# Shivaji University Kolhapur

# Department of Mathematics

# Revised Syllabus for M.A. / M. Sc. Mathematics (Part-II)

**Choice Based Credit System**

**Syllabus to be implemented from June 2014 onwards**

# M. A. / M. Sc. Mathematics (Part II) (Semester III)
# (Choice Based Credit System)
# (Introduced from June 2014 onwards)

## Compulsory Papers

| Paper | Title of Paper |
|---|---|
| 301 | Functional Analysis |
| 302 | Advanced Discrete Mathematics |

## Optional Papers

| Paper | Title of Paper |
|---|---|
| 303 | Number Theory |
| 304 | Integral Equations |
| 305 | Riemannian geometry -I |
| 306 | General Relativity I |
| 307 | Operations Research I |
| 308 | Lattice Theory –I |
| 309 | Approximation Theory |
| 310 | Dynamical Systems- I |
| 311 | Fluid Dynamics |
| 312 | Graph Theory-I |
| 313 | Fuzzy Mathematics |
| 314 | Algebraic Topology |
| 315 | Measure and Integration |
| 316 | Topological Vector Spaces |
| 317 | Commutative Algebra I |

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 301**
**Title of Paper: Functional Analysis**

**Unit I**: 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. **15 Lectures**

**Unit II:** 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. **15 Lectures**

**Unit III:** 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. **15 Lectures**

**Unit IV**: 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. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw Hill, 1963.


**Reference Books:**


1. Erwin Kreyszig: Introductory Functional Analysis with Applications, John Wiley and Sons, 1978
2. G. Bachman and L. Narici: Functional Analysis, Academic Press, 1972.
3. A. E. Taylor: Introduction to Functional analysis, John Wiley and sons,1958.
4. J. B. Convey, A course in Functional Analysis, Springer-Verlag, 1985.
5. B. V. Limaye: Functioned Analysis, New age international, 1996.

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 302**
**Title of Paper: Advanced Discrete Mathematics**

**Unit I**: 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. **15 Lectures**

**Unit II**: 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. **15 Lectures**

**Unit III**: 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. **15 Lectures**

**Unit IV**: 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 **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Books:**


1. Discrete Mathematics (second edition) by Seymon Lipschutz and Mark Lipson.Tata Mc Graw Hill Publishing Company Ltd. New Delhi
2. John Clark and Derek Holton : A first book at Graph Theory Applied Publishers Ltd.
3. C. T. Liu : Discrete Mathematics


**Reference Books:-**


1. Gorrett Birkhoff : Lattice Theory
2. Rich and Brualdi : Combinatorics

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 303**
**Title of Paper: Number Theory**

**Unit I**: Review of divisibility : The division algorithm, G.C.D., Euclidean algorithm, Diophontine equation ax + by = C. Primes and their distribution : Fundamental theorem of Arithmetic, The Goldbach Conjecture **15 Lectures**

**Unit II**: Congruences : Properties of Congruences, Linear congruences, Special divisibility tests. Fermats theorem : Fermats factorization method, Little theorem, Wilsons theorem Number theoretic functions : The functions $\tau$ and $\sigma$. The Mobius Inversion formula, The greatest integer function. **15 Lectures**

**Unit III**: 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. **15 Lectures**

**Unit IV**: 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 . **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book:**

1. D.M.Burton : Elementary Number Theory, Universal book stall, New Delhi

**Reference Books**

1. S.B.Malik : Baisc Number theory Vikas publishing House.
2. George E.Andrews : Number theory, Hindusthan Pub. Corp.(1972)
3. Niven, Zuckerman : An Introduction to theory of numbers. John Wiley & Sons
4. S. G. Telang , Number Theory, Tata Mc.Graw-Hill Publishing Co., New Delhi

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 304**
**Title of Paper: Integral Equations**

**UNIT– I** 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 eigenfunctions. **15 Lectures**

**UNIT –II** Solutions of Fredholm integral equations by: Successive approximations Method, Successive substitution Method, Adomian 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. **15 Lectures**

**UNIT –III** 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.
**15 Lectures**

**UNIT – IV** 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.
**15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. R. P. Kanwal, Linear Integral Equation- Theory and Technique, Academic Press, 1971.
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations-Methods and Applications, Springer, 2011


**Reference Books:**


1. L. G. Chambers, Integral Equations- A Short Course, International Text Book Company, 1976.
2. M. A, Krasnov, et.al. Problems and exercises in Integral equations, Mir Publishers, 1971.
3. J. A. Cochran, The Analysis of Linear Integral Equations, Mc Graw Hill Publications, 1972.
4. C. D. Green, Integral Equation Methods, Thomas Nelson and sons, 1969.

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 305**
**Title of Paper: Riemannian geometry -I**

**Unit I:** Space of N-dimensions, curves, subspaces and hypersurfaces, transformation of co-ordinates, summation convention, contravariant vectors, covariant vectors, scalar product of two vectors, symmetric and skew symmetric tensors, contraction, composition of tensors, Quotient law, reciprocal symmetric tensor of the second rank, Quadratic forms, real quadratic forms, Quadratic differential forms. **15 lectures**

**Unit II:** Riemannian metric, Riemannian space, length of a curve, magnitude of a vector, inclination of two vectors, orthogonal vectors, co-ordinate hypersurfaces, co-ordinate curves, field of normals to the hypersurface, n-ply orthogonal system of hypersurfaces, congruences of curves, orthogonal enuples, Principal directions for a symmetric covariant tensor of the second rank, Euclidean space of n- dimensions, simple properties. **15 lectures**

**Unit III:** Three index symbols, second derivatives of the x s' with respect to x s', covariant derivative of a covariant and contravariant vectors, curl of a vector, derived vector in a given direction, covariant differentiation of tensors, divergence of a vector, Laplacian of a scalar invariants. **15 lectures**

**Unit IV:** Curvature of a curve, Principal normal, Euler's conditions, Differential equations of geodesic, Geodesic co-ordinates, Riemannian co-ordinates, Geodesic form of the linear element. Parallel displacement of a vector of constant magnitude, parallelism for a vector of variable magnitude, subspaces of a Riemannian manifold, parallelism in a subspace. Tendency and divergence of vectors with respect to subspaces or enveloping space. **15 lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. C. E. Weatherburn: An Introduction to Riemannian Geometry and Tensor Calculus, Cambridge University Press, (1963)
2. L. P. Eisenhart: Riemannian Geometry, University Press Princeton (1926)

