equivalence relations, Fuzzy Compatibility Relations, Fuzzy ordering Relations Fuzzy morphisms Sup-i Compositions and inf-w_i compositions.	
UNIT II	**Fuzzy Relational Equations**	**(15)**
	Fuzzy Relation Equation, Problem Partitioning, solution methods, Fuzzy relational equations based on sup-I and inf-wi compositions, Approximate solutions	
UNIT III	**Fuzzy Propositions**	**(15)**
	Fuzzy propositions, Fuzzy Quantifiers, Linguistic Hedges, Inference from conditional fuzzy propositions, Qualified and quantified propositions	
UNIT IV	**Fuzzy Approximate Reasoning**	**(15)**
	Approximate Reasoning: -Fuzzy expert systems, Fuzzy implications, selection of Fuzzy implications, Multi-conditional Approximate Reasoning, Role of fuzzy relational equations, Interval valued Approximate Reasoning	

Course Outcomes: Student should be able to:

1. understand fuzzy relations in different forms.
2. apply various methods of solutions for solving Fuzzy relational equations.
3. classify Fuzzy Propositions into qualified and quantified propositions.
4. design Fuzzy expert system using approximate reasoning.

References: -

1. George J Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and applications, PHI, Ltd.2000 (Unit I, II, III, IV)
2. M.Grabish, Sugeno, and Murofushi, Fuzzy Measures and Integrals: theory and Applications, PHI, 1999 (Unit I, II, III, IV)
3. M. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi (Unit I, II, III, IV)

MMT 407 Graph Theory II

Course Objectives: Student will be able to: -

1. understand incidence matrix and its properties.
2. study Adjacency matrix and non-singular trees.
3. understand Laplacian matrix and Edge Laplacian of a tree.
4. study Adjacency algebra of regular graphs and algebraic connectivity.

Credits=5	**SEMESTER-IV** **MMT 407: Graph Theory II**	**No. of hours per unit/ credits**
UNIT I	**Incidence matrix**	**(15)**
	Preliminaries, Incidence Matrix: Rank, Minors, Path Matrix, Integer generalized, inverse, Moore-Perose inverse, 0-1 incidence matrix, Matchings in bipartite graph.	
UNIT II	**Adjacency matrix**	**(15)**
	Adjacency Matrix, Eigenvalues of some graphs, Determinant, Bounds, Energy of graph, Anti-adjacency matrix of directed graph, non-singular trees.	
UNIT III	**Laplacian matrix**	**(15)**
	Laplacian Matrix: Basic properties, Computing Laplacian eigenvalues, Matrix tree theorem, Bounds for Laplacian special radius, Edge-Laplacian of a tree, Cycles and cuts, Fundamental cycles and fundamental cut, Fundamental matrices.	
UNIT IV	**Regular graphs**	**(15)**
	Regular Graphs: Perron –Frobinius Theory, Adjacency algebra of regular graphs, Strongly regular graph and Friendship theorem, Graphs with maximum energy, Algebraic connectivity, classification of trees, distance matrix of tree, Eigenvalues of distance matrix of tree.	

Course Outcomes: Student should be able to:

1. understand incidence matrix, Path matrix and Moore Perose inverse.
2. apply Eigenvalues of some graphs and Determinant.
3. classify fundamental cycles, cuts and matrices.
4. derive strongly regular graph and Friendship theorem.

References: -

1. R. B. Bapat, Graphs and Matrices, Hindustan Book Agency (Unit I, II, III, IV)
2. Douglas B. West, Introduction to Graph Theory 2nd Edition, Pearson Education Asia,2015 (Unit I, II, III, IV)
3. K. R. Parthsarthy, Basic Graph Theory, Tata McGraw Hill publishing Co. Ltd. New Delhi (Unit I, II, III, IV)