Savitribai Phule Pune University

(Formerly University of Pune)

Two Year Degree Program in

MATHEMATICS

(Faculty of Science & Technology)

Revised Syllabi for

M.A. / M.Sc. (Mathematics)

(For Department of Mathematics, Savitribai Phule Pune University, Pune-411 007).

Choice Based Credit System Syllabus

To be implemented from Academic Year 2018-2019

(1) **Title** : M.A./M. Sc. (Mathematics)

(2) **Duration** : TWO years (Four semester) full time programme

(3) **Total number of credits** : 80

(4) **Preamble of the syllabus**: This program is offered at the Department of Mathematics, Savitribai Phule Pune University. For obtaining M.A./M.Sc. (Mathematics) degree a student has to acquire minimum 80 credits. The structure of the program is as follows:
   (a) In semesters I and II there will be FIVE core courses per semester.
   (b) In semesters III and IV a student should acquire 40 credits from elective courses. He/She can register for minimum THREE courses and maximum upto SEVEN courses in each semester.
   (c) Each course is of 4 credits having 4 hours of classroom teaching and one/two hour(s) of lab work/problem solving session/ tutorial/ related activity per week for fifteen weeks.

(5) **Evaluation Rules** :
   (a) Each course will carry 100 marks. There will be Continuous Assessment (CA) and End Term Examination (ETE) for each course of 50 marks each.
   (b) For CA, 50% of the marks will be based on tests (minimum 2). In addition, a teacher may consider one or more of the following evaluation options.
      (i) Home Assignment(s)
      (ii) Seminar/Presentation by the student
      (iii) Laboratory assignment
      (iv) Group Discussions
      (v) Research Paper Review
      (vi) Technology Demonstration
      (vii) Mini projects in group of maximum 2 members.
   (c) For passing a course a student has to earn 30% marks in both CA and ETE separately and minimum 40% marks in the combined grading of the CA and ETE.
   (d) If a student fails in a course in any semester then he/she can appear only for the End Term Examination (ETE) of the following semester. However he/she can improve the continuous assessment (CA) performance in any of the forthcoming semesters in which the course is subsequently conducted and in this case, the student will have to appear for the ETE also for the said course.

(6) **ATKT Rules** : Student who wishes to take admission to the second year of M. A. /M. Sc. (Mathematics) should have obtained at least 20 credits out of the 40 credits of the First year M. A./M. Sc. (Mathematics).

(7) **Completion of the Degree Programme** :
   (a) In order to pass the M.A./M.Sc. (Mathematics), a student has to earn 80 credits and complete the audit courses floated by the University time to time.
   (b) If a student fails in a course then the said course will not be taken into account for calculation of GPA and overall grade. Only those courses in which the student has passed will be taken into account for calculating the GPA and overall grade.

(c) The policies and procedures determined by the University will be followed for the conduct of examinations and declaration of the result of the candidate.

(8) The overall course structure is summarized in the table below.

Course Type	**Course(s)**	**Minimum Credits**
Core	Core Mathematics Courses (10)	40
Elective	Elective Courses (A student can take elective courses from Other Departments maximum upto 20 credits)	40
	Total Credits	**80**

(9) Department may introduce additional elective course(s) on recommendations of the Departmental Committee. The syllabus of the elective courses will be prepared by the concerned teacher and will be flexible to accommodate new developments in that area. Whenever such an optional course is floated, the concerned syllabus will be discussed and approved in the Departmental Committee.

(10) **Course Structure :**

Semester I : (Total Credits 20)

Course Type	**Course Code**	**Course Title**	Number of Credits
Core	MT-101	Linear Algebra	4
Core	MT-102	Topology	4
Core	MT-103	Measure and Integration	4
Core	MT-104	Algebra	4
Core	MT-105	Numerical Analysis	4

Semester II : (Total Credits 20)

Course Type	**Course Code**	**Course Title**	Number of Credits
Core	MT-201	Functional Analysis	4
Core	MT-202	Complex Analysis	4
Core	MT-203	Field Theory	4
Core	MT-204	Advanced Calculus I	4
Core	MT-205	Differential Equations	4

Semester III and IV :

Course Type	**Course Code**	**Course Title**	Number of Credits
Elective	MT-01	Operations Research	4
Elective	MT-02	Integral Equations and Transforms	4
Elective	MT-03	Number Theory	4
Elective	MT-04	Coding Theory	4
Elective	MT-05	Graph Theory	4
Elective	MT-06	Lattice Theory	4
Elective	MT-07	Computational Geometry	4
Elective	MT-08	Cryptography	4
Elective	MT-09	Financial Mathematics	4
Elective	MT-10	Symmetries	4
Elective	MT-11	Wavelet Analysis	4
Elective	MT-12	Combinatorics	4
Elective	MT-13	Partial Differential Equations	4
Elective	MT-14	Logic and Set Theory	4
Elective	MT-15	Statistics and Probability	4
Elective	MT-16	Fluid Dynamics	4
Elective	MT-17	Banach Algebra	4
Elective	MT-18	Advanced Real Analysis	4
Elective	MT-19	Matroid Theory	4
Elective	MT-20	Differential Equations and Dynamical Systems	4
Elective	MT-21	Mechanics	4
Elective	MT-22	Algebraic Topology	4
Elective	MT-23	Advanced Calculus II	4
Elective	MT-24	Rings and Modules	4
Elective	MT-25	Differential Geometry	4
Elective	MT-26	Fourier Analysis	4
Elective	MT-27	Commutative Algebra	4
Elective	MT-28	Advanced Complex Analysis	4
Elective	MT-29	Representation Theory of Groups	4
Elective	MT-30	Fourier Analysis on Finite Groups	4
Elective	MT-31	Topics in Lie Groups	4
Elective	MT-32	Advanced Linear Algebra	4
Elective	MT-33	Projective Geometry	4
Elective	MT-34	Algebraic Geometry	4
Elective	MT-35	Algebraic Number Theory	4
Elective	MT-36	Algebraic Curves	4
Elective	MT-37	Advanced Lattice Theory	4
Elective	MT-38	Spectral Graph Theory	4
Elective	MT-39	Advanced Combinatorics	4
Elective	MT-40	Topics in Group Theory	4

Semester III and IV :

Course Type	**Course Code**	**Course Title**	Number of Credits
Elective	MT-41	Commutative Ring Theory	4
Elective	MT-42	Topics in Non-Commutative Rings	4
Elective	MT-43	Homological Algebra	4
Elective	MT-44	Topics in Galois Theory	4
Elective	MT-45	Advanced Measure Theory	4
Elective	MT-46	Topics in Discrete Mathematics	4
Elective	MT-47	Topics in Algebraic Topology	4
Elective	MT-48	Manifolds	4
Elective	MT-49	Topics in Number Theory	4
Elective	MT-50	Computer Programming	4

MT 101 : Linear Algebra

(1) **Vector Spaces:** Definition and Examples, Subspaces, Bases and Dimensions, Linear Transformations, Quotient Spaces, Direct Sum, The matrix of Linear Transformation, Duality.