**Reference Books:**

1. J.A. Schouten: Ricci Calculus, Springer Verlag, Berlin
2. T. Y. Thomas: Concepts from Tensor Analysis and differential Geometry, Academic Press, New York

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 306**
**Title of Paper: General Relativity I**

**Unit I:** Review of the special theory of relativity and the Newtonian theory of gravitation. Distinction between Newtonian space and relativistic space. The conflict between Newtonian Theory of gravitation and special Relativity. Non-Euclidean space time. General Relativity and gravitation, desirable features of gravitational theory. Principle of equivalence and principle of covariance. **15 Lectures**

**Unit II:** Transformation of co-ordinates. Tensor, Algebra of tensors. Symmetric and skew symmetric tensors. Contraction of tensors and quotient law. Tensor Calculus: Christoffel Symbols, Covariant derivative. Intrinsic derivative. Riemannian Christoffel Curvature tensor and its symmetric properties. Bianchi identities and Einstein tensor. **15 Lectures**

**Unit III:** Riemannian metric. Generalized Kronecker delta, alternating symbol and Levi-Civita tensor, Dual tensor. Parallel transport and Lie derivative. Geodesic: i) geodesic as a curve of unchanging direction ii) geodesic as the curve of shortest distance and iii) geodesic through variational principle. The first integral of geodesic and types of geodesics. Geodesic deviation and geodesic deviation equation. **15 Lectures**

**Unit IV:** Killing vector fields. Isometry. Necessary and sufficient conditions for isometry. Integrability condition, Homogeneity and isometry. Maximally symmetric space-time. Einstein space. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. L. N. Katkar: Mathematical Theory of General Relativity. Narosa Publishing House, New Dehli, (2014).
2. J.V. Narlikar: Lectures on General Relativity and Cosmology, The Mac Millan com. (1978).


**Reference Books:**


1. R. Adler, M. Bazin and M. Schiffer: Introduction to General Relativity, McGraw-Hill Book Com. (1975).
2. M. Carmeli: Classical Fields: General Relativity and Gauge Theory, Wiley-Interscience Publication (1982)
3. . J. L. Synge: The General Relativity, North Holland Publishing Com. (1976)
4. L.D. Landau and E.M. Lifshitz: The classical Theory of fields, Pergamon Press. (1980)
5. B.F. Shutz: A first course in General Relativity, Cambridge University Press. (1990).
6. H. Stepheni: General Relativity: An Introduction to the theory of gravitational field. Cambridge University Press. (1982)

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 307**
**Title of Paper: Operations Research I**

**Unit I**: 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. **15 Lectures**

**Unit II**: Revised simplex method in standard form I, Duality in linear programming duality theorems, Integer linear programming, Gomory's cutting plane method, Branch and Bound method. **15 Lectures**

**Unit III**: Dynamic programming. Bellman's principle of Optimality, solution of problems with a finite number of stages. Application of dynamic programming in production, inventory control and linear programming. **15 Lectures**

**Unit IV**: Non linear programming unconstrained problems of maximum and minimum Lagrangian method Kuhn Tucker necessary and sufficient conditions, Wolfe's method, Beale's method

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Books:**


1. S.D.Sharma : Operations Research, Kedar Nath Ram Noth and co


**Reference Books:-**


1. Kanti Swarup , P.K.Gupta and Manmohan : Operations research, S.Chand & Co.
2. Hamady Taha : Operations Research :Mac Millan Co.
3. S.D.Sharma :Linear programming, Kedarnath,Romnath & Co.
4. S.D.Sharma : Nonlinear and Dynamic programming Kedar Nath Ram Nath and Co. Meerut
5. R.K.Gupta : Operations Research Krishna Prakashan Mandir, Meeru
6. G.Hadley : Linear programming, Oxford and IBH Publishing Co.

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 308**
**Title of Paper: Lattice Theory –I**

**Unit I: Basic concepts** **15 Lectures**

1. Posets, Definition and examples of posets.
2. Two definitions of lattices and their equivalence, examples of lattices.
3. Description of Lattices, some algebraic concepts.
4. Duality principle, Specialelements.
5. Homomorphism, Isomorphism and isotone maps.

**Unit II: Special types of Lattices** **15 Lectures**

1. Distributive lattices – Properties and characterizations.
2. Modular lattices – Properties and characterizations.
3. Congruence relations.
4. Boolean algebras – Properties and characterizations.

**Unit III: Ideal theory** **15 Lectures**

1. Ideals and filters in lattices.
2. Lattice of all ideals I(L).
3. Properties and characterizations of I(L).
4. Stone's theorem and its consequences.

**Unit IV: Stone algebra** **15 Lectures**

1. Pseudo complemented lattices.
2. S(L) and D(L) – special subsets of pseudo complemented lattices.
3. Distributive pseudo complemented lattice.
4. Stone lattices – properties and characterizations.

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. Lattice theory: First concepts and distributive lattices by George Gratzer, W. H. Freeman and company, San Francisco, 1971.
2. Lattice theory by G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973


**Reference Books: ---**

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**Paper: 309**
**Title of Paper: Approximation Theory**

**Unit – I:** Uniform Approximation: Uniform Approximation by Polynomials; The Weierstrass Theorem and Bernstein Polynomial Approximation, Jackson's Theorems; Characterization of Best Approximations. **15 Lectures**

**Unit – II:** Interpolation: Algebraic Formulation of Finite Interpolation; Lagrange Form; Extended Haar Subspaces and Hermite Interpolation; Hermite-Fejer Interpolation; Divided Differences and the Newton Form. **15 Lectures**

**Unit–III:** Fourier Series: Introduction, Preliminaries, Convergence of Fourier Series, Summability, Convergence of Trigonometric Series, Convergence in Mean. **15 Lectures**

**Unit – IV:** Orthogonal Polynomials: Introduction; Jacobi Polynomials: Elementary Properties, Asymptotic Properties; General Properties of Orthogonal Polynomials: Existence and Uniqueness, The Recurrence Relation and Zeros, Interpolation and Quadrature. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Books:**


1. Theodore J. Rivlin : An Introduction To The Approximation Of Functions, Dover Publications, Inc. New York.
2. Hrushikesh N. Mhaskar and Devidas V.Pai : Fundamentals of Approximation Theory, Narosa Publishing House.


**References Books:**


1. Stoponet: Uniform approximation by trigonometric polynomials,VSP, Lriden

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 310**
**Title of Paper: Dynamical Systems- I**

**Unit 1: First order systems- Qualitative Analysis:**
Introduction; First order linear systems, equilibrium points- classification, stability, bifurcation, phase portraits. Scalar autonomous non-linear systems, Stability (linearization, equilibrium points), phase portraits- slope fields, Examples, two-parameter family. **15 Lectures**

**Unit 2: Planer systems- Qualitative Analysis:**
Second order linear ODE as a system of first order ODEs, preliminaries from algebra, eigen-values and eigen-vectors, solution of planar linear systems. Phase portraits for planar systems: Real distinct eigen-values, complex eigen-values, repeated eigen-values; changing co-ordinates. Classification of planar systems: the trace-determinant plane.
**15 Lectures**

**Unit 3: Higher order systems:**
Preliminaries from linear algebra; Higher order ODEs as a vector differential equation; real distinct, complex and repeated eigen-values.Yet another elegant way to find solution: The *Exponential of a Matrix* (Definition, properties of exponential of a matrix, application to the solution of a system). Non-autonomous systems of the form $X'(t)=AX(t) + G(t)$, Variation of parameters. **15 Lectures**

**Unit 4: Discrete dynamical systems:**
Introduction to the discrete maps (iterative maps), orbit, periodic points, cobweb plots. Fixed points of a map, stability analysis of a fixed point (sink, source, saddle). Bifurcation and chaos; Standard examples (Logistic map, tent map, doubling map).
**15 Lectures**

**Unit 5:** Examples, seminars, group discussion on above four units. **15 Lectures**

**Recommended Book:**
1. Differential equations, dynamical systems, and an introduction to chaos by M. Hirsch, S. Smale and R. L. Devaney, Elsevier Academic Press, USA, 2004.

**Reference Books:**
1. Chaos - an introduction to dynamical systems, Alligood, Sauer and Yorke, Springer, New York.
2. Differential Equations and Dynamical Systems, Perko, Springer, New York.
3. Dynamics and Bifurcations, Hale and Kocak, Springer, New York.

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 311**
**Title of Paper: Fluid Dynamics**

**Unit I: Physical properties of fluids and kinematics of fluids:** Concepts of fluids, continuum hypothesis, density, specific weight, specific volume, pressure, viscosity, surface tension, Eulerion & Lagrangian methods of description of fluids, Equivalence Eulerian and Lagrangian method, General motion of a fluid element, Integrability and compatibility conditions, stream lines, path lines, streak lines, stream function, vortex lines, circulation. **15 Lectures**

**Unit II. Stresses in fluids:** Strain rate tensor, stress tensor, normal stress, shearing stress, symmetry of stress tensor, Transformation of stress components from one co-ordinate system to another, principle axes and principle values of stress tensor. Newtonian fluids, non Newtonian fluids, purely viscous fluids, Constitutive equations. **15 Lectures**

**Unit III. Conservation laws:** Equation of conservation of mass, equation of conservation of momentum, Navier-Stokes equation, equation of moment of momentum, Equation of energy, Basic equations in different co-ordinate systems: Cartesian co-ordinate system, Cylindrical co-ordinate system, Spherical co-ordinate system, general orthogonal curvilinear co-ordinate system, boundary conditions. **15 Lectures**

**Unit IV. Rotational and irrotational flows, Dynamic Similarity:** Theorems about rotational and irrotational flows: Kelvins minimum energy theorem, Gauss theorem, Kinetic energy of an infinite fluid, uniqueness of irrotational flows Bernoullis's equation, Bernoullis equation for irrotational flows, Two dimensional irrotational incompressible flows, Blasius theorem, circle theorem, Sources and sinks, sources, sinks and doublets in two dimensional flows, Methods of images. Dimensional analysis, Non dimensional numbers, some applications of non-dimensional anylysis. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Books:**


1. An introduction to Fluid Dynamics' R. K. Rathy, Oxford & IBH publishing company
2. Text book of Fluid Dynamics' F. Chorton CHS Publishers, Delhi, 1985


**Reference Books:**


1. Fluid Mechanics' L. D. Landay & E. M. Lipschitz Pergamon Press London 1985
2. Fluid Mechanics' Kundu & Cohen, Elsevier pub 2004

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 312**
**Title of Paper: Graph Theory-I**

**Unit – I :** Trees and connectivity: Definitions and simple properties, Bridges, spanning trees, cut vertices and connectivity. Euler Tours: Eular graphs, Properties of Euler graph, The Chinese postman problem **15 Lectures**

**Unit – II :**Homiltonian Cycles:, Hamiltonion graphs. The travelling salesman problem. Matchings : Matchings and Augmenting path, The marriage problem, The Personal Assignment problem, **15 Lectures**

**Unit – III** The Optimal Assignment problem, A chinese postman Problem, Postscript.
Planer Graphs : Plane and Planar graphs, Eulers formula, Platonic bodies Kurotowskis theorem. Non Homiltonian plane graphs. The dual of a plane graph. **15 Lectures**

**Unit – IV** 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 sets **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. John Clark and Derek Holton : A first look at graph theory, Allied publishers Ltd. Bombay.