(2) **Canonical Forms:** Eigenvalues and Eigenvectors, The minimal Polynomial, Diagonalisability, Triangulable Operators, Jordan Cannonical Form, Rational Cannonical Form.

(3) **Inner Product Spaces:** Inner Product Spaces, Orthogonally, The Adjoint of Linear Transformation, Unitary operators, Self-Adjoint and Normal Operators.

(4) **Bilinear Forms:** Definition and Examples, The matrix of a Bilinear Form, orthogonality, Symmetric Bilinear form.

Reference Books:

- Vivek Sahai and Vikas Bist, Linear Algebra, (Narosa Publishing House, Third Edition), 2008.
- K. Hoffman and R. Kunze, Linear Algebra (Prentice Hall, Second Edition), 1971.

MT 102 : Topology

(1) **Prerequisites:** Cartesian Products, Finite Sets, Countable and Uncountable Sets, Infinite Sets and Axiom of Choice, Well Ordered Sets.

(2) **Topological Spaces:** Basis for a topology, Order topology, Subspace Topology, Product topology, closed sets and limit points, Continuous functions, Metric Topology, Quotient spaces.

(3) **Connected and Compact Spaces:** Connected spaces, Connected Subspaces of Real Line, Components and Local Connectedness, Compact spaces, Compact Subspaces of the Real Line, Limit point compactness, Local Compactness.

(4) **Countablity and Separation Axioms:** Countability Axioms, Separation axioms Normal Spaces, Urysohn's Lemma, Tietze Extension Theorem, Metrization Theorem, Tychonoff's Theorem.

Reference Books:

- J.R. Munkres, Topology: A First Course, (Prentice Hall, Second Edition), 2000

MT 103 : Measure and Integration

(1) **Prerequisites:** Cardinal Numbers and Countability, Properties of Open Sets, Cantor Like Sets.

(2) **Measure on Real Line:** Lebesgue Outer Measure, Measurable Sets, Regularity, Measurable Functions, Borel and Lebesgue Measurability.

(3) **Integration of Functions on Real Variable:** Integration of Non-Negative Functions, General Integral, Integration of Series, Riemann and Lebesgue Integral.

(4) **Differentiation:** Functions of Bounded Variation, Lebesgue Differentiation Theorem, Differentiation Theorem, Differentiation and Integration.

(5) **Inequalities and L^P spaces:** The L^p Spaces, The Convex Functions, Jensen's Inequalities, Inequalities of Holder and Minkowski, Completion of L^p.

(6) **Convergence:** Convergence in Measure, Almost Uniform Convergence, Convergence Diagrams, Counter Examples.

Reference Books:

- G. de Barra, Measure Theory and Integration, (New Age International Ltd, Publishers), 1981.
- H. L. Roydon, Real Analysis, (Prentice Hall, Third Edition), 1995.

MT 104 : Algebra

(1) **Introduction to Groups:** Symmetries of a square, dihedral group, rotation groups, Elementary Properties of Groups, subgroups and cyclic groups, properties of cyclic groups, Lagranges theorem and consequences.

(2) **Permutation Groups:** properties of permutations, cycle decomposition, structure of conjugacy in permutation groups, Alternating subgroups, An is simple

(3) **Group Homomorphism and Isomorphism:** The First Isomorphism Theorem, automorphisms, Cayleys theorem

(4) **Normal Subgroups and Factor Groups:** Normal Subgroups, Factor Groups, Applications of Factor Groups, Internal Direct Products, external direct product

(5) **Group Actions :** Definition and examples, Orbit Stabilizer theorem, Conjugacy and Class equation.

(6) **Sylow theorems and Applications:** Normal series, composition series, Jordan Holder theorem, Solvable groups, p-groups, Nilpotent groups.

(7) **Fundamental Theorem of Finite Abelian Groups:** Structure theorem of finitely generated Abelian groups, Isomorphism classes of finitely generated Abelian Groups.

Reference Book:

- Joseph Rotman, An Introduction to the Theory of Groups, (Springer, Fourth Edition), 1995.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, (Cambridge University Press, Second Edition), 1995 (Indian Edition).
- Michael Artin, Algebra, (Pearson, second edition), 2010.
- Vivek Sahai & Vikas Bist, Algebra, (Alpha Science International Ltd, Second Edition),2003.

MT 105 : Numerical Analysis

(1) **Iterative solutions of nonlinear equation:** bisection method, fixed-point interation, Newton's method, secant method, Aitken's method, Rate of convergece of each method, Newton's method for a system of two non linear equations.

(2) **Polynomial interpolation:** interpolation polynomial, divided difference interpolation, Aitken's formula, finite difference formulas, Hermite's interpolation, double interpolation.

(3) **Linear systems of Equations:** Gauss Elimination, Gauss-Jordan method, LU decomposition, iterative methods, and Gauss- Seidel iteration, Bounds on Eigen values, Jacobi method for symmetric matrices.

(4) **Eigenvalue Problems :** Power method, Jacobi method, Householder method.

(5) **Numerical Calculus :** Numerical differentiation, Errors in numerical differentiation, Numerical Integration, Trapezoidal rule, Simpson's 1/3 - rule, Simpson's 3/8 rule, error estimates for Trapezoidal rule and Simpson's rule.

(6) **Numerical Solution of Ordinary differential Equations :** Solution by Taylor series, Picard Method of successive approximations, Euler's Method, Modifed Euler Method, Runge- Kutta Methods, Predicator-Corrector Methods.

Reference Books:

- K. E. Atkinson: An Introduction to Numerical Analysis, (John Wiley & Sons, second edition), 1989.
- M. K. Jain, S. R. K. Iyengar, P. K. Jain, Numerical Methods for Scientific and Engineering Computations, (New Age International Publishers, Sixth Edition), 2012.
- J. I. Buchaman and P. R. Turner, Numerical Methods and Analysis, (McGraw-Hill), 1992.

MT 201 : Functional Analysis

Motivation, Normed linear spaces and continuity of linear maps, linear functionals and Hahn Banach theorems, Banach spaces, Uniform boundedness principle, Closed graph and Open mapping theorems, Bounded Inverse theorem, Hilbert spaces, Orthonormal sets, projections and Riesz representation theorem.

Reference Books:

- Balmohan Limaye, Functional Analysis (second edition)
- John B. Conway, A course in functional analysis, Springer (1997)
- Karen Saxe, Beginning Functional Analysis
- Béla Bollabás, Linear Analysis, (secon Edition, CUP), 2018.

MT 202: Complex Analysis

(1) Stereographic projection, Elementary Functions, Exponential function, mapping properties, logarithmic function, complex exponents, branch of logarithm.

(2) Mobius Transformations, Symmetry and orientation principle, Conformal mappings.

(3) Analytic Functions: Cauchy-Riemann Equations, analyticity, harmonic functions, Power Series.

(4) Complex Integration and Cauchy's Theorem, Cauchy's integral formula, Cauchy's estimate and applications, Homotopic version of Cauchys theorem, Open mapping theorem, Gourasats theorem

(5) Singularities- Classification, Laurent series, Residue theorem and applications to evaluation of real integrals, Casorati-Weistrass theorem, Argument principle

(6) Maximum modulus theorem, Schwarzs lemma

Reference Book:

- J. B. Conway, Functions of one complex variables, Narosa Publishing House.
- Ponnusamy, S., Silverman, H., Complex Variables with Applications.
- Brown J. and Churchill R., Complex variables and Applications, (8th Edition).

MT 203 : Field Theory

(1) **Field Extensions :** Basic theory of field extensions, algebraic extensions, classical straightedge and compass Constructions, splitting fields and algebraic closures, Separable and Inseparable Extensions, cyclotomic polynomials and extensions

(2) **Galois Theory :** Basic definitions, normal extensions, The Fundamental Theorem of Galois Theory, finite fields, composite and simple extensions, symmetric polynomials, Fundamental theorem on Symmetric Polynomials, Galois groups of polynomials, solvable and radical extensions, insolvability of the quintic.

Reference Books:

- Joseph Rotman, Galois Theory (Springer, Second Edition)
- Dummit and Foote, Abstract Algebra, 2nd Edition, Wiley Eastern Ltd.
- P. Bhattacharya and S. Jain, Basic Abstract Algebra, Second Edition,Cambridge University Press.

MT 204 : Advanced Calculus I

(1) **Differentiation :** Derivative, Continuously Differentiable functions, Chain rule, Inverse function theorem, Implicit function theorem.

(2) **Integration:** integral over a rectangle, existence of the integral, evaluation of the integral, integral over a bounded set and rectifiable sets, improper integrals

(3) **Change of Variables Theorem:** partitions of unity, Change of Variables theorem, applications of Change of Variables theorem, Line integrals with applications

Reference Books:

- J. R. Munkres, Analysis on Manifolds
- Michael Spivak, Calculus on Manifolds

MT 205 : Differential Equations

(1) **Prerequisites:** Linear equations of the first order.

(2) **Linear equations with constant coefficients:** Second order homogeneous equations, Initial value problems, Linear dependence and independence, Non homogeneous equations of nth order, Algebra of constant coefficients.

(3) **Linear equations with variable coefficients :** Initial value problems, Solutions of the homogeneous equation, Wronskian and linear independence, Reduction of order, Non homogeneous equations, Legendre equation.

(4) **Linear Equations with regular singular points:** Euler equation, Second order equation with regular singular points, Exceptional cases, Bessels equation.

(5) **Existence and uniqueness of solutions to first order equations:** Separation of variables, exact equations, Method of successive approximations, Lipschitz condition, approximation to and uniqueness of solutions.

(6) **Existence and uniqueness of solutions to systems and n-th order equations:** Complex n-dimensional space, Systems as vector equations, Existence and uniqueness of solutions to systems, Uniqueness for linear systems and equations of order n.

Reference Books:

- E. A. Coddington, An Introduction to Ordinary Differential Equations (Prentice- Hall).
- G. F. Simmons and S. G. Krantz, Dfferential Equatins (Tata McGraw-Hill).

MT-EM 01: Operation Research

(1) **Modeling with Linear Programming :** Two variable LP model, graphical LP solutions, selected LP applications.

(2) **Simplex method and Sensitivity Analysis :** LP model in equation form, transition from graphical to algebraic solution, simplex method, artificial starting solution, special cases in the simplex method, sensitivity analysis.

(3) **Duality and Post-Optimal Analysis :** Definition of the dual problem, primal-dual relationships, economic interpretation of duality, additional simplex algorithms.

(4) **Transportation Model and its Variants :** Definition of the transportation model, non traditional transportation models, transportation algorithm, assignment model.

(5) **Network Model :** Scope and definition of network models, minimal spanning tree algorithm, shortest root problem, maximal flow model, CPM and PERT.

(6) **Advanced Linear Programming :** Simplex method fundamentals, revised simplex method, bounded variable algorithm, duality.

(7) **Integer Linear programming :** Illustrative applications, integer programming algorithms.

NB : Use suitable mathematical software to solve relevant problems.

Reference Book(s):

- Hamy A.Taha, Operations Research, (Eightth Edition, Prentice Hall of India), 2008.
- J. K. Sharma, Operations Research, (Third Edition, Macmillan India Ltd.), 2008.
- P. K. Gupta and D. S. Haria, Operations Research, (Fifth Edition, S. Chand), 2014.

MT 02 : Integral Equations and Transforms

(1) **Classification of Liner Integral Equations :** Fredholm, Volterra, Integro-Differential Equations, Singular Integral Equations, Converting Volterra Equation to ODE, Conversion of IVP to Volterra equation Conversion of BVP to Fredholm equation

(2) **Fredholm Intergral Equations:** Decomposition method, Direct Computation method, successive approximation method, method of successive substitutions, Homogeneous Fredholm Equations, Comarison between alternative methods.

(3) **Volterra Integral Equation:** Adomian Decomposition method, Series solution method, converting Volterra equation to VIP, Successive Approximation method, successive substitution method, comparison between alternative methods.

(4) **Integro-Differential Equations:** Introduction, Direct Computation method, Adomian Decomposition Method. Conversion to Fredholm integral Equation. Volterra Integro-Differential equations Series Solution, Decomposition Method, Conversion to IVP.

(5) **Singular Integral Equations:** Abel problem, Generalized Abel Integral Equation, Weakly-singular Volterra Equations.

(6) **Non Linear Integral Equations:** Non linear Fredholm Integral equations, Direct Computation, decomposition method, Non liner Volterra Integral Equation, Series solution, Decomposition method. Existence and uniqueness of solutions using fixed-point theorems in cash of Linear and nonlinear Volterra and Fredholm integral equations.

(7) **Fourier Transforms[FT]:** Definition Properties evaluation of Fourier and inverse Fourier transforms of functions, Convolution theorem for FT. Sine and Cosine Fourier transforms. Solving differential equations and integral equations using FT.

(8) **Laplace Transform:** Definition Properties, evaluation of Laplace and Inverse Laplace transforms of functions. Convolution theorem for Laplace Transforms. Solving initial value problem using Laplace Transforms. Solving integral equation using Laplace Transforms.

Reference Books:

- A.M. Wazwaz, A First course in integral equations (World Scientific,1997)
- A.J. Jerri, Introduction to Integral Equation with Applications (1999) (Second edition Wiley Interscience).

MT 03 : Number Theory

(1) **Unique Factorization:** Unique factorization in integers and Gaussian integers, some arithmetic functions (Mobius, Eulers phi function etc), divergence of series of reciprocal of primes.

(2) **Congruence and Primitive Roots:** Elementary properties of modular arithmetic, solutions of congruences, Chinese remainder theorem, group of units in Z_n and its group structure

(3) **Quadratic Reciprocity :** Quadratic residues, Law of quadratic reciprocity with proof.

(4) **Algebraic Numbers :** Algebraic numbers and algebraic integers, Quadratic Gauss sums, integral bases

Reference Books:

- K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory (Second Edition, Springer)
- Niven and Zuckerman, An introduction to the Theory of Numbers, Wiley Publishers.
- David Burton, Elementary Number Theory.

MT 04 : Coding Theory

(1) **Error detection:** correction and decoding: Communication channels, Maximum likelihood decoding, Hamming distance, Nearest neighbor / minimum distance decoding, Distance of a code.

(2) **Linear codes:** Vector spaces over finite fields, Linear codes, Hamming weight, Bases of linear codes, Generator matrix and parity check matrix, Equivalence of linear codes, Encoding with a linear code, Decoding of linear codes, Cossets, Nearest neighbor decoding for linear codes, Syndrome decoding.

(3) **Cyclic codes:** Definitions, Generator polynomials, Generator and parity check matrices, Decoding of cyclic codes, Burst-error-correcting codes.

(4) **Some special cyclic codes:** BCH codes, Definitions, Parameters of BCH codes

Reference Books:

- San Ling and Chaoing xing, Coding Theory- A First Course
- Raymod Hill, A First Course in Coding Theory (Oxford)
- Lid and Pilz, Applied Abstract Algebra Second Edition

MT 05 : Graph Theory

(1) **Fundamental Concepts :** Basic definitions and examples of paths, cycles, walks, trails etc, Bipartite graphs and characterization, Eulerian graphs and characterization, Degree sum formula, counting and bijection, hypercubes, directed graphs, orientations

(2) **Trees :** Trees and its properties, spanning trees, enumeration of trees, Matrix tree theorem, Minimum spanning tree, Kruskals algorithm and Dijkstras algorithm, Trees in Computer Science.

(3) **Matchings and Factors :** Notions of matching, perfect matiching, Halls theorem, Independent sets and covers

Reference Books:

- Douglas B. West, Introduction to Graph Theory (Prentice Hall, Second Edition)
- R. J. Wilson, Introduction to graph theory, Pearson, (2003)
- John Clarke and D.A. Holton, A First Look at Graph Theory, Allied Publisher (1991)
- Nora Harsfield and Gerhard Ringel, Pearls Theory, Academic Press (1990)
- Harary, Graph Theory, Narosa Publishers, New Delhi (1989)

MT 06 : Lattice Theory

(1) Two definitions of lattices, Hasse diagrams, homomorphism, isotone maps, ideals, congruence relations, congruence lattices, the homorphism theorem, product of lattices, complete lattice, ideal lattice, distributive modular inequalities and identifies, complements, pseudocomplements, Boolean lattice of pseudocomplements, join and meet-irreducible elements.

(2) Characterization theorems and representation theorems-Dedekind‘s modularity criterion Birkhoff‘s distributivity criterion, hereditary subsets, rings of sets, Stone theorems, Nachbin theorem, statements of Hashimotos theorem.

(3) Modular lattices, isomorphism theorem, Upper and lower covering conditions, Kuros-Ore theorem, independent sets (Drops results involving projectivity and sublattice generated by sets / elements)

(4) Semimodular lattices Jordan-Holder chain condition, Modular pair, M-sysmmetric lattices.

Reference Books:

- G. Gratzer, General Lattice Theory (Birkhauser, Second Edition 1998)

MT 07 : Computational Geometry

(1) **Transformations of the Plane:** Translations, reflections, rotations, shears, concatenation of transformations, applications

(2) **Homogenous coordinates:** Homogenous coordinates, points at infinity, projective plane, transformations in homogenous coordinates

(3) **Transformations of the Space:** Translations, scalings, reflections, rotations about coordinate axes, rotation about an arbitrary line, reflection in an arbitrary plane, applications to Computer-aided Design, projections

(4) **Curves :** Curve rendering, parametric Curves, arclength and reparametrization, Classification of Conics, Intersections of a Conic with a Line, parametrization of an irreducible conic, Conics in space, applications of conics

(5) **Bezier Curves:** Bezier curves of low degree, linear Bezier curves, quadratic Bezier curves, cubic Bezier curves, the general Bezier curve, properties of the Bernstein polynomials, properties of Bezier curves, applications

(6) **B-splines :** Introduction to B-splines, properties of the B-spline Curve

Reference Books:

- Duncan Marsh, Applied Geometry for Computer Graphics and CAD (Springer, Second Edition)
- de Berg, van Kreveld, Overmars, and Schwarzkopf, Computational Geometry Algorithms and Applications, 2nd Edition, (Springer-Verlag, 2000).

MT- 08 : Cryptography

Divisibility and Euclidean Algorithm, Congruences, Factorizations, finite fields and quadratic residues, some simple cryptosystems, integer factorization, discrete logarithm, public key cryptography, hash functions, RSA, Diffie Hellman key exchange system, the ElGamal cryptosystem, digital signatures, primality and factoring, primality tests, pseudo primes, Miller-Rabin primality test, elliptic curve cryptograhy, elliptic curve cryptosystems.

Reference Books:

- Neal Koblitz, A Course in Number Theory and Cryptography (Springer, Second Edition)
- Robert Edward Lewand: Cryptological Mathematics (Mathematical Association of America).
- D. R. Stinson: CRYPTOGRAPHY, Theory and practice, CRC Press, 1995
- Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: An introduction to Mathematical Cryptography, Springer
- Adam J. Elbirt: (CRC press): Understanding and Applying cryptography and Data security.
- Bruice Schneier: Applied Cryptography (Wiley India Edition)
- Atul Kahate: Cryptography and Network security (Tata McGraw Hill)

MT 09 : Financial Mathematics

(1) **Introduction to options and markets:** types of options, interest rates and present values.

(2) **Black Sholes model :** arbitrage, option values, pay offs and strategies, put call parity, Black Scholes equation, similarity solution and exact formulae for European options, American option, call and put options, free boundary problem.

(3) **Binomial methods :** option valuation, dividend paying stock, general formulation and implementation.

(4) **Monte Carlo simulation :** valuation by simulation

(5) **Finite difference methods :** explicit and implicit methods with stability and conversions analysis methods for American options- constrained matrix problem, projected SOR, time stepping algorithms with convergence and numerical examples.

(6) **Lab component :** implementation of the option pricing algorithms and evaluations for Indian companies.

Reference Books:

- D.G.Luenberger, Investment Science, Oxford University Press,1998.
- J.C.Hull , Options, Futures and Other Derivatives, 4th ed., Prentice- Hall ,New York,2000.
- J.C.Cox and M.Rubinstein, Option Market, Englewood Cliffs,N.J.: Prentice- Hall,1985.
- C.P. Jones. Investments, Analysis and Measurement, 5th ed.,John Wiley and Sons,1996.

MT 10 : Symmetries

(1) Symmetry of plane figures of motions of the plan, finite groups of motions, discrete groups of motion, symmetry, cosets, counting formula, permutation representations, finite subgroups of the generators and relations

(2) Operation of a group on itself, class equation of the isocahedral groups operations on subsets groups of order12, platonic solids, free group generators and relations.

(3) Bilinear forms, symmetric forms, orthogonality, geometry associated to a positive from, Hermitian forms, spectral theorem, conics and quadrics, normal operators, skew symmetric forms.

Reference Books:

- Michael Artin, Algebra, (Prentice-Hall).

MT 11 : Wavelet Analysis

(1) **Fourier Transform :** Fourier transform on $L^1(R)$ and $L^2(R)$ and basic properties and examples

(2) **Windowed Fourier Transform :** Motivation and definition of Windowed Fourier Transform and examples, Time frequency localization, the reconstruction formula.

(3) **Continuous Wavelet Transform :** Motivation and Definition of the wavelet transform and examples, Basic properties, The reconstruction formula, Frequency localization, Orthonormal Wavelets.

(4) **Multiresolution Analysis :** Definition of MRA and examples, Properties of scaling functions and orthonormal wavelets bases, Construction of orthonormal wavelets.

Reference Books:

- Bachman G, L. Narici & E. Beckensterin, Fourier and Wavelet Analysis, Springer-Verlage (2000).
- Chui C. K., An Introduction to Wavelets, Academic Press (1992).

MT 12 : Combinatorics

(1) **Counting Methods for selections arrangements:** Basic counting principles, simple arrangements and selections, arrangements and selection with repetition, distributions, binomial, generating permutations and combinations and programming projects.

(2) **Generating functions :** Generating function models, calculating of generating functions, partitions exponential generating functions, a summation method.

(3) **Recurrence Relations :** Recurrence relation model, divide and conquer relations, solution of inhomogeneous recurrence relation, solution with generating functions.

(4) **Inclusion-exclusion:** Counting with Venn diagrams inclusion formula, restricted positions and rook polynomials.

(5) **Ramsey Theory:** Ramsey theorem, applications to geometrical problems.

Reference Books:

- Alan Tucker, Applied Combinatorics (third edition), John Wiley & sons, New York (1995)
- V. Krishnamurthy, Combinatorial, Theory and Applications, East West Press, New Delhi (1989).

MT 13 : Partial Differential Equations

(1) **First and second order linear equations:** terminologies, superposition principle, linear dependence, First order linear equations, initial value problem, classification of second order equations, well posedness

(2) **Heat equation:** Derivation of heat equation, initial boundary value problems, homogeneous boundary conditions, non-homogeneous boundary conditions, Robin boundary conditions, Infinite domain problems, maximum principle, energy method, uniqueness of solutions.

(3) **Wave equation:** Derivation of wave equation, Initial value problems, wave reflection problems, Initial boundary value problems, Energy method

(4) **Laplace equation:** boundary value problems, separation of variables, Fundamental solution, Greens identity, Greens function, Properties of harmonic function, Well posedness issues

(5) First order quasilinear equations, scalar conservation law, Rankine-Hugoniot condition, weak solutions, entropy condition, traffic flow problem, First order nonlinear equations, systems of first order equations

(6) **Fourier series and Eigenvalue problems:** Fourier convergence theorems, Derivations of Fourier series, Sturm-Liouville Problems.

Reference Books:

- H. Hattori, Partial Differential Equations, Methods, Applications and Theories, World Scientific publications, 2014.
- T. Amaranath, An Elementary Course in Partial Differential Equations, Narosa, 2003.
- J. Brown and R.V. Churchill, Fourier Series and Boundary Value Problems, (McGraw-Hill)

MT 14 : Logic and Set Theory

(1) **Basic notions in set Theory :** Axiom of choice, Zorns Lemma, Hausdorff maximality principle, Well-ordering theorem, Schrder-Bernstein theorem

(2) **Propositional Calculus:** Truth tables, truth values, logical equivalence, disjunctive normal forms, complete connector systems

(3) **Predicate Calculus:** Its language, formulas, structures, satisfaction, normal forms, definability, isomorphisms of structures

(4) **Axiomatic Systems :** Zermelo-Fraenkel Axioms, the Continuum Hypothesis, different systems of logic.

Reference Books:

- K. Kuratowski, Introduction to Set Theory and Topology
- E. Mendelson, Introduction to Mathematical Logic

MT 15 : Statistics and Probability

(1) Introduction to Probability: Sample space, events, probability of an event, additive rules, conditional probability, multiplicative rule, Bayes' rule

(2) Concept of a random variable, discrete probability distribution, continuous probability distribution, joint probability distribution, independent random variables, Chebyshev's theorem.

(3) Mean of a random variable, variance and covariance, means and covariances of linear combinations of random variables.

(4) Some discrete probability distributions: discrete uniform distribution, binomial and multinomial distributions, hypergeometric distribution, negative binomial and geometric distribution, Poisson distribution and Poisson process.

(5) Some continuous probability distributions: continuous uniform distribution, normal distribution, area under the normal curve, applications of the normal distribution, normal approximation to the binomial distribution, gamma and exponential distribution, chi-squared distribution, lognormal distribution.

(6) Functions of random variables, transformations of variables, moments and moment generating functions

(7) Statistical hypothesis: general concepts, testing a statistical hypothesis, use of p values for decision making, tests concerning a singular mean (variance known), confidence interval estimation, tests on a single mean (variance unknown).

Reference Books:

- R. Walpole, R.H. Myers, S.L. Myers, and K. Ye, Probability and Statistics for Engineers and Scientists, (Seventh Edition, Pearson India), 2011.
- S Ross, A first course in probability, (Pearson, ninth edition), 2016.

MT 16 : Fluid Dynamics

(1) Physical Properties of fluids. Concept of fluids, Continuum Hypothesis, density, specific weight, specific volume.

(2) **Kinematics of Fluids**: Eulerian and Lagrangian methods of description of fluids, Equivalence of Eulerian and Lagrangian method, General motion of fluid element, integrability and compatibility conditions, strain rate tensor, stream line, path line, streak lines, stream function vortex lines, circulation.

(3) **Stresses in Fluids:** Stress tensor, symmetry of stress tensor, transformation of stress components from one co-ordinate system to another, principle axes and principle values of stress tensor.

(4) **Conservation Laws:** Equation of conservation of mass, equation of conservation of momentum, Navier Stokes equation, equation of moments of momentum, Equation of energy, Basic equations in different co-ordinate systems, boundary conditions.

(5) **Irrotational and Rotational Flows:** Bernoullis 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.

Reference Books:

- R.K. Rathy, An introduction to fluid dynamics, (Oxford and IBH Publishing Co. 1976).
- L. N. Milne Thomson, Theoretical Hydrodynamics, (Macmillan and Co. Ltd.).
- F. Chorlton, Textbook of fluid dynamics (CBS Publishers, Delhi).
- L. D. Landau and E.N. Lipschitz, Fluid Mechanics, (Pergamon Press, London, 1985)

MT 17 : Banach Algebra

(1) Relatively compact sets, compactly continuous operators, finite dimensional operators, transformation that is bounded but not completely continuous, a type of transformation that is always completely continuous, further properties of completely continuous transformations.

(2) Spectra and the resolvent set, Approximate proper values, Banach Algebra with identity, compactness of the spectrum, the resolvent operator, Spectral radius and spectral mapping theorem for polynomials, the Gelfand Theory.

(3) Sesquilinear functions: Spectral results for normal and completely continuous operators, numerical range

(4) The Fredholm alternative theory, the spectral theorem for bounded, normal Finite dimensional operators.

(5) Commutative Banach Algebras, ideals and homomorphisms.

Reference Books:

- Walter Rudin, Functional Analysis (Tata Mac Grow Hill Publishing co. New Delhi)

MT 18 : Advanced Real Analysis

(1) Fundamental notions: Bases and countability, The separation axioms and continuous real-valued functions, Product spaces, Connectedness, Baire Category theorem.

(2) Countable compactness and the Bolzano-Weierstrass property, Products of compact spaces, Locally compact spaces, The Stone-Cech compactification, The Stone- Weierstrass theorem, The Ascoli theorem

Reference Books:

- H. L. Royden, Real Analysis (MacMillan, Second Edition)
- C. D. Aliprantis, O. Burkinshaw, Principles of Real Analysis (Academic Press, Third Edition)
- Walter Rudin, Real and Complex Analysis (McGraw Hill, Third Edition)

MT 19 : Matroid Theory

(1) **Introduction:** Basic definitions and examples, Independent sets and circuits, bases, rank, closure, geometric representations of matroids of small rank, transversal matroids, the lattice of flats, the greedy algorithm.

(2) **Duality:** The definition and basic properties, duals of representable matroids, duals of graphic matroids, duals of traversal matroids.

(3) **Minors:** Contraction, Minors of certain matroids, flats and the sum theorem

(4) **Connectivity:** Connectivity, for graphs and matroids, properties of matroid connectivity, more properties of connectivity.

Reference Books:

- James G. Oxley, Matroid Theory Science Publications, Oxford (1992)

MT 20 : Differential Equations and Dynamical Systems

(1) **Fundamental Theorems:** Existence and uniqueness of solutions of a system of non-autonomous differential equations, numerical approximation, continuation of solutions, continuity in initial conditions, Picard-Lindelf theorem

(2) Qualitative point of view, Differential inequalities

(3) **Linear Differential Equations:** Fundamental matrix solutions, Higher order equations, complex linear differential equations.

(4) **Constant Coefficients:** Exponential of a matrix, Generalized eigenspaces, Canonical forms, Higher order equations

(5) **Stability:** Stability at fixed points, Stability and constant coefficients, Stability and general linear systems, linear systems with periodic coefficients

Reference Books:

- N. G. Markley, Principles of Differential Equations, Wiley Inter-Science, 2004.
- L. Perko, Differential Equations and Dynamical systems, Springer-Verlag, 1991.
- Hirsch and Smale, Differential Equations, Dynamical Systems, and Liner Algebra-Academic Press, New York, 1974.

MT 21 : Mechanics

Survey of Elementary Principles, Variational Principles & Lagrange's Equation, Central Force problem, Kinematics of rigid body motion, Hamilton Equations of motion, Canonical Transformations

Reference Books:

- Goldstein, Poole and Safko, Classical Mechanics, (Third Edition, Pearson Education Inc.), 2002.
- Rana & Joag, Classical Mechanics (Tata McGraw Hill)

MT 22 : Algebraic Topology

Quotient spaces, examples and properties of quotient spaces, homotopy of paths, fundamental group, covering spaces, retraction and fixed points, Algebraic topological proof of Fundamental Theorem of Algebra, Borsuk-Ulam theorem, deformation retracts and homotopy type, fundamental group of S_n, Seifert-van Kampen theorems, free groups, fundamental group of wedge of circles, fundamental group of torus and dunce cap, group of covering transformations(optional).

Reference Books:

- James Munkres , Topology (Pearson, Second Edition)
- Allen Hatcher, Algebraic Topology

MT 23 : Advanced Calculus II

Multilinear Algebra, alternating tensors, wedge product, tangent vectors and differential forms, differential operator, Vector fields, Integrating forms, orientable manifolds, Stokes theorem, Closed and exact forms, Poincares lemma, manifolds in the abstract setting(abstract manifolds).

Reference Books:

- J. R. Munkers : Analysis on Manifolds , Addison Wesley (1993)
- Michael Spivak, Calculus on Manifolds, Addison-Wesley Publishing Co.

MT 24 : Rings and Modules

Rings, ideals, ring homomorphisms, polynomial and power series rings, phomomorphism theorems, integral domains, Euclidean domains, principal ideal domains, unique factorization domains, Gauss' lemma, UFD property for polynomial rings, irreducibility criteria, Eisenstein's criterion, Modules, bases and linear independence over rings, free and non-free modules, torsion freenes, modules over PID, Elementary divisors and Invariant Factors, Jordan and Rational Cannonical form via modules over PID. (Note: For modules over PID book by Steven Roman on Advanced Linear Algebra can be used.)

Reference Books:

- C. Musili, Rings and modules, Narosa, (1999).
- Steven Roman, Advanced Linear Algebra, (Springer, Second Edition)

MT 25 : Differential Geometry

Graphs and level sets, vector fields, tangent spaces, surfaces, vector fields on surfaces, orientation, gauss map, geodesics, parallel transport,Weingarten map, curvature, arc length and line integrals, curvature of surfaces, parametrized surfaces, surface area and volume, exponential map, surfaces with boundary.

Reference Books:

- John A. Thorpe, Elementary topics in differential Geometry, Springer, (2004)
- B Oneill : Elementary differential Geometry, (Academic - New York)

MT 26 : Fourier Analysis

Vibrating string, heat equation, basic properties of Fourier series, convergence of Fourier series, applications of Fourier series, Fourier transform on R, Plancherels theorem, Fourier series and Poisson's summation formula.

Reference Books:

- E. Stein and Shakarachi, Fourier Analysis, (Princeton University).
- Chandrasekharan K., Classical Fourier Transforms, (Springer Verlag).

MT 27 : Commutative Algebra

Rings and homomorphisms, Nilradical and Jacobson radical, extension and contraction of ideals, Modules, Nakayama lemma, exact sequences, rings and modules of fraction, primary decomposition of ideals, first and second uniqueness theorems, integral dependence and integral extensions, Going-Up theorem, chain conditions (ACC and DCC), Noetherian rings,

Hilbert's Basis theorem, primary decomposition in Noetherian rings, Artin rings, Dedekind domains.

Reference Books:

- M. F. Atiyah and I. G. Macdonald, Introduction to commutative algebra,
- N. S. Gopalkrishnan, Commutative Algebra

MT 28 : Advanced Complex Analysis

Compactness and Convergence in spaces of Analytic functions, spaces of meromorphic functions, the Reimann mapping theorem, Weierstrass Factorization theorem, Factorization of the sine function, Gamma function, the Reimann Zeta function, Runges theorem, simple connectedness, Mittag-Lefflers theorem, Analytic continuation, Reimann surfaces, Monodromy.

Reference Books:

- John B. Conway, Functions of One Complex Variables, (Springer Verlag, Second Edition)
- Lars Ahlfors, Complex Analysis, (McGraw Hill Inc, Third Edition)
- Theodore Gamelin , Complex Analysis, (UTM) (Springer, 2003)

MT 29 : Representation Theory of Groups

Group actions, basic definitions and examples of group representations, irreducible and indecomposable representations, Maschke's theorem and complete reducibility, schur's lemma, orthogonality relations, characters and class functions, the regular representation, permutation representation, representations of Abelian groups, Fourier analysis on finite groups, convolutions, applications to graph theory, Burnside's theorem, Induced Representations (Optional).

Reference Books:

- Benjamin Steinberg, Representation Theory of Finite Groups
- J. P. Serre, Linear Representations of Groups
- James Leibeck, Representation Theory
- Michael Artin, Algebra.

MT 30 : Fourier Analysis on Finite Groups

The Discrete Fourier Transform on the Finite Circle Z/nZ, Graphs of Z/wZ, Adjacency Operators, Eigenvalues, Random Walks on Cayley Graphs, The Fast Fourier Transform or FFT, The DFT on Finite Abelian Groups - Finite Tori, The Uncertainty Principle, Fourier Transform and Representations of Finite Groups, The Finite $ax+b$ Group, The Heisenberg Group, The General Linear Group $GL(2,F_q)$.

Reference Books:

- Audrey Terras, Fourier Analysis on Finite Groups and Applications, (Cambridge University Press, London Mathematical Society Texts-43).

MT 31 : Topics in Lie Groups

(1) **Matrix Lie Groups:** Basic definitions and examples, general linear group, special linear groups, orthogonal and unitary groups, compactness, connectedness, simple connectedness, Polar Decomposition for $S(n,R)$ and $SL(n,C)$.

(2) **Lie Algebras and Exponential Mapping :** The matrix exponential, matrix logarithm, Lie Algebra of a Matrix Lie group, properties of Lie Algebra.

Reference Books:

- Brian C. Hall, Lie Groups, Lie Algebras and Representations, Springer, 2003.
- M. Artin, Algebra (Pearson, Second Edition).

MT 32 : Advanced Linear Algebra

(1) Normal, unitary and self-adjoint operators, spectral theorem for normal operators, quadratic forms, orthogonal reduction, Discrete Fourier Transform (DFT), orthogonal decomposition, singular value decomposition, orthogonal projections, least squares solutions, Perron Frobenius theory, stochastic matrices and applications to Markov chains.

(2) Modules over PID: Modules over PIDs, smith normal form, elementary divisors, invariant factors, Jordan and / or Rational cannonical forms via modules over PIDs.

Reference Books:

- K. Hoffman and R. Kunze,Linear Algebra, (Prentice Hall, Second Edition).
- C. D. Meyer, Matrix Analysis and Applied Linear Algebra (SIAM 2001).
- Steven Roman, Advanced Linear Algebra
- Peter Lax, Linear Algebra

MT 33 : Projective Geometry

Affine spaces and Projective spaces, Basic definitions and examples affine spaces and projective spaces, projective co-ordinates, projective transformations, Mobius transformations, Affine and Projective classification of Conics and Quadrics, projective plane curves, intersection numbers, Bezouts theorem.

Reference Books:

- Pierre Samuel, Projective Geometry, (Springer Verlag).
- Emil Artin, Geometric Algebra, (Wiley Classic Library).
- William Traves, Karen Smith et al., Invitation to Algebraic Geometry

MT 34 : Algebraic Geometry

Affine space and affine varieties, parametrizations of affine varieties, orderings on the monomials in n-variable polynomial ring, monomial ideals, Hilbert Basis theorem, Grobner bases, Hilbert's Nullstellensatz, Ideal-Variety correpsondence, irreducible varieties, decomposition of variety into irreducibles, polynomial mappings and rational functions, coordinate ring of an affine variety, algorithmic computations in the quotient of a polynomial ring, Bezouts theorem.

Reference Books:

- David Cox, John Little and Donal O'Shea, Ideals, Varieties and Algorithms
- David Cox, John Little and Donal O'Shea, Using Algebraic Geometry
- William Fulton, Algebraic Curves (An Introduction to Algebraic Geometry)
- William Traves, Karen Smith et al., Invitation to Algebraic Geometry

MT 35 : Algebraic Number Theory

(1) **Algebraic Methods :** Algebraic numbers and integers, Number fields and ring of integers, Integral basis and discriminant, norms and traces, Rings of algebraic integers, Quadratic and Cyclotomic fields, factorization into irreducibles, Prime factorization of ideals, norm of an ideal, non-unique factorization of ideals

(2) **Geometric Methods :** Lattices and quotient torus, Minkowskis theorem, Two Squares Theorem, Four Squares Theorem, Geometric representation of algebraic numbers, Class-group and Class number, finiteness of Class group

(3) **Computational Methods :** Factorization of a Rational prime, some class number calculations

Reference Books:

- Ian Stewart and David Tall, Algebrauc Number Theory and Fermats Last Theorem (A K Peters Ltd, Third Edition).
- Jurgen Neukirch, Algebraic Number Theory, (Springer).

MT 36 : Algebraic Curves

Affine varieties and affine algebraic subsets, vanishing ideals, Zariski topology, irreducible varieties, decomposition of varieties into irreducible varieties, Noetherian rings, Hilbert's Basis theorem, ideals and varieties correspondence, Hilbert's Nullstellensatz, projective plane curves, Algebraic curves in the complex projective plane, Reimann surfaces, smooth points, tangent spaces, singularities of plane algebraic curves, concept of normalization, divisors, intersection numbers and Bezouts theorem

Reference Books:

- Phillip Griffiths, Introduction to Algebraic Curves, (AMS Mathematical Monographs)
- William Fulton, Algebraic Curves (An Introduction to Algebraic Geometry)
- William Traves, Karen Smith et al., Invitation to Algebraic Geometry

- M. F. Atiyah, I .G. McDonald, Introduction to Commutative Algebra

MT 37 : Advanced Lattice Theory

(1) Distributive Lattices: congruence relations, Boolean algebras generated by distributive lattices, topological representation, distributive lattices with pseudo-complementation

(2) Congruences and Ideals: distributive elements, standard elements, neutral elements, standard ideals, Neutral ideals, structure theorems,

(3) Complete Lattices, conditional lattices, fixed point theorems

Reference Books:

- G. Gratzer, General Lattice Theory, (Birkhauser, Second Edition 1998).
- G. Birkhoff, Lattice Theory, American Math. Soc. Colloquium Publications(Vol-XXV).

MT 38 : Spectral Graph Theory

Incidence matrix, path matrix, integer generalized inverse, Moore-penrose inverse, adjacency matrix, eigenvalues of some graphs, trees, Laplacian matrix, Matrix-Tree theorem, non-singular trees, regular graphs, Perron-Frobenius theory, adjancency algebra of a regualar graph, strongly regular graphs, eigenvalues of Caley graphs, Zeta functions on graphs(optional).

Reference Books:

- R. B. Bapat, Graphs and Matrices, (Hindustan Book Agency, Second Edition)
- Norman Biigs, Algebraic Graph Theory, (Cambridge University Press)
- Audrey Terras, Zeta Functions of Graphs, (Cambridge University Press)

MT 39 : Advanced Combinatorics

Sets and multisets, cycles and inversions, descent, Euler numbers, partition identities , q-analogues of permutations, rational power series, quasi-polynomials, Magic squares, Polyas enumeration theorem.

Reference Books:

- Richard Stanley, Enumerative Combinatorics, (Cambridge University Press, Second Edition).

MT 40 : Topics in Group Theory

Review of semidirect products, linear representations of finite and compact groups, the group algebra, induced representations, reciprocity formula, Sylows theorems, Artins theorem, rationality questions, representation theory of symmetric groups (optional), Fourier transforms on finite groups, some applications.

Reference Books:

- Serre J. P., Linear Representations of Finite Groups, (Springer).
- William Fulton, Joe Harris, Representation Theory, A First Course, (Springer Verlag).

MT 41 : Commutative Ring Theory

Dedekind domains and discrete valuation rings, Tensor products, Completions of rings, graded rings and modules, Dimension theory, Hilbert functions, dimension theory of local rings, transcendental dimension, regular local rings.

Reference Books:

- N. S. Gopalkrishnan, Commutative Algebra
- M. F. Atiyah and I.G. Macdonanld, Introduction to Commutative Algebra
- Hideyuki Matsumura, Commutative Ring Theory

MT 42 : Topics in Non-Commutative Rings

Topics in Non-Commutative Rings Wedderburn Artin Theory, semisimplicity, structure of semisimple rings, Jacobson radical, behaviour under change of rings, group rings, modules over finite dimensional algebras, representations of groups, division rings.

Reference Books:

- T. Y. Lam , A First Course in Non-commutative rings
- Joseph Rotman, Introduction to Homological Algebra
- Serre J. P., Linear Representations of Finite Groups (Springer)

MT 43 : Homological Algebra

Categories and functors, idea of homology, singular homology, Hom and Tensor, exactness, sums and products, direct limits and inverse limits, free modules, projective modules, injective modules, resolutions, derived functors, Tor and Ext.

Reference Books:

- Joseph Rotman, An Introduction to Homological Algebra
- Allen Hatcher, Algebraic Topology

MT 44 : Topics in Galois Theory

(1) Galois extensions, linear independence of characters, the norm and trace, cyclic extensions, solvable and radical extensions, Abelian Kummer theory.
(2) Extensions of Rings : Integral ring extensions, integral Galois extensions.
(3) Finte Fields : Construction and properties, factorization of polynomials over finite fields, Berlekamps algorithm.

Reference Books:

- Serge Lang, Algebra, (Springer, Third Edition).

MT 45 : Advanced Measure Theory

Review of basic measure theory, measurable transformations, Induced measures, distribution functions, The Lebesgue-Radon-Nikodym theorem, product spaces and product measures, probability spaces, Kolmogorovs probability model, Random variables and random vectors, Kolmogorovs consistency theorem, Independent events and random variables, Weak laws of large numbers, Strong laws of large numbers.

Reference Books:

- Krishna B. Athreya, S. N. Lahiri, Measure Theory and Probability Theory, (Springer).
- Walter Rudin, Real and Complex Analysis, (Third Edition McGraw Hill)

MT 46 : Topics in Discrete Mathematics

Ihara zeta function, Ihara determinant formula, Covering graphs, Graph theory prime number theorem, Ihara zeta function of a weighted graph, Edge zeta functions, Definitions and Basss proof of the Ihara three-term determinant formula, Path zeta functions, Galois coverings of connected graphs, examples of coverings.

Reference Books:

- Audrey Terras, Zeta Functions of Graphs, (Cambridge University Press).
- Audrey Terras, Fourier Analysis on Finite Groups and Applications, (Cambridge University Press, London Mathematical Society Texts-43).

MT 47 : Topics in Algebraic Topology

Classification of surfaces, homology of surfaces, equivalence of covering spaces, the universal covering space, covering transformations, covering spaces of a graph, the fundamental group of a graph, free groups, singular homology.

Reference Books:

- James Munkres , Topology
- Allen Hatcher, Algebraic Topology

MT 48 : Manifolds

Topological Manifolds, Smooth Structures, Examples of Smooth Manifolds, Smooth Functions and Smooth Maps, Tangent Vectors, The Tangent Bundle, Vector Bundles, Local and Global Sections of Vector Bundles, Bundle Homomorphisms, The Cotangent Bundle, Tensors, Symmetric and Alternating Tensors.

Reference Books:

- John M. Lee, Introduction to Smooth Manifolds, (Second Edition, Springer).

MT 49 : Topics in Number Theory

(1) Dirichlets unit theorem, Dedekinds domains, Hilbert's ramification theory, cyclotomic fields,localization, orders, p-adic numbers, p-adic absolute value, valuations, completions, extensions of valuations, primes, different and discriminant.

(2) Reimann zeta function, Dirichlet L-series, Dedekind zeta function.

Reference Books:

- Ian Stewart and David Tall, Algebrauc Number Theory and Fermats Last Theorem, (A K Peters Ltd, Third Edition).
- Jurgen Neukirch, Algebraic Number Theory, (Springer).

MT 50 : Computer Programming