**Reference Books:**

1. Douglas B.West : Introduction to Graph Theory Pearson Education Asia.
2. F. Harary - Graph Theory, Narosa Publishing House (1989)
3. K. R. Parthsarthy : Basic Graph Theory, Tata McGraw Hill publishing Co.Ltd.New Delhi

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 313**
**Title of Paper: Fuzzy Mathematics**

**Unit I:** Fuzzy sets and crisp sets, Examples of fuzzy sets, Basic types and basic concepts, Standard operations, cardinality, degree of subsethood, Level cuts. **15 Lectures**

**Unit II:** 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. **15 Lectures**

**Unit III:** 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. **15 Lectures**

**Unit IV:** Fuzzy numbers, Characterization theorem, Linguistic variables, Arithmetic operations on intervals, arithmetic operations on fuzzy numbers, Lattice of fuzzy numbers, Fuzzy equations. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. George J. Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and applications, PHI, Ltd.(2000)


**Reference Books:-**


1. M.Grabish, Sugeno, and Murofushi Fuzzy Measures and Integrals: theory and Applications,PHI, 1999.
2. H.J.Zimmerermann, fuzzy set Theory and its Applications, Kluwer, 1984.
3. M. Hanss, Applied Fuzzy Arithmetic, An Introduction with Engineering Aplications,Springer-Verlag Berlin Heidelberg 2005.
4. M. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi.
5. Bojadev and M. Bojadev, Fuzzy Logic and Application

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 314**
**Title of Paper: Algebraic Topology**

**Unit I:** Homotopy of paths, The fundamental group, covering spaces, the fundamental group of the circle, retractions and fixed points, deformation retracts and homotopy type,
**15 Lectures**

**Unit II:** The fundamental group of $S^n$, fundamental groups of some surfaces, the Jordan separation theorem, the Jordan curve theorem, direct sums of Abelian groups.
**15 Lectures**

**Unit III:** Free products of groups, free groups, the Seifert-van Kampen theorem, the fundamental group of a wedge of circles. **15 Lectures**

**Unit VI:** Equivalence of covering spaces, the universal covering space, covering transformations, covering spaces of a graph, the fundamental group of a graph.
**15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Book:**

1. Topology by J.R. Munkers, Prentice Hall, (Second Edition)

**Reference Book:**

2. Croom F.H. : Basic concepts in Algebraic Topology, Springer Verlag 1978.

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**Paper: 315**
**Title of Paper: Measure and Integration**

**Unit I:** Measure and Integration: Measurable space, Measure space and its properties, finite, sigma finite and semi finite measures, complete measure space, Locally measurable sets, saturated measure. Signed measure: Definition, Positive, negative and null sets and their properties, Hahn Decomposition, mutually singular measures, Jordan Decomposition theorem.
**15 Lectures**

**Unit II:** The Caratheodory measure induced by an outer measure. The construction of outer measure. Measurable functions. Integration of a non negative measurable function, Fatou's lemma, Monotone convergence Theorem, Integrable functions and their properties, Lebesgue convergence Theorem. Integration of general measurable function. **15 Lectures**

**Unit III:** Absolute or total variation of a signed measure, The Radon Nikodym theorem, Radon – Nikodym derivative, Lebesgue decomposition theorem Product measure, measurable rectangles, Cross sections and their measurabilities, Fubini's and Tonelli's theorems. **15 Lectures**

**Unit IV:** Lp spaces. The completeness of $L^p(\mu,X)$. Riesz representation Theorem. Inner measure and its properties **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. Royden, H. L. , Fitzpatric,P. Real Analysis. Prentice Hall of India, New Delhi.


**Reference Books:-**


1. Berberian, S. K. Measure and Integration. (1965) Mc Millan, New York.
2. Rana, I. K. An Introduction to Measure and Integration. (1997) Narosa Book Company.
3. Halmos, P. K. Measure Theory. (1950) Van Nostrand.

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 316**
**Title of Paper: Topological Vector Spaces**

**Unit I:** Preliminary concepts, linear spaces, topological spaces, mappings, metric spaces, topological vector spaces, separation properties, linear mappings. **15 Lectures**

**Unit II:** Finite dimensional spaces, metrization, boundedness and continuity, seminorm and local convexity, quotient spaces **15 Lectures**

**Unit III:** Completeness, Baire category, The Banach Steinhaus theorem, The open mapping theorem. The closed graph theorem, bilinear mapping. **15 Lectures**

**Unit IV:** Convexity, Hahn Banach theorem, weak topologies, compact convex sets, duality in Banach spaces, compact operators. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books :**

1. Functional analysis by Walter Rudin, Tata McGraw Hill publishing company 1986

**Reference Books:**

1. Introductory theory of topological vector spaces, Yau-Chuen Wong, Marcel Dekker, Inc, New York 1992

**M. A. / M. Sc. Mathematics (Part II) (Semester III)**
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**Paper: 317**
**Title of Paper: Commutative Algebra I**

**Unit I:** Rings and ring homomorphism, Ideals. Quotient ring, Zero-divisors. Nilpotent elements. Units, Prime ideals and maximal ideals, Nilradical and Jacobson radical, Operations on ideals, Extension and contraction. **15 Lectures**

**Unit II:** Modules and module homomorphisms , Submodules and quotient modules ,Operations on submodules, Direct sum and product,Finitely generated modules ,Exact sequences. **15 Lectures**

**Unit III:** Tensor product of modules,Restriction and extension of scalars ,Exactness properties of the tensor product ,Algebras . Tensor product of algebras. **15 Lectures**

**Unit IV:** Rings and modules of Fractions,Local properties,Extended and contracted ideals in rings of fractions, primary decomposition. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. M. F. Atiyah and I. G. MacDonald – Introduction to Commutative Algebra, Addison Wesley publishing company


**Reference Books:-**


1. M. D. Larsen and P. J. McCarthy: Multiplicative theory of ideals, Academic press, 1971
2. D. G. Northcot, Ideal theory, Cambridge University, press, 1953
3. Oscar Zariski and P. Samual – Commutative Algebra, Vol I, Affiliated East West press pvt. Ltd. New Delhi.

# M. A. / M. Sc. Mathematics (Part II) (Semester IV)
# (Choice Based Credit System)
# (Introduced from June 2014 onwards)

## Compulsory Papers

| Paper | Title of Paper |
|---|---|
| 401 | Field Theory |
| 402 | Partial Differential Equations |

## Optional Papers

| Paper | Title of Paper |
|---|---|
| 403 | Algebraic Number Theory |
| 404 | Fractional Differential Equations |
| 405 | Riemannian Geometry -II |
| 406 | General Relativity II |
| 407 | Operations Research –II |
| 408 | Lattice Theory –II |
| 409 | Wavelet Analysis |
| 410 | Dynamical Systems- II |
| 411 | Computational Fluid Dynamics |
| 412 | Graph Theory-II |
| 413 | Fuzzy Relations and Logic |
| 414 | Analysis on Manifolds |
| 415 | Combinatorics |
| 416 | Theory of Distributions |
| 417 | Commutative Algebra – II |

**Note:**

1. **Student from Department of Mathematics, Shivaji University Kolhapur, who has passed Algebra-II at M.Sc. Part-I (AF/Credit System) must opt for Differential Geometry in the place of Field Theory.**
2. **Student from Sangli centre and Distance mode students, who has passed Algebra - II at M.Sc. Part-I (Regular) must opt for Linear Algebra in the place of Field Theory.**

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 401**
**Title of Paper: Field Theory**

**Unit I:** Field Extensions
Extension of a field,Algebraic extensions,Algebraically closed fields,Derivatives and multiple roots,Finite Fields. **15 Lectures**

**Unit II:** Galois Theory
Separable and normal extensions,Automorphism groups and fixed fields,Fundamental theorem of Galois theory. **15 Lectures**

**Unit III:** Finite Fields
Prime fields,Fundamental theorem of algebra,Cyclic extensions,Cyclotomic extensions.
**15 Lectures**

**Unit IV:** Applications of Galois theory
Constructions by ruler and compass ,Solvable groups ,Polynomials solvable by radicals.
**15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. U. M. Swamy, A. V. S. N. Murthy, Algebra: Abstract and Modern, Pearson Education, 2012.
2. M. Artin, Algebra, PHI, 1996 .


**Reference Books:**


1. Basic Algebra I, second edition, Nathan Jacobson, W. H. Freeman and company, New York .
2. I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd.
3. Bhattacharya, Jain and Nagpal,Basic Abstract Algebra, 2nd edition, Narosa Publishing House, New Delhi.
4. A first course in Abstract Algebra by John Fraleigh (3rd edition) Narosa publishing house, New Delhi
5. I. T. Adamson, Introduction to Field Theory, second edition, Cambridge University Press,1982.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 402**
**Title of Paper: Partial Differential Equations**

**Unit I:** 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. **15 Lectures**

**Unit II:** Charpits method, Jacobi method of solving partial differential equations, Cauchy Problem, Integral surfaces through a given curve for a linear partial differential equations, for a non-linear partial differential equations, Method of characteristics to find the integral sueface of a quasi linear partial differential equations and nonlinear first order partial differential equations. **15 Lectures**

**Unit III:** 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 an 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. **15 Lectures**

**Unit IV:** 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: Dirichlets problems and Neumann problems. maximum and minimum principles, Stability theorem. Dirichlet Problems and Neumann problems for a circle, for a rectangle and for a upper half plane. Riemann's Method of solution of Linear Hyperbolic equations. Harnacks theorem. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. T. Amarnath: An elementary course in Partial differential equations, Narosa publication, 1987.

**Reference Books:**

1. I. N. Sneddon: Elements of Partial Differential Equations, McGraw Hill Int.
2. Frite John: Partial Differential Equations.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 403**
**Title of Paper: Algebraic Number Theory**

**Unit I:** Revision of basic module theory, Fundamental concepts and results, Free modules and matrices, Direct sums of modules, Finitely generated modules over a P.I.D., Equivalence of matrices with entries in a P.I.D., Structure theorem for finitely generated modules over a P.I.D. , Applications to abelian groups, Algebraic Numbers, Quadratic and cyclotomic fields.
**15 Lectures**

**Unit II:**Factorization into irreducibles , Euclidean quadratic fields. **15 Lectures**

**Unit III:** Prime factorization of ideals, Lattices, Minkowski's theorem. **15 Lectures**

**Unit IV:** Geometric Representation of algebraic numbers, class groups and class numbers, computational methods. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**

1. N.Jacobson, Basic Algebra - I, Hindustan Publishing Corporation (India), Delhi (Unit-I)
2. Algebraic Number Theory by I.N. Stewart & D.O. Tall, Academic press. (Chapters 2 to 10) (Unit-II to Unit-IV)

**Reference Books:**

1. Algebraic Number Theory : Mathematical Pamphlet, TIFR, Bombay .
2. Paulo Ribenboim, Classical Theory of Algebraic Numbers, Springer , New York(2001).
3. N.S.Gopalkrishnan, University Algebra, New Age International(P) Ltd. Publishers.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 404**
**Title of Paper: Fractional Differential Equations**

**Unit I**: 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 $(t-a)^{\beta}$, 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 $(t-a)^{\beta}$.

**15 Lectures**

**Unit II**: 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, Behaviour near the lower terminal, Behaviour far from the lower terminal.

**15 Lectures**

**Unit III**: 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. **15 Lectures**

**Unit IV**: 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 **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. Igor Podlubny, Fractional differential equations. San Diego: Academic Press; 1999.


**Reference Books:**


1. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.
2. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010.
3. L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press, 2010.
4. Shantanu Das, Functional Fractional Calculus, Springer, 2011.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 405**
**Title of Paper: Riemannian Geometry -II**

**Unit I:** Ricci's coefficients of rotation, Curvature of congruence, Geodesic congruences, commutation formula for second derivatives along the arcs of the enuple. Coefficients of rotation, condition for normal congruence, curl of a congruence, congruences canonical with respect to a given congruence . **15 Lectures**

**Unit II:** Curvature of a Riemannian Space: Curvature Tensor and Ricci tensor, covariant curvature tensor, The identity of Bianchi. Riemannian Curvature of a $V_n$ Formula for Riemannian curvature. Theorem of Schur, Mean Curvature of a space for a given direction. Einstein space. **15 Lectures**

**Unit III:** Hypersurfaces: Notations, unit normal, generalized covariant differentiation. Gauss's Formulae, second fundamental form. Curvature of a curve in a hypersurface. Normal curvature. Meunier's theorem, Generalisation of Dupin's theorem. Principal normal curvature, Lines of curvature, conjugate directions and asymptotic directions in a hypersurface. Euler's Formula, Umbilical points, **15 Lectures**

**Unit IV:** Totally geodesic hypersurfaces. Tensor derivative of the unit normal. The equations of Gauss and Codazzi for a Hypersurface, Gauss and Codazzi equations for a hypersurface of a Euclidean space and a space of constant curvature. Hypersurface in Euclidean space. Riemannian curvature of a hypersphere in a Euclidean space. Hyperplanes and hypersphere in a Euclidean space. Geodesics in a space of positive constant curvature. Gauss formulae for subspace $V_n$ of $V_m$, curvature of a curve in a subspace. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. C. E. Weatherburn: An Introduction to Riemannian Geometry and Tensor Calculus, Cambridge University Press, (1963).
2. L. P. Eisenhart: Riemannian Geometry, University Press Princeton (1926).


**Reference Books:**


1. J.A. Schouten: Ricci Calculus, Springer Verlag, Berlin
2. T. Y. Thomas: Concepts from Tensor Analysis and differential Geometry,

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**(Introduced from June 2014 onwards)**

**Paper: 406**
**Title of Paper: General Relativity II**

**Unit I:** The action principle, Einstein's field equations from action principle and its Newtonian approximation. Poisson's Equation as an approximation of Einstein's Field equations. Flat space-time and empty space-time. Local conservation laws associated with perfect fluid distribution, the energy momentum tensor. The stress-energy momentum tensor for perfect fluid, electromagnetic field. Schwarzschild space-time. Spherical symmetry. Einstein field equations under spherical symmetry. Schwarzschild exterior solution. **15 Lectures**

**Unit II:** Planetary orbits and Kepler's laws, Relativistic analogues of Kepler's laws. Three crucial tests for general Theory of relativity: 1. Perihelion of the planet Mercury, 2. Bending of light, 3. Gravitational red shift. Isotropic co-ordinates. Retarded time. Isotropic form of Schwarzschild exterior solution. **15 Lectures**

**Unit III:** The exterior calculus: The tangent space. Transformation properties of vector components. The co-tangent space. Basis in co-tangent space. Transformation laws of dual basis. Basis vector and 1-form.Tensor product and components of tensors. The law of transformation of tensors. Exterior product (wedge Product). Exterior derivative, p-forms. Hodge's star operator, Maxwell's field equations in Exterior form. **15 Lectures**

**Unit IV:** Frame components of Riemannian Curvature tensor. Covariant differentiation. Ricci's rotation coefficients. Cartan's first equation of structure, Cartan's second equation of structure. Curvature 2-forms. Bianchi identities in tetrad form, Calculation of tetrad components of Riemannian tensor and Ricci tensor of spherically and axially symmetric metrics. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**


1. L. N. Katkar: Mathematical Theory of General Relativity, Narosa Publishing House, New Dehli, (2014).


**Reference Books:**


1. J.V. Narlikar: Lectures on General Relativity and Cosmology. The MacMillan com. (1978).
2. R. Adler, M. Bazin and M. Schiffer: Introduction to General Relativity, McGraw-Hill Book Com. (1975).
3. W. Israel : Defferential forms in General Relativity. Dublin University Press (1970).
4. Flander: Defferential forms in General Relativity (1963)
5. F. De Felice and C.J.S. Clarke: Relativity on curved Manifold, Cambridge University Press, (1990).

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
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**Paper: 407**

**Title of Paper: Operations Research –II**

**Unit I:** Replacement Problems, Failure mechanism of items, Replacement policy for items whose maintenance cost increases with time and money values is constant, Group replacement of items that fail completely. **15 Lectures**

**Unit II:** Inventory – Cost involved in inventory problems, variables in inventory problem, symbols in inventory concept of EOQ, Methods with calculus method ,Model I (a) The economic lot size system with uniform demand, Model I (b) Economic lot size with different rates of demand in different cycles.,Model I (c) Economic lot size with finite Rate of Replenishment.,(EOQ production model) EOQ model with shortages , Model II(a) The EOQ with constant rate of demand, scheduling, time constant.,Model II (c) The production lot size model with shortages,Probabilistic inventory Models, Instantaneous demand, no set up cost model , Model VI(a) Discrete case ,Model VI(b) continuous case. **15 Lectures**

**Unit III:** Queuing Theory ,Queuing systems , Queuing Problems: transient and steady states, traffic intensity ,Probability distributions in Queuing systems Poisson process, Properties , Exponential process, Classification of Queuing Models,Model I : ( M/M/I) : ( $\infty$ /FCFS), Model II (a) : General Erlang queuing model. **15 Lectures**

**Unit IV:** Information Theory : Communication process, Quantitative measure of information, A binary unit of information, measure of uncertainty of entropy, basic properties of entropy function (H) Joint and conditional entropies, Uniqueness theorem, Chanel capacity, efficiency and redundancy Encoding, Shannon Fano encoding procedure, PERT / CPM : Applications of PERT /CPM techniques, Network diagram, representations. Rules for constructing the Network diagram, determination of the critical path. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**

1. S.D.Sharma : Operations Research Kedarnath and co. 1999.

**Reference Books:**

1. Kanti Swarup , P.K.Gupta and Manmohan : Operations research, S.Chand & Co.
2. Hamady Taha : Operations Research :Mac Millan Co.
3. S.D.Sharma :Linear programming, Kedarnath,Romnath & Co.
4. S.D.Sharma : Nonlinear and Dynamic programming Kedar Nath Ram Nath and Co. Meerut
5. R.K.Gupta : Operations Research Krishna Prakashan Mandir, Meeru
6. G.Hadley : Linear programming, Oxford and IBH Publishing Co.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**(Introduced from June 2014 onwards)**

**Paper: 408**
**Title of Paper: Lattice Theory –II**

**Unit I:** Congruences and Ideals: Week projective and congruences, Distributive, Standard and Neutral elements, Distributive, Standard and Neutral Ideals, Structure Theorems. **15 Lectures**

**Unit II:** Modular and Semimodular Lattices: Modular lattices, Semimodular Lattices, Geometric lattices, Partition of Lattices, Complemented modular Lattices, Direct decompositions, Jordon – Holder theorem, Kurosh – Ore theorem, Ore's theorem, sub group lattices. **15 Lectures**

**Unit III:** Semimodular Lattices with Finite Length: Rank and covering Inequalities, Embeddings, Geometric closure operators, Semimodular Lattices and selectors,consistent semimodular lattices, Pseudomodular lattices **15 Lectures**

**Unit IV:** Local Distributivity and Modularity: The characterization of Dilworth and Crawley, Avann's characterization Theorem, Meet-distributive lattices and Convexity, The Kurosh-Ore Replacement property Dually consistent semimodular lattices, Lattices of subnormal subgroups. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. Lattice theory: First concepts and distributive lattices by George Gratzer, W. H. Freeman and company, San Francisco, 1971.

**Reference Books:**

1. Semimodular Lattices Theory and Applications by Manfred Stern, Cambridge University Press, 1999
2. Lattice theory by G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973.

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**Paper: 409**
**Title of Paper: Wavelet Analysis**

**Unit I:** Fourier analysis: Fourier series, Fourier transform, Windowed Fourier transform, The Heisenberg uncertainty principle, The Shannon sampling theorem **15 Lectures**

**Unit II:** The continuous wavelet transform: Wavelet transform, Definitions and examples, A Plancherel formula, Inversion formulas, The kernel function, Decay of the wavelet transform **15 Lectures**

**Unit III:** Frames: Geometrical considerations, The general notion of a frame, The discrete wavelet transfom. **15 Lectures**

**Unit IV:** Multiresolution analysis: Axiomatic description, The scaling function, Constructions in the Fourier domain, Orthonormal wavelets with compact support. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Book(s):**

1. Christian Blatter ,Wavelets a primer ,Universities press 1998

**Reference Books:**

1. Mark A. Pinsky : Introduction To Fourier Analysis and Wavelets
2. Gerald Kaiser : A friendly guide to wavelets ., Springer 1994

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**Paper: 410**
**Title of Paper: Dynamical Systems- II**

**Unit I: Basic concepts of nonlinear dynamics:**
Introduction, Historical developments; Autonomous system of nonlinear ODEs: fundamental existence and uniqueness of solution; dependence of solution on initial conditions and parameters; The maximal interval of existence. **15 Lectures**

**Unit II: Stability analysis:**
The flow defined by a differential equation; Linearization; Stable manifold theorem; Hartman-Grobman theorm; Stability and Lyapunov functions; Bifurcation. **15 Lectures**

**Unit II: Chaos:**
Concept, properties;Limit sets and attractors; Poincare-Bendixson theorem, The Poincare map, Lyapunov exponents in flows, Numerical computation of Lyapunov exponents, Examples: Lorenz system, Chua circuit, Rossler attractor; Forced oscillators; Chaos synchronization.
**15 Lectures**

**Unit IV: Applications and computer experiments:**
Application of chaos to secure communication; Introduction to fractals; Use of computer softwares to solve problems in Dynamical Systems: Solving linear and nonlinear systems; data visualization-2D and 3D plots, vector field plots, chaotic phase portraits; solving discrete systems- cobweb plots. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. Differential Equations and Dynamical Systems, Perko, Springer, New York.
2. Chaos - an introduction to dynamical systems, Alligood, Sauer and Yorke, Springer, New York.


**Reference Books:**

1. Differential equations, dynamical systems, and an introduction to chaos, M. Hirsch, S. Smale and R. L. Devaney, Elsevier Academic Press, USA, 2004.
2. Nonlinear dynamics and chaos, Strogatz, Perseus Books, New York.
3. Introduction to applied nonlinear dynamics and chaos, Wiggins, Springer, New York. (Algorithms)
4. Dynamical systems: differential equations, maps and chaotic behavior, Arrowsmith and Place, Chapman and Hall, London. (Applications)
5. Differential dynamical systems, Meiss, SIAM, Philadelphia.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**Paper: 411**
**Title of Paper: Computational Fluid Dynamics**

**Unit I.** Comparison of experimental, Theoretical and numerical approaches, Governing equations, continuity equation, momentum equation (in viscid, viscous flows) energy equation, incompressible viscous flow, laminar boundary layer flow. **15 Lectures**

**Unit II.** Nature of a well posed problems, physical classification and Mathematical Classification of partial differential equations: hyperbolic, parabolic, elliptic partial differential equations, traditional solution method: separation of variables, Transformation relationships, Evaluation of transformation parameters, forward, backward, centered difference formulae, Generalized co-ordinates structure of first and second order partial differential equation. **15 Lectures**

**Unit III:** Stability, Convergence & consistency at finite difference scheme, Explicit, Implicit and Crank- Nicolson methods for heat equation, Von Neumann analysis, Euler's explicit method, Upstream differencing method, Lax method, Euler implicit method for wave equation. Finite difference representation of Laplace equation, five point method. **15 Lectures**

**Unit IV:** Burgers equation (inviscid ) Lax method, implicit methods, Burgers equation (viscous) FTCS method, Briley – Mc Donald method, Convergence and stability, Grid generation, orthogonal gird generation, order of magnitude analysis, flow in a straight rectangular duct, flow in a curved rectangular duct. Introduction to Finite Element Methods (FEM) **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Book(s):**


1. Computational Fluid Dynamics' Chung 2002 Cambridge University, Press.
2. Computational Fluid Mechanics & Heat Transfer, Dale A Anderson, John Tannelhill, R. H. Fletcher, Hemisphere publishing corporation 1984.


**Reference Books:**


1. Computational Techniques for Fluid Dynamics Vol. I & II, C. A.J. Fletcher Springer Verlag 1988.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 412**
**Title of Paper: Graph Theory-II**

**Unit – I** Preliminaries, Incidence Matrix: Rank, Minors, Path Matrix, Integer generalized inverse, Moore-Perose inverse, 0-1 incidence matrix, Matchings in bipartite graphs. **15 Lectures**

**Unit – II** Adjacency Matrix, Eigenvalues of some graphs, Determinant, Bounds, Energy of graph, Antiadjacency matrix of directed graph, nonsingular trees. **15 Lectures**

**Unit – III** 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, Minors. **15 Lectures**

**Unit – IV** 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. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s):**

1. R. B. Bapat : Graphs and Mitrices, Hindustan Book Agency.

**Reference Books:**

1. Douglas B.West : Introduction to Graph Theory Pearson Education Asia.
2. F. Harary - Graph Theory, Narosa Publishing House (1989)
3. K. R. Parthsarthy : Basic Graph Theory, Tata McGraw Hill publishing Co.Ltd.New Delhi

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**Paper: 413**
**Title of Paper: Fuzzy Relations and Logic**

**Unit-I :** 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 **15 Lectures**

**Unit – II:** Fuzzy Relation Equation, Problem Partitioning, solution methods, Fuzzy relational equations based on sup-I and inf-wi compositions, Approximate solutions **15 Lectures**

**Unit – III :** Fuzzy propositions. Fuzzy Quantifiers, Linguistic Hedges, Inference from conditional fuzzy propositions, Qualified and quantified propositions **15 Lectures**

**Unit – IV:** Approximate Reasoning:-Fuzzy expert systems, Fuzzy implications, selection of Fuzzy implications, Multi-conditional Approximate Reasoning, Role of fuzzy relational equations, Interval valued Approximate Reasoning **15 Lectures**

**Unit – V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. George J Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and applications, PHI, Ltd.(2000)


**Reference Books:-**


1. M.Grabish, Sugeno, and Murofushi Fuzzy Measures and Integrals: theory and Applications ,PHI, 1999.
2. H.J.Zimmerermann, fuzzy set Theory and its Applications, Kluwer, 1984.
3. M. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic; PHI Learning Private Limited, NewDelhi. 2011.

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**Paper: 414**
**Title of Paper: Analysis on Manifolds**

**Unit I:** Change of variables theorem: Diffeomorphsims in $R^n$, proof of the change of variables theorem, Application. **15 Lectures**

**Unit II:** Manifolds: the Volume of a parallelpiped, volume of a parametrized manifold, manifold in $R^n$ , the boundary of a manifold, integrationon a manifold. **15 Lectures**

**Unit III:** Differential forms: Multilinear algebra, alternating tensors, wedge product, tangent vectors and differential forms, the differential operator, action of differential map. **15 Lectures**

**Unit IV:** Stokes theorem: Integrating forms over parametrized manifolds, orientable manifolds, integrals over orientable manifolds, Stokes theorem. **15 Lectures**

**Unit V:** Examples, seminars, group discussion on above four units. **15 Lectures**

**Recommended Book:**

1. Analysis on Manifolds by J.R. Munkers (Addision Wesely) Section 18-37

**Reference Book:**

1. Calculus on Manifolds: A Modern Approach To Classical Theorems of Advanced Calculus by Michael Spivak.

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**(Introduced from June 2014 onwards)**

**Paper: 415**
**Title of Paper: Combinatorics**

**Unit I :** The sum Rule and the product Rule ,Permutations and combinations ,The Pigeonhole Principle ,Ramsey Numbers ,Catalan Numbers ,Stirling Numbers. **15 Lectures**

**Unit II:** Generalized Permutations and combinations, Multinomial Theorem ,The Inclusion – Exclusion principle, Sieve's formula ,Derangements ,System of Distinct Representatives (SDR), Combinatorial Number theory. **15 Lectures**

**Unit III :**Rook- Polynomial ,Ordinary and Exponential generating functions ,Partitions of a positive integer ,Recurrence Relations, Fibonacci sequence. **15 Lectures**

**Unit IV :**Group Theory in Combinatories ,The Burnside Frobenius Theorem,Permutation Groups and Their Cycle Indices , Polya's Enumeration Theorems. **15 Lectures**

**Unit V:**Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Book(s):**

1. V.K. Balakrishnan Schum's Outline of Theory and problems of combinatorics. Schum's Outline Series Mc. Grew Hill INC
2. Richard A Broadly, Introductory combinatorics New Holland.

**Reference Books:**

1. Alan Tucker – Applied Combinatorics. – John Willey Sons.
2. Sharad Sane- Combinatorial Techniques-Hindustan Book Agency

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
**(Choice Based Credit System)**
**(Introduced from June 2014 onwards)**

**Paper: 416**
**Title of Paper: Theory of Distributions**

**Unit I:** Locally convex spaces, topological vector spaces, seminorms, locally convex spaces, examples of locally convex spaces. **15 Lectures**

**Unit II:** Test functions and distributions: space of test functions, distributions, Diffrentiation of distributions, convergence of distributions, Multiplication by smooth functions. **15 Lectures**

**Unit III:** Local properties of distributions, Distributions of finite order, distributions defined by powers of x, dual spaces of $C^{\infty}(\Omega)$, tensor product. **15 Lectures**

**Unit IV:** Distribution with compact support, convolution, regularization of distributions, local structure of distributions, Applications to differential equations. **15 Lectures**

**Unit V**: Examples, seminars, group discussions on above four units. **15 Lectures**

**Recommended Book(s)**:

1. Theory of distributions, M.A.Al Gawaiz, Marcel Dekkar, Inc New York 1992

**Reference Book(s):**

1. Functional analysis, Walter Rudin, Tata McGraw Hill publishing company 1986
2. Distribution Theory and transform analysis, A.H. Zemanian , Dover publication 1987

**M. A. / M. Sc. Mathematics (Part II) (Semester IV)**
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**Paper: 417**
**Title of Paper: Commutative Algebra – II**

**Unit I:** Integral dependence ,The going-up theorem . Integrally closed integral domains. The going-down theorem. Valuation rings. **15 Lectures**

**Unit II:** Chain Conditions and theorems. **15 Lectures**

**Unit III:**Noetherian Rings ,Primary decomposition in Noetherian ring, Artin Rings. **15 Lectures**

**Unit IV**: Discrete valuation rings ,Dedekind domains ,Fractional ideals. **15 Lectures**

**Unit V:** Examples, Seminars and group discussion on the above four units. **15 Lectures**

**Recommended Books:**


1. M. F. Atiyah and I. G. MacDonald – Introduction to Commutative Algebra, Addison Wesley publishing company


**Reference Books:**


1. M. D. Larsen and P. J. McCarthy: Multiplicative theory of ideals, Academic press, 1971
2. .D. G. Northcot, Ideal theory, Cambridge University, press, 1953
3. Oscar Zariski and P. Samual – Commutative Algebra, Vol I, Affiliated East West press pvt. Ltd. New Delhi